ISSN 0042-8469
e-ISSN 2217-4753
УДК 623 + 355/359

Вол. 67, бр. 1
2019

ВТГ

НАУЧНИ ЧАСОПИС МИНИСТАРСТВА ОДБРАНЕ РЕПУБЛИКЕ СРБИЈЕ

ВОЈНОТЕХНИЧКИ ГЛАСНИК

1 2019 ВОЈНОТЕХНИЧКИ ГЛАСНИК

втг.мо.упр.срб

www.vtg.mod.gov.rs

ISSN 0042-8469
e-ISSN 2217-4753
УДК 623 + 355/359

Том 67, №1
2019

НАУЧНЫЙ ЖУРНАЛ МИНИСТЕРСТВА ОБОРОНЫ РЕСПУБЛИКИ СЕРБИЯ

ВОЕННО-ТЕХНИЧЕСКИЙ ВЕСТНИК

ВОЕННО-ТЕХНИЧЕСКИЙ ВЕСТНИК
1 2019

ВТГ.МО.УПР.СРБ
www.vtg.mod.gov.rs

ISSN 0042-8469
e-ISSN 2217-4753
UDC 623 + 355/359

Vol 67, No 1
2019

SCIENTIFIC JOURNAL OF THE MINISTRY OF DEFENCE OF THE REPUBLIC OF SERBIA

MILITARY TECHNICAL COURIER

MILITARY TECHNICAL COURIER
1 2019

ВТГ.МО.УПР.СРБ

www.vtg.mod.gov.rs

ISSN 0042-8469
e-ISSN 2417-4753
UDC 623 + 355/359

НАУЧНИ ЧАСОПИС МИНИСТАРСТВА ОДБРАНЕ РЕПУБЛИКЕ СРБИЈЕ

ВОЈНОТЕХНИЧКИ ГЛАСНИК

ВОЛУМЕН 67 • БРОЈ 1 • ЈАНУАР – МАРТ 2019.

NAUČNI ČASOPIS MINISTARSTVA ODBRANE REPUBLIKE SRBIJE

VOJNOTEHNIČKI GLASNIK

VOLUMEN 67 • BROJ 1 • JANUAR – MART 2019.

втг.мо.упр.срб
www.vtg.mod.gov.rs
COBISS.SR-ID 4423938

ISSN 0042-8469
e-ISSN 2417-4753
UDC 623 + 355/359

НАУЧНЫЙ ЖУРНАЛ МИНИСТЕРСТВА ОБОРОНЫ РЕСПУБЛИКИ СЕРБИЯ

ВОЕННО-ТЕХНИЧЕСКИЙ ВЕСТНИК

ТОМ 67 • НОМЕР ВЫПУСКА 1 • ЯНВАРЬ – МАРТ 2019.

SCIENTIFIC JOURNAL OF THE MINISTRY OF DEFENCE OF THE REPUBLIC OF SERBIA

MILITARY TECHNICAL COURIER

VOLUME 67 • ISSUE 1 • JANUARY – MARCH 2019

втг.мо.упр.срб
www.vtg.mod.gov.rs
COBISS.SR-ID 4423938

Издавач:
МИНИСТАРСТВО ОДБРАНЕ РЕПУБЛИКЕ СРБИЈЕ
УНИВЕРЗИТЕТ ОДБРАНЕ У БЕОГРАДУ

Ректор
Доц. др Горан Радовановић, генерал-мајор

Институт за научне информације
Директор
Проф. др Силва Добрић

ГЛАВНИ И ОДГОВОРНИ УРЕДНИК ВОЈНОТЕХНИЧКОГ ГЛАСНИКА
мр Небојша Гаћеша, потпуковник
e-mail: nebojsa.gacesa@mod.gov.rs, tel.: 011/3603-260, 066/87-00-123, http://orcid.org/0000-0003-3217-6513

Адреса редакције: ВОЈНОТЕХНИЧКИ ГЛАСНИК, Генерала Павла Јуришића Штурма 1, 11040 Београд
http://www.vtg.mod.gov.rs
http://aseestant.ceon.rs/index.php/vtg/issue/current
http://scindeks.nb.rs/journaldetails.aspx?issn=0042-8469
http://elibrary.ru/title_about.asp?id=53280
https://doaj.org/toc/2217-4753
e-mail: vojnotehnicki.glasnik@mod.gov.rs
Претплата на штампано издање: e-mail: vojnotehnicki.glasnik@mod.gov.rs; тел. 066/87-00-123
Рукописи се не враћају
Часопис излази тромесечно
Први штампани број *Војнотехничког гласника* објављен је 1. 1. 1953. године
Прво електронско издање *Војнотехничког гласника* на Интернету објављено је 1. 1. 2011. године
Војнотехнички гласник је лиценциран код EBSCO Publishing-a, највећег светског агрегатора часописа, периодике и осталих извора у пуном тексту. Комплетан текст *Војнотехничког гласника* доступан је у базама података EBSCO Publishing-a.
Штампа: Војна штампарија – Београд, Ресавска 40б, e-mail: vojna.stamparija@mod.gov.rs

Издательство:
МИНИСТЕРСТВО ОБОРОНЫ РЕСПУБЛИКИ СЕРБИЯ
УНИВЕРСИТЕТ ОБОРОНЫ В Г. БЕЛГРАД

РЕКТОР
Генерал-майор доц. д-р Горан Радованович

Институт научной информации
Директор
Профессор д-р Силва Добрич

Адрес редакции: ВОЈНОТЕХНИЧКИ ГЛАСНИК, Ул. Генерала Павла Юришича Штурма 1, 11040 Белград
http://www.vtg.mod.gov.rs
http://aseestant.ceon.rs/index.php/vtg/issue/current
http://scindeks.nb.rs/journaldetails.aspx?issn=0042-8469
http://elibrary.ru/title_about.asp?id=53280
https://doaj.org/toc/2217-4753
e-mail: vojnotehnicki.glasnik@mod.gov.rs

Подписка на печатную версию журнала: e-mail: vojnotehnicki.glasnik@mod.gov.rs; тел. +381 66 87 00 123
Присланные в редакцию журнала статьи не возвращаются.
Журнал выпускается ежеквартально
Первый номер журнала «Военно-технический вестник» выпущен 1.1.1953 года.
Первая электронная версия журнала размещена на интернет странице 1.1.2011 года.
«Военно-технический вестник» включен в систему EBSCO – всемирная академическая база данных и сервисов.
Типография: Војна штампарија – Београд, Ресавска 40б, e-mail: vojna.stamparija@mod.gov.rs

Publisher:
MINISTRY OF DEFENCE OF THE REPUBLIC OF SERBIA
UNIVERSITY OF DEFENCE IN BELGRADE

Rector
Major General Goran Radovanović, PhD, Assistant Professor

Institute for scientific information
Director
Professor Silva Dobrić, PhD

Address: VOJNOTEHNIČKI GLASNIK/MILITARY TECHNICAL COURIER, Gener. Pavla Jurišića Šturma 1, 11040 Belgrade
http://www.vtg.mod.gov.rs/index-e.html
http://aseestant.ceon.rs/index.php/vtg/issue/current
http://scindeks.nb.rs/journaldetails.aspx?issn=0042-8469
http://elibrary.ru/title_about.asp?id=53280
https://doaj.org/toc/2217-4753
e-mail: vojnotehnicki.glasnik@mod.gov.rs
Subscription to print edition: e-mail: vojnotehnicki.glasnik@mod.gov.rs; Tel. +381 66 87 00 123
Manuscripts are not returned
The journal is published quarterly
The first printed issue of the *Military Technical Courier* appeared on 1st January 1953.
The first electronic edition of the *Military Technical Courier* on the Internet appeared on 1st January 2011.
Military Technical Courier has entered into an electronic licensing relationship with EBSCO Publishing, the world's most prolific aggregator of full text journals, magazines and other sources. The full text of Military Technical Courier can be found on EBSCO Publishing's databases.
Printed by Vojna štamparija – Beograd, Resavska 40b, e-mail: vojna.stamparija@mod.gov.rs

С А Д Р Ж А Ј

С О Д Е Р Ж А Н И Е

C O N T E N T S

ОРИГИНАЛНИ НАУЧНИ ЧЛАНЦИ
ОРИГИНАЛЬНЫЕ НАУЧНЫЕ СТАТЬИ
ORIGINAL SCIENTIFIC PAPERS

A NOTE ON THE MEIR-KEELER THEOREM IN THE CONTEXT OF *b*-METRIC SPACES

Mirjana V. Pavlović[a], *Stojan* N. Radenović[b]

[a] University of Kragujevac, Faculty of Science, Department of Mathematics and Informatics, Kragujevac, Republic of Serbia,
e-mail: mpavlovic@kg.ac.rs,
ORCID iD: http://orcid.org/0000-0001-6257-8666,
[b] King Saud University, College of Science, Mathematics Department, Riyadh, Saudi Arabia,
e-mail: radens@beotel.rs,
ORCID iD: https://orcid.org/0000-0001-8254-6688

DOI: 10.5937/vojtehg67-19220; https://doi.org/10.5937/vojtehg67-19220

FIELD: Mathematics (Mathematics Subject Classification: primary 47H10, secondary 54H25)
ARTICLE TYPE: Original Scientific Paper
ARTICLE LANGUAGE: English

Abstract:

In this note we consider the famous Meir-Keeler's theorem in the context of b-metric spaces. Our result generalizes, improves, compliments, unifies and enriches several known ones in the existing literature. Also, our proof of Meir-Keeler's theorem in the context of standard metric spaces is much shorter and nicer than the ones in (Ćirić, 2003) and (Meir & Keeler, 1969, pp.326-329).

Keywords: b-metric space, b-complete, b-Cauchy, Meir-Keeler conditions, Picard sequence.

Definitions, notations and preliminaries

Let (X,d) be a standard metric space and $f: X \to X$ be a self-mapping. In the context of these spaces, the following (Meir-Keeler) conditions are well known: For each $\varepsilon > 0$ there exists $\delta = \delta(\varepsilon) > 0$ such that for all $x, y \in X$ holds

ACKNOWLEDGMENT: The first author is grateful for the financial support from the Ministry of Education and Science and Technological Development of the Republic of Serbia (Metode numeričke i nelinearne analize sa primenama, 174002).

$\varepsilon \le d(x,y) < \varepsilon + \delta$ implies $d(fx, fy) < \varepsilon$ (1)

or

$\varepsilon < d(x,y) < \varepsilon + \delta$ implies $d(fx, fy) \le \varepsilon$ (2)

or f is contractive and

$\varepsilon \le d(x,y) < \varepsilon + \delta$ implies $d(fx, fy) \le \varepsilon$. (3)

One says that the mapping f defined on the standard metric space (X,d) is contractive if $d(fx, fy) < d(x,y)$ holds, whenever $x \ne y$.

For more details, see (Ćirić, 2003, pp.30-33, pp.56-58).

In 1969, Meir-Keeler proved the following:

Theorem 1 (Meir & Keeler, 1969, pp.326-329, Theorem) Let (X,d) be a complete metric space and let f be a self-mapping on X satisfying (1). Then f has a unique fixed point, say $u \in X$, and for each $x \in X, \lim_{n\to\infty} f^n x = u$.

Inspired by the above Meir-Keeler theorem, Ćirić proved the following, slightly more general result:

Theorem 2 (Ćirić, 2003, Theorem 2.5) Let (X,d) be a complete metric space and let f be a self-mapping on X satisfying (2). Then f has a unique fixed point, say $u \in X$, and for each $x \in X, \lim_{n\to\infty} f^n x = u$.

The example which follows shows that Ćirić's result is a proper generalization of the famous Meir-Keeler theorem:

Example 3 Let $X = [0,1] \cup \{3n-1\}_{n\in N} \cup \left\{3n + \frac{1}{3n}\right\}_{n\in N}$ be a subset of real numbers with the Euclidean metric and let f be a self-mapping on X defined by

$fx = 0,\ if\ 0 \le x \le 1\ and\ x \in \{3n-1\}_{n\in N}$,

$fx = 1,\ if\ x \in \left\{3n + \frac{1}{3n}\right\}_{n\in N}$.

Then one can verify that f satisfies (2) while it does not satisfy Meir-Keeler condition (1). For all details, see (Ćirić, 2003, p.33).

Remark 1 Both previous theorems are true if the self-mapping $f : X \to X$ satisfies condition (3).

Bakhtin (Bakhtin, 1989, pp.26-37) and Czerwik (Czerwik, 1993, pp.5-11) introduced *b*-metric spaces (as a generalization of metric spaces) and proved the contraction principle in this context. In the last period, many authors have obtained fixed point results for single-valued or set-valued functions, in the context of *b*-metric spaces. Now we give the definition of a *b*-metric space:

Definition 1.1 (Bakhtin, 1989, pp.26-37), (Czerwik, 1993, pp.5-11) Let X be a nonempty set and let $s \geq 1$ be a given real number. The function $d : X \times X \to [0, \infty)$ is said to be a *b*-metric if, and only if, for all $x, y, z \in X$ the following conditions hold:

b1) $d(x, y) = 0$ if, and only if, $x = y$;

b2) $d(x, y) = d(y, x)$;

b3) $d(x, z) \leq s[d(x, y) + d(y, z)]$.

A triplet $(X, d, s \geq 1)$ is called a *b*-metric space with the coefficient s.

It should be noted that the class of *b*-metric spaces is effectively larger than that of standard metric spaces, since a b-metric is a metric when $s = 1$. The following example shows that, in general, a *b*-metric does not necessarily need to be a metric (Chandok et al, 2017, pp.331-345), (Došenović et al, 2017, pp.851-865), (Dubey et al, 2014), (Dung & Hang, 2018, pp.298-304), (Faraji & Nourouzi, 2017, pp.77-86), (Jovanović et al, 2010), (Jovanović, 2016), (Kir & Kiziltunc, 2016, pp.13-16), (Kirk & Shahzad, 2014).

Example 4 Let (X, ρ) be a standard metric space, and $d(x, y) = (\rho(x, y))^p$, $p > 1$ is a real number. Then d is a *b*-metric with $s = 2^{p-1}$, but d is not a standard metric on X.

Otherwise, for more concepts such as *b*-convergence, *b*-completeness, *b*-Cauchy and *b*-closed set in *b*-metric spaces, we refer

the reader to (Došenović et al, 2017, pp.851-865), (Dubey et al, 2014), (Dung & Hang, 2018, pp.298-304), (Faraji & Nourouzi, 2017, pp.77-86), (Jovanović et al, 2010), (Jovanović, 2016), (Kir & Kiziltunc, 2016, pp.13-16), (Kirk & Shahzad, 2014), (Koleva & Zlatanov, 2016, pp.31-34), (Chifu & Petruşel, 2017, pp.2499-2507), (Kumar et al, 2014, pp.19-22), (Miculescu & Mihail, 2017, pp.1-11), (Paunović et al, 2017, pp.4162-4174), (Singh et al, 2008, pp.401-416), (Sintunavarat, 2016, pp.397-416), (Suzuki, 2017), (Zare & Arab, 2016, pp.56-67).

The following two lemmas are very significant in the theory of a fixed point in the context of *b*-metric spaces.

Lemma 1.2 (Jovanović et al, 2010, p.15, Lemma 3.1) Let $\{a_n\}_{n\in N\cup\{0\}}$ be a sequence in a *b*-metric space $(X,d,s\geq 1)$ such that

$$d(a_n,a_{n+1})\leq kd(a_{n-1},a_n)$$

for some $k\in\left[0,\frac{1}{s}\right)$, and each $n=1,2,...$ Then $\{a_n\}$ is a *b*-Cauchy sequence in a *b*-metric space $(X,d,s\geq 1)$.

Lemma 1.3 (Miculescu & Mihail, 2017, pp.1-11, Lemma 2.2) Let $\{a_n\}_{n\in N\cup\{0\}}$ be a sequence in a *b*-metric space $(X,d,s\geq 1)$ such that

$$d(a_n,a_{n+1})\leq kd(a_{n-1},a_n)$$

for some $k\in[0,1)$, and each $n=1,2,...$ Then $\{a_n\}$ is a *b*-Cauchy sequence in a *b*-metric space $(X,d,s\geq 1)$.

Remark 2 In (Došenović et al, 2017, pp.851-865), it is proven that the previous lemmas are equivalent.

Since in general a *b*-metric is not necessarily continuous, many papers related with *b*-metric spaces used the following lemmas to prove the main results.

Lemma 1.4 (Aghajani et al, 2014, pp.941-960, Lemma 2.1) Let $(X,d,s\geq 1)$ be a *b*-metric space. Suppose that $\{a_n\}$ and $\{b_n\}$ are *b*-convergent to a and b, respectively. Then

$$\frac{1}{s^2}d(a,b)\leq\liminf_{n\to\infty}d(a_n,b_n)\leq\limsup_{n\to\infty}d(a_n,b_n)\leq s^2d(a,b).$$

In particular, if $a=b$, then we have $\lim_{n\to\infty} d(a_n, b_n) = 0$. Moreover, for each $c \in X$, we have

$$\frac{1}{s} d(a,c) \le \liminf_{n\to\infty} d(a_n, c) \le \limsup_{n\to\infty} d(a_n, c) \le s d(a,c).$$

Lemma 1.5 (Paunović et al, 2017, pp.4162-4174, Lemma 2.3) Let $(X, d, s \ge 1)$ be a *b*-metric space and $\{a_n\}$ a sequence in X such that

$\lim_{n\to\infty} d(a_n, a_{n+1}) = 0$.

If $\{a_n\}$ is not *b*-Cauchy, then there exist $\varepsilon > 0$ and two sequences $\{m(k)\}$ and $\{n(k)\}$ of positive integers such that the following items hold:

$$\varepsilon \le \liminf_{k\to\infty} d(a_{m(k)}, a_{n(k)}) \le \limsup_{k\to\infty} d(a_{m(k)}, a_{n(k)}) \le \varepsilon s,$$

$$\frac{\varepsilon}{s} \le \liminf_{k\to\infty} d(a_{m(k)}, a_{n(k)+1}) \le \limsup_{k\to\infty} d(a_{m(k)}, a_{n(k)+1}) \le \varepsilon s^2,$$

$$\frac{\varepsilon}{s} \le \liminf_{k\to\infty} d(a_{m(k)+1}, a_{n(k)}) \le \limsup_{k\to\infty} d(a_{m(k)+1}, a_{n(k)}) \le \varepsilon s^2,$$

$$\frac{\varepsilon}{s^2} \le \liminf_{k\to\infty} d(a_{m(k)+1}, a_{n(k)+1}) \le \limsup_{k\to\infty} d(a_{m(k)+1}, a_{n(k)+1}) \le \varepsilon s^3.$$

In particular, if $s = 1$ and $\{a_n\}$ is not a *b*-Cauchy sequence, then there exists $\varepsilon > 0$ as well as two sequences $\{m(k)\}$ and $\{n(k)\}$ of positive integers such that the sequences

$$d(a_{m(k)}, a_{n(k)}), d(a_{m(k)}, a_{n(k)+1}), d(a_{m(k)+1}, a_{n(k)}) \text{ and } d(a_{m(k)+1}, a_{n(k)+1}) \quad (4)$$

tend to ε^+ as $k \to \infty$.

Main result

Now, according to the last Lemma (the condition $s = 1$), we formulate and prove the following result:

Theorem 5 Let (X, d) be a complete metric space and let f be a contractive self-mapping on X satisfying the next condition:

Given $\varepsilon > 0$, there exists $\delta > 0$ such that for all $x, y \in X$

$$\varepsilon \le d(x,y) < \varepsilon + \delta \text{ implies } d(fx, fy) \le \varepsilon. \quad (5)$$

Then f has a unique fixed point, say $u \in X$, and for each $x \in X$, $\lim_{n\to\infty} f^n x = u$.

Proof. Let x_0 in X be arbitrary. Consider the sequence of iterates $\{f^n x_0\}_{n=0}^{+\infty}$. If $d(f^n x_0, f^{n+1} x_0) = d(f^n x_0, ff^n x_0) = 0$ for some $n \in N$, then $a_n = f^n x_0$ is a fixed point of f. Assume now that $d(f^n x_0, f^{n+1} x_0) > 0$ for all $n \in N$. Since f is contractive, the sequence $\{d(f^n x_0, f^{n+1} x_0)\}_{n=0}^{+\infty}$ is strictly decreasing. Therefore, there exists the limit of this sequence, say ε, and $d(f^n x_0, f^{n+1} x_0) > \varepsilon$ for all $n \in N$. Assume that $\varepsilon > 0$. In this case, by hypothesis, there exists a suitable $\delta = \delta(\varepsilon) > 0$ such that (5) holds. From the definition of ε, it follows that there is $n \in N$ such that

$$\varepsilon \le d(f^n x_0, f^{n+1} x_0) < \varepsilon + \delta. \tag{6}$$

According to (5), we get that

$$d(ff^n x_0, ff^{n+1} x_0) = d(f^{n+1} x_0, f^{n+2} x_0) \le \varepsilon,$$

a contradiction. Therefore $\lim_{n\to\infty} d(f^n x_0, f^{n+1} x_0) = 0$.

Now we show that $\{f^n x_0\}_{n=0}^{+\infty}$ is a Cauchy sequence. If this is not the case, by applying Lemma 1.5 to the sequence $\{f^n x_0\}_{n=0}^{+\infty}$, we get that there exist $\varepsilon > 0$ and two sequences of positive integers $\{m(k)\}$ and $\{n(k)\}$ such that $n(k) > m(k) > k$, and sequences (4) tend to ε^+ as $k \to \infty$. Using the condition (5) with $x = a_{m(k)}, y = a_{n(k)}$ and the $\delta = \delta(\varepsilon) > 0$, ones obtains that there exists a positive integer l such that for each $k \ge l$, we have

$$\varepsilon \le d(a_{m(k)}, a_{n(k)}) = d(fa_{m(k)-1}, fa_{n(k)-1}) < \varepsilon + \delta \text{ implies } d(fa_{m(k)}, fa_{n(k)}) \le \varepsilon.$$

This contradicts the fact that

$$d(fa_{m(k)}, fa_{n(k)}) = d(a_{m(k)+1}, a_{n(k)+1}) \to \varepsilon^+ \text{ as } k \to \infty.$$

Hence, $\{f^n x_0\}_{n=0}^{+\infty}$ is a Cauchy sequence.

The proof is further as in (Ćirić, 2003) and (Meir & Keeler, 1969, pp.326-329).

To our knowledge, it is not known whether Meir-Keeler's and Ćiric's theorems hold in the context of a b-metric space. Also, there is no known example that confirms that conditions (1) or (2) or (3) holds in the context of *b*-metric spaces but that *f* does not have a fixed point.

However, with a stronger condition than (1), we have the positive result. Hence, our main result is the following:

Theorem 6 Let $(X, d, s>1)$ be a *b*-complete *b*-metric space and let f self-mapping on X satisfy the following condition:

Given $\varepsilon > 0$, there exists $\delta > 0$ such that

$$\varepsilon \le d(x, y) < \varepsilon + \delta \text{ implies } s^a d(fx, fy) < \varepsilon, \quad (7)$$

where $a > 0$ is given.

Then f has a unique fixed point, say $u \in X$, and for each $x \in X$, $\lim_{n\to\infty} f^n x = u$.

Proof. It is clear that for all $x, y \in X$ we obtain

$$d(fx, fy) \le kd(x, y), \quad (8)$$

where $k = \frac{1}{s^a} \in [0,1)$.

Let $a_0 \in X$ be an arbitrary point. Define the sequence $\{a_n\}$ by $a_{n+1} = fa_n$ for all $n \ge 0$. If $a_n = a_{n+1}$ for some *n*, then a_n is a fixed point (unique) of *f* and the results follows.

So, suppose that $a_n \ne a_{n+1}$ for all $n \ge 0$. From the condition (8), we obtain

$$d(a_n, a_{n+1}) \le kd(a_{n-1}, a_n). \quad (9)$$

Further, according to (Miculescu & Mihail, 2017, pp.1-11, Lemma 2.2.) we obtain that $\{a_n\}$ is a *b*-Cauchy sequence in a *b*-metric space (X, d). By the *b*-completeness of (X, d), there exists $u \in x$ such that

$$\lim_{n\to\infty} a_n = u. \quad (10)$$

Finaly, (8) and (10) imply that $fu = u$, i.e. *u* is a unique fixed point of *f* in *X*.

For the following facts and definitions, we refer to (Aghajani et al, 2014, pp.941-960), (Jovanović, 2016) and (Kirk & Shahzad, 2014) and the references therein.

Definition 2.1 Let f and g be self-mappings of a nonempty set X such that $f(X) \subset g(X)$. Let $x_0 \in X$ be an arbitrary point. Then $fx_0 \in g(X)$, so we can assume that $fx_0 = gx_1 = y_0$ (say) for some $x_1 \in X$. Again, $fx_1 \in g(X)$, so we can choose $x_2 \in X$ such that $fx_1 = gx_2 = y_1$ (say). Similarly, we can construct two sequences $\{x_n\}$ and $\{y_n\}$ such that $y_n = fx_n = gx_{n+1}$ for all $n \geq 0$. Here the sequence $\{y_n\}$ is called a corresponding Jungck sequence for the point $x_0 \in X$.

Definition 2.2 Let f and g be the self-mappings of a nonempty set X. If $z = fx = gx$ for some x in X, then x is called a coincidence point of f and g, and z is called a point of coincidence of f and g. The mappings f and g are called weakly compatible if they commute at their coincidence points.

Lemma 2.3 Let f and g be the weakly compatible self-maps of a nonempty set X. If f and g have a unique point of coincidence $z = fx = gx$, then z is the unique common fixed point of f and g.

Now, we announce the following result which generalizes Theorem 5 in several directions:

Theorem 7 Let $(X, d, s > 1)$ be a *b*-complete *b*-metric space and let $f, g : X \to X$ be two self-maps such that $f(X) \subset g(X)$, one of these two subsets of X being b-complete. Suppose the following conditions hold:

$$\text{for each } \varepsilon > 0 \text{ there exists } \delta > 0 \text{ such that}$$

$$\varepsilon \leq d(gx, gy) < \varepsilon + \delta \text{ implies } s^a d(fx, fy) < \varepsilon$$

$$\text{and } fx = fy \text{ whenever } gx = gy,$$

where $a > 0$ is given.

Then f and g have a unique point of coincidence, say $z \in X$. Moreover, for each $x_0 \in X$, the corresponding Jungck sequence $\{y_n\}$ can be chosen such that $\lim_{n\to\infty} y_n = z$. In addition, if f and g are weakly compatible, then they have a unique common fixed point.

Finally, we have an open question:

Prove or disprove the following:

- Let $(X, d, s>1)$ be a *b*-complete b-metric space and $f, g : X \to X$ be two given mappings such that $f(X) \subset g(X)$, one of these two subsets of X being *b*-complete. Assume that the following conditions hold:

for each $\varepsilon > 0$, there exists $\delta = \delta(\varepsilon) > 0$ such that $\varepsilon \le d(gx, gy) < \varepsilon + \delta$ implies $d(fx, fy) < \varepsilon$ and $fx = fy$, whenever $gx = gy$.

Then f and g have a unique point of coincidence, say $z \in X$. Moreover, if f and g are weakly compatible, then they have a unique common fixed point.

References

Aghajani, A., Abbas, M., & Roshan, J. 2014. Common fixed point of generalized weak contractive mappings in partially ordered b-metric spaces. *Mathematica Slovaca,* 64(4), pp.941-960. Available at: https://doi.org/10.2478/s12175-014-0250-6.

Bakhtin, I.A. 1989. The contraction principle in quasimetric spaces. *Funct. Anal,* 30, pp.26-37.

Chandok, S., Jovanovic, M., & Radenovic, S. 2017. Ordered b-metric spaces and Geraghty type contractive mappings. *Vojnotehnički glasnik/Military Technical Courier,* 65(2), pp.331-345. Available at: https://doi.org/10.5937/vojtehg65-13266.

Chifu, C., & Petruşel, G. 2017. Fixed point results for multivalued hardy-rogers contractions in b-metric spaces. *Filomat,* 31(8), pp.2499-2507. Available at: https://doi.org/10.2298/fil1708499c.

Czerwik, S. 1993. Contraction mappings in b-metric spaces. *Acta Math. Inform., Univ. Ostrav,* 1(1), pp.5–11. Available at: https://dml.cz/handle/10338.dmlcz/120469. Accessed: 10.10.2018.

Ćirić, Lj. 2003. *Fixed Point Theory: Contraction Mapping Principle*.Belgrade: Faculty of Mechanical Engineering.

Došenović, T., Pavlović, M., & Radenović, S. 2017. Contractive conditions in b-metric spaces. *Vojnotehnički glasnik/Military Technical Courier,* 65(4), pp.851-865. Available at: https://doi.org/10.5937/vojtehg65-14817.

Dubey, A.K., Shukla, R., & Dubey, R.P. 2014. Some fixed point results in b-metric spaces. *Asian J. Math. Appl.,* article ID ama0147.

Dung, N.V., & Hang, V.T.L. 2018. On The Completion Of b-Metric Spaces. *Bulletin of the Australian Mathematical Society,* 98(2), pp.298-304. Available at: https://doi.org/10.1017/s0004972718000394.

Faraji, H., & Nourouzi, K. 2017. A generalization of Kannan and Chatterjea fixed point theorem on complete b-metric spaces. *Sahand Communications in Mathematical Analysis (SCMA),* 6(1), pp.77-86. Available at: https://doi.org/10.22130/SCMA.2017.23831.

Jovanović, M., Kadelburg, Z., & Radenović, S. 2010. Common Fixed Point Results in Metric-Type Spaces. *Fixed Point Theory and Applications,* 2010, Article ID:978121. Available at: https://doi.org/10.1155/2010/978121.

Jovanović, M. 2016. *Contribution to the theory of abstract metric spaces*. Belgrade. Available at: http://nardus.mpn.gov.rs/handle/123456789/7975. Accessed: 10.10.2018.

Kir, M., & Kiziltunc, H. 2016. On Some Well Known Fixed Point Theorems in b-Metric Spaces. *Turkish Journal of Analysis and Number Theory,* 1(1), pp.13-16. Available at: https://doi.org/10.12691/tjant-1-1-4.

Kirk, W., & Shahzad, N. 2014. *Fixed Point Theory in Distance Spaces*. Switzerland: Springer International Publishing.

Koleva, R., & Zlatanov, B. 2016. On fixed points for Chatterjea's maps in b-metric spaces. *Turkish Journal of Analysis and Number Theory,* 4(2), pp.31–34. Available at: http://www.sciepub.com/TJANT/abstract/6009. Accessed: 10.10.2018.

Kumar, M.P., Sachdeva, S., & K. Banerjee, S. 2014. Some Fixed Point Theorems in b-metric Space. *Turkish Journal of Analysis and Number Theory,* 2(1), pp.19-22. Available at: https://doi.org/10.12691/tjant-2-1-5.

Meir, A., & Keeler, E. 1969. A theorem on contraction mappings. *Journal of Mathematical Analysis and Applications,* 28(2), pp.326-329. Available at: https://doi.org/10.1016/0022-247x(69)90031-6.

Miculescu, R., & Mihail, A. 2017. New fixed point theorems for set-valued contractions in b-metric spaces. *Journal of Fixed Point Theory and Applications,* 19(3), pp.2153-2163. Available at: https://doi.org/10.1007/s11784-016-0400-2.

Paunović, Lj., Kaushik, P., & Kumar, S. 2017. Some applications with new admissibility contractions in b-metric spaces. *The Journal of Nonlinear Sciences and Applications,* 10(08), pp.4162-4174. Available at: https://doi.org/10.22436/jnsa.010.08.12.

Singh, S.L., Czerwik, S., Krol, K., & Singh, A. 2008. Coincidences and fixed points of hybrid contractions. *Tamsui Oxf. J. Math. Sci.,* 24, pp.401-416.

Sintunavarat, W. 2016. Nonlinear integral equations with new admissibility types in b-metric spaces. *J. Fixed Point Theory Appl.,* 18(2), pp.397–416. Available at: https://doi.org/10.1007/s11784-015-0276-6.

Suzuki, T. 2017. Basic inequality on a b-metric space and its applications. *Journal of Inequalities and Applications,* 2017:256. Available at: https://doi.org/10.1186/s13660-017-1528-3.

Zare, K., & Arab, R. 2016. Common fixed point results for infinite families in partially ordered b-metric spaces and applications. *Electronic Journal of Mathematical Analysis and Applications,* 4(2), pp.56–67. Available at: http://math-frac.org/Journals/EJMAA/Vol4(2)_July_2016/Vol4(2)_Papers/06_EJMAA_Vol4(2)_July_2016_pp_56-67.pdf. Accessed: 15.10.2018.

ЗАМЕТКА О ТЕОРЕМЕ МЕИРА-КИЛЕРА В КОНТЕКСТЕ *b*-МЕТРИЧЕСКИХ ПРОСТРАНСТВ

Мирьяна В. Павлович[а], *Стоян* Н. Раденович[б]
[а] Университет в г. Крагуевац, Естественно-математический факультет, г. Крагуевац, Республика Сербия,
[б] Университет короля Сауда, Естественно-математический факультет, Департамент математики, Рияд, Саудовская Аравия

ОБЛАСТЬ: математика (математическая тематическая классификация: первичная 47H10, вторичная 54H25)
ВИД СТАТЬИ: оригинальная научная статья
ЯЗЫК СТАТЬИ: английский

Резюме:

В данной работе рассматривается знаменитая теорема Меира-Килера в контексте b-метрических пространств. Наш результат обобщает, улучшает, дополняет и объединяет ранее полученные результаты, которые были опубликованы в научной литературе. Наше доказательство намного короче и лучше, чем доказательства, представленные в иных работах (Ћирић, 2003) и (Meir & Keeler, 1969, pp.326-329).

Ключевые слова: b-метрическое пространство, b-полная система функций, b-Коши, условия Меира-Килера, последовательности Пикарда.

БЕЛЕШКА О MEIR-KEELER-OBOJ ТЕОРЕМИ У КОНТЕКСТУ *b*-МЕТРИЧКИХ ПРОСТОРА

Мирјана В. Павловић[а], *Стојан* Н. Раденовић[б]
[а] Универзитет у Крагујевцу, Природно-математички факултет, Крагујевац, Република Србија,
[б] Универзитет краља Сауда, Природно-математички факултет, Департман математике, Ријад, Саудијска Арабија

ОБЛАСТ: математика (математичка тематска класификација:
примарна 47H10, секундарна 54H25)
ВРСТА ЧЛАНКА: оригинални научни чланак
ЈЕЗИК ЧЛАНКА: енглески

Сажетак:

У овом раду разматрана је позната Meir-Keeler-ова теорема у контексту b-метричких простора. Наш резултат генерализује, побољшава, даје допринос, уједињује и обогаћује познате резултате у научној литератури. Такође, наш доказ Meir-Keeler-ове теореме у контексту стандардних метричких простора је много краћи и прикладнији него у радовима Ћирића, (2003) и Meir & Keeler-a (1969, pp.326-329).

Кључне речи: b-метрички простор, b-комплетан, b-Cauchy-јев, Meir-Keeler-ови услови, Picard-ов низ.

Paper received on / Дата получения работы / Датум пријема чланка: 18.10.2018.
Manuscript corrections submitted on / Дата получения исправленной версии работы / Датум достављања исправки рукописа: 26.11.2018.
Paper accepted for publishing on / Дата окончательного согласования работы / Датум коначног прихватања чланка за објављивање: 28.11.2018.

ASSESSMENT OF THE SINGLE SHOT HIT PROBABILITY AS A FUNCTION OF THE HORIZONTAL RANGE TAKING INTO ACCOUNT DIFFERENT TARGET TYPES AND POINTS OF AIM

Vadim L. Khaikov
independent researcher, Krasnodar, Russian Federation,
e-mail: wadimhaikow@inbox.ru,
ORCID iD: http://orcid.org/0000-0003-1433-3562

DOI: 10.5937/vojtehg67-18522; https://doi.org/10.5937/vojtehg67-18522

FIELD: Applied Mathematics, Operations Research
ARTICLE TYPE: Original Scientific Paper
ARTICLE LANGUAGE: English

Abstract:

This article presents a method for assessing the hit probability for stationary shooting targets as a function of the projectile horizontal range (PHR), the target type and the point of aim (POA) location. The proposed procedure consists of three blocks. Block I is devoted to the double integral formula taking into account changes in the point of impact (POI) location as a function of the PHR. The characteristics of bullet accuracy and precision versus the PHR are determined in block II. The basis of blocks I and II is the bi-variate uncorrelated Laplace-Gauss probability distribution. The functions of the POI location (ordinate/abscissa) versus the PHR and the functions of the characteristics of the bullet dispersion versus the PHR are represented in the form of polynomials. The description of the target silhouette contour is given in block III. Mathematically, the target contour is a piecewise function which defines the upper and lower edges of the shooting target and it also represents the limit for the double integral formula of block I. The proposed method is built on a modular basis and allows a user to change types of weapons and shooting targets. For demo calculations, the accuracy and precision characteristics of the 5.45×39 Kalashnikov assault rifle model MPi AK-74N were selected. Five types of Swiss military targets imitating an OPFOR combatant's silhouette were used as shooting targets. For illustrating the operability of the proposed method, the hit probabilities for the K, H, G, F, and E shooting targets were evaluated for the PHR from 50 to 400 m. All computations are implemented in the PTC Mathcad v.15.

Key words: hit probability, numerical solution, shooting target, double integrals, bullet dispersion, horizontal range, Mathcad.

Introduction

Estimation of the hit probability is an important part of the shooting effectiveness assessment (Rodney, 2012), (Svateev, 2013), (Svateev, 2014), (Peelen, 2017), (Wollschläger, 2017). In (Khaikov, 2018), we show how to estimate the single shot hit probability by shooting to a fixed target with an arbitrary contour form owing to a numerical solution of the double integral. During the calculation process, the following parameters are set: the position of the mean point of impact (*POI*) and the characteristics of the bullet dispersion ellipse. However, during firing, there is uncertainty about the horizontal range to the selected target; it is also necessary to have a priori information about the change in the hit probability for the interval from the minimum to the maximum distances.

Since the position of the dispersion center and the dispersion characteristics are the functions of the projectile horizontal range (*PHR*), the hit probability can be expressed as a function of the «target-shooter» distance[1].

The aim of this contribution is to show how to calculate the hit probability (P_{hit}) as a function of the *PHR* with respect to different target types and the location of the *POA*. As a result, we get not only one (or a point) estimation of the P_{hit} for a single (selected) value of the horizontal range, but also a change of this parameter within a certain distance interval. As in (Khaikov, 2018), all calculations will be implemented in the computer algebra system (*CAS*) Mathcad v.15.

In order to make the estimations original and more diverse, we will use here Swiss military targets and the external ballistics of the 5.45×39 Kalashnikov assault rifle model MPi AK-74N[2]. The information about this firearm can be found in (NVA der DDR, 1985), (TRADOC, 1975, 2015), (http://weaponland.ru, nd).

Creating a mathematical model

Let us assume that the attacking opposing force (*OPFOR*) is represented by running or lying combatants whose silhouettes can be replaced by plane (or 2D) shooting targets with a certain equivalent area[3]

[1] In this article, the expressions “the target-shooter distance“ and “the projectile horizontal range“ are synonymous.

[2] MPi AK-74N – (in German) Mashinenpistole-Automat Kalaschnikow AK-74 für Nachtsichtgerat. Assault rifles MPi AK-74N were manufactured on “VEB Fahrzeug und Waffenfabrik Ernst Thälmann“, Suhl (Thuringia).

[3] As a rule, shooting targets are a set of geometric primitives: rectangles, trapezoids, triangles, and squares.

(Fig. 1a). Human silhouette targets of different types are used for military and police firearms training. More schematized targets are applied for firearm sports competitions.

Let it be necessary to estimate the hit probability for several targets at the distances x_I, x_{II}, and x_{III} (Fig. 1b). All shooting targets at different distances are the same and in Fig. 1b they are rotated for 90 degrees counter-clockwise. The targets are rotated only for the simplicity of visualization.

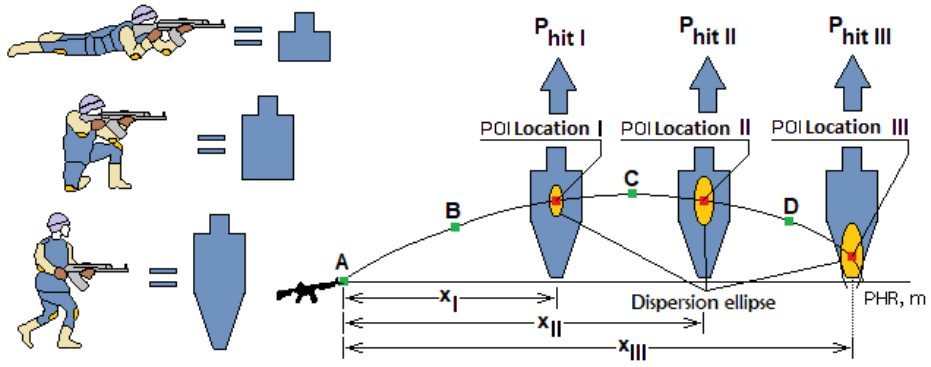


Figure 1 – Replacement of combatant silhouettes with shooting targets (a) and the change in the POI location and the characteristics of the dispersion ellipse as a function of the PHR (b)

Рис. 1 – Замена силуэтов комбатантов в виде стрелковых мишеней (а) и изменение местоположения СТП и характеристик эллипса рассеивания в зависимости от горизонтальной дальности «стрелок - мишень» (b)

Слика 1 – Замена силуета војника у облику мета за гађање (а) и промена локација тачака погодака (ТП) и карактеристика елипсе дисперзије у зависности од хоризонталног растојања између стрелца и мете (ХРМ) (б)

When firing at a shooting target, depending on the *PHR*, the mean bullet (ballistic) trajectory[4] will pass through the target or above (below) it (Fig. 1). The difference in the *PHR* between the shooter and the shooting target (x_I, x_{II}, x_{III}) determines the difference in the *POI* location and the constantly increasing parameters of the dispersion ellipse for each target. The location of the *POA* in Fig. 1 is not indicated.

[4] This trajectory is a projectile path obtained by theoretical calculation and agreed upon with experimental shooting tests. In this way, the mean ballistic trajectory (*MBT*) is the space curve near which the remaining trajectories are grouped taking into account the regularity of bullet dispersion.

Let us define that the shooting mode (single shots) and the aiming parameters are not changed by shooting. The ABCD curve (Fig. 1b) is the mean ballistic trajectory (*MBT)* with respect to the specified angle of departure (or number/clicks of sight) and the previously specified zero range. Uncertainty in the *PHR* magnitude is transformed into a vertical projectile dispersion at a chosen shooting target. Naturally, the hit probability value ($P_{hit\ I}$, $P_{hit\ II}$, $P_{hit\ III}$) will change with the variations of the *POI* location and with the change in the dispersion ellipse characteristics[5].

The mathematical model of the hit-probability vs the *PHR* will consist of three blocks. Block I will be devoted to the double integral formula taking into account the changes in the *POI* location and bullet dispersion. Block II will include the bullet dispersion characteristics vs the horizontal range. Finally, block III will describe the functions of a target silhouette contour.

Block I. This block of the mathematical model is based on the results of (Khaikov, 2018). If the *T* region (letter "*T*" means a target) is a plane figure, and the hit probability of random variables *Z* and *Y* is determined by the 2D uncorrelated Laplace-Gauss distribution $f(z,y)$, then the target hit probability is defined by formula (1) (Venttsel', 2006, p.196)

$$P\left[(Z,Y)\subset T\right]=\iint_{T} f(z,y)dzdy \tag{1}$$

where: *T* – the region of integration in the zy-plane; *z, y* – the Cartesian coordinates; σ_z, σ_y – the standard deviation of the continuous random variables *Z*, *Y*; m_z, m_y – the coordinates of the center of dispersion (the mean of *Z* and *Y*) or the *POI*, since it is the same one; $f(z,y)$ – the integrand and the uncorrelated bi-variate Laplace-Gauss distribution (2):

[5] The first important factor is the type of weapon and the type of cartridge used. In the second place, the *POI* location depends on the target type. For the pre-selected weapon, the cartridge and the shooting target, the *POI* location and the characteristics of the dispersion ellipse are the functions of the *PHR*. In the case under consideration, skills of the shooter and combat stress as psychophysical conditions are not taken into account.

$$f(z,y)=\frac{1}{2\pi\sigma_z\sigma_y}\exp\left(-\left[\frac{(z-m_z)^2}{2\sigma_z^2}+\frac{(y-m_y)^2}{2\sigma_y^2}\right]\right) \quad (2)$$

In (Khaikov, 2018, pp.739-756), it is shown that if the target silhouette is described by two functions (the function of the bottom contour line of the target $\varphi_1(z)$ and the function of the upper line of the target's contour) $\varphi_2(z)$ and two constants a and b ($a<b$), then the hit probability can be expressed as

$$P[(Z,Y)]=\int_a^b\int_{\varphi_1(z)}^{\varphi_2(z)}\frac{1}{2\pi\sigma_z\sigma_y}\exp\left(-\left[\frac{(z-m_z)^2}{2\sigma_z^2}+\frac{(y-m_y)^2}{2\sigma_y^2}\right]\right)dzdy. \quad (3)$$

If in formula (3) the constants m_z, m_y, σ_z, σ_y are transformed into functions that depend on the distance x "shooter – target" ($m_z(x)$, $m_y(x)$, $\sigma_z(x)$, $\sigma_y(x)$), we get a formula that realizes the transition from $P[(Z,Y)]$ to $P[(Z,Y,X)]$

$$P[(Z,Y,X)]=\int_a^b\int_{\varphi_1(z)}^{\varphi_2(z)}\frac{1}{2\pi\sigma_z(x)\sigma_y(x)}\exp\left(-\left[\frac{(z-m_z(x))^2}{2\sigma_z(x)^2}+\frac{(y-m_y(x))^2}{2\sigma_y(x)^2}\right]\right)dzdy. \quad (4)$$

The method of determining the functions $m_z(x)$, $m_y(x)$, $\sigma_z(x)$, and $\sigma_y(x)$ for the assault rifle MPi AK-74N will be described in block II.

Block II. Characteristics of $m_z(x)$, $m_y(x)$, $\sigma_z(x)$, $\sigma_y(x)$ functions.

The trajectories of the steel core bullet of the 5.45×39 Kalashnikov cartridge (bullet weight - 3.4 g; muzzle velocity - 960 m/s) under the line of departure and over/under the line of sight for mechanical sight from 1 to 10 are described in (NVA der DDR, 1985, pp.90-93) as tabulated data. Let us visualize this table and obtain the approximation formula (Fig. 2).

The data corresponding to sight number 3 (NVA der DDR, 1985, pp.90-93) can be approximated using a polynomial. As a result, we obtain the function

$$m_y=-0.029+1.969\cdot10^{-3}x-2.645\cdot10^{-6}x^2-1.192\cdot10^{-8}x^3, \quad (5)$$

where *x* is the *PHR* («shooter-target» distance) in meters (50 ≤ x ≤ 400 m) and m_y is the ballistic trajectory profile in meters for the sight setting 3 (position 3 for standard mechanical sight of the Kalashnikov assault rifle). The red curve in Fig. 2 shows the change of the *POI* height. At 50 m, shots will be about 6 centimeters=0.06 m high. The vertex of the flight path is 27.66 cm = 0.267 m, observed for the *PHR* 168.3 m (Fig. 2a). The zero distance is 300 m. Beyond 300 m (*PHR*>300 m), the bullet trajectory will drop rapidly to about 43 centimeters ≈ 0.427 m low at 400 m.

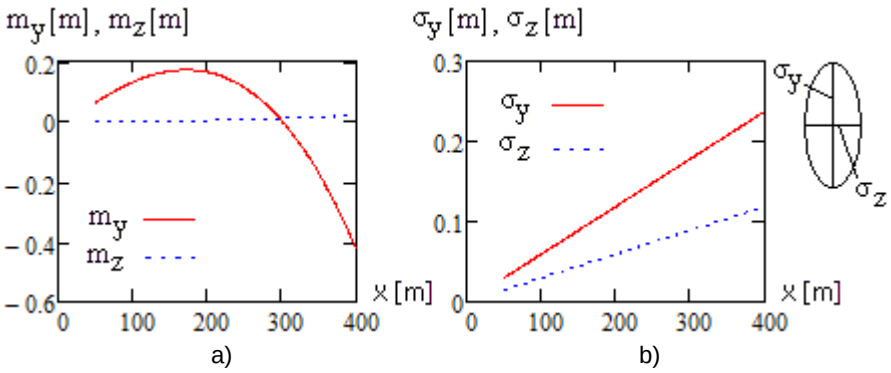


Figure 2 – Characteristics of the location of the center of dispersion (a) and the characteristics of the dispersion ellipse (b) as a function of the PHR
Рис. 2 – Характеристики положения центра рассеивания (а) и эллипса рассеивания (b) как функция дистанции до цели
Слика 2 – Карактеристике положаја центра дисперзије (а) и карактеристике елипсе дисперзије (б) у функцији растојања до мете

The right-hand bullet drift or the bias of the *POI* to the right side due to the bullet gyroscopic stabilization can be expressed by the polynomial model

$$m_z = -1.667 \cdot 10^{-5} x + 1.667 \cdot 10^{-7} x^2 , \quad (6)$$

where *x* is the *PHR* in meters (50 ≤ x ≤ 400 m) and m_z is the right-hand bullet drift in meters (the blue dotted curve in Fig. 2a).

The bullets dispersion in the vertical (σ_y) and the lateral directions (σ_z) in the form of standard deviation are expressed as two polynomial functions *PHR*-argument (Fig. 2b)

$$\sigma_y = 5.935 \cdot 10^{-4} x , \quad (7)$$

$$\sigma_z = 2.967 \cdot 10^{-4} x, \quad (8)$$

where x is the *PHR* in meters (50 ≤ x ≤ 400 m), and σ_y and σ_z represent the standard deviation in meters.

Thus, two functions ($\sigma_y(x)$ and $\sigma_z(x)$) determine the shape of the dispersion ellipse and two more, i.e. $m_y(x)$, $m_z(x)$, determine the locations of the dispersion center versus the *PHR* from 50 to 400 m.

In order to use formula (4), we need to determine the functions $\varphi_1(z)$, $\varphi_2(z)$ and the constants *a and b*.

Block III. Functions of the target silhouette contour $\varphi_1(z)$ and $\varphi_2(z)$.

Depending on an *OPFOR* combatant silhouette seen by a shooter, there are «head», «head-shoulders», «head-burst», «head-hip», and «man sized» military targets (Fig. 3)[6].

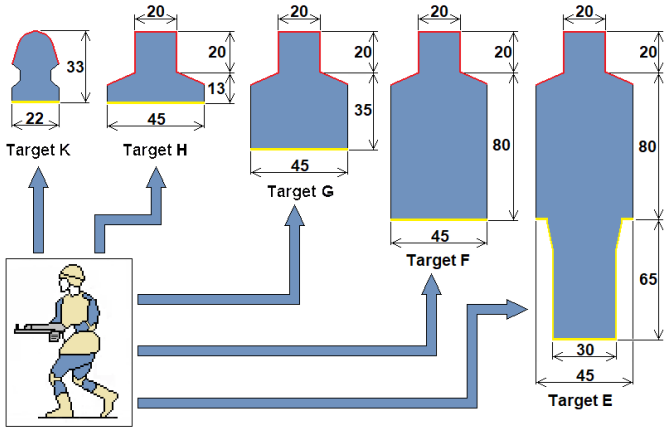


Figure 3 – Military shooting targets (cibles de campagne): K, H, G, F, and E
Рис. 3 – Армейские мишени K, H, G, F, E для стрельб
Слика 3 – Војне мете за гађање K, H, G, F и E

Among the five shooting targets, the *K* and *H* targets have the minimum height of 33 centimeters (0.33 m); conversely, the *E* target has the maximum height of 1.65 m. The target area is increased in the

[6] in comparison with Fig. 1, the number of types of targets in Fig. 3 was increased from 3 to 5. In different countries, shooting targets of the same type (for example, the *K* target «head in a protective helmet» or the *E* target «man sized target») may have different shapes and different geometric areas. These characteristics are determined in individual countries by their armed forces regulations.

direction from *K* to *E*. The *K, H, G, F,* and *E* human silhouette targets[7] are used in the armed forces of the Swiss Confederation for shooting training (http://www.wikiwand.com, nd).

The target contour can be designated in two ways (Khaikov, 2018, pp.739-756): in option I, the upper (lower) contour should be identified as the y(z) functions or, in option II, the right (left) contour should be identified as the z(y) curves. For all five targets in Fig. 3, the upper contour lines (*UCL*) are red, and the bottom counter lines (*BCL*) are yellow. If we consider the *UCL* of the target *K*, then we use the notation UCL_K. This procedure for the *BCL* of the target *E* is similar: BCL_E.

The geometry analysis and the contour lines identification for the *G* target are shown in Fig. 4. It is a flat shooting target which can be described as the ABCDEFGHIJ polygon. The *G* target has an axis of symmetry that passes through the EJ (Fig. 4a). The left side of the *G* target is the ABCDEJ polygon, and the right-hand side is the EFGHIJ polygon. The areas of these polygons are the same. The presence of the right-hand bullet drift causes the *POI* to be located on the right side (the red ellipse in Fig. 4b).

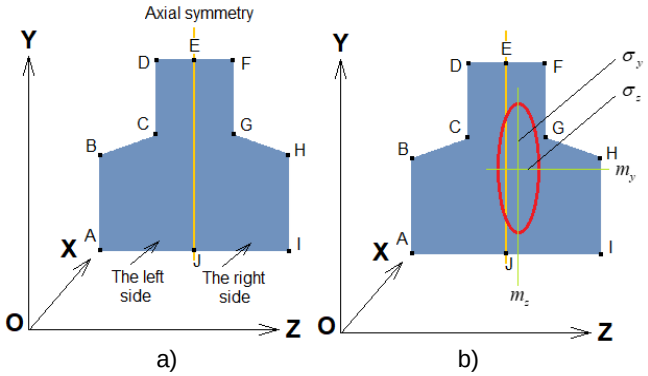


Figure 4 – Analysis of the geometry of the G shooting target (a). A location of the dispersion ellipse (b)
Рис. 4 – Анализ геометрии стрелковой мишени G (а). Положение эллипса рассеивания (b)
Слика 4 – Анализа геометрије мете за гађање G (а). Локација елипсе дисперзије (б)

[7] The following names are used for target designation (*in German*): Feldscheiben, Ordonanzscheiben, *K*-Sheibe, *G*-Sheibe, *H*-Sheibe, and so on.

Not taking into account the symmetry of the *G* target, its *UCL* can be described as the BCDEFGH line. When symmetry is taken into account, the geometric formula of the left-hand side is BCDE. Similar reasoning applies to the description of the *BCL*: AJI (without symmetry) and AJ (the left side of the figure with symmetry taken into account).

It is necessary to determine the coordinates of the vertices of the ABCDEFGHIJ polygon and to obtain an analytical expression of the sides of the *G* target. The coordinates of the points for the *G* target contour and its analytic functions are collected in Table 1.

Table 1 – Coordinates of the points for the G target contour line
Таблица 1 – Координаты точек контура мишени типа G
Табела 1 – Координате тачака контуре мете типа G

Points	Z, m	Y, m	Boundary points of line	Analytic function
A	-0.225	0.0	A-B	z(y)=-0.225
B	-0.225	0.302	B-C	y(z)= 0.384*z + 0.388
C	-0.1	0.35	C-D	z(y)=-0.1
D	-0.1	0.55	D-E	y(z)=0.55
E	0.0	0.55	E-F	y(z)=0.55
F	0.1	0.55	F-G	z(y)=0.1
G	0.1	0.35	G-H	y(z)= -0.384*z + 0.388
H	0.225	0.302	H-I	z(y)= 0.225
I	0.225	0.0	I-J	y(z)= 0
J	0.0	0.0	J-A	y(z)= 0
Notes: The coordinates of the points are given according to Fig. 3. The symmetry of points is shown with the orange and blue background. The locations of the vertices for the G target can be used in the analysis of the H target and the F target.				

The contour line (*CL*) $CL_G(z)$ of the *G* shooting target (the *UCL* (BCDEFGH) $UCL_G(z)$ and the *BCL* (AJI) $BCL_G(z)$) can be described by a piecewise function:

$$CL_{\mathrm{G}}(z)=\begin{cases} UCL_{\mathrm{G}}(z)=\begin{pmatrix} 0.384z+0.388 & -0.225\le z<-0.1 \\ 0.55 & -0.1\le z<0.1 \\ -0.384z+0.388 & 0.1\le z\le 0.225 \end{pmatrix} \\ BCL_{\mathrm{G}}(z)=\begin{pmatrix} 0 & -0.225\le z\le 0.225 \end{pmatrix} \end{cases}.$$

Since the geometry of the *G* target has an axis of symmetry (EJ axis) and if the *POI* lies on the EJ axis, then the hit probabilities for the

right and left parts are the same. If the *POI* location is not on the EJ axis, then the hit probabilities for the right and left parts of the *G* target are different. The side of the target where the *POI* is located has a higher hit probability. In view of the fact that the bullet gyroscopic stabilization causes a shift of the POI to the right, the right-hand side of the *G* target has a larger hit probability than the left one.

The coordinates of the points for the *H* target contour line are collected in Table 2.

Table 2 – Coordinates of the points for the H target contour line
Таблица 2 – Координаты точек контура мишени типа H
Табела 2 – Координате тачака контуре мете типа H

Points	Z, m	Y, m	Boundary points of line	Analytic function
A	-0.225	0.0	A-B	z(y)=-0.225
B	-0.225	0.082	B-C	y(z)= 0.384*z + 0.1684
C	-0.1	0.13	C-D	z(y)= -0.1
D	-0.1	0.33	D-E	y(z)=0.33
E	0.0	0.33	E-F	y(z)=0.33
F	0.1	0.33	F-G	z(y)=0.1
G	0.1	0.13	G-H	y(z)= -0.384*z + 0.168
H	0.225	0.082	H-I	z(y)= 0.225
I	0.225	0.0	I-J	y(z)= 0
J	0.0	0.0	J-A	y(z)= 0
Notes: The coordinates of the points are given according to Fig. 3. The symmetry of the points is shown with the orange and blue background.				

The analysis of Table 2 allows us to describe the contour needed for integrating the double integral (4) and determining the hit probability. The contour of the *H* shooting target (the *UCL* (BCDEFGH) and the *BCL* (AJI)) can be described by a piecewise function:

$$CL_{\text{H}}(z)=\begin{cases} UCL_{\text{H}}(z)=\begin{pmatrix} 0.384z+0.1684 & -0.225\le z<-0.1 \\ 0.33 & -0.1\le z<0.1 \\ -0.384z+0.1684 & 0.1\le z\le 0.225 \end{pmatrix} \\ BCL_{\text{H}}(z)=\begin{pmatrix} 0 & -0.225\le z\le 0.225 \end{pmatrix} \end{cases}.$$

The coordinates of the points for the *F* target contour line are presented in Table 3.

Table 3 – Coordinates of the points for the F target contour line
Таблица 3 – Координаты точек контура мишени типа F
Табела 3 – Координате тачака контуре мете типа F

Points	Z, m	Y, m	Boundary points of line	Analytic function
A	-0.225	0.0	A-B	z(y)=-0.225
B	-0.225	0.752	B-C	y(z)= 0.384*z + 0.838
C	-0.1	0.8	C-D	z(y)=-0.1
D	-0.1	1.0	D-E	y(z)=1.0
E	0.0	1.0	E-F	y(z)=1.0
F	0.1	1.0	F-G	z(y)=0.1
G	0.1	0.8	G-H	y(z)= -0.384*z + 0.838
H	0.225	0.752	H-I	z(y)= 0.225
I	0.225	0.0	I-J	y(z)= 0
J	0.0	0.0	J-A	y(z)= 0
Notes: The coordinates of the points are given according to Fig. 3. *The symmetry of the points is shown with the orange and blue background.*				

The contour of the *F* shooting target (the *UCL* (BCDEFGH) and the *BCL* line (AJI)) can be described by a piecewise function:

$$CL_{\mathrm{F}}(z)=\begin{cases} UCL_{\mathrm{F}}(z)=\begin{pmatrix} 0.384z+0.838 & -0.225\le z<-0.1 \\ 1.0 & -0.1\le z<0.1 \\ -0.384z+0.838 & 0.1\le z\le 0.225 \end{pmatrix} \\ BCL_{\mathrm{F}}(z)=\begin{pmatrix} 0 & -0.225\le z\le 0.225 \end{pmatrix} \end{cases}.$$

The coordinates of the points for the *E* target contour line are listed in Table 4.

Table 4 – E shooting target: coordinates of the points
Таблица 4 – Координаты точек контура мишени типа E
Табела 4 – Координате тачака контуре мете типа E

Points	Z, m	Y, m	Boundary points of line	Analytic function
A	-0.15	0.0	A-B	z(y)=-0.15
B	-0.15	0.4973	B-C	y(z)= -5.817*z - 0.375
C	-0.17625	0.65	C-D	y(z)=0.65
D	-0.225	0.65	D-E	z(y)=-0.225
E	-0.225	1.402	E-F	y(z)= 0.384*z + 1.488
F	-0.1	1.45	F-G	z(y)=-0.1
G	-0.1	1.65	G-H	y(z)=1.65

Points	Z, m	Y, m	Boundary points of line	Analytic function
H	0.0	1.65	H-I	y(z)=1.65
I	0.1	1.65	I-J	z(y)= 0.1
J	0.1	1.45	J-K	y(z)= -0.384*z + 1.488
K	0.225	1.402	K-L	z(y)=0.225
L	0.225	0.65	L-M	y(z)=0.65
M	0.17625	0.65	M-N	y(z)=5.817*z – 0.375
N	0.15	0.4973	N-O	z(y)=0.15
O	0.15	0.0	O-P	y(z)=0
P	0.0	0.0	P-A	y(z)=0
Notes: The coordinates of the points are given according to Fig. 3. The symmetry of the points is shown with the orange and blue background.				

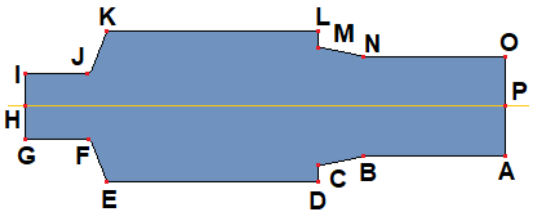


Figure 5 – Geometric analysis of the E target (turn 90° counterclockwise)
Рис. 5 – Геометрический анализ фигуры E (повёрнута на угол 90° против часовой стрелки)
Слика 5 – Геометријска анализа мете E (окренуте супротно од правца казаљке на сату за 90°)

The contour of the *E* shooting target (the *UCL* (EFGHIJK) and the *BCL* (DCBAPONML) (Fig. 5)) can be described by a piecewise function:

$$CL_{\mathrm{E}}(z)=\begin{cases} UCL_{\mathrm{E}}(z)=\begin{pmatrix} 0.384z+1.488 & -0.225\le z<-0.1 \\ 1.65 & -0.1\le z<0.1 \\ -0.384z+1.488 & 0.1\le z\le 0.225 \end{pmatrix} \\ BCL_{\mathrm{E}}(z)=\begin{pmatrix} 0.65 & -0.225\le z<-0.176 \\ -5.817z-0.375 & -0.176\le z<-0.15 \\ 0 & -0.15\le z<0.15 \\ 5.817z-0.375 & 0.15\le z<0.176 \\ 0.65 & 0.176\le z\le 0.225 \end{pmatrix} \end{cases}.$$

The *K* target has the smallest area. The silhouette and the geometry of the target are shown in Fig. 6.

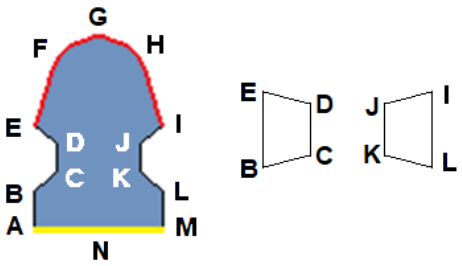


Figure 6 – Geometric constituent parts of the K target (see Fig. 3)
Фиг. 6 – Геометрические составляющие мишени К (см. рис. 3)
Слика 6 – Геометријски елементи мете К (видети слику 3)

The hit probability of this target can be found as an algebraic subtraction of the hit probabilities of its three domains

$$P_{hitK} = P_{hit}(ABEFGHILM) - P_{hit}(BEDC) - P_{hit}(KJIL) .$$

The coordinates of the vertices of the *K* target as a geometric figure and the analytical functions of its sides are collected in Table 5.

Table 5 – K shooting target: coordinates of the points
Таблица 5 – Координаты точек контура мишени типа К
Табела 5 – Координате тачака контуре мете типа К

Points	Z, m	Y, m	Boundary points of line	Analytic function
A	-0.11	0.0	A-B	z(y)=-0.11
B	-0.11	0.0652	B-C	y(z)= 0.795*z + 0.153
C	-0.0714	0.0959	C-D	z(y)=-0.0714
D	-0.0714	0.1458	D-E	y(z)= -0.795*z + 0.089
E	-0.11	0.1765	E-F	y(z)= 2.883*z + 0.494
F	-0.0714	0.2878	F-G	$y(z)= S_1(z)$
G	0.0	0.33	G-H	$y(z)= S_2(z)$
H	0.0714	0.2878	H-I	y(z)= -2.883*z + 0.494
I	0.11	0.1765	I-J	y(z)= 0.795*z + 0.089
J	0.0714	0.1458	J-K	z(y)=0.0714
K	0.0714	0.0959	K-L	y(z)= -0.795*z + 0.153
L	0.11	0.0652	L-M	z(y)=0.11
M	0.11	0.0	M-N	y(z)=0
N	0.0	0.0	N-A	y(z)=0
$S_1(z)$ = -57.9679*z^3 - 12.4167*z^2 + 0.33 z [-0.0714; 0]				
$S_2(z)$ = 57.9679*z^3 - 12.4167*z^2 + 0.33 z [0; 0.0714]				

The piecewise functions *CL* for the *K* target are determined below.

$$CL_{\text{all}}(z)=\begin{cases} UCL_{\text{all}}(z)=\begin{pmatrix} 2.883z+0.494 & -0.11\le z<-0.0714 \\ -57.9679z^3-12.4167z^2+0.33 & -0.0714\le z<0 \\ 57.9679z^3-12.4167z^2+0.33 & 0\le z<0.0714 \\ -2.883z+0.494 & 0.0714\le z<0.11 \end{pmatrix} \\ BCL_{\text{all}}(z)=(0 \quad -0.225\le z\le 0.225) \end{cases}$$

$$CL_{\text{BEDC}}(z)=\begin{cases} UCL_{\text{BEDC}}(z)=(-0.795\cdot z+0.089 \quad -0.11\le z\le -0.0714) \\ BCL_{\text{BEDC}}(z)=(0.795\cdot z+0.153 \quad -0.11\le z\le -0.0714) \end{cases}$$

$$CL_{\text{KJIL}}(z)=\begin{cases} UCL_{\text{KJIL}}(z)=(0.795\cdot z+0.089 \quad 0.0714\le z\le 0.11) \\ BCL_{\text{KJIL}}(z)=(-0.795\cdot z+0.153 \quad 0.0714\le z\le 0.11) \end{cases}$$

The sequence steps – the development of the calculation program in the *CAS* Mathcad will be described in the next section.

Calculation in the CAS Mathcad

The projectile horizontal range (in meters) is defined in the Mathcad as a range of variable *x* with the initial value of 50, the end value of 400 and the increment of 51 (the step size is 1 meter)

$$x:= 50, 51 .. 400 \quad .$$

The text below shows the usage of the variable range to define the values of the vectors σy and σz (eqs. 7 and 8) which characterize the bullet dispersion in the vertical and lateral directions

$$\sigma y_x:= 5.935\cdot 10^{-4}\cdot x ,$$
$$\sigma z_x:= 2.967\cdot 10^{-4}\cdot x ,$$

and the values of the vectors my and mz (eqs. 5 and 6) (which assign the *POI* location according to the *MBT* with the zero range at 300 meters)

$$my_x:=a -0.029 +1.969\cdot 10^{-3}\cdot x -2.645\cdot 10^{-6}\cdot x^2 -1.192\cdot 10^{-8}\cdot x^3 ;$$
$$a:=0 ; \qquad mz_x:= -1.667\cdot 10^{-5}\cdot x + 1.667\cdot 10^{-7}\cdot x^2 .$$

Using the constant a, the my vector can be displaced vertically in the up-down direction. If a>0, then the zero range increases (>300 m). Usually, a is equal to 0 (zero range = 300 m). Thus, the parameter a makes it possible to simulate the position of the *POA* along the height of the shooting target.

For each value of x, set the x^{th} element of the vector variables σy and σz, and my and mz with a corresponding value of x. The tables of numbers for the vector variables σy, σz and my, mz are of the same size. Each of them consists of 351 numbers. Using the variables sYi and sZi, we determine the center of the shooting target. For the *K* target, its center will be defined as (sYK, sZK). For the *H* target, as (sYH, sZH), and so on. The data on the position of the centers of the *K, H, G, F, and E* targets are shown in Table 6 (in meters).

Table 6 – Coordinates of the shooting target centers
Таблица 6 – Координаты центра стрелковых мишеней
Табела 6 – Координате центара мета за гађање

Number	Type (kind) of targets	Center height coordinates, m	Center coordinates in width, m
1	K	sYK= 0.165	sZK= 0
2	H	sYH= 0.165	sZH= 0
3	G	syG= 0.275	sZG= 0
4	F	syF= 0.5	sZF= 0
5	E	syE= 0.825	sZE= 0

For the *K* target, the following expression can be proposed:

$P_{hitK} = P_{hit}(ABEFGHILM) – P_{hit}(BEDC) – P_{hit}(KJIL) = P_{hit}A – P_{hit}L – P_{hit}R,$

here $P_{hit}(ABEFGHILM)$, $P_{hit}A$ – probability of hitting the ABEFGHILM domain as a function of the *PHR*; $P_{hit}(BEDC)$, $P_{hit}AL$ – probability of hitting the BEDC domain as a function of the *PHR*; $P_{hit}(KJIL)$, $P_{hit}R$ – probability of hitting the KJIL domain as a function of the *PHR*.

Due to the conditional operator if, the *UCL* and the *BCL* of the constituent elements for the *K* shooting target are defined as:

$$UCL_{all}(z) = \begin{pmatrix} 2.883z + 0.494 & if(-0.11 \le z < -0.0714) \\ -57.9679z^3 - 12.4167z^2 + 0.33 & if(-0.0714 \le z < 0) \\ 57.9679z^3 - 12.4167z^2 + 0.33 & if(0 \le z < 0.0714) \\ -2.883z + 0.494 & if(0.0714 \le z < 0.11) \end{pmatrix},$$

$$BCL_{\text{all}}(z)=(0 \quad if(-0.225\le z\le 0.225)),$$

$$UCL_{\text{BEDC}}(z)=(-0.795\cdot z+0.089 \quad if(-0.11\le z\le -0.0714)),$$
$$BCL_{\text{BEDC}}(z)=(0.795\cdot z+0.153 \quad if(-0.11\le z\le -0.0714)),$$

$$UCL_{\text{KJIL}}(z)=(0.795\cdot z+0.089 \quad if(0.0714\le z\le 0.11)),$$
$$BCL_{\text{KJIL}}(z)=(-0.795\cdot z+0.153 \quad if(0.0714\le z\le 0.11)).$$

The assessment of the hit probabilities of the elements of the *K* target is realized by the following formulas

$$Phit\_A_x := \int_{-0.225}^{0.225}\int_{BCL_{\text{all}}(z)}^{UCL_{\text{all}}(z)}\left[\frac{1}{2\pi\sigma z_x\sigma y_x}\cdot\exp\left[-\left[\frac{[z-mz_x]^2}{2(\sigma z_x)^2}+\frac{[y-my_x]^2}{2(\sigma y_x)^2}\right]\right]\right]dydz$$

$$Phit\_L_x := \int_{(-0.11)}^{(-0.0714)}\int_{(0.795\cdot z+0.153)}^{(-0.795\cdot z+0.089)}\left[\frac{1}{2\pi\sigma z_x\sigma y_x}\cdot\exp\left[-\left[\frac{[z-mz_x]^2}{2(\sigma z_x)^2}+\frac{[y-my_x]^2}{2(\sigma y_x)^2}\right]\right]\right]dydz$$

$$Phit\_R_x := \int_{(0.11)}^{(0.0714)}\int_{(0.795\cdot z+0.153)}^{(-0.795\cdot z+0.089)}\left[\frac{1}{2\pi\sigma z_x\sigma y_x}\cdot\exp\left[-\left[\frac{[z-mz_x]^2}{2(\sigma z_x)^2}+\frac{[y-my_x]^2}{2(\sigma y_x)^2}\right]\right]\right]dydz$$

For the *UCL* of the *H*, *G* and *F* target silhouettes, there are the expressions

$$UCL_H(z):=\begin{vmatrix}(0.384z+0.1684) & if(-0.225\le z<-0.1)\\ (0.33) & if(-0.1\le z<0.1)\\ (-0.384z+0.1684) & if(0.1\le z\le 0.225)\end{vmatrix},$$

$$UCL_G(z):=\begin{vmatrix}(0.384z+0.388) & if(-0.225\le z<-0.1)\\ (0.55) & if(-0.1\le z<0.1)\\ (-0.384z+0.388) & if(0.1\le z\le 0.225)\end{vmatrix},$$

$$UCL_F(z) := \begin{vmatrix} (0.384z + 0.838)\ \ if\,(-0.225 \le z < -0.1) \\ (1.0)\ \ if\,(-0.1 \le z < 0.1) \\ (-0.384z + 0.838)\ \ if\,(0.1 \le z \le 0.225) \end{vmatrix} .$$

Finally, the *UCL* ($UCL_E(z)$) and the *BCL* ($BCL_E(z)$) of the *E* target silhouettes are designed by the formula:

$$UCL_E(z) := \begin{vmatrix} (0.384z + 1.488)\ \ if\,(-0.225 \le z < -0.1) \\ (1.65)\ \ if\,(-0.1 \le z < 0.1) \\ (-0.384z + 1.488)\ \ if\,(0.1 \le z \le 0.225) \end{vmatrix} .$$

$$BCL_E(z) := \begin{vmatrix} (0.65)\ \ if\,(-0.225 \le z < -0.176) \\ (-5.817z - 0.375)\ \ if\,(-0.176 \le z < -0.15) \\ (0)\ \ if\,(-0.15 \le z < 0.15) \\ (5.817z - 0.375)\ \ if\,(0.15 \le z < 0.176) \\ (0.65)\ \ if\,(0.176 \le z \le 0.225) \end{vmatrix} ,$$

The hit probability assessment for the *H* target is

$$P_{hit\_H_x} := \int_{-0.225}^{0.225} \int_{0}^{UCL_H(z)} \left[\frac{1}{2\pi\sigma z_x \sigma y_x} \cdot \exp\left[-\left[\frac{[z - mz_x]^2}{2(\sigma z_x)^2} + \frac{[y - my_x]^2}{2(\sigma y_x)^2} \right] \right] \right] dydz .$$

The formulas for the *G* and *F* targets are given in the appendix of this paper. The hit probability assessment for the *E* target is

$$P_{hit\_E_x} := \int_{-0.225}^{0.225} \int_{BCL_E(z)}^{UCL_E(z)} \left[\frac{1}{2\pi\sigma z_x \sigma y_x} \cdot \exp\left[-\left[\frac{[z - mz_x]^2}{2(\sigma z_x)^2} + \right. \right. \right.$$

$$+\frac{\left[y-my_x\right]^2}{2\left(\sigma y_x\right)^2}\Bigg]\Bigg]\Bigg]dydz \quad .$$

Results of the calculation

The curves characterizing the hit probabilities functions of five different types of targets (*K, H, G, F, and E*) that were determined using the *MBT* (5) are shown in Fig. 7. The space under the curve in the interval 50-400 m is highlighted in yellow. For all five targets, the *POA* (red square) was the same location – the middle of the *BCL*. The shooting conditions were considered to be ideal.

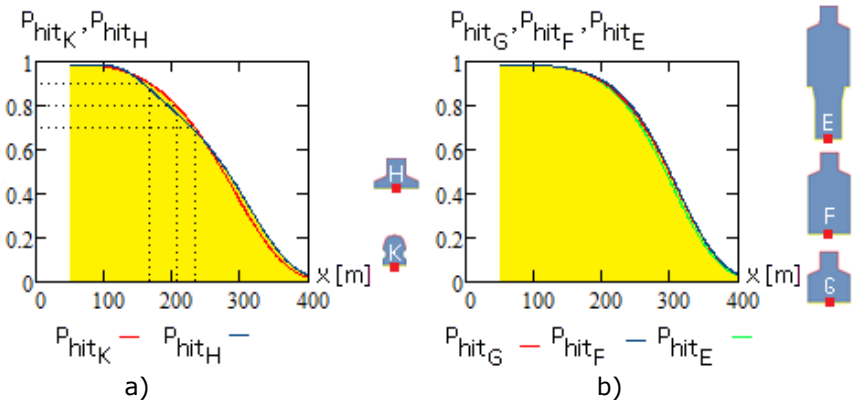


Figure 7 – Hit probability vs the PHR for the K and H targets (a) and the G, F, and E targets (b) for the range of 50-400 m
Рис. 7 – Функции вероятности попадания в мишени K, H и мишени G, F, E для дистанций 50-400 м
Слика 7 – Функције вероватноће погодака мета K, H и мета G, F, E на растојању од 50 до 400 м

The hit probability change vs the *PHR* for all five targets is a classical decreasing curve (Shereshevskiy et al, 1979). The dashed lines in Fig. 7a show the ranges that correspond to the hit probabilities of 0.9, 0.8, and 0.7 for the *K* target.

Changing the shape for the hit probability vs the *PHR* with respect to the *F* target and the location of the *POA* (red square) is shown in Fig. 8.

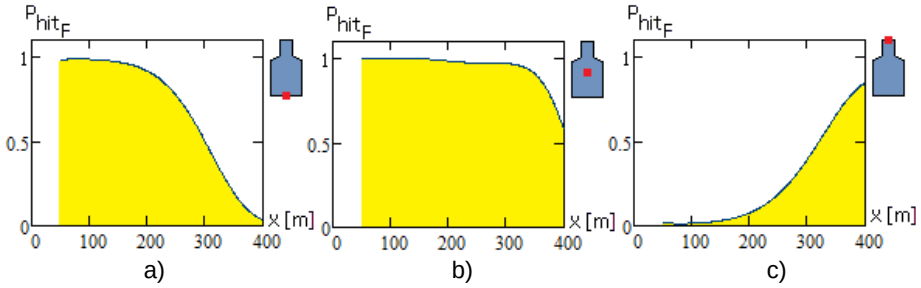


Figure 8 – Hit probability vs the location of the POA for the F target for the range of 50-400 m
Рис. 8 – Вероятности попадания в мишени F для дистанций 50-400 м и положения точки прицеливания
Слика 8 – Вероватноће погодака мете F на растојању од 50 до 400 м и положаја тачке нишањења

Fig. 8 shows that if the range to the shooting target is 200 meters and if the *POA* is positioned on the *BCL* (see the red square as the graphical symbol), then the hit probability is 0.92 (Fig 8a). If the *POA* is 0.5 m higher, then the hit probability for the *PHR*=200 m is increased to be 0.98 (Fig. 8b). If the *POA* is increased to 1.0 meters, then the hit probability decreases to 0.08. Thus, if the distance to the shooting (real) target is known as well as the target geometric dimensions and the ballistic characteristics of the bullet flight path (*MBT* and bullet dispersion), the *POA* determining algorithm for a remote weapon station of a ground combat vehicle can be proposed.

Conclusions and Implications

This paper represents a method for assessing the single shot hit probability for a stationary (fixed) shooting target as a function of the *PHR,* the selected target type and the location of the *POA*. The proposed procedure has three blocks. The proposed method is built on a modular basis and allows a user to change types of weapons and types of shooting targets.

The single shot hit probability depends on five variables: height of the *POI*; lateral displacement of the *POI* relative to the target; bullet dispersion in the height (vertical direction); lateral bullet dispersion (horizontal direction); and the forms of the shooting target contour. To order these variables, three auxiliary quantities can be introduced. These are the projectile horizontal range (*PHR*), the altitude of the point of aim

and the lateral displacement of the point of aim. The last two variables can be combined into the «*POA* location».

For demo calculations, the external ballistics and the bullet dispersion characteristics of the 5.45×39 Kalashnikov assault rifle model MPi AK-74N were selected. Five types of Swiss military targets imitating *OPFOR* combatant silhouettes were used as shooting targets. For illustrating the operability of the proposed method, the hit probability for the *K, H, G, F,* and *E* shooting targets was evaluated as well as for the *PHR* from 50 to 400 m. The calculations have shown that the *PHR* and the form of the target cause a complex dependence between the P_{hit} and the shooter-target distance.

The developed mathematical model can be used in tactical computer interactive simulators that emulate combat situations of a tactical strike. Likewise, the proposed mathematical models of shooting targets can be used for improving digital target range simulators or in fire-control systems of remote weapon stations.

Appendix

Formulas for the hit probability assessment of some shooting targets

The hit probability P_{hit} vs the *PHR* for the *G* and *F* targets can be expressed as

$$P_{hit\_G_x} := \int_{-0.225}^{0.225} \int_{0}^{UCL_G(z)} \left[\frac{1}{2\pi\sigma z_x \sigma y_x} \cdot \exp\left[-\left[\frac{[z - mz_x]^2}{2(\sigma z_x)^2} + \frac{[y - my_x]^2}{2(\sigma y_x)^2} \right] \right] \right] dydz \ ;$$

$$P_{hit\_F_x} := \int_{-0.225}^{0.225} \int_{0}^{UCL_F(z)} \left[\frac{1}{2\pi\sigma z_x \sigma y_x} \cdot \exp\left[-\left[\frac{[z - mz_x]^2}{2(\sigma z_x)^2} + \frac{[y - my_x]^2}{2(\sigma y_x)^2} \right] \right] \right] dydz \ .$$

References

http://weaponland.ru/load/avtomat_shturmovaja_vintovka_serii_mpi_k_mpi_ak/10-1-0-31. (in Russian). Accessed: 20.06.2018.

http://www.wikiwand.com/en/Shooting_target. Accessed: 20.06.2018.

Khaikov, V.L. 2018. Single shot hit probability estimation as a result of a numerical solution of double integrals using Mathcad. *Vojnotehnički glasnik/Military Technical Courier*, 66(4), pp.739-756. Available at: https://doi.org/10.5937/vojtehg66-17433.

*-NVA der DDR. 5.45-mm-Maschinenpistole AK74 und leichtes Maschinengewehr RPK74. Beschreibung und Nutzung*1985 (in German).

Peelen, J. 2017. *There is more to short barrels than just velocity*. [Internet]. Available at: www.quarryhs.co.uk/shortbarrel2.pdf. Accessed: 20.06.2018.

Rodney, S. 2012. RPG encounter modeling. *SURVIAC Bulletin,* 27(1), pp.1-5.

Svateev, V.A. 2013. Avtomatchik dolzhen i mozhet porazhat' golovnuyu figuru. *Bulletin of the Academy of Military Sciences*, 43(2), pp.127-131 (in Russian). (In the original: Сватеев В.А. 2013. Автоматчик должен и может поражать головную фигуру, *Вестник академии военных наук,* №.2(43). С.127-131).

Svateev, V.A. 2014. Tochniy sposob raschota veroyatnosti popadaniya v figurnuyu tsel'. *Bulletin of the Academy of Military Sciences*, 49(4), pp.61-66 (in Russian). (In the original: Сватеев В.А. 2014. Точный способ расчёта вероятности попадания в фигурную цель, *Вестник Академии военных наук*. 2014. Т.49, № 4. С.61-66.)

-TRADOC. 1975. *Range and lethality of US and Soviet anti-armor weapons*.

-TRADOC. 2015. *Worldwide Equipment Guide, Ground Systems*. Vol. 1.

Venttsel' Ye.S. 2006. *Teoriya veroyatnostey*. Moscow: Vysshaya shkola (in Russian). (In the original: Вентцель Е.С. 2006. *Теория вероятностей*. Москва: Высшая школа).

Wollschläger, D. 2017. *Analyzing shape, accuracy, and precision of shooting results with shotGroups*. [Internet] Available at: https://cran.r-project.org/web/packages/shotGroups/vignettes/shotGroups.pdf. Accessed: 20.06.2018.

МЕТОДИКА ОЦЕНКИ ВЕРОЯТНОСТИ ПАПАДАНИЯ ОДИНОЧНЫМ ВЫСТРЕЛОМ КАК ФУНКЦИЯ ГОРИЗОНТАЛЬНОЙ ДАЛЬНОСТИ С УЧЁТОМ ВИДА СТРЕЛКОВОЙ МИШЕНИ И ПОЛОЖЕНИЯ ТОЧКИ ПРИЦЕЛИВАНИЯ

Вадим Л. Хайков,
независимый исследователь, г. Краснодар, Российская Федерация

ОБЛАСТЬ: прикладная математика, исследование операций
ВИД СТАТЬИ: оригинальная научная статья
ЯЗЫК СТАТЬИ: английский

Резюме:

Оценка вероятности попадания является важной частью процедуры анализа эффективности стрельбы. В статье предложен метод оценки вероятности попадания в статическую стрелковую мишень как функция горизонтальной дальности до мишении (ГДМ), её типа и положения точки прицеливания. Предлагаемая процедура оценки состоит из трех частей. Часть I посвящена двойной интегральной формуле с учётом изменений в местоположении средней точки попадания (СТП) на поверхности мишени в зависимости от ГДМ. Характеристики дисперсии пуль в зависимости от ГДМ определены в части II. Основой части I и части II является двумерное некоррелированное распределение вероятностей Лапласа-Гаусса. Как правило, функции ординат (абсцисс) СТП от аргумента ГДМ и функции ординат (абсцисс) рассеивания пули как функции ГДМ представлены в виде классических полиномов. В части III даётся описание контура мишени. В математическом плане контур цели является кусочной функцией, которая описывает верхний и нижний края стрелковой мишени, а во-вторых, контур цели в формуле двойного интеграла выступает как предел интегральной формулы части I. Все вычисления реализованы в PTC Mathcad. Предлагаемый метод построен на модульной основе и позволяет пользователю изменять типы оружия и виды мишеней. Для демонстрационных расчётов использованы данные характеризующие внешнюю баллистику и характеристики рассеивания 5.45×39 автомата Калашникова. В качестве рассматриваемой модели автомата была выбрана MPi AK-74N. В качестве стрелковых мишеней использовались пять видов швейцарских армейских мишеней, которые имитируют различные части силуэта комбатанта. Для иллюстрации работоспособности предложенного метода оценена вероятность попадания в мишени K, H, G, F, E и для диапазона ГДМ от 50 до 400 м.

Ключевые слова: вероятность попадания, численное решение, стрелковая мишень, двойной интеграл, рассеивание пуль, горизонтальная дальность, Mathcad.

ОДРЕЂИВАЊЕ ВЕРОВАТНОЋЕ ПОГОТКА ЈЕДНИМ ХИЦЕМ У ЗАВИСНОСТИ ОД ХОРИЗОНТАЛНЕ РАЗДАЉИНЕ, РАЗЛИЧИТИХ ВРСТА МЕТА И ПОЛОЖАЈА ТАЧКЕ НИШАЊЕЊА

Вадим Л. Хајков
независни истраживач, Краснодар, Руска Федерација

ОБЛАСТ: примењена математика, операциона истраживања
ВРСТА ЧЛАНКА: оригинални научни чланак
ЈЕЗИК ЧЛАНКА: енглески

Сажетак:

У чланку је представљена метода за одређивање вероватноће поготка стационарних мета у зависности од хоризонталног растојања до мете (ХРМ), врсте мете и локације тачке циља. Предложени поступак састоји се од три блока. Први блок се бави формулом двоструког интеграла која узима у обзир промене у локацији тачке поготка у зависности од ХРМ. Карактеристике дисперзије метка, у зависности од ХРМ, одређују се у другом блоку. Биваријантна некорелисана Гаус- Лапласова расподела вероватноће узета је за основ прва два блока. Функције локације тачке циља (ордината/апциса) у зависности од ХРМ и функције карактеристика дисперзије погодака у зависности од ХРМ приказане су у облику полинома. У трећем блоку наведен је опис контура силуета мета. У математичком смислу, контура мете је хибридна функција која дефинише горње и доње ивице мете и, такође, представља границу формуле двоструког интеграла првог блока. Сви прорачуни су се вршили у PTC Mathcad. Предложени метод заснован је на модуларном принципу и омогућава кориснику да мења врсте оружја и мета. За илустрацију је изабран приказ израчунавања карактеристика дисперзије поготка који је постигнут из аутоматске пушке „калашњиков", калибра 5.45×39, модел MPi AK-74N. За мете је изабрано пет типова швајцарских војних мета које имитирају различите делове силуете војника. Операбилност предложеног метода илустрована је одређивањем вероватноћа погађања мета K, H, G, F и E на удаљености од 50 до 400 м.

Кључне речи: вероватноћа поготка, нумеричко решавање, мета за гађање, двоструки интеграли, дисперзија погодака, хоризонтално растојање, Mathcad.

Paper received on / Дата получения работы / Датум пријема чланка: 06.08.2018.
Manuscript corrections submitted on / Дата получения исправленной версии работы / Датум достављања исправки рукописа: 26.11.2018.
Paper accepted for publishing on / Дата окончательного согласования работы / Датум коначног прихватања чланка за објављивање: 28.11.2018.

CHARACTERIZATION OF NiO NANOPARTICLES PREPARED USING GELATIN AND A LOW-COST SYNTHESIS

Violeta N. Nikolić[a], *Martina* D. Gilić[b], *Vojislav* V. Spasojević[c]

[a] University of Belgrade, Vinča Institute of Nuclear Sciences, Department of Theoretical Physics and Condensed Matter Physics, Belgrade, Republic of Serbia,
e-mail: violeta@vin.bg.ac.rs,
ORCID iD: https://orcid.org/0000-0002-5685-3219

[b] University of Belgrade, Institute of Physics, Department of research in the field of electronic materials, Belgrade, Republic of Serbia,
e-mail: martina@ipb.ac.rs,
ORCID iD: https://orcid.org/0000-0002-5715-7717

[c] University of Belgrade, Vinča Institute of Nuclear Sciences, Department of Theoretical Physics and Condensed Matter Physics, Belgrade, Republic of Serbia,
e-mail: vojas@vin.bg.ac.rs,
ORCID iD: http://orcid.org/0000-0002-6134-8989

DOI: 10.5937/vojtehg67-18535; https://doi.org/10.5937/vojtehg67-18535

FIELD: Chemical Technology
ARTICLE TYPE: Original Scientific Paper
ARTICLE LANGUAGE: English

Summary:

Nanocomposite material containing NiO nanoparticles decorated on WO_3 nanowires could be used for monitoring levels of H_2S gas. The effectiveness of this material is mostly determined by NiO properties. The performed study presents the first stage in the preparation of modified NiO/WO_3 nanocomposite material. In this article, NiO nanoparticles are prepared by a simple, low-cost method.The behavior of nano-sized NiO particles is probed by X-ray diffraction, Fourier transform Infrared Spectroscopy, Raman spectroscopy, and hysteretic measurement.

Key words: NiO, diffraction measurements, spectroscopy, nanoparticles, materials.

ACKNOWLEDGMENT: This work has been supported by the Ministry of Education, Science and Technological Development of the Republic of Serbia (2011-2018), under Grant No. III 45015.

Introduction

Transition metal (Fe, Co, Ni and Mn) oxide nanoparticles have been thoroughly examined in recent years due to discoveries of new applications of these materials (Sellmyer et al, 2001), (Jana et al, 2004), (Nikolić et al, 2016), (Nikolić et al, 2017), which is enabled by their modified properties that are significantly improved in comparison to bulk materials. Today, NiO nanoparticles are intensively investigated because of their various potential applications in different industries.

Nickel oxide materials are recognized as interesting for usage in catalytic reactions in industrial processes and electrochromic devices (Salimi et al, 2017), (You et al, 2003), (Xing et al, 2004), (Kamal et al, 2005), (Lee et al, 2014). One of potential applications of NiO nanoparticles in this field presents the fabrication of a glucose biosensor based on the electrochemical co-deposition of NiO and GOx (glucose oxidase) onto the surface of the GC (glucose consumption) electrode (Salimi et al, 2017). Further, the investigation of the influence of the NiO properties on the electrochemical properties of NiO/reduced graphene oxide-based supercapacitor electrodes is of importance for designing high performance energy storage devices constructed from materials with limited conductivity (Lee et al, 2014).

It is noteworthy that the examination of the properties of composite materials containing NiO nanoparticles could contribute to the development of inexpensive resistive sensors able to monitor the presence of H_2S in the environment, which is of significance for military industry. Jeffrey pointed to many potential hazards for workers involved in operation and maintenance of water and wastewater treatment systems (Jeffrey, 2015). Workers in navy air forces are often faced with the problem of the presence of explosive gases (such as methane (CH_4), carbon monoxide (CO) and hydrogen sulfide (H_2S)). In combination with the air and a spar, the mentioned gases are prone to strong explosions that could lead to significant damage in confined spaces (tanks, underground lift stations, manholes) (Jeffrey, 2015). Also, it is important to notice that in wastewater treatment systems, H_2S gas is present more often than any other hazardous gas (Jeffrey, 2015). After longer exposure, workers experience over-stimulation of all sensors and are not capable of registering H_2S odor. With the aim to overcome the mentioned problem, scientific community have performed more detailed research in H_2S sensors properties; literature data show that the behavior of H_2S sensors varies depending on the properties of material used for their construction (Rout et al, 2008), (Lin et al, 1994), (Wang et al, 2008),

(Kapse et al, 2008), (MalekAlaie et al, 2015). Navarrete et al. found that tungsten oxide (WO_3) nanowires decorated with NiO nanoparticles could be applied onto substrates for developing resistive metal oxide gas sensors (Navarrete et al, 2018). These nanocomposite materials showed increased sensitivity and selectivity to H_2S, and achieved a five-fold increase in the response, which is ascribed to the NiO high chemical adsorption effect as well as to the high electronic sensitization effect (NiO nanoparticles become metallic Ni_xS_x upon exposure to H_2S).

The well-known gas sensing properties of the material consisting of nickel oxide (NiO) nanoparticles decorating tungsten oxide (WO_3) nanowires are significantly dependent on the properties of both present phases: NiO and WO_3 nanostructures. Although Navarrete et al obtained the mentioned material by performing a two-step synthesis (the first step presented the formation of pure tungsten oxide nanowires, and the second step considered loading these wires with 2 nm-sized NiO nanoparticles) (Navarrete et al, 2018), experience with other nanomaterials has revealed that the same material could be characterized by different properties if it is obtained by the modified synthesis procedure (Milić et al, 2017). Navarrete started the synthesis from expensive nickel(II)acetylacetonate (Navarrete et al, 2018) that is not appropriate for industry usage since industry always looks for low-cost solutions. One of potential synthesis approaches for the production of NiO/WO_3 nanocomposite material is to change the synthesis route performed for the preparation of NiO nanoparticles in order to estimate the best candidate for the discussed purpose.

Also, the literature review has revealed that it is not clear how variations in the size of NiO nanoparticles influence their chemical and electronic sensitization properties to H_2S. In Ref. (Navarrete et al, 2018), it is shown that the increased sensitivity and selectivity to H_2S is achieved by using 2 nm NiO nanoparticles. Having in mind that nanoparticles lower in size than 10 nm show different behavior compared to the nanoparticles of the same chemical composition but bigger in size (which is a consequence of more pronounced surface effects (Alkilany et al, 2009), (Cheng et al, 2006), (Kossyrev et al, 2005), (Müller et al, 2005), (Tramsdorf et al, 2007), it is difficult to predict whether NiO nanoparticles bigger than 10 nm will experience higher or lower sensitivity to H_2S gas detection, and this still has not been investigated in literature.

In order to investigate suitability of bigger NiO nanoparticles (~ 40 nm) for the detection of H_2S, this article presents the synthesis of NiO nanoparticles by a simple and low-cost coprecipitation method. This investigation is the first stage in the preparation of NiO/WO_3

nanocomposite material whose sensitivity and selectivity for H_2S will be investigated further in the future.

The characterization of the prepared NiO phase was performed by several techniques. X-ray diffraction (XRD) measurements were done by a Rigaku RINT-TTRIII using CuKα (λ = 1.5418 A). Diffraction patterns were recorded in the 2θ range (10-70°) with a scanning rate of 0.02 °/min. The Qualx Program was used for data analysis. Pure NiO nanoparticles were further investigated by Fourier transform infrared spectroscopy (Nicolet IS 50 FTIR Spectrometer, using the attenuated total reflectance (ATR) sampling technique). Raman spectroscopy was performed by micro Raman and the results analyzed using a Jobin–Yvon T64000 spectrometer equipped with a nitrogen cooled charge-coupled device detector. The measurement was done at 20 mW, using 532 nm green line as the excitation source, and the spectrum was recorded in back scattering geometry. Hysteretic measurement of the sample was carried out using a Quantum Design superconducting quantum interference device (SQUID). Hysteresis was recorded in a temperature range of 2 - 300 K for the applied magnetic fields from -50 to +50 kOe.

Experimental results and discussion

Synthesis of the samples

Two samples were prepared by a combination of the coprecipitation method and the annealing treatment (Maia et al, 2006). 6.365 g of nickel (II) chloride ($NiCl_2 \cdot 6H_2O$) and 15.913 g of commercial colorless gelatin were dissolved in 636 ml of distilled H_2O. The solution was magnetically stirred for 10 minutes at 40 °C and subsequently kept at 80 °C for several days. The obtained gel was annealed at 700 °C for 30 minutes. When the annealing process was completed, green powder was rinsed several times with distilled water. Finally, the excess of water was evaporated.

Another sample was obtained in the same way, with the only difference that sodium hydroxide (2.2 g of NaOH dissolved in a small amount of water) was poured into the stirring solution. The sample was further subjected to the identical procedure. After the annealing treatment, the obtained powder was green and its surface was covered by a thin layer of white powder. The washing process was repeated 4 times.

X-ray diffraction measurements

The diffraction patterns of the samples obtained with and without using NaOH are presented in Figure 1 and Figure 2, respectively.

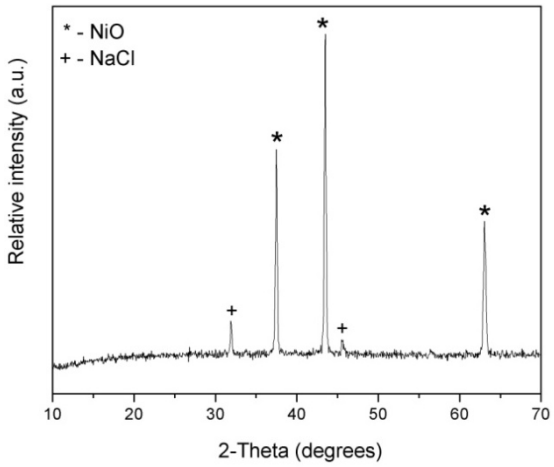


Figure 1 – XRD pattern of the sample prepared by using NaOH
Рис. 1 – Дифрактограмма образца, подготовленного при использовании NaOH
Слика 1 – Дифрактограм узорка припремљеног коришћењем NaOH

The sample presented in Fig.1 contained two phases, NiO (Qualx card No. 00-101-0093) and sodium chloride, NaCl (Qualx card No. 00-100-0041). Scherrer's formula was used to estimate the diameter crystallite size, d_{cr}. Both observed phases are nano-sized: d_{cr} (NiO, 2θ = 43.6°) = 34 nm, d_{cr} (NaCl, 2θ = 31.9°) = 36 nm, although the difference in the quantity and crystallinity of the observed phases resulted in significantly different intensity of the characteristic diffraction maxima.

Literature data proposed a mechanism for the preparation of NiO nanoparticles by using NaOH (Bahari Molla Mahaleh et al, 2008):

$$2NaOH_{(s)} \rightarrow 2Na^{+}{}_{(aq)} + 2OH^{-}{}_{(aq)}$$

$$NiCl_2 \cdot 6H_2O_{(s)} \rightarrow Ni^{2+}{}_{(aq)} + 2Cl^{-}{}_{(aq)} + 6H_2O_{(aq)}$$

$$Ni(OH)_{2x} \cdot (H_2O)_{(s)} \rightarrow Ni(OH)_{2(s)} +_x H_2O_{(g)}$$ (lower temperatures)

$$Ni(OH)_{2(s)} \rightarrow NiO_{(s)} + H_2O_{(g)}$$ (higher temperatures).

The absence of the usage of surfactant (polyvinilpyrolidone, polyethylene glycol, or cetyl trimethyl ammonium bromide) during the synthesis procedure resulted in the pronounced reaction:

$$2Na^{+}{}_{(aq)} + 2Cl^{-}{}_{(aq)} \rightarrow 2NaCl_{(aq)}.$$

When the solubility product of NaCl is overcome, a physical transformation

$NaCl_{(aq)} \rightarrow NaCl_{(s)}$ takes place, and NaCl arises as an impurity. The observed presence of NaCl pointed to the fact that the sample had been washed with an insufficient amount of water.

Figure 2 presents the sample obtained without NaOH. According to 2θ positions of the diffraction maxima, the sample contained a pure NiO phase of high crystallinity, d_{cr} (2θ = 43.6°) = 42 nm. The hkl planes corresponding to the positions of the diffraction maxima are shown in Fig. 2.

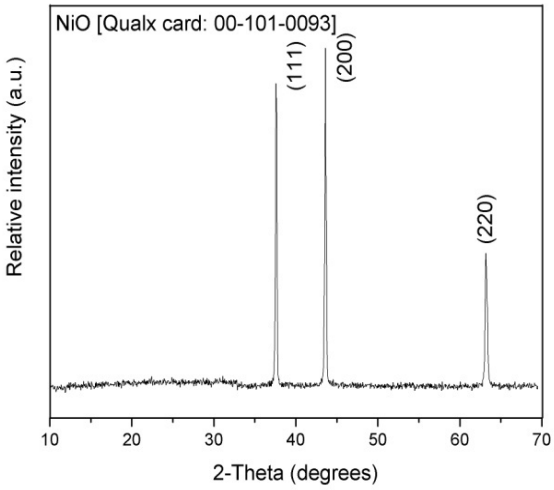


Figure 2 – XRD pattern of the sample prepared without using NaOH
Рис. 2 – Дифрактограмма образца, подготовленного без NaOH
Слика 2 – Дифрактограм узорка припремљеног без NaOH

If we recall the literature data, it can be noticed that Maia et al. obtained pure NiO by using NaOH in the synthesis, but performing annealing at 350 °C for different annealing times (9-12 hours) (Maia et al, 2006). On the other hand, they reported that the synthesis procedure without NaOH, followed by annealing at 700 °C for 30 minutes, resulted in the formation of bigger NiO nanoparticles, 62 - 78 nm (nearly two time bigger size than the size of the prepared NiO particles - Figure 2). The observed discrepancies between the experimental results could be explained in term of the differences in the composition of the used commercial gelatin.

Based on Figures 1 and 2, it can be concluded that the obtained NiO nanoparticles had a lot of similarities in size and structural properties (the

diffraction maxima ascribed to the NiO phase in both samples appeared very similar). For this reason, the investigation of the properties of NiO nanoparticles continued with the sample containing pure NiO nanoparticles.

FTIR measurement

To investigate the surface of the prepared NiO nanoparticles, the FTIR spectrum was recorded in the mid-wave infrared region, between 2000 and 400 cm^{-1}. Figure 3 presents the spectrum in the range 1300 - 400 cm^{-1}, since in the region 1300 - 2000 cm^{-1} the curve is presented as a straight line.

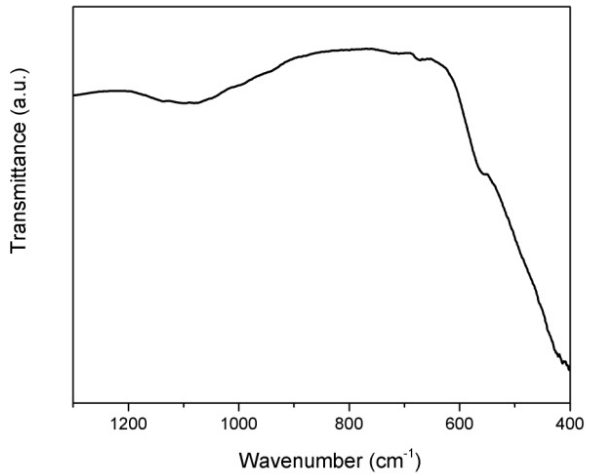


Figure 3 – FTIR spectrum of the sample prepared without using NaOH
Рис. 3 – FTIR спектра образца, подготовленного без NaOH
Слика 3 – FTIR спектар узорка припремљеног без NaOH

In the low-wavenumber part of the spectrum, there is a shoulder noticeable around 530 cm^{-1} and it can be ascribed to Ni - O vibration (Rahdar et al, 2015). A small peak at 640 cm^{-1} could be ascribed to stretching vibrations of the Ni - O - H bond (Rahdar et al, 2015). The observed vibrations confirmed the formation of NiO nanoparticles although the positions of both vibrations were shifted to higher wavenumber values, which is often a consequence of the presence of moisture in the sample. This is confirmed by the presence of a broad bond around 1080 cm^{-1}. Since one of the precursors in the synthesis was gelatin, and having in mind that C - O and C - C vibrations appear in the FTIR spectrum in the region 1090 - 1050 cm^{-1} (Faust, 1997), the

observed bond points to the presence of gelatin carbon residues attached to the surface of NiO nanoparticles. It is important here to notice that the observed gelatin moisture is present after annealing at 700 °C, although Chuaynukul et al found that the degradation of gelatin occurred around 250 °C (Chuaynukul et al, 2014). This is a neither usual nor surprising result, since literature data reveal a well-known fact that substantial variations in the compositions of many commercial gelatins result in shifting gelatin degradation temperatures (Ling, 1978).

According to Figure 2 and Figure 3, it can be assumed that the investigated sample contained NiO nanoparticles, and that carbon residues were attached to the NiO nanoparticle surface.

Raman measurement

The Raman spectrum of the investigated sample in the spectral range from 100 to 1200 cm^{-1} is shown in Figure 4.

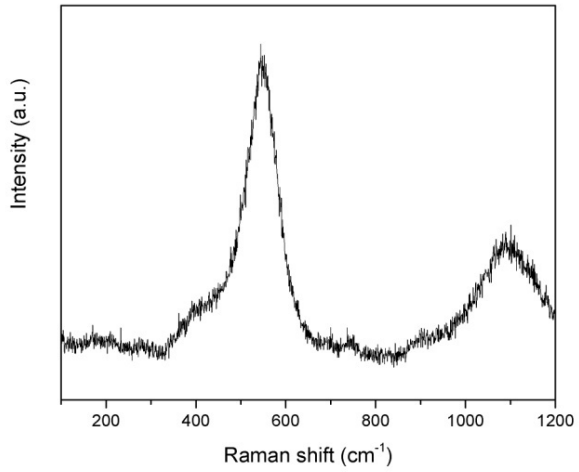


Figure 4 – Raman spectrum of the sample prepared without using NaOH
Рис. 4 – Рамановский спектр образца, подготовленного без NaOH
Слика 4 – Раманси спектар узорка припремљеног без NaO

It can be easily observed that Figure 4 is in accordance with Figure 3. The peak about 530 cm^{-1} points to the presence of NiO nanoparticles, and arises due to the Ni-O stretching mode (Cordoba-Torresi et al, 1991). The mode around 1085 cm^{-1} depicts the appearance of carbon moisture. The results obtained by using Raman spectroscopy confirmed the data observed by FTIR spectroscopy.

To understand the observed results, it is important to elucidate the mechanism of the formation of NiO nanoparticles by using gelatin in the synthesis procedure.

In literature, the chemical content of gelatin is often described as a mixture of hydroxyproline ($C_5H_9NO_3$), proline ($C_5H_9NO_2$) and glycine ($C_2H_5NO_2$), in different ratios (Jagadeesh et al, 2016). The sequence that describes gelatin, Gly-X-Y (where Gly refers to glycine, and X and Y are proline and hydroxyproline, respectively (Samouillan et al, 2011)), presents the triple helical structure of three left-handed polyproline type helices twisted into a superhelix. Thermal treatment initiated triple helix unfolds to produce random chains of gelatin (Harrington & von Hippel, 1969), that could be covalently linked to each other or not, depending on the annealing temperature (Privalov et al, 1979) (Balian & Bowes, 1977).

The proposed mechanism of the performed synthesis could be described in terms of the reaction between nickel salt and glycine:

$$NiCl_2 \cdot 6H_2O_{(s)} + C_2H_5NO_{2(s)} \rightarrow [NiCl_2(C_2H_5NO_2(H_2O)_2)]_{n(s)}$$

Fleck & Bohaty (Fleck & Bohaty, 2004) pointed out the main characteristic of this compound - containing helical chains of $[NiO_4Cl_2]$ octahedra connected by glycine molecules. It is noteworthy that literature data reveal that octahedral nickel-chloride complexes are characterized by a low value for the octahedral Ni-Cl bond order, which is caused by steric interactions between Cl^- and other ligands in the octahedral coordination sphere (See et al, 1998). Accordingly, the annealing process results in the release of chloride ions and their transformation to chloride gas. As a result, NiO nanoparticles containing surface organic impurities (originated from glycine molecules that connected $[NiO_4Cl_2]$ units) are obtained.

It is important to notice that gelatin could be obtained from vegatable origin (algae), or from animal origin (fish or bovine). Also, literature data confirmed that different manufacturers sometimes add formaldehyde or glutaraldehyde in the gelatin preparation in order to ensure hardening of gelatin (Chiellini et al, 2001). Since the chemical composition of gelatin varies dependent on the origin of gelatin, as well as on the manufacturing procedure, the purity of NiO nanoparticles could be improved by varying the synthesis parameters, which could be done by two different approaches: to change the type of gelatin, or to use gelatin manufactured by different producers.

SQUID measurement

Although SQUID measurements allowed the investigation of the magnetic properties of the sample, this type of examination is important for the estimation of the suitability of NiO nanoparticles for gas sensing application due to the coupling between the electric and magnetic fields in the NiO nanoparticle system. Since NiO nanoparticles showed different magnetic properties dependent on the type of synthesis and their structural properties, a significant deviation from the desired magnetic properties could be ascribed to the alteration of NiO electronic properties.

The hysteretic loops of the sample are shown in Figure 5.

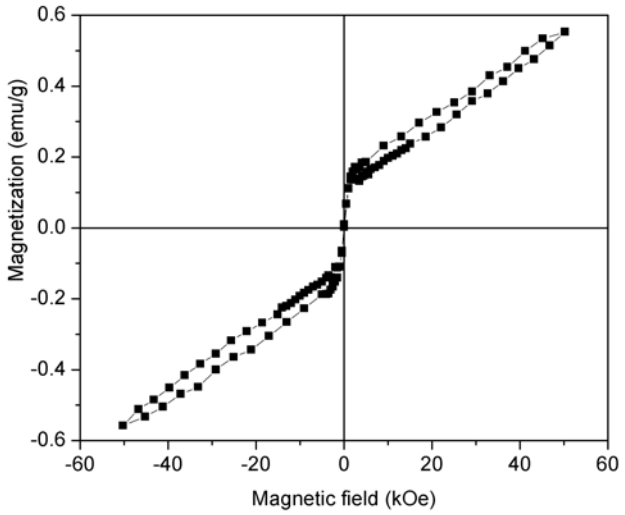


Figure 5 – M(H) curves of the sample prepared without using NaOH
Рис. 5 – M(H) кривые образца, подготовленного без NaOH
Слика 5 – M(H) криве узорка припремљеног без NaOH

Recording the hysteretic curves enabled the estimation of the intrinsic coercivity field value (H_{ci} = 65 Oe) and saturation magnetization (M_s = 0.55 Oe). The obtained Ms value is expected for NiO nanoparticles (Taghizadeh, 2016). It is shown in literature that although bulk coercivity of NiO is around 0.8 Oe, NiO nanoparticles showed increased averaged coercivity due to size effects (around 49 Oe) (Taghizadeh, 2016). Accordingly, the coercivity observed in Figure 5 is characteristic for NiO nanoparticles.

It is noteworthy that the measured hysteretic loops possess constricted middles, so-called "wasp-waisted" curves (Tauxe et al, 1996), that are often oversimplifyingly interpreted, which could result in erroneous conclusions. This shape of the curves could be a consequence of the presence of other phases in the samples. If we consider Figure 1, the presence of other phases is unlikely. Another reason of the modified shape of the hysteretic curves could be the presence of the surface moisture reflecting in the lowered saturation magnetization value and the modification of other hysteretic parameters (Durmus et al, 2011), (Lu et al, 2002). Since the investigated sample showed the M_s and H_{ci} values characteristic for NiO nanoparticles, it is clear that the observed feature could not appear for this reason. For a more precise interpretation of the magnetic properties of the investigated sample, in-depth magnetic investigation consisting of the application of different measurement protocols and a comprehensive interpretation of the obtained results should be carried out.

Conclusion

This article presents a preliminary investigation of the properties of NiO nanoparticles that could be used for the preparation of sensors for H_2S gas detection. Two samples are obtained by a combination of the coprecipitation method and the annealing treatment at 700 °C for 30 minutes. XRD measurements of the samples have revealed that the presence of NaOH in the synthesis route influences the purity of the samples. The samples obtained by using NaOH contained moisture - NaCl; the observed moisture could be eliminated by washing the sample with a significant amount of water. The sample prepared without NaOH contained pure NiO nanoparticles. FTIR and Raman spectroscopy have confirmed the presence of carbon moisture in the form of C - C or C - O bonds, attached to the surface of NiO nanoparticles. The noticed obstacle could be overcome by using commercial gelatin of some other producer, which would experience thermal degradation at lower temperatures. Hysteretic measurements have revealed the presence of wasp-wasted curves although the Ms (0.55 emu/g) and Hci (65 Oe) values are characteristic for NiO nanoparticles. Further investigation will be performed in the future.

Notations and symbols

ATR - attenuated total reflection
d_{cr} - crystallite diameter
FTIR - Fourier transform infrared spectroscopy
hkl - Miller indices of the plane
H_{ci} - intrinsic coercivity field
M_s - saturation magnetization
SQUID - superconducting quantum intereference device
XRD - X-ray diffraction
λ - Cu Kα radiation wavelength
θ - Bragg angle

References

Alkilany, A.M., Nagaria, P.K., Hexel, C.R., Shaw, T.J., Murphy, C.J., & Wyatt, M.D. 2009. Cellular uptake and cytotoxicity of gold nanorods: molecular origin of cytotoxicity and surface effects. *Small*, *5*(6), pp.701-708. Available at: https://doi.org/10.1002/smll.200801546.

Bahari Molla Mahaleh, Y., Sadrnezhaad, S.K., & Hosseini, D. 2008. NiO Nanoparticles Synthesis by Chemical Precipitation and Effect of Applied Surfactant on Distribution of Particle Size. *Journal of Nanomaterials,* 2(8), pp.1-5. Available at: https://doi.org/10.1155/2008/470595.

Balian, G., & Bowes, J.H. 1977. *The Science and Technology of Gelatin*, Ward, A.G., Courts, A., Eds.; Academic Press: London, UK.

Cheng, Y.T., Rodak, D.E., Wong, C.A., & Hayden, C.A. 2006. Effects of micro-and nano-structures on the self-cleaning behaviour of lotus leaves. *Nanotechnology*, *17*(5), pp.1359-1362. Available at: https://doi.org/10.1088/0957-4484/17/5/032.

Chiellini, E., Cinelli, P., Grillo Fernandes, E., Kenawy E.R.S., & Lazzeri, A. 2001. Gelatin-Based Blends and Composites. Morphological and Thermal Mechanical Characterization. *Biomacromolecules*, 2(1), pp.806-811. Available at: https://doi.org/10.1021/bm015519h.

Chuaynukul, K., Prodrpan, T., & Benjakul, S. 2014. Preparation, thermal properties and characteristics of gelatin molding compound resin. *Res J. Chem. Environ. Sci*, 2014, 2(1), pp.1-9. ISSN 2321-1040.

Cordoba-Torresi, S.I., Hugot-Le Goff, A., & Joiret, S. 1991. Electrochromic Behavior of Nickel Oxide Electrodes II. Identification of the Bleached State by Raman Spectroscopy and Nuclear Reactions. *Journal of the Electrochemical Society*, 138*(*6), pp.1554-1559. Available at: https://doi.org/10.1149/1.2085831.

Durmus, Z., Kavas, H., Baykal, A., Sozeri, H., Alpsoy, L., Çelik, S.Ü., & Toprak, M.S. 2011. Synthesis and characterization of l-carnosine coated iron oxide nanoparticles. *Journal of Alloys and Compounds*, 509(5), pp.2555-2561. Available at: https://doi.org/10.1016/j.jallcom.2010.11.088.

Faust, C.B. 1997. *Modern chemical techniques: An Essential Reference for Students and Teachers.* Royal Society Of Chemistry, London, UK.

Fleck, M., & Bohaty, L. 2004. Three novel non-centrosymmetric compounds of glycine: glycine lithium sulfate, glycine nickel dichloride dihydrate and glycine zinc sulfate trihydrate, *Acta Crystallographica Section C*, 60(5), pp.291-295. Available at: https://doi.org/10.1107/S0108270104009825.

Harrington, W.F., & von Hippel, P.H., 1962. The structure of collagen and gelatin. *Advances in Protein Chemistry*, 16(1), pp.1-138. Available at: https://doi.org/10.1016/S0065-3233(08)60028-5.

Jagadeesh, D., Prashantha, K., Mithil Kumar Nayunigari N., & Maity, A. 2016. Effect of Gelatin Content on Potato Starch Green Composite Films. *Indian Journal of Advances in Chemical Science,* 4(4), pp.355-361.

Jana, N.R., Chen, Y. & Peng, X. 2004. Size-and Shape-Controlled Magnetic (Cr, Mn, Fe, Co, Ni) Oxide Nanocrystals via a Simple and General Approach. *Chemistry of materials*, 16(20), pp.3931-3935. Available at: https://doi.org./10.1021/cm049221k.

Jeffrey, F.J. 2015. *Manuals Combined: Navy Air Force And Army Occupational Health And Safety - Including Fall Protection And Scaffold Requirements*. Department of the Navy Fall Protection Guide. Available at: http://www.public.navy.mil/navsafecen/Documents/OSH/FP/FALL_PROTECTION_GUIDE_MAY_15.pdf. Accessed: 05.05.2018.

Kamal, H., Elmaghraby, E.K., Ali, S.A., & Abdel-Hady, K. 2005. The electrochromic behavior of nickel oxide films sprayed at different preparative conditions. *Thin solid films*, 483(2), pp.330-339. Available at: https://doi.org/10.1016/j.tsf.2004.12.022.

Kapse, V.D., Ghosh, S.A., Chaudhari, G.N., & Raghuwanshi, F.C. 2008. Nanocrystalline In_2O_3-based H_2S sensors operable at low temperatures. *Talanta*, 76(3), pp.610-616. Available at: https://doi.org/10.1016/j.talanta.2008.03.050.

Kossyrev, P.A., Yin, A., Cloutier, S.G., Cardimona, D.A., Huang, D., Alsing, P.M., & Xu, J. M. 2005. Electric field tuning of plasmonic response of nanodot array in liquid crystal matrix. *Nano Letters*, 5(10), pp.1978-1981. Available at: https://doi.org/10.1021/nl0513535.

Lee, G., Cheng, Y., Varanasi, C.V., & Liu, J. 2014. Influence of the nickel oxide nanostructure morphology on the effectiveness of reduced graphene oxide coating in supercapacitor electrodes. *The Journal of Physical Chemistry C*, 118(5), pp.2281-2286. Available at: https://doi.org/10.1021/jp4094904.

Lin, H.M., Hsu, C.M., Yang, H.Y., Lee, P.Y., & Yang, C.C. 1994. Nanocrystalline WO_3-based H_2S sensors. *Sensors and Actuators B: Chemical*, 22(1), pp.63-68. Available at: https://doi.org/10.1016/0925-4005(94)01256-3.

Ling, W.C. 1978. Thermal degradation of gelatin as applied to processing of gel mass, *Journal of pharmaceutical sciences*, 67(2), pp.218-223. Available at: https://doi.org/10.1002/jps.2600670223.

Lu,Y., Yin,Y., Mayers, B.T., & Xia, Y. 2002. Modifying the surface properties of superparamagnetic iron oxide nanoparticles through a sol−gel approach. *Nano letters*, 2(3), pp.183-186. Available at: https://doi.org/10.1021/nl015681q.

Maia, A.O.G., Meneses, C.T., Menezes, A.S., Flores, W.H., Melo, D.M.A., & Sasaki, J.M. 2006. Synthesis and X-ray structural characterization of NiO nanoparticles obtained through gelatin. *Journal of non-crystalline solids*, 352(32-35), pp.3729-3733. Available at: https://doi.org/10.1016/j.jnoncrysol.2006.03.103.

MalekAlaie, M., Jahangiri, M., Rashidi, A.M., HaghighiAsl, A., & Izadi, N. 2015. Selective hydrogen sulfide (H_2S) sensors based on molybdenum trioxide (MoO_3) nanoparticle decorated reduced graphene oxide. *Materials Science in Semiconductor Processing*, 38(5), pp.93-100. Available at: https://doi.org/10.1016/j.mssp.2015.03.034.

Milić, M.M., Nikolić, V.N. & Jovanović, S. 2017. Synthesis and characterization of nanocrystalline $Fe_xO_y/Gd_2O_3/SiO_2$ composite powder. *Ceramics International*, 43(16), pp.14044-14049. Available at: https://doi.org/10.1016/j.ceramint.2017.07.138.

Müller, J., Lupton, J. M., Rogach, A.L., Feldmann, J., Talapin, D.V., & Weller, H. 2005. Monitoring surface charge migration in the spectral dynamics of single Cd Se /Cd S nanodot/nanorod heterostructures. *Physical Review B*, 72(20), p.205339. Available at: https://doi.org/10.1103/physrevb.72.205339.

Navarrete, E., Bittencourt, C., Umek, P., & Llobet, E. 2018. AACVD and gas sensing properties of nickel oxide nanoparticle decorated tungsten oxide nanowires. *Journal of Materials Chemistry C*, 6(19), pp.5181-5192. Available at: https://doi.org/10.1039/c8tc00571k.

Nikolić, V.N., Milić, M., Jovanović, S. & Girman, V. 2017. Fe_3O_4 Nanoparticles as Additives for GAMMA-Ray Shielding: Structural and Surface Characterization. *Scientific Technical Review*, 67(2), pp.20-26. ISSN: 1820-0206.

Nikolić, V.N., Tadić, M., & Spasojević, V. 2016. Thermal stability and magnetic properties of ε-Fe_2O_3 polymorph. In: *VII International Scientific Conference on Defensive Technologies, OTEH,* Belgrade, pp.1-21. October 6-7. Available at: https://www.researchgate.net/profile/Srdjan_Zivkovic3/publication/321973454_SURFACE_TEXTURE_FILTRATION__INTERNATIONAL_STANDARDS_and_FILTRATIONS_TECHNIQUE_OVERVIEW/links/5a3baf67a6fdccb29dc873ba/SURFACE-TEXTURE-FILTRATION-INTERNATIONAL-STANDARDS-and-FILTRATIONS-TECHNIQUE-OVERVIEW.pdf.

Privalov, P.L., Tiktopulo, E.I., & Tischenko, V.M.1979. Stability and mobility of the collagen structure. *Journal of Molecular Biology*, 127(2), pp.203-216. Available at: https://doi.org/10.1016/0022-2836(79)90240-7.

Rahdar, A., Aliahmad, M., & Azizi, Y. 2015. NiO nanoparticles: synthesis and characterization. *Journal of Nanostructures*, 5(2), pp.145-151. ISSN: 2251-788X.

Rout, C.S., Hedge, M., & Rao, C.N.R. 2008. H_2S sensors based on tungsten oxide nanostructures. *Sensors and Actuators B: Chemical*, 128(2), pp.488-493. Available at: https://doi.org/10.1016/j.snb.2007.07.013.

Salimi, A., Sharifi, E., Noorbakhsh, A., & Soltanian, S. 2017. Immobilization of glucose oxidase on electrodeposited nickel oxide nanoparticles: direct electron transfer and electrocatalytic activity. *Biosensors and Bioelectronics*, 22(12), pp.3146-3153. Available at: https://doi.org/10.1016/j.bios.2007.02.002.

Samouillan, V., Delaunay, F., Dandurand, J., Merbahi, N., Gardou J., Yousfi, M., Gandaglia A., Spina M., & Lacabanne, C., 2011. The Use of Thermal Techniques for the Characterization and Selection of Natural Biomaterials. *Journal of Functional Biomaterials, 2*(1), pp.230-248. Available at: https://doi.org/10.3390/jfb2030230.

See, R.F., Kruse, R.A., & Strub, W.M. 1998. Metal-Ligand Bond Distances in First-Row Transition Metal Coordination Compounds: Coordination Number, Oxidation State, and Specific Ligand Effects. *Inorganic Chemistry*, 37(1), pp.5369-5375. Available at: https://doi.org/10.1021/ic971462p.

Sellmyer, D.J., Zheng, M., & Skomski, R. 2001. Magnetism of Fe, Co and Ni nanowires in self-assembled arrays. *Journal of Physics: Condensed Matter*, 13(25), pp.433-447. Available at: https://doi.org/10.1088/0953-8984/13/25/201.

Taghizadeh, F. 2016. The Study of Structural and Magnetic Properties of NiO Nanoparticles. *Optics and Photonics Journal*, 6(08), pp.164-169. Available at: https://doi.org/10.4236/opj.2016.68B027.

Tauxe, L., Mullender, T.A.T., & Pick, T. 1996. Potbellies, wasp-waists, and superparamagnetism in magnetic hysteresis, *Journal of Geophysical Research: Solid Earth*, 101(B1), pp.571-583. Available at: https://doi.org/10.1029/95jb03041.

Tramsdorf, U. I., Bigall, N. C., Kaul, M. G., Bruns, O. T., Nikolic, M. S., Mollwitz, B., & Förster, S. 2007. Size and surface effects on the MRI relaxivity of manganese ferrite nanoparticle contrast agents. *Nano letters*, *7*(8), pp.2422-2427. Available at: https://doi.org/10.1021/nl071099b.

Wang, Y., Cao, J., Kong, F., Xia, H., Zhang, J., & Wu, S. 2008. Low-temperature H_2S sensors based on Ag-doped α-Fe_2O_3 nanoparticles. *Sensors and Actuators B: Chemical*, 131(1), pp.183-189. Available at: https://doi.org/10.1016/j.snb.2007.11.002.

Xing, W., Li, F., Yan, Z., & Lu, G.Q. 2004. Synthesis and electrochemical properties of mesoporous nickel oxide. *Journal of Power Sources*, 134(2), pp.324-330. Available at: https://doi.org/10.1016/j.jpowsour.2004.03.038.

You, T., Niwa, O., CHEN, Z., Hayashi, K., Tomita, M., & Hirono,S. 2003. An amperometric detector formed of highly dispersed Ni nanoparticles embedded in a graphite-like carbon film electrode for sugar determination. *Analytical chemistry*, 75(19), pp.5191-5196. Available at: https//doi.org/10.1021/ac034204k.

ХАРАКТЕРИСТИКИ НАНОЧАСТИЦ NiO, ПОДГОТОВЛЕННЫХ С ПОМОЩЬЮ ЖЕЛАТИНА ПРИ ПРОСТОМ И НЕДОРОГОМ МЕТОДЕ ОБОБЩЕНИЯ

Виолетта Н. Николич[а], *Мартина* Д. Гилич[б], *Воислав* В. Спасоевич[а]
[а] Белградский университет, Институт ядерных наук „Винча“,
Лаборатория теоретической физики и физики конденсированного Состояния, г. Белград, Республика Сербия
[б] Белградский университет, Институт физики,
Лаборатория для исследований в области электронных материалов,
г. Белград, Республика Сербия

ОБЛАСТЬ: химические технологии
ВИД СТАТЬИ: оригинальная научная статья
ЯЗЫК СТАТЬИ: английский

Резюме:

Нанокомпозитные материалы, содержащие наночастицы NiO, нанесенные на нанопровода WO_3 можно использовать для мониторинга уровня H_2S-газа. Эффективность данного материала в основном определяется свойствами этапа NiO. Проведенное исследование представляет собой первый этап в подготовке модифицированного материала NiO/WO_3. В данной статье представлено получение наночастиц NiO простым и недорогим методом обобщения. Поведение наноразмерных частиц NiO исследуется с помощью рентгеновской дифракции, инфракрасной спектроскопии с Фурье-преобразованием, рамановской спектроскопии и гистерезисных измерений.

Ключевые слова: NiO, дифракционные измерения, спектроскопия, наночастицы, материалы.

КАРАКТЕРИЗАЦИЈА NiO НАНОЧЕСТИЦА ПРИПРЕМЉЕНИХ ПОМОЋУ ЖЕЛАТИНА ТОКОМ ПОСТУПКА „LOW-COST" СИНТЕЗЕ

Виолета, Н. Николић[а], *Мартина* Д. Гилић[б], *Војислав* В. Спасојевић[а]
[а] Универзитет у Београду, Институт за нуклеарне науке „Винча",
Лабораторија за теоријску физику и физику кондензоване материје,
Београд, Република Србија
[б] Универзитет у Београду, Институт за физику,
Лабораторија за истраживања у области електронских материјала,
Београд, Република Србија

ОБЛАСТ: хемијске технологије
ВРСТА ЧЛАНКА: оригинални научни чланак
ЈЕЗИК ЧЛАНКА: енглески

Сажетак:

Нанокомпозитни материјал који садржи наночестице NiO нанете на WO_3 наножице може се користити за мониторинг нивоа H_2S гаса. Ефикасност овог материјала највећим је делом одређена својствима NiO фазе. Изведена студија представља прву фазу у припреми модификованог материјала NiO/WO_3. У овом раду NiO наночестице су припремљене једноставним „low-cost" методом синтезе. Понашање наноструктурних NiO честица испитивано је рентгенском дифракцијом, инфрацрвеном спектроскопијом са Фуријеовом трансформацијом, раманском спектроскопијом и хистерезним мерењем.

Кључне речи: NiO, дифракциона мерења, спектроскопија, наночестице, материјали.

Paper received on / Дата получения работы / Датум пријема чланка: 08.08.2018.
Manuscript corrections submitted on / Дата получения исправленной версии работы / Датум достављања исправки рукописа: 03.09.2018.
Paper accepted for publishing on / Дата окончательного согласования работы / Датум коначног прихватања чланка за објављивање: 05.09.2018.

A NOVEL METHOD FOR DETERMINING A NEWBORN BABY'S IDENTITY BASED ON FINGERPRINTS

Komlen G. Lalović[a], *Ivan* A. Tot[b], *Mladen* B. Trikoš[c]

[a] ITS – Information Technology School, Belgrade, Republic of Serbia,
e-mail: komlen.lalovic@its.edu.rs,
ORCID iD: http://orcid.org/0000-0002-4590-2185

[b] University of Defence in Belgrade, Military Academy, Department for information systems and telecommunication engineering, Belgrade, Republic of Serbia,
e-mail: ivan.tot@va.mod.gov.rs,
ORCID iD: http://orcid.org/0000-0002-5862-9042

[c] University of Defence in Belgrade, Military Academy, Department for information systems and telecommunication engineering, Belgrade, Republic of Serbia,
e-mail: mladen.trikos@va.mod.gov.rs,
ORCID iD: http://orcid.org/0000-0002-5243-1326

DOI: 10.5937/vojtehg67-18709; https://doi.org/10.5937/vojtehg67-18709

FIELD: IT, Patent
ARTICLE TYPE: Original Scientific Paper
ARTICLE LANGUAGE: English

Summary:

This work presents a novel method for biometric identity verification for newborn babies in maternity wards based on fingerprint minutiae. The information system realized combines contemporary program languages such as: Java and Python as object-oriented languages, C programming language for device programming as structural (line) and SQL for storing encrypted data in a relational database management system. Also, there is the RSA asynchronous cryptographic algorithm as well as keys for storing the encrypted data of fingerprint minutiae. The information system implements a device for biometric verification of maternity i.e. a dual fingerprint scanner that provides data of mother's and baby's fingerprints at the very moment of childbirth and further guarantees maternity for each newborn baby with 100% accuracy, by generating a unique ID reference and encrypting these data with cancelable biometrics. This is a novel method for determining identity based on baby's fingerprint minutiae.

Keywords: biometry, fingerprint, security, baby, method, information system.

ACKNOWLEDGMENT: The authors thank the Ministry of Defence of the Republic of Serbia through VA-TT/3/18-20 project.

Introduction

Biometry is a scientific and technological discipline that measures and analyzes biological characteristics of people. It is part of advanced security systems widely used in today's modern society and protection systems.

Fingerprints and their minutiae represent the highest level of persistence in biometry and the lowest possibility of compromising the data - that is why the aim of this novel approach is based on it, implementing a device for biometric identification based on this part of biometry.

This device scans fingerprints and put into storage encrypted personal data in order to prevent any possible theft or switching of babies' identity with 100% accuracy. It has one goal - to confirm maternity for each newborn baby in hospitals. Scanning finger minutiae from both the baby and the mother, at the same time, at the very moment of childbirth, generates a unique reference and binds it with scanned data. It provides total protection and removes potential fears - it is a guarantee of identity. By encrypting these data, the whole process is raised to the highest level of security in any maternity ward worldwide. This novel method completely removes fear that almost every mother has in this period, i.e. it removes the question: "Is this my baby?". This method presents a new implementation of information technology security in the public health system and upgrades it to a higher level.

This novel method encapsulates three main parts: information system, device for biometric identification of a newborn baby, and procedures needed to be realized so that the new approach could be implemented. It solves one huge human problem - possible theft or switching of identities of newborn babies; it also removes fears that women have at the moment of childbirth, and makes it easier for gynaecologists, midwives and nurses.

This work will also present all the functionality that the device possesses, how to build the model (in figures), a picture of a cross-state and how it is designed and developed. We will give possible advantages and benefits representing a qualitative leap in public health care systems, precisely in maternity wards over the globe.

It is possible to establish wireless communication and storage types for fingerprints scanned from mothers and babies simultaneously at the moment of childbirth and generated with a unique identity reference which will be encrypted and will guarantee maternity in 100% for every baby.

The innovation is placed in the field of Applied Information Technology, Biometry Systems: the device will be a dual fingerprint scanner – with two fields scanning simultaneously (one mother's and one baby's finger); after that, the device will allocate a unique Identification reference which will be the Identifier for each mother-baby pair for every newborn baby in maternity wards. It is listed in the International Classification of Patents, classified under G06F21/00 i.e. Biometry Systems.

Solving a technical problem

The main technical problem which has to be solved with this new method consists of:

- Building a solution for our device – a dual fingerprint scanner for scanning fingers of the mother and the baby at the very moment of childbirth. This device will differ slightly from today's existing classic fingerprint scanners - it will have two fields for scanning fingers of two different persons (mother and baby). After this process, the device will encrypt data and store them.
- It will be effective, highly practical and easy to work with, easy to control and manipulate. Its maintenance is easy, classic and similar to other fingerprint scanners. Besides scanning two fingers of different persons at the same moment, it will provide a unique ID reference (like a Primary Key) which will be a basis for every scanned mother-baby pair.
- The realised Information system (IS) presents an optimal solution for this type of work defining strict procedures needed to be obeyed. Also, the IS will implement IT technology in public health systems.

Main technological overview

In today's known technical devices, various fingerprint scanners use secure algorithms to determine and verify identity of individuals. In the Serbian National Patents base, there are no similar devices which consider this aim; namely, there are no dual biometric scanners which contain their own light and power supply. (Kaplan-Sandquist et al, 2014, pp.68-77)

Today's biometrics devices can scan one or more fingers from **one** person, and then from another person, but there are not fingerprint scanners which scan fingers of two different people at the same time on one device, especially not devices which during scanning create a unique reference which will be linked to the record of fingerprints scanned and earlier stored data. (Elgendi, 2012, pp.14-25)

This scanner will possess two fields for scanning one or more fingers of two different people (mother and baby) and in that moment will generate a unique ID reference which will secure that record of fingerprints.

The question is: Can Biometry and its part – fingerprint scanning be applied for two people at the same time with one device?

It definitely can, and it will be realized with high quality, which will be shown in this work and Patent – Innovation presentation. This is a **device for biometric verification of maternity**. Further development of the functionality of this device will deal with the implementation of encrypted data which will carry the information about two people (mother and baby) and will be bound by a unique ID reference.

Today's patents and devices and present scanners do not have similar functions, and, most importantly, do not have a fingerprint scanning possibility for two people at the same time.

The published Patent Confirmation **13848069.4** of April 2nd 2013, with Remark **WO2014059761** and Classification **G06F21/00,** shows a classic scanner named "Fingerprint identification device", describing a device which has a scanning function and acquires data about a fingerprint of a person (extractor software for *minutiae*[1]). (Moujahdi et al, 2014, pp.189-196), (Elgendi, 2012, pp.14-25)

However, this device does not have two fields for scanning fingers of two different people at the same time, which in the same time generates a unique unchangeable ID reference which will be an additional guarantee of person's identity and a guarantee of maternity for each newborn baby.

Another important aspect is the question of economy and time needed for scanning both persons' fingerprints with supporting information technology (*IT*) in the future of the existing system which now provides only one person's data. This innovative device provides improvements in economy and time spent during the process of scanning, enabling lower costs for each device, with benefits of less time needed for processing data obtained from an image of the finger scanner. The device also gives an optimal solution for the resource usage in the case of processing data acquired during the process of fingerprint scanning, particularly when considering the memory usage and the activity of the microcontroller – the Central Processing Unit (*CPU*).

[1] Minutiae – fingerprint specific points visible on a finger image

Finally, regarding all these benefits, both hardware and software, the device will provide a qualitative jump in health care systems of every country where it is implemented as well as in IT industry – Biometry in particular.

Information system

The Information system created for this new method of baby identification based on fingerprints consists of parts for acquiring data, encrypting, storing and verifying data. The next step is following the procedures needed to be done. The figures show the Use Case and the Sequence diagram for this Information system.

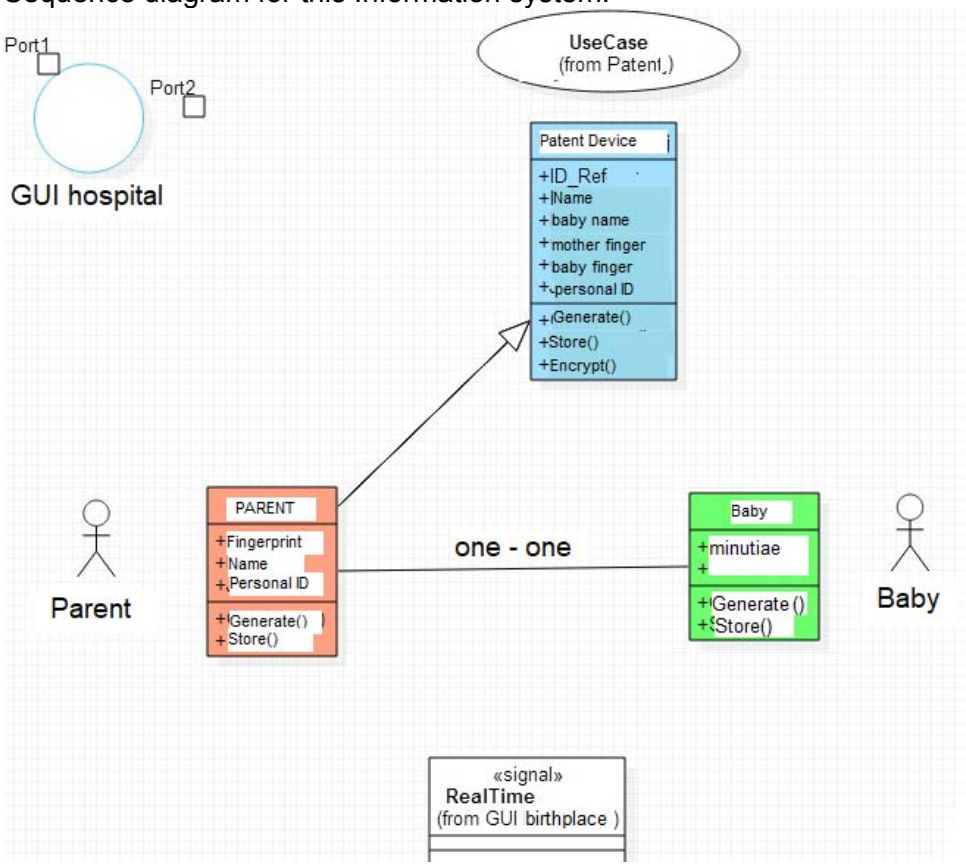


Figure 1 – Use Case diagram of the Information system
Рис. 1 – Диаграмма случаев применения Информационной системы
Слика 1 – Дијаграм случајева употребе информационог система

This Use Case diagram shows the members of this new information system based on their roles. They are strictly determined by every role they have in hospital.

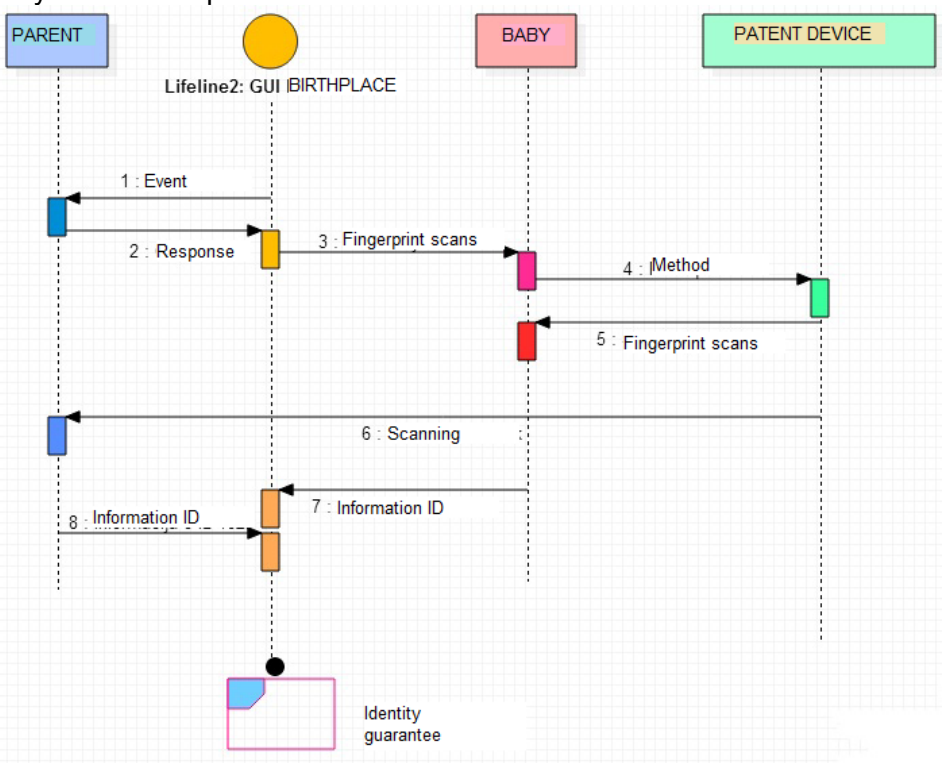


Figure 2 – Diagram of the information system sequences
Рис. 2 – Диаграмма последовательностей Информационной системы
Слика 2 – Дијаграм секвенци информационог система

Can baby fingerprint minutiae be acquired?

The main purpose of this device, a dual biometric fingerprint scanner, is to scan the fingerprints of the mother and the newborn baby at the same time at the very moment of childbirth. It has two fields, one larger with a classic scanning resolution of 500 dpi and another physically smaller but with a larger scanning resolution – minimum 1000 dpi so it can make scans of a baby fingerprint that is very small. (Lalović, 2018, pp.366-379) (Lalović et al, 2016ab), (Ferguson et al, 2013, pp.67-72)

In Biometry as a branch of advanced security systems, Discipline - Informatics and Computing, Science Field - Natural Sciences and

Mathematics, there is a s**cientific fact, better to say an axiom, that a fingerprint is formed during the prenatal period for every fetus and it stays constant in the shape of minutiae during the whole life.** (Moujahdi et al, 2014, pp.189-196), (Elgendi, 2012, pp.14-25), (Kaplan-Sandquist et al, 2014, pp.68-77), (Lalović et al, 2016ab, pp.65-81), (Lalović et al, 2015, pp.293-302)

According to many research studies realized on fingerprints of fetuses, using ultra waves and biometry scanning, the minutiae on each finger are formed by the end of 7th month during pregnancy. It is important to mention that babies born prematurely, during 8th month, and also **by the end of 7th month of pregnancy, have already formed fingerprints on all fingers and toes.** (Anil, 2008), (Gutiérrez-Redomero et al, 2014, pp.199-207), (Elsevier, 2014, p.12), (Dahlen & Caplice, 2014, pp.266-270)

This scientific fact is essential for our patent and this device, this research and this project realization that will provide a qualitative jump in gynaecology, midwifery and nursing in every hospital in the world.

The 100% guarantee of baby's identity and maternity for each newborn baby will be simultaneous scanning of the mother's and the baby's fingerprints at the moment of childbirth, when the mother sees her baby for the first time. Doctors and nurses measure the weight and height of the baby, and then clean one of baby's fingers with alcohol or some other liquid and place it on the smaller field of the fingerprint scanner together with the mother's finger on the larger field of the scanner so that the device scans and generates a unique ID reference for that mother-baby pair. And this is the crucial proof that a particular newborn baby is given birth from a particular mother. After a few days, when the mother and her baby are to leave the maternity ward, the check is made on the same device which confirms baby's identity via the stored ID reference of that particular mother-baby pair. That procedure will bring about new quality, it will prevent any possibility of making errors. (Lee et al, 2012, pp.1253-1254), (Juhola et al, 2013, pp.42-50), (Maček et al, 2015, pp.43-60)

Since the fingerprint minutiae – ridges and valleys are the only biometry that is formed prenatally, they can be used for the purpose of biometry identity guarantee. The whole idea for this Patent Innovation is based on this science fact confirmed by both biometry systems as computer science and gynaecology – midwifery as branch of the health care protection system. (Anil, 2008), (Gutiérrez-Redomero et al, 2014, pp.199-207), (Grzybowski & Pietrzak, 2015, pp.117-121).

Other biometrics such as iris recognition is unstable because, until children are 4th year old, the pigmentation in their eyes changes in shape and color, so it cannot be used for this purpose. (IEEE, 2011, pp.32-46)

The head, the hand and the body shape and size rapidly change during growing up so it is clear why they cannot be used either. The scientific fact that the fetus fingerprint is formed prenatally by the end of 7th month in the belly of the pregnant mother and that it stays constant throughout the whole life with the same construction of minutiae is so incredibly amazing. (Anil, 2008), (Grzybowski & Pietrzak, 2015, pp.117-121)

There are a number of various fears during the childbirth process coming from both the mother and the medical care staff in maternity wards. Based on the research carried out in Australia and New Zealand from 2009 to 2011 and 17 workshops with over 700 midwives, one of the biggest fears is dealing with the unknown (n=32). This device can help in reducing a part of it (Grzybowski & Pietrzak, 2015, pp.117-121)

All the data obtained during the process of mother's and baby's fingerprint scanning, together with the unique ID reference, are encrypted and stored into the device memory or onto a server in the encrypted form. The device is neither open access nor available for public, it is intended just for authorized nurses, doctors and midwives in maternity wards. (Gutiérrez-Redomero et al, 2014, pp.199-207), (Grzybowski & Pietrzak, 2015, pp.117-121)

Further on, maternity is confirmed for each mother-baby pair when an authorized person – maternity ward representative and the mother enter the PIN[2] code that only they possess for their data. Changing the stored data will be disabled and the identity of a newborn baby is guaranteed 100%; therefore, there is no possibility of making a mistake during this process with the patent device.

In every moment, it is possible to check maternity for every baby in each maternity ward worldwide. The information stored in the device or server with its backup copy are always in the encrypted form and there is no possibility of corrupting or deleting this data. The possibility of archiving data is enabled after the confirmation of the mother that everything is normal and after the mother-baby pair has left the maternity ward - that is the moment when a need for the guarantee of maternity in the maternity ward is no longer necessary.

The last check is performed at the moment when the mother and the baby are to leave the maternity ward. The device scans the mother's and

[2] PIN – Personal Identification Number

baby's fingers simultaneously, compares them with the existing encrypted data stored at the childbirth moment for that pair and if the verification is successful – It is your baby! There is no place for fear neither for mothers nor for nurses, doctors, or midwives.

With this device and procedure, a possibility of making a mistake is avoided. The device and the system guarantee baby's identity 100% for every newborn baby. It prevents any possible theft or switching of baby identities, which unfortunately probably happened in some parts of the world, especially in South-East Europe, Balkan peninsula, and countries of the former Yugoslavia. The device will now be proof and evidence of maternity for newborn babies.

The patent inventor took Maternity symbolically because, for all living beings, the strongest instinct in the nature is that of a mother. As a respect to that instinct, the inventor decided to verify the mother's fingerprint together with the baby's and to make a unique ID reference that no one could change or delete. The cost is not high for this information system so it can be installed in every maternity ward of health care systems in every country.

Benefits with this new method

This new method which combines an information system and a device for biometric identification of newborn babies based on fingerprints provides:

- proof and evidence of maternity for every newborn baby,
-no possibilities of stealing or switching identities of newborn babies,
- safety for all future parents in maternity wards,
- cost-effectivenness, and
- wide range of applications.

It is portable, small and light, as well as environmentally friendly.

For a better understanding of the functionality and application of the device and its practical realization, there are three figures that show the device from different aspects and the cross-section of the patent device.

Figure 3 shows the device for biometric identification of maternity with a digital display, a switch and two fields for fingerprint scanning. The details in the figure are marked as follows:

B – Body of device, **I** – Ignition switch which can be in two positions (on/off), and can be connected with timers for delayed on/off. **D** – Display of the device for displaying all current activities in real time, such as start of scanning, success of process, results of generating unique ID references generated during the process of fingerprint scanning.

S – Set button for starting the scanning process and reading the parameters obtained by fingerprint scanning. **R** – Reset button for resetting the acquired and processed data, after storing them. **R1** – Command button to save and store data after the scanning process.

S1 – Field for fingerprint scanning of a baby's finger, much smaller than the field for mother's fingerprint scanning. **S2** – Field for mother's fingerprint scanning, larger that the S1 field.

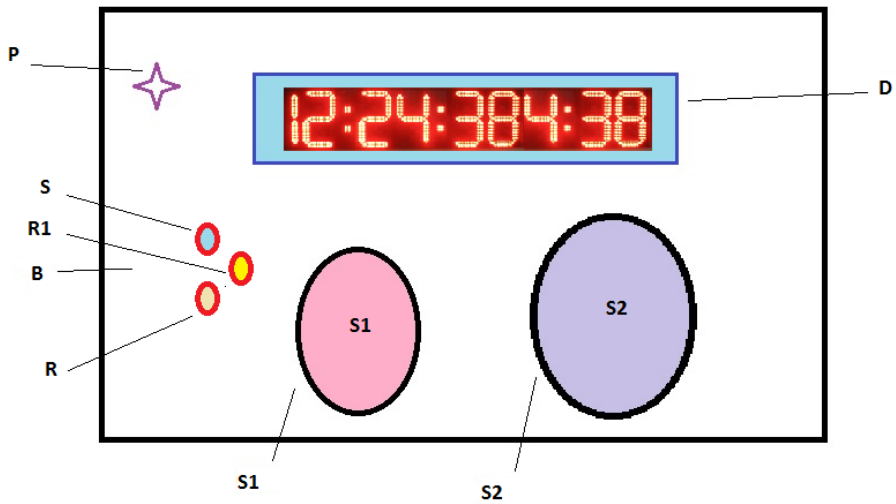


Figure 3 – Detailed description of how the device operates
Рис. 3 – Подробное описание работы устройства
Слика 3 – Детаљан приказ функционалности уређаја

The device, started by switching **P** in the ON position, displays that it functions normally and that there are no errors. Pressing the **S** button starts fingerprint scanning on both fields (**S1** and **S2**) at the same time, with both mother's and baby's fingers being already placed on the fields. After the scanning, pressing the **R1** button will store the data and a unique ID reference is shown on the display **D**. The ID reference can be both numerical and alphanumerical (number systems can be octal, decimal, binary or hexadecimal). The main fact is that the generated ID is unique.

Acquiring an algorithm in a pseudo code

Here is the algorithm in a pseudo code listed to present the logic and all possible features of the software that the device possesses and to explain in detail how the whole system is planned to fulfill its purpose and

to provide new quality by implementing information technologies. (Lalović et al, 2017)

```
--------------------------------------------------------------------------------
01      BEGIN
02      LOOP 1 TO 3
03      FIELD-1 F1 SCANN
04      IF F1 OK THEN GOTO GENERATE UNIQE ID
                ELSE IF LOOP < 3 GOTO END
05      LOOP 1 TO 3
06      FIELD-2 F2 SCANN
07      IF F2 OK THEN GOTO GENERATE UNIQE ID
                ELSE IF LOOP < 3 GOTO END
08      GENERATE UNIQE ID
09      GENERATE PIN
10      ENCRYPTING DATA
11      GENERATING HASH VALUE
12      STORE AND SAVE DATA
13      DISPLAY SUCCESS MESSAGE
14      END
--------------------------------------------------------------------------------
```

Possibilities of further development

This novel method implements a completely new device with the idea of a biometric verification of maternity and scanning of each newborn baby which can be used as a model in public health systems of all countries. Similar biometric systems can be further developed in day-care centers and in preschool institutions where there are various problems regarding constant monitoring of small children.

Beside this primary purpose, it can also can be used as part of much larger health care systems dealing with small children (pediatrics) where it can be used in providing basic data about possible allergies or some specific details of each child thus making improvements in that part of health care systems at the global level.

Conclusion

This novel model encapsulates the benefits from three various projects: Patent device, information system and Safe birthplace project. It can improve the level of public health in the Republic of Serbia. The system is modular, it can be updated and, most importantly, it can be a basis for some future developments in biometrics systems. The device can be applied in many countries in a battle against organized crime and can help prevent theft or replacement of newborn babies, especially on territories with low IT infrastructure and technological development.

Each biometrics tends to minimize both FAR3 and FRR4 in order to be much more accurate and secure. This device accomplishes this goal since it combines two scanned data and its accuracy grows exponentially. In modern IoT (Internet of things), most countries try to provide new quality of health care services, help staff in maternity wards, make the process of childbirth much easier, and more relaxed in some ways for future mothers as well as for gynaecology doctors, midwives, nurses, and others.

References

Anil, J.K. 2008. *Handbook of Biometrics*.USA: Michigan State University / Patric Flynn-University Of Notre Dame / Arun A. Ross-West Virginia University.

Dahlen, H.G. & Caplice, S. 2014. What do midwives fear? *Women and Birth*, 27(4), pp.266-270. Available at: https://doi.org/10.1016/j.wombi.2014.06.008.

Elgendi, M. 2012. On the Analysis of Fingertip Photoplethysmogram Signals. *Current Cardiology Reviews,* 8(1), pp.14-25. Available at: https://doi.org/10.2174/157340312801215782.

–Elsevier. 2014. NIST publishes compression guidance for fingerprint. *Biometric Technology Today*, 2014(4), p.12. Available at: https://doi.org/10.1016/S0969-4765(14)70073-6.

Ferguson, S., Nicholson, L., Farrugia, K., Bremner, D., Gentles, D. 2013. A preliminary investigation into the acquisition of fingerprints on food. *Science and Justice*, 53(1), pp.67–72. Available at: https://doi.org/10.1016/j.scijus.2012.08.001

Grzybowski, A. & Pietrzak K. 2015. Jan Evangelista Purkynje (1787–1869): First to describe fingerprints. *Clinics in Dermatology*, 33(1), pp.117–121. Available at: https://doi.org/10.1016/j.clindermatol.2014.07.011.

[3] FAR – False Accept Rate
[4] FRR – False Reject Rate

Gutiérrez-Redomero, E., Rivaldería, N., Alonso-Rodríguez, C., Sánchez-Andrés, A. 2014. Assessment of the methodology for estimating ridge density in fingerprints and its forensic application. *Science & Justice*, 54(3), pp.199–207. Available at: https://doi.org/10.1016/j.scijus.2013.11.004

–IEEE, 2011. Using Fingerprint Authentication to Reduce System Security: An Empirical Study, pp.32-46. In: *Security and Privacy (SP), IEEE Symposium*, Berkeley(CA), 22-25 May. E-ISBN: 978-0-7695-4402-1.

Juhola, M., Zhang, Y., Rasku, J. 2013. Biometric verification of a subject through eye movements. *Computers in Biology and Medicine*, 43(1) pp.42–50. Aailable at: https://doi.org/10.1016/j.compbiomed.2012.10.005.

Kaplan-Sandquist, K., LeBeau, M.A., & Miller, M.L. 2014. Chemical analysis of pharmaceuticals and explosives in fingermarks using matrix-assisted laser desorption ionization/time-of-flight mass spectrometry. *Forensic Science International,* 235, pp.68-77. Available at: https://doi.org/10.1016/j.forsciint.2013.11.016.

Lalović, K. 2018. Patent Overview: Device for Fingerprint Identity Guarantee. *Vojnotehnički glasnik*/*Military Technical Courier,* 66(2), pp.366-379. Available at: https://doi.org/10.5937/vojtehg66-15868.

Lalović, K., Maček, N., Milosavljević, M., Veinović, M., Franc, I., Lalović, J., & Tot, I. 2016a. Biometric Verification of Maternity and Identity Switch Prevention in Maternity Wards. *Acta Polytechnica Hungarica,* 13(5), pp.65-81. Available at: https://doi.org/10.12700/aph.13.5.2016.5.4.

Lalović, K., Milosavljević, M., Tot, I., & Maček, N. 2015. Device for biometric verification of maternity. *Serbian Journal of Electrical Engineering,* 12(3), pp.293-302. Available at: https://doi.org/10.2298/sjee1503293l.

Lalović, K., Nikolić, J., Tot, I., & Lalović, Ž. 2016b. Software Algorithm of Device for biometric identification of Parenthood. In *BISEC 2016 - International conference in Security ICT, October 15th-Belgrade, Serbia*.

Lalović, K., Tot, I., & Andjelić, S. 2017. How to Guarantee Baby Identity Based on Fingerprint Biometry. In *BISEC 2017 - International conference in Security ICT, October 18th-Belgrade, Serbia*.

Lee, C., Shin, H.S., Park, J., & Lee, M. 2012. The Optimal Attachment Position for a Fingertip Photoplethysmographic Sensor With Low DC. *IEEE Sensors Journal,* 12(5), pp.1253-1254. Available at: https://doi.org/10.1109/jsen.2011.2164904.

Maček, N., Borislav, Đ., Gavrilović, J., & Lalović, K. 2015. An Approach to Robust Biometric Key Generation System Design. *Acta Polytechnica Hungarica,* 12(08), pp.43-60. Available at: https://doi.org/10.12700/aph.12.8.2015.8.3.

Moujahdi, C., Bebis, G., Ghouzali, S., Rziza, M. 2014. Fingerprint shell: Secure representation of fingerprint template. *Pattern Recognition Letters*, 45, pp.189-196. Available at: https://doi.org/10.1016/j.patrec.2014.04.001.

НОВЕЙШИЙ МЕТОД ИДЕНТИФИКАЦИИ НОВОРОЖДЕННОГО РЕБЕНКА, ОСНОВАННЫЙ НА ОТПЕЧАТКЕ ПАЛЬЦА

Комлен Г. Лалович[а], *Иван* А. Тот[б], *Младен* Б. Трикош[б]

[а] КИТ - Колледж информационных технологий,
г. Белград, Республика Сербия

[б] Университет обороны в г. Белград, Военная академия,
Кафедра информационных систем и телекоммуникационной инженерии,
г. Белград, Республика Сербия

ОБЛАСТЬ: Информационные технологии (ИТ), патент
ВИД СТАТЬИ: оригинальная научная статья
ЯЗЫК СТАТЬИ: английский

Резюме:

В данной работе описан новый метод биометрической идентификации новорожденных детей в родильных домах, на основании минуций (признаков) отпечатка пальца. Информационная система комбинирует все существующие языки программирования, такие как: Java и Python в объектно-ориентированном программировании, C язык для структурного программирования устройств (линейных) и SQL для хранения зашифрованных данных в системе управления реляционными базами данных. Кроме того, используется RSA алгоритм ассиметричного шифрования и ключи (пароли) для хранения зашифрованных минуций отпечатков пальцев. Информационная система, внедряет устройство для биометрической идентификации материнства в виде одновременного двумерного биометрического сканера, предоставляющего данные об отпечатке пальца матери и новорожденного ребенка, непосредственно после его рождения, что в течение дальнейшего процесса полностью гарантирует предотвращение потенциальной опасности от подмены новорожденного ребенка, так как приобретенные данные сгенерированы в единый ИД код, зашифровав биометрические данные, с возможностью отмены. В статье мы представляем новейшую систему, основанную на снятии отпечатков пальца, которую мы разработали.

Ключевые слова: биометрия, отпечаток пальца, безопасность, новорожденный ребенок, метод, информационная система.

НОВИ МЕТОД ЗА ОДРЕЂИВАЊЕ ИДЕНТИТЕТА НОВОРОЂЕНЧЕТА, ЗАСНОВАН НА БИОМЕТРИЈИ ОТИСКА ПРСТА

Комлен Г. Лаловић[в], *Иван* А. Тот[б], *Младен* Б. Трикош[б]

[а] ИТС – Висока школа струковних студија за информационе технологије,
Београд, Република Србија

[б] Универзитет одбране у Београду, Војна академија,
Катедра информационих система и телекомуникационог инжењерства,
Београд, Република Србија

ОБЛАСТ: информационе технологије, патент
ВРСТА ЧЛАНКА: оригинални научни чланак
ЈЕЗИК ЧЛАНКА: енглески

Сажетак:

Овај рад презентује нови поступак биометријске идентификације новорођених беба у породилиштима који је заснован на минуцијама отиска прста. Информациони систем који је реализован комбинује све данашње програмске језике као што су: Јава, Пајтон у објектно-оријетисаном програмирању, C програмски језик за програмирање уређаја као структирни (линијски) и SQL систем за управљање релационим базама података за чување. Поред тога, користи се RSA асинхрони шифарски алгоритам и кључеви за чување шифрованих вредности минуција отиска прста. Информациони систем имплементира уређај за биометријску идентификацију родитељства као дуални биометријски скенер који даје податке о отиску прста мајке и бебе при самом моменту рођења, што отклања опасност од замене новорођенчета. Генеришући јединствене ID референце и шифрујући те податке са цанцелабле биометријом. развили смо један потпуно нови систем и поступак заснован на минуцијама отиска прста.

Кључне речи: биометрија, отисак прста, безбедност, беба, метода, информациони систем.

Paper received on / Дата получения работы / Датум пријема чланка: 29.08.2018.
Manuscript corrections submitted on / Дата получения исправленной версии работы / Датум достављања исправки рукописа: 26.11.2018.
Paper accepted for publishing on / Дата окончательного согласования работы / Датум коначног прихватања чланка за објављивање: 28.11.2018.

ASSESSMENT OF EFFICIENCY OF MILITARY TRANSPORT UNITS USING THE DEA AND SFA METHODS

Dejan R. Despić[a], *Nebojša* J. Bojović[b],
Milorad J. Kilibarda[c], *Marko* V. Kapetanović[d]

[a] Ministry of Defence of the Republic of Serbia,
Material Resources Sector, Department for General Logistics,
Belgrade, Republic of Serbia,
e-mail: dejandespic79@gmail.com,
ORCID iD: https://orcid.org/0000-0001-5256-3436

[b] University of Belgrade, Faculty for Transport and Traffic Engineering,
Belgrade, Republic of Serbia,
e-mail: nb.bojovic@sf.bg.ac.rs,
ORCID iD: https://orcid.org/0000-0001-5600-3807

[c] University of Belgrade, Faculty for Transport and Traffic Engineering,
Belgrade, Republic of Serbia,
e-mail: m.kilibarda@sf.bg.ac.rs,
ORCID iD: https://orcid.org/0000-0003-3794-7380

[d] University of Belgrade, Faculty for Transport and Traffic Engineering,
Belgrade, Republic of Serbia,
e-mail: m.kapetanovic@sf.bg.ac.rs,
ORCID iD: https://orcid.org/0000-0002-5703-6536

DOI: 10.5937/vojtehg67-18508; https://doi.org/10.5937/vojtehg67-18508

FIELD: Mathematics, Logistics, Traffic Engineering
ARTICLE TYPE: Original Scientific Paper
ARTICLE LANGUAGE: English

Summary:

The aim of the paper is to make an analysis of the efficiency of selected transport units in the military logistics and military vehicles in carrying out the tasks of cargo transport using the method of stochastic frontier analysis (SFA) and the data envelopment analysis (DEA), and creating the basis for further investigation of the parameters that influence the efficiency of military transport units and military vehicles. The research was carried out in ten military transport units intended for the realization of tasks dealing with the logistic function of movement and transportation. The efficiency analysis was done for military vehicles used for carrying out cargo transportation tasks for the needs of supply and special needs of command, units and military institutions. The data was obtained from the software package used to monitor the exploitation of military motor vehicles in the period of one calendar year. The results show that the method selection has a major impact on the obtained technical efficiency

assessments, and therefore on possible management decisions based on the performed efficiency analysis.

Key words: efficiency, military transport units, military vehicles, data envelopment analysis, stochastic frontier analysis.

Introduction

A modern military organization together with its missions and tasks in the function of state defense cannot be imagined without its dynamic determinant i.e. its transport and transportation system that allows it to be mobile in its totality or in its parts. Increasing transport needs and demands as products of more dynamic engagement of the military in modern conditions, with a tendency of increasing efficiency and reducing operating costs, make it complicated because of the existing organizational structure of the management and transport units.

In the economy and society in general as well as in the military, logistic processes are an important factor in the functioning of the organization. The performance of the entire logistic system depends largely on the performance of the transport system as its segment. The efficiency of transport is thus imposed as a necessity in order to create a predisposition of the defense system in response to the contemporary challenges and threats to security in accordance with the needs and possibilities of the state.

Efficiency is a very important indicator of a company business analysis and it is one of the most basic and most used performances (Andrejić et al, 2016). The essence of measuring efficiency in transport is to improve efficiency.

The aim of this paper is to carry out an analysis of the efficiency of selected transport units in the military logistics and military vehicles in carrying out cargo handling tasks using the method of stochastic frontier analysis (SFA) and the data envelopment analysis (DEA) in order to create a basis for further research of the parameters that influence the efficiency of the work of the military transport units and military vehicles.

The research was, therefore, carried out in ten military transport units intended for the realization of tasks in the logistic function of movement and transportation. The efficiency analysis was carried out for military vehicles used for carrying out cargo transportation tasks for the needs of supply and special needs of command, units and military institutions. The actual data obtained from the software package used to monitor the use and exploitation of military motor vehicles were used, and they relate to a period of one calendar year.

The efficiency analysis was realized at three levels: first level - efficiency of transport units, second level - vehicle efficiency, and third level - vehicle efficiency within defined classes (clusters). The DEA and SFA methods were used to evaluate and analyze the efficiency of transport units and vehicles. First, the selected decision units (DMUs) of relative efficiency were also defined. Then, the input and output parameters suitable for assessing the relative technical efficiency of the selected DMUs were determined, and then the corresponding DEA and SFA models were selected. Finally, the DEA and SFA models were solved and the results analyzed and interpreted.

Besides the introduction, the paper consists of four chapters. The second chapter provides the basic remarks on the functioning of transport in the defense system and defines the concept of efficiency. The third chapter describes the SFA and DEA methods used in the work to evaluate efficiency. The selection of the input and output parameters and the results of the analysis are given in the fourth chapter. Finally, the conclusion and directions for future research are given in the last chapter.

Transportation function in the defense system and the definition of the concept of efficiency

In accordance with the Rulebook on Transportation of Personnel and Assets in the Ministry of Defense and the Serbian Armed Forces (hereinafter: the Rulebook on Transportation) (Službeni vojni list, 9/2013), transportation of personnel and assets in the Ministry of Defense and the Serbian Armed Forces (hereinafter: transport) is performed by units and institutions of the Serbian Armed Forces and the Ministry of Defense dealing with the tasks of transporting personnel and assets for their own needs, or for the needs of other units and institutions in the Ministry of Defense and the Serbian Armed Forces.

According to the Rulebook on Transportation (Službeni vojni list, 9/2013), the objectives of the movement and transportation function are to provide conditions for satisfying transport needs of the Ministry of Defense and the Serbian Armed Forces, the continuous performance of transport tasks, as well as the economy, efficiency and effectiveness of transport.

The general tasks of the movement and transportation management encompass monitoring, analyzing and proposing measures for improving the organization and use of transport and transport capacities of the army (Dozet et al, 1988).

According to the Rule on Transportation (Službeni vojni list, 9/2013), the principles of effectiveness and efficiency are:

- the principle of effectiveness which means that the planning and realization of transport allow full satisfaction of the transport needs of the military;
- principle of efficiency, which means that the transportation needs of the army are met in a timely and efficient manner by using the comparative advantages of each of the aspects and modes of transport.

On the other hand, in the Vujaklija's Leksikon stranih reči i izraza (Vujaklija, 1980), efficiency (lat. Efficacitas) is "action, activity, craftiness, success"; while the term "effectiveness" is not mentioned. Gleason and Barnum (1982) emphasize that the term "effectiveness" often means the degree of accomplishment of goals ("doing the right things"), and under the term efficiency - achieving these goals in the best way ("doing things in the right way") (Andrejić & Kilibarda, 2017).

The efficiency of the vehicle refers to the minimal energy consumption achieved by the design of the vehicle, but also by the technologies of their use. (Andrejic & Kilibarda, 2017).

The use of military vehicles is carried out on the basis of acts of command (orders, commands, instructions) or approved plans of use or extracts from these plans. By coordinating the planning of the use of military vehicles, the capabilities of the planner and the needs of the users are coordinated, so that the same number of military vehicles accomplishes a greater number of tasks during the day.

Planning in peace, organization and monitoring of the operation of transport means are performed in accordance with tasks such as transport of people and transport of cargo.

The paper analyzes the efficiency of only vehicles used for the realization of cargo transportation tasks for the needs of supply and the special needs of the commands, units and institutions of the Ministry of Defense and the Serbian Armed Forces, all of which are freight cars and terrain vehicles for towing and transport, regardless of their specific purpose, and according to the plan of the competent body for organization and planning of transport and transport.

Methods

Data Envelopment Analysis – DEA

In addition to using traditional measures, the assessment of the organization's performance can be carried out using parametric and non-parametric techniques. In practice, it is often necessary to consider

multiple inputs and outputs that are diverse by their nature (financial, technical, environmental) and are expressed in different measuring units. Farel's technical efficiency measure (Farrell, 1957) allows the inclusion of either multiple inputs or multiple outputs in the analysis. This macroeconomic theory served as the basis for the development of the Data Envelopment Analysis (DEA) as a methodology for assessing efficiency.

The DEA method creators (Charnes et al, 1978) assumed that in assessing the efficiency of units there should not be an objective procedure for determining the values of weight coefficients. By subsequent analysis, it is possible to show which of the units considered are efficient and which are not. The DEA is a mathematical programming technique that allows determining whether the entity, based on data on its inputs and outputs, is efficient or not, relative to other entities involved in the analysis.

There are a large number of models, given in detail in the overview published on the occasion of 30 years of the development of the DEA method (Cook & Seiford, 2009). The basic models and basic extensions are described in detail in the doctoral dissertation (Martić, 1999) published at the Faculty of Organizational Sciences.

DEA models with constant returns to scale

Let x_{ij} - the observed amount of input of the i-th type for DMU_j ($x_{ij} > 0$, i = 1,2,...,m, j= 1,2,...,n), and y_{ij} the observed amount of the output r-th type of DMU_j ($y_{rj} > 0$, r = 1,2,...,s, j = 1,2,...,n). Charnes, Cooper and Rouds proposed in (Charnes et al, 1978) that for each DMU_k, k=1,2,...,n, the optimization task, known as CCR model, MODEL (M.1), should be solved:

$$(\max)\mathrm{h_k} = \frac{\sum_{r=1}^{s} u_r y_{rk}}{\sum_{i=1}^{m} v_i x_{ik}} \tag{1}$$

subject to:

$$\frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{i=1}^{m} v_i x_{ij}} \le 1,\ j = 1,2,....,n \tag{2}$$

$$u_r \ge 0, r = 1,2,...,s \tag{3}$$

$$v_i \geq 0, i = 1,2,...,m \tag{4}$$

where: h_k – is the relative efficiency of k-th DMU; n - the number of DMUs to be compared; m – the number of inputs; s – the number of outputs; u_r – the weight coefficient for the output r; v_i - the weight coefficient for the input i.

The relative efficiency of $h_к$ for DMU_k is defined as the ratio of the weights of its outputs (virtual output) and the weights of its inputs (virtual input). The CCR ratio model calculates total technical efficiency that includes both pure technical efficiency and efficiency as a result of different business volumes.

Since condition (2) is valid for the k-th DMU required for the maximum efficiency (1), it is obvious that $0 < h_к \leq 1$. If the value for $h_к$ in the function of the target is equal to 1, then the DMU is relatively efficient, and if it is less than 1, the $DMU_к$ is relatively inefficient and the value of $h_к$ shows how many percent of this unit needs to reduce its inputs.

The linear fractional programming problem, described by relations (1) - (4), can be reduced to an equivalent linear program using simple Charns-Cooper transformations (Cooper et al, 1999) - MODEL (M.2):

$$(\max) h_k = \sum_{r=1}^{s} u_r y_{rk}$$

subject to:

$$\sum_{i=1}^{m} v_i x_{ik} = 1 \tag{5}$$

$$\sum_{r=1}^{s} u_r y_{rj} - \sum_{i=1}^{m} v_i x_{ij} \leq 0, \; j = 1,2,...,n$$

$$v_i \geq \varepsilon, i = 1,2,...,m$$

$$u_r \geq \varepsilon, r - 1,2,...,s$$

In the M.2 model for k-th DMU, the virtual output is maximized and its virtual input is equal 1. The limitations by the data relation (5) indicate that the optimal weights for the k-th DMU must satisfy the requirement that for each of the DMUs its virtual output cannot be larger than its virtual input.

DEA model with variable returns to scale

The first extension of the core CCR DEA model was introduced by Banker, Charnes and Cooper (Banker et al, 1984). The BCC model measures pure technical efficiency, i.e. it gives an efficiency measure that ignores the impact of the volume of operations by comparing the k-th DMU with other units of the same size.

In relation to the CCR model, the primary BCC model contains an additional variable in u_* which defines the position of an auxiliary hyper plane that lies on or above each DMU included in the analysis. The value of the parameter u_* directly indicates the nature of the economies of scale allowed by the DEA model. This is shown in the theorem that Banker and Thrall proved in (Banker & Thrall, 1992).

The primary BCC DEA model proposed in (Banker et al, 1984) has the following form - MODEL M.3:

$$(\max) h_k = \sum_{r=1}^{s} u_r y_{rk} + u_*$$

subject to:

$$\sum_{i=1}^{m} v_i x_{ik} = 1$$

$$\sum_{r=1}^{s} u_r y_{rj} - \sum_{i=1}^{m} v_i x_{ij} + u_* \le 0,\ j = 1,2,...,n$$

$$v_i \ge \varepsilon, i = 1,2,...,m$$

$$u_r \ge \varepsilon, r - 1,2,...,s$$

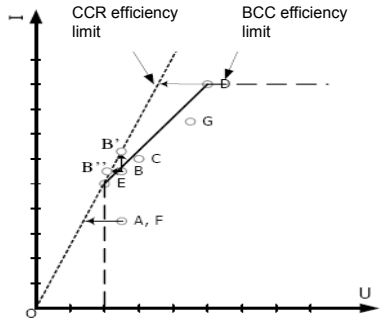


Figure 1 – Forms of efficiency limit
Рис. 1 – Пределы эффективности
Слика 1 – Облици границе ефикасности

The orientation of the DEA model (input or output) determines the direction of the ineffective DMU projection to the efficiency limit. In an input-oriented model, efficiency improves through a proportional input reduction, and the output orientation requires a proportional increase in output.

Stochastic Frontier Analysis - SFA

The SFA is a statistical parametric technique used to estimate deviations in the performance of production units from the production frontier (Aigner et al, 1977) and (Meeusen & Van den Broeck, 1977). The basic concept of the SFA model is that deviations are not entirely due to inefficiencies, as they confirm that random effects beyond unit control can affect production. The main advantage of the SFA is that it can isolate the contribution of random effects to variations in technical efficiency.

The original specification of the model included the production function defined for crosssectional data, and later it received a number of different modifications and shapes. The function contained an error component, consisting of two elements - noise (random errors) and technical inefficiency. This model, in the case of Cobb-Douglas frontier function, has the following form:

$$\ln(y_i) = \beta_0 + \sum_{k=1}^{K} \beta_k \ln(x_{ik}) + v_i - u_i$$

where: y_i – the output (production) of the i-th company; x_{ik} - k-th input of the i-th firm (k = 1, ..., k); β_k – an unknown parameter to be evaluated (k = 1, ..., K); $v_i \sim N(0,\sigma_v^2)$ is a random variable that represents fault (noise) and has an independent distribution of the distribution of technical inefficiency; $u_i \sim |N(0,\sigma_v^2)|$ - a non-negative random variable that represents technical inefficiency.

For example, the input values are displayed on the x-axis and the output values on the y-axis. The firm A uses the input x_A to generate the output q_A (indicated by x), while the firm B uses the input x_B to generate the output q_B (shown by x). If there are no inefficiency effects, i.e. if (u_A=0, u_B=0), then the so-called exits of the frontier area are $q_A^* = \exp(\beta_0 + \beta_1 \ln x_A + v_A)$ and $q_B^* = \exp(\beta_0 + \beta_1 \ln x_B + v_B)$. In Figure 2, these values are represented by the sign $\otimes$. Obviously, the frontier exit of A is above the deterministic part of the frontier region because the effect of the statistical noise is positive v_A>0, and the B-frontier output is

below, because the effect of the statistical noise is negative $v_B<0$ (Kumbhakar & Knox Lovell, 2003).

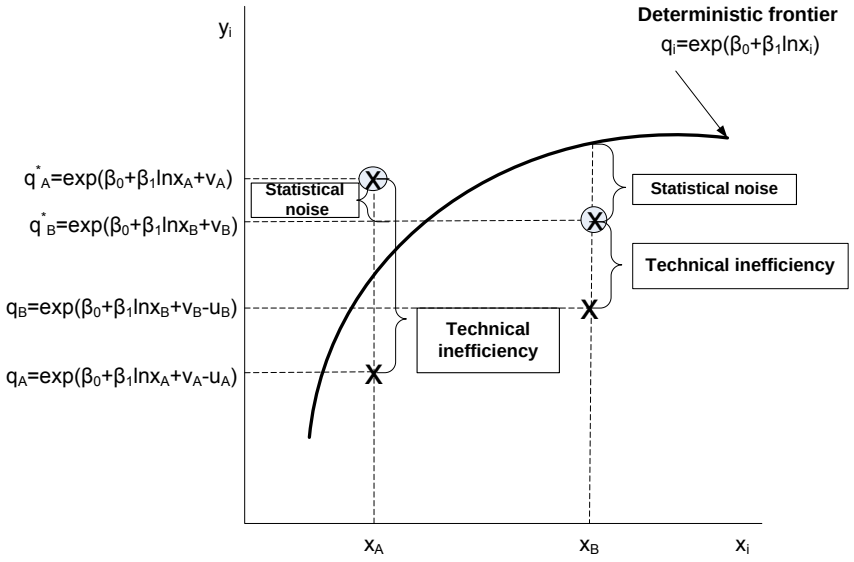


Figure 2 – Kob-Douglas model
Рис. 2 – Модель Кобба-Дугласа
Слика 2 – Коб-Дагласов модел

Function modifications included additional assumptions regarding the distribution of technical inefficiencies u_i, such as a truncated normal or gamma distribution; other forms of the frontier function; consideration of panel data and technical efficiencies variability in time; expanding models with cost functions, etc.

Although it contains a number of parameters to be assessed against the Cobb-Douglas function, the transcedental logarithmic form of the frontier form of the function is much more flexible and provides more consistent technical efficiency estimates. It represents the generalization of the Cobb-Douglas function, and has the following form (Knežević et al, 2015):

$$\ln(y_i) = \beta_0 + \sum_{k=1}^{K} \beta_k \ln(x_{ik}) + \sum_{k=1}^{K} \sum_{k'=1}^{K} \beta_{kk'} \ln(x_{ik}) \ln(x_{ik'}) + v_i - u_i$$

The main disadvantage of standard SFA models is the inability to observe multiple outputs, i.e. the existence of only one output. Coelli and Perelman (Coelli & Perelman 1996, 2000), Knezević, Bojović,

Kapetanović (Knezević et al, 2015) dealt with the frontier function in the case of multiple inputs and multiple outputs. In the case of the existence of the K input and the L output, the functional form can be written as:

$$-\ln(y_L) = \alpha_0 + \sum_{k=1}^{K} \alpha_k \ln(x_k) + \sum_{l=1}^{L-1} \beta_l \ln(\frac{y_l}{y_L}) + \frac{1}{2}\sum_{k=1}^{K}\sum_{k'=1}^{K} \alpha_{kk'} \ln(x_k)\ln(x_{k'}) +$$

$$+ \sum_{k=1}^{K}\sum_{l=1}^{L-1} \gamma_{kl} \ln(x_k)\ln(\frac{y_l}{y_L}) + \frac{1}{2}\sum_{l=1}^{L-1}\sum_{l'=1}^{L-1} \beta_{ll'} \ln(\frac{y_l}{y_L})\ln(\frac{y_{l'}}{y_L}) + v_i - u_i$$

where y_L represents an arbitrary chosen output. In the case of two entrances and two exits:

$$-\ln(y_1) = \alpha_0 + \alpha_1 \ln(x_1) + \alpha_2 \ln(x_2) + \beta_1 \ln(\frac{y_2}{y_1}) + \frac{1}{2}\alpha_3 \ln^2(x_1) +$$

$$+ \frac{1}{2}\alpha_4 \ln^2(x_2) + \frac{1}{2}\alpha_5 \ln(x_1)\ln(x_2) + \gamma_1 \ln(x_1)\ln(\frac{y_2}{y_1}) + \quad (6)$$

$$+ \gamma_2 \ln(x_2)\ln(\frac{y_2}{y_1}) + \frac{1}{2}\beta_2 \ln^2(\frac{y_2}{y_1}) + v_1 - u_1$$

Selection of parameters and the efficiency analysis

In order to improve the efficiency of the organization's work, it is necessary to select relevant indicators whose monitoring and analysis can provide the necessary information in order to generate actions to improve the process and improve the efficiency of the organization's operation.

Transport is a process characterized by high costs: number of vehicles and drivers, energy consumption, realized transport work, space and time use of the vehicle, are just some of the factors that influence the efficiency of the transport process.

The goal of transportation planning, due to the specific nature of the military organization, is to find the conditions for meeting the transport needs of units and military institutions, regardless of the respect of other transport principles: rationality, economy, etc. For these reasons, there are cases of inefficient use of vehicles.

The basic efficiency criteria should contribute to meeting the goal of the existence of a system - meeting the transport needs of the army in peace, during the mobilization period and in the war. The basic criteria of transport in general can be taken as the basic criteria of efficiency for achieving these goals - the performance of the fleet and the cost of transport services, since most of the parameters of the transport process are related to them. The performance of the transport fleet of transport units is assessed with two interconnected parameters of the incineration

criterion; the volume of transported cargo (volume of transport) in tonnes and the number of tonne-kilometers achieved (cargo traffic) in tkm (Dozet et al, 1988).

The indicators of efficiency in transport in literature:

Byrne and Markham (1991): tkm / total transport costs, transported quantity / total transport costs, total transport capacity / capacity costs.

Cruijssen et al (2010): labor power (salaries, driver experience, total hours of work, number of employees), equipment (number of trucks, number of trailers, total capacity), intangible assets (market information, contact with users), profit.

Kim (2010): costs of employees, fuel costs, lubricant costs, taxes, insurance, mileage, transported quantity, transport distance.

The division of the indicators of the efficiency of logistics processes can also be carried out according to the subsystem or process described by Andrejić and Kilibarda (2017). Thus, groups of indicators can be distinguished:

- storage indicators;
- transport indicators (number of vehicles, total number of kilometers traveled, realized transport work, fuel consumption, etc.);
- stock indicators.

The data used in the paper were collected through an application intended for automated processing of data on the condition and use of non-combat vehicles and connecting vehicles and other fuel consumers in the information system of the traffic service in the military. This application allows tracking the traveled route, fuel used, the number of persons transported and the amount of transported cargo for a specified period of time (month, year) for the vehicle or the entire unit.

Data on the performance indicators of military transport units and vehicles which can be obtained from the above application coincide with the often used indicators of efficiency in transport in the literature, first of all in the book Efficiency of Logistic Processes (Andrejić & Kilibarda, 2017). For this reason, the following data were used in the analysis of the efficiency of the observed military transport units and vehicles - Table 1.

Two input parameters were used to evaluate the efficiency of the transport units: the number of vehicles used for the transport of cargo and the total fuel consumption of these vehicles (l). Two parameters were also used as output indicators: the total distance driven by vehicles used for transport of goods (km) and the total quantity of transported cargo (t).

For the assessment of the efficiency of vehicles (in total and by classes), the parameters were used - two inputs: total fuel consumption per vehicle (l) and total available vehicle load for the days of use in the

observed time (t) and two outputs: distance driven per vehicle (km) and the total quantity of cargo carried per vehicle (t).

Table 1 – Aspects of measuring the efficiency of transport
Таблица 1 – Аспекты измерения эффективности транспорта
Табела 1 – Аспекти мерења ефикасности транспорта

	Efficiency of transport unit	Efficiency of the vehicle	Vehicle efficiency by class
Management level	Operating level	Tactical level	Tactical level
Input indicators	1. number of vehicles 2. fuel (l)	1. fuel (l) 2. the total available vehicle load in the observed time (t)	1. fuel (l) 2. the total available vehicle load in the observed time (t)
Output indicators	1. distance driven(km) 2. transported cargo (t)	1. distance driven (km) 2. transported cargo (t)	1. distance driven (km) 2. transported cargo (t)
DMU number	10 transport units	173 vehicles	6 class vehicles: 24 vehicles up to 3t capacity 78 vehicles up to 6t capacity 17 vehicles up to 12t capacity 11 vehicles over 12t capacity 21 vehicle ACG 22 vehicles ACV
Applied model	DEA and SFA analysis		

The vehicle classes are defined according to load capacity (up to 3t, from 3t to 6t, from 6t to 12t and over 12t) and the specific type of cargo being transported by them (ACG - fuel tanks and ACV – water tank), Table 2. In this analysis, vehicles used for fewer than 10 working days and covering fewer than 500 kilometers during the year were not observed.

The paper analyzes the relative technical efficiency of ten military transport units and 173 vehicles engaged in cargo transportation tasks for supplies and special needs of the army.

It should be emphasized that until now, to a certain extent, mainly through the annual analysis of logistics in the military, the problem of organization and structure of transport units and their efficiency was partially taken into account, but not comprehensively approached in the research of the subject matter.

Table 2 – Overview of the number of vehicles by classes and units
Таблица 2 – Обзор количества транспортных средств по классам и единицам
Табела 2 – Преглед броја возила по класама и јединицама

	up to 3t	up to 6t	up to 12t	over 12t	ACG	ACV	TOTAL
DMU 1	2	9	1	5	0	0	17
DMU 2	0	12	1	0	1	2	16
DMU 3	0	7	3	3	3	0	16
DMU 4	2	4	3	2	3	0	14
DMU 5	3	5	1	1	1	3	14
DMU 6	2	8	1	0	0	3	14
DMU 7	2	10	4	0	5	9	30
DMU 8	3	7	1	0	6	2	19
DMU 9	3	4	0	0	1	2	10
DMU 10	7	12	2	0	1	1	23
TOTAL	24	78	17	11	21	22	173

Table 3 – Descriptive input and output statistics for transport units
Таблица 3 – Описательная статистика ввода и вывода транспортных единиц
Табела 3 – Дескриптивна статистика улаза и излаза за транспортне јединице

	I/O	Parameter	Var	Obs	Mean	Std. Dev.	Min	Max
DMU	output	distance driven (km)	y1	10	137133.3	68275.3	62682	296695
	output	transported cargo (t)	y2	10	4156.7	4694.2	808	15763
	input	fuel (l)	x1	10	35138.5	19019.4	16717	78223
	input	the number of vehicles	x2	10	17.3	5.6	10	30

The calculation of the efficiency of transport units and vehicles was done whith:

- Input CCR and BCC DEA models - DEAP Version 2.1 software used for calculating (Softver DEAP Version 2.1., 2018).
- SFA model (using (6)), halfnormal and truncatednormal distribution - STATA13 software used for calculating (Softver STATA13, 2018).

The input-oriented model was selected as transport unit managers can influence more the reduction of input (the number and type of vehicles used, i.e. fuel consumption and vehicle load), and less the increase of output (quantity of transported cargo).

The DEA CCR model, which shows only three efficient units, has the greatest discriminatory power. On the other hand, the SFA model, with the assumed distribution of technical inefficiency, recognizes all units as effective.

As said, the SFA model, with the hnorm and tnorm distribution, recognizes all units as efficient. The DEA BCC model recognizes three (conditionally two) inefficient units, while the DEA CCR model recognizes only three units as effective - DMU3, DMU6 and DMU8 and therefore has the highest discriminatory power - Table 4.

Table 4 – Results of the analysis of the efficiency of transport units
Таблица 4 – Результаты анализа эффективности транспортных единиц
Табела 4 – Резултати анализе ефикасности транспортних јединица

	DEA CCR	DEA BCC	SFA tnorm	SFA hnorm	DEA CCR	DEA BCC	SFA tnorm	SFA hnorm
					rank			
DMU1	0.727	0.798	0.998363	0.999526	10	10	1	10
DMU2	0.771	1	0.998362	0.999545	9	1	7	2
DMU3	1	1	0.998362	0.999547	1	1	7	1
DMU4	0.997	1	0.998363	0.999526	4	1	1	9
DMU5	0.856	0.961	0.998363	0.999534	7	9	1	6
DMU6	1	1	0.998362	0.999528	1	1	7	8
DMU7	0.983	1	0.998363	0.999535	5	1	1	5
DMU8	1	1	0.998362	0.999536	1	1	7	4
DMU9	0.773	1	0.998363	0.999537	8	1	1	3
DMU10	0.968	0.999	0.998363	0.999531	6	8	1	7

Thus, the comments on the results obtained are as follows. The average efficiency of transport units by models is:
DEA CCR-0.91 <DEA BCC-0.98 <SFA tnorm ~ 1.00 <SFA hnorm ~ 1.00

DMU8 and DMU6, as efficient, do not have a high-capacity vehicle (tow truck). The greatest contribution to the efficiency of DMU8 is a vehicle marked mv127 ACG which was used to transport by far the largest amount of cargo - 13613t (i.e. liters of fuel). Without the mentioned vehicle, DMU8 would have had efficiency of 0.847 under the CCR model, and 0.849 according to the BCC model, i.e. it would not be at the limit of efficiency. DMU8 transported the largest amount of cargo.

DMU3 does not have a vehicle carrying capacity of up to 3t or ACV. Only one of the four units with high-capacity vehicles was declared effective (DMU3). It is interesting to note that the lowest efficiency in both the CCR and BCC model is DMU1, with a percentage of the largest number of heavy-duty vehicles (trucks) being 29% of the vehicle unit.

DMU2 is inefficient even though there are no vehicles with high load capacity, and the highest number of used vehicles is 3t to 6t capacity (75%). Also, DMU2 covered the fewest number of kilometers and transported the smallest amount of cargo. The reason for relative

inefficiency of DMU9 can be the size of the unit (the smallest number of vehicles), besides being the third transport unit in one region. The largest number of kilometers covered is in DMU7, but it is not at the limit of efficiency because it is the unit with the largest number of vehicles used.

If the efficiency of transport units is analyzed through the average efficiency of the observed vehicles of the transport units, given in Table 5, the lowest results of efficiency are still given by the DEA CCR: DEA CCR-0.37 <DEA BCC-0.46 <SFA hormone -0.74 <SFA tnorm -0.8

Table 5 – Average efficiency of vehicles by transport units
Таблица 5 – Средняя эффективность транспортных средств по транспортным единицам
Табела 5 – Просечна ефикасност возила по транспортним јединицама

	DEA CCR	DEA BCC	SFA tnorm	SFA hnorm	DEA CCR	DEA BCC	SFA tnorm	SFA hnorm
					rank			
DMU1	0.33	0.42	0.82	0.75	8	8	5	5
DMU2	0.31	0.51	0.85	0.79	10	3	1	1
DMU3	0.31	0.37	0.83	0.77	9	10	2	3
DMU4	0.42	0.51	0.76	0.67	2	2	9	9
DMU5	0.37	0.49	0.81	0.74	5	4	7	7
DMU6	0.46	0.53	0.71	0.65	1	1	10	10
DMU7	0.41	0.45	0.79	0.72	3	7	8	8
DMU8	0.39	0.47	0.81	0.74	4	5	6	6
DMU9	0.33	0.41	0.83	0.76	6	9	3	4
DMU10	0.33	0.47	0.83	0.78	7	6	4	2

Somewhat higher results of vehicle efficiency in the SFA model are obtained for the assumed truncatednormal relative to the halfnormal distribution of technical inefficiency. The DEA CCR model yields less efficacy results than the DEA BCC, as it assumes constant returns to scale.

By analyzing the obtained average efficiency of vehicles used by transport units, it is noticed that DMU6 is still the most efficient for both DEA models, but according to the SFA models it has the worst results. Observing the results in this way, the SFA models rated DMU2 as the most efficient, which, according to DEA CCR, I has the worst results of vehicle efficiency, and the opposite case is with DMU3.

When the number of vehicles used is taken as the input parameter, the results of the efficiency of transport units differ from the results obtained when the average values of the efficiency of the vehicles used for the transport within the unit are observed.

It is noted that the efficiency of the vehicles is small, which can be explained by using a vehicle for transporting freight often without the criterion of better utilization of the load (the need for transport has the quantity of cargo within the defined time limit). Out of 173 vehicles observed:

- according to the DEA CCR model, only three vehicles are efficient, as many as 146 vehicles have an efficiency of less than 0.5, and the average efficiency is 0.37.
- according to the DEA BCC model, 8 vehicles are effective, 124 vehicles have efficiency lower than 0.5, and the average efficiency is 0.46.
- according to the SFA tnorm model, the highest efficiency of 0.94 was found in two vehicles, 54 vehicles have efficiency below average, and the average efficiency is 0.8.
- according to the SFA hnorm model, one vehicle has the highest efficiency of 0.93, 72 vehicles have efficiency below average, and the average efficiency is 0.74.

The vehicle carrying capacity up to 3t with the mark mv172 is efficient according to the DEA CCR and BCC models, while it is among the two worst ones in the efficiency evaluation of the SFA models. On the other hand, the ACG vehicle with the mv152 tag has the best efficiency according to the SFA models, while according to the DEA CCR it has the lowest efficiency, and according to the DEA BCC, it is among the least efficient.

Among the most efficient vehicles, there are no vehicles with greater capacity (from 6t to 12t and over 12t), and the reasons for this should be sought in the fact that their efficiency is more reflective of the inexorability of their load capacity.

When considering the efficiency of all vehicles in the entire group of 173 vehicles per cluster, Table 7, it is noted that the vehicles with a minimum carrying capacity of up to 3t have the highest average efficiency according to the DEA methods, which can be explained with the smallest loss of available load capacity and lower average fuel consumption.

Table 6 – Descriptive statistics of inputs and outputs for vehicles
Таблица 6 – Описательная статистика вводов и выводов транспортных средств
Табела 6 – Дескриптивна статистика улаза и излаза за возила

	I/O	Parameter	Var	Obs	Mean	Std. Dev.	Min	Max
All 173 vehicles	O	distance driven (km)	a1	173	7927	8249	423	40576
	O	transported cargo (t)	a2	173	240	1057	5	13613
	I	fuel (l)	b1	173	2031	2059	110	11531
	I	available vehicle load (t)	b2	173	379	443	33	3984
Vehicles up to 3t capacity	O	distance driven (km)	ti1	24	9918	10663	779	39908
	O	transported cargo (t)	ti2	24	70	82	5	344
	I	fuel (l)	tu1	24	1347	1243	238	4728
	I	available vehicle load (t)	tu2	24	215	180	39	843
Vehicles up to 6t capacity	O	distance driven (km)	si1	78	7430	7354	423	35330
	O	transported cargo (t)	si2	78	71	77	6	446
	I	fuel (l)	su1	78	1874	1653	110	8107
	I	available vehicle load (t)	su2	78	290	172	35	800
Vehicles up to 12t capacity	O	distance driven (km)	di1	17	7255	3975	1767	15544
	O	transported cargo (t)	di2	17	109	80	19	292
	I	fuel (l)	du1	17	1981	1106	523	4349
	I	available vehicle load (t)	du2	17	418	243	147	960
Vehicles over 12t capacity	O	distance driven (km)	oi1	11	11099	11248	927	31102
	O	transported cargo (t)	oi2	11	557	651	40	1748
	I	fuel (l)	ou1	11	4172	4145	385	11397
	I	available vehicle load (t)	ou2	11	970	811	180	2574
Vehicles ACG	O	distance driven (km)	gi1	21	7873	11330	479	40576
	O	transported cargo (t)	gi2	21	870	2938	14	13613
	I	fuel (l)	gu1	21	2162	2832	213	11531
	I	available vehicle load (t)	gu2	21	592	894	35	3984
Vehicles ACV	O	distance driven (km)	vi1	22	6498	5168	487	17195
	O	transported cargo (t)	vi2	22	370	268	25	980
	I	fuel (l)	vu1	22	2177	1786	256	6005
	I	available vehicle load (t)	vu2	22	344	226	33	952

Table 7 – Average efficiency of all vehicles by defined groups
Таблица 7 – Средняя эффективность всех транспортных средств по определенным группам
Табела 7 – Просечна ефикасност свих возила по дефинисаним групама

Vehicles capacity	DEA CCR	DEA BCC	SFA tnorm	SFA hnorm	DEA CCR	DEA BCC	SFA tnorm	SFA hnorm
					rank			
up to 3t	0.56	0.70	0.68	0.61	1	1	6	6
up to 6t	0.32	0.40	0.83	0.76	5	4	2	3
up to 12t	0.33	0.38	0.81	0.74	4	5	4	4
over 12t	0.27	0.31	0.88	0.83	6	6	1	1
ACG	0.33	0.45	0.83	0.76	3	3	3	2
ACV	0.45	0.58	0.78	0.72	2	2	5	5

According to the SFA method, the vehicles up to 3t capacity have the lowest efficiency. Completely opposing ranking is found in the vehicles carrying over 12t. According to the SFA method, they have the highest efficiency, while according to the DEA methods in both cases they have the lowest average efficiency. Conditional consistency, as far as the average vehicle efficiency rating is concerned, is found in all methods in the case of the groups of ACG vehicles and the vehicle with a carrying capacity from 6t to 12t. The highest standard deviation of the results is with the vehicles with a carrying capacity up to 3t, ACV and ACG.

It is noteworthy that the results of the DEA and SFA models vary greatly; therefore, decision makers must be aware of that and choose the model in which they want to perform an efficiency assessment.

The results of vehicle efficiency, when calculations were made for vehicles within defined groups (clusters), are given in Table 8.

In small vehicle groups, the SFA models show all vehicles within the group as efficient, and there is certain discrimination only in larger vehicle groups. In this sense, the SFA model will not be commented on in this part of the paper.

The most homogeneous group of vehicles (and the smallest one) consists of the vehicles over 12t capacity – with the average efficiency of 0.92. According to the DEA CCR, the efficient vehicles are those with mv7, mv44 and mv61 markings, and the least efficient is the mv8 vehicle, while the BCC model has 7 efficient vehicles.

In the group of the vehicles up to 12t of capacity, there are 6 or 10 efficient vehicles according to the DEA models and they are evenly distributed in transport units.

Table 8 – Average efficiency of vehicles per class
Таблица 8 – Средняя эффективность транспортных средств по классам
Табела 8 – Просечна ефикасност возила по класама

Vehicles up to 12t capacity	DEA CCR	DEA BCC	SFA tnorm	SFA hnorm
up to 3t	0.66	0.83	1.00	0.71
up to 6t	0.60	0.65	0.86	0.74
up to 12t	0.89	0.93	1.00	1.00
over 12t	0.92	0.96	0.99	0.99
ACG	0.62	0.77	1.00	1.00
ACV	0.80	0.91	0.91	0.91

A group of vehicles with a minimum mean efficiency of 0.60 and 0.65 consists of the vehicles of 3t to 6t capacity, respectively, most of them being in group 78.

The vehicles with a carrying capacity up to 3t may have unexpectedly low mean efficiency. Six vehicles have an efficiency of less than 0.5 which says they are often used to transport very small loads.

ACGs within the group have 2 or 4 efficient vehicles, and, according to the DEA CCR model, 7 vehicles have efficiency below 0.5. All ACVs have efficiency within a group higher than 50%.

The comparison of the average efficiency of transport units in relation to the vehicle groups was not considered in the work due to the relatively small number of vehicles by defined groups in transport units. In other words, it could not be concluded where and in which transport units certain groups of vehicles are used better.

The comparison of the efficiency of vehicles in general and by defined groups showed that only three vehicles were declared effective in both cases: mv63 to 3t capacity, mv127 ACG and mv152 ACG.

The dependence of data on input and output parameters of transport units and vehicles was tested using the Spearman and Pearson correlation tests. The test results show that the input and output data are independent for all pairs of input and output data except in the case of input data for the vehicles with a capacity of 6t to 12t.

The results show that the choice of the method of evaluation of technical efficiency has a major impact on the obtained efficiency estimates, and, consequently, on the decisions made and implemented after the efficiency analysis.

Conclusion

The paper presents the application of the DEA and SFA methods for evaluating the efficiency of the work of the selected ten military transport units and 173 military motor vehicles used in cargo transportation tasks for the needs of supply and special needs of the army, individually and within six defined classes. It can be deduced from the estimate that the CCR DEA model has the highest discriminatory power that shows the lowest number of efficient units and gives the lowest mean value of efficiency of both transport units and vehicles.

The CCR DEA estimates that three transport units are efficient (with an average efficiency of 0.91), as well as three vehicles (average vehicle efficiency 0.37). The BCC DEA model estimates seven transport units as efficient as well as eight vehicles (average vehicle efficiency 0.46). No transport unit has been declared extremely inefficient (DMU1 has the lowest calculated efficiency with a score of 0.727 per CCR DEA model). Since the carrying capacity of the used vehicles has a large impact on the results of the efficiency of transport units, only one unit with high-capacity vehicles was declared effective, while the least efficient unit has the largest proportion of these vehicles.

With the SFA model, all transport units are rated as efficient. The same is the case with the assessment of the efficiency of vehicles in groups with few vehicles. For this reason, in assessing the efficiency of transport units and military vehicles, the SFA model is applicable in measuring the efficiency of a larger number of DMUs. Of all vehicles, two have the highest efficiency of 0.94, while the average vehicle efficiency according to the SFA models is 0.74 and 0.8. Low-capacity vehicles are rated as more efficient according to the DEA models, while the SFA models rate vehicles with higher load capacity as more efficient.

The choice of the method for calculating efficiency can be a determining factor for making management decisions, as it has been shown that the results of the DEA and SFA models differ significantly, about which decision makers must be informed in order to choose the model in which they want to perform efficiency assessment.

The DEA method makes it easier to compare DMUs across multiple inputs or outputs, and for each inefficient unit, it defines respectable units and required changes to the input or output in order to achieve efficiency. The CCR DEA model gives the lowest efficacy results because it allows a constant return to scale and measures the overall technical efficiency and efficiency of the business volume, while the BCC model measures

only pure technical efficiency, which makes a number of units more efficient.

Since this paper deals with the military context, certain specific information related to the organization, as well as the actual names of transport units, and data on the marks, kind and type of specific vehicles could not be included.

It has been shown that the conducted analysis and efficiency assessment provide a basis for a different approach to the problems of military transport management and more efficient use of vehicles. This paper explores the efficiency of military transport units in a different way than usual. The obtained efficiency results indicate that there is a space for increasing the efficiency of the transport units, especially the efficiency of vehicles. Increased efficiency can be achieved by better vehicle selection in relation to the amount of cargo in order to better utilize the vehicle's capacity. Also, the planning of return transport and better planning of freight transport through reduction of off-plan tasks, with fewer engaged vehicles and, consequently, lower fuel consumption, can increase output, i.e. quantity of transported cargo. By equipping newer vehicles with lower fuel consumption and greater reliability, the input resource needed to complete the tasks can also be reduced.

By choosing an appropriate method for assessing efficiency, input / output parameters and a good analysis of the obtained results, one can obtain a model of transport in the army that would increase the efficiency of transport units and vehicles to a higher level in order to achieve better operational capabilities of the military.

Numerous parameters influence transport efficiency, both at the level of transport units and vehicles. In this sense, the direction of further research on efficiency measurement,would be the influence of the parameters not observed in this paper: type of cargo, vehicle and driver time, organizational structure of the transport unit, distances to which goods are transported, the age of the vehicle, etc. Also, in further work, the influence of the factors on which the organization does not have influence i.e. weather conditions, road conditions, etc, can be investigated.

The work should be the initial phase of the research devoted to the parameters of the efficiency of the military transport units and military vehicles. The efficiency analysis is an important tool that can enable military organization management and transport management to find common solutions in order to achieve the goals of the organization. This would identify proposals for optimizing the use of vehicles for the transport of cargo as well as the engagement of the transport unit as a

whole, which would increase the quality and quantity of execution of transport tasks in support of the missions and tasks of the Serbian Armed Forces.

References

Aigner, D., Lovell, C., & Schmidt, P.1977. Formulation and estimation of stochastic frontier production function models. *Journal of Econometrics*, 6(1), pp.21-37. Available at: https://doi.org/10.1016/0304-4076(77)90052-5.

Andrejić, M., Bojović, N., & Kilibarda, M. 2016. A framework for measuring transport efficiency in distribution centers. *Transport Policy*, 45, pp.99-106. Available at: https://doi.org/10.1016/j.tranpol.2015.09.013.

Andrejić, M., & Kilibarda, M. 2017. *Efikasnost logističkih procesa*. Belgrade: Univerzitet u Beogradu - Saobraćajni fakultet (in Serbian).

Banker, R.D., Charnes, A., & Cooper, W.W. 1984. Some Models for Estimating Technical and Scale Inefficiencies in Data Envelopment Analysis. *Management Science*, 30(9), pp.1078-1092. Available at: https://doi.org/10.1287/mnsc.30.9.1078.

Banker, R.D., & Thrall, R.M. 1992. Estimation of returns to scale using data envelopment analysis. *European Journal of Operational Research*, 62(1), pp.74-84. Available at: https://doi.org/10.1016/0377-2217(92)90178-c.

Byrne, P.J., & Markham, W.J. 1991. *Improving Quality and Productivity in the Logistics Process: Achieving Customer Satisfaction Breakthroughts*. Council of Logistics Management.

Charnes, A., Cooper, W.W., & Rhodes, E. 1978. Measuring the efficiency of decision making units. *European Journal of Operational Research*, 2(6), pp.429-444. Available at: https://doi.org/10.1016/0377-2217(78)90138-8.

Coelli, T., & Perelman, C. 1996. Efficiency Measurement, Multiple-output Technologies and Distance Functions: With Application to European Railways. In *CREPP Working Paper*.Liege, Wallonia, Belgium: University of Liege.

Coelli, T., & Perelman, S. 2000. Technical efficiency of European railways: a distance function approach. *Applied Economics*, 32(15), pp.1967-1976. Available at: https://doi.org/10.1080/00036840050155896.

Cook, W.D., & Seiford, L.M. 2009. Data envelopment analysis (DEA) – Thirty years on. *European Journal of Operational Research*, 192(1), pp.1-17. Available at: https://doi.org/10.1016/j.ejor.2008.01.032.

Cooper, W.W., Seiford, L.M., & Tone, K. 1999. *Data Envelopment Analysis: A Comprehensive Text with Models, Applications, References and DEA-Solver Software*. Boston: Kluwer Academic Publishers.

Cruijssen, F., Dullaert, W., & Joro, T. 2010. Freight transportation efficiency through horizontal cooperation in Flanders. *International Journal of Logistics Research and Applications*, 13(3), pp.161-178. Available at: https://doi.org/10.1080/13675560903224962.

Dozet, S., Miladinović, V., Jovanović, G., Plaznić, R., Jušković, M., Trifković, M., & Ostojić, S. 1988. *Saobraćajno obezbeđenje oružanih snaga*. Belgrade: SSNO, Saobraćajna uprava (in Serbian).

Farrell, M.J. 1957. The Measurement of Productive Efficiency. *Journal of the Royal Statistical Society, Series A (General),* 120(3), p.253. Available at: https://doi.org/10.2307/2343100.

Gleason, J.M., & Barnum, D.T. 1982. Toward Valid Measures of Public Sector Productivity: Performance Measures in Urban Transit. *Management Science*, 28(4), pp.379-386. Available at: https://doi.org/10.1287/mnsc.28.4.379.

Kim, T. 2010. Efficiency of trucks in logistics: technical efficiency and scale efficiency. *Asian Journal on Quality*, 11(1), pp.89-96. Available at: https://doi.org/10.1108/15982681011051859.

Knežević, N., Bojović, N., & Kapetanović, M. 2015. Komparativna analiza efikasnosti jedinica poštanske mreže primenom DEA i SFA metoda. In *XXXIII Simpozijum o novim tehnologijama u poštanskom i telekomunikacionom saobraćaju - PosTel 2015*. Belgrade, pp.9-18. December 01-02 (in Serbian).

Kumbhakar, S.C., & Knox Lovell, C.A. 2003. *Stochastic Frontier Analysis*. New York: Cambridge University Press.

Martić, M. 1999. *Analiza obavijenih podataka sa primenama*. Belgrade: University of Belgrade, The Faculty of Organizational Sciences. Ph.D. thesis (in Serbian).

Meeusen, W., & van Den, B.J. 1977. Efficiency Estimation from Cobb-Douglas Production Functions with Composed Error. *International Economic Review*, 18(2), p.435. Available at: https://doi.org/10.2307/2525757.

Službeni vojni list 2013. *Pravilnik o transportu ljudi i sredstava u Ministarstvu odbrane i Vojsci Srbije*. Belgrade: Ministarstvo odbrane Republike Srbije (in Serbian).

Softver DEAP Version 2.1. [Internet]. Available at: http://www.uq.edu.au/economics/cepa/deap.php. Accessed: 26.03.2018.

Softver STATA13. [Internet]. Available at: http://www.stata.com. Accessed: 13.02.2018.

Vujaklija, M. 1980. *Leksikon stranih reči i izraza*. Belgrade: Prosveta, III dopunjeno izdanje (in Serbian).

ОЦЕНКА ЭФФЕКТИВНОСТИ ТРАНСПОРТНЫХ СРЕДСТВ ВООРУЖЕННЫХ СИЛ МЕТОДАМИ DEA И SFA

Деян Р. Деспич[а], *Небойша* Й. Бойович[б],
Милорад Й. Килибарда[б], *Марко* В. Капетанович[б]

[а] Министерство обороны Республики Сербия, Сектор материальных ресурсов, Управление логистикой, г. Белград, Республика Сербия
[б] Белградский университет, Транспортный факультет, г. Белград, Республика Сербия

ОБЛАСТЬ: математика, логистика, транспорт
ВИД СТАТЬИ: оригинальная научная статья
ЯЗЫК СТАТЬИ: английский

Резюме:

Целью данной работы являлось проведение анализа эффективности выбранных транспортных средств и военных боевых машин для осуществления заданий по перевозке груза при применении метода стохастической границы (SFA), а также анализа оболочки данных (DEA), создавая тем самым основание для дальнейших исследований параметров, влияющих на эффективность работы транспортных средств Вооруженных сил и военных боевых машин. Исследование проведено на основании десяти транспортных средств Вооруженных сил, предназначенных для осуществления логистических задач по транспорту и перевозкам. Анализ эффективности проведен для военных машин, используемых для выполнения заданий по транспорту и перевозкам груза для нужд снабжения и нужд специального назначения командования, воинских частей и учреждений Вооруженных сил. В работе использованы данные, полученные благодаря программному обеспечению, с помощью которого ведется наблюдение за пользованием и эксплуатацией военных машин в течение одного календарного года. Результаты показали, что выбор метода оказывает большое влияние на полученную оценку технической эффективности, и соответственно на возможные управленческие решения, принимаемые на основании проведенного анализа эффективности.

Ключевые слова: эффективность, транспортные средства Вооруженных сил, военные боевые машины, анализ оболочки данных, метод анализа стохастической границы.

ПРОЦЕНА ЕФИКАСНОСТИ ТРАНСПОРТНИХ ЈЕДИНИЦА ВОЈСКЕ МЕТОДАМА DEA И SFA

Дејан Р. Деспић[а], *Небојша* Ј. Бојовић[б],
Милорад Ј. Килибарда[б], *Марко* В. Капетановић[б]

[а] Министарство одбране Републике Србије, Сектор за материјалне ресурсе, Управа за општу логистику, Београд, Република Србија
[б] Универзитет у Београду, Саобраћајни факултет, Београд, Република Србија

ОБЛАСТ: математика, логистика, саобраћај
ВРСТА ЧЛАНКА: оригинални научни чланак
ЈЕЗИК ЧЛАНКА: енглески

Сажетак:

Циљ рада јесте да се изврши анализа ефикасности изабраних транспортних јединица у логистици Војске и војних возила у реализацији задатака транспорта терета применом метода

анализе стохастичких граница (SFA) и анализе обавијања података (DEA), као и стварање основе за даље истраживање параметара који утичу на ефикасност рада транспортних јединица Војске и војних возила.

Истраживање је извршено у десет транспортних јединица Војске, намењених за реализацију послова из логистичке функције саобраћај и транспорт. Анализа ефикасности извршена је за војна возила коришћена за реализацију задатака транспорта терета за потребе снабдевања и посебне потребе команди, јединица и установа Војске. Коришћени су подаци добијени из програмског пакета којим се прати коришћење и експлоатација војних моторних возила у периоду од једне календарске године. Резултати показују да избор методе има велики утицај на добијене оцене техничке ефикасности, а самим тим и на евентулане управљачке одлуке на основу извршене анализе ефикасности.

Кључне речи: ефикасност, транспортне јединице Војске, војна возила, анализа обавијања података, анализа стохастичких граница.

Paper received on / Дата получения работы / Датум пријема чланка: 04.08.2018.
Manuscript corrections submitted on / Дата получения исправленной версии работы / Датум достављања исправки рукописа: 25.09.2018.
Paper accepted for publishing on / Дата окончательного согласования работы / Датум коначног прихватања чланка за објављивање: 27.09.2018.

ПРЕГЛЕДНИ ЧЛАНЦИ

ОБЗОРНЫЕ СТАТЬИ

REVIEW PAPERS

DECISION MAKING MODEL IN FOREST ROAD NETWORK MANAGEMENT*

Srđan H. Dimić[a], *Srđan* D. Ljubojević[b]

[a] University of Defence in Belgrade, Military Academy, Department of Logistics, Belgrade, Republic of Serbia
e-mail: srdjan.dimic@mod.gov.rs,
ORCID iD: http://orcid.org/0000-0003-0673-4710

[b] University of Defence in Belgrade, Military Academy, Department of Logistics, Belgrade, Republic of Serbia,
e-mail: srdjan.ljubojevic@va.mod.gov.rs,
ORCID iD: http://orcid.org/ 0000-0002-2696-3062

DOI: 10.5937/vojtehg67-18446; https://doi.org/10.5937/vojtehg67-18446

FIELD: Traffic Engineering
ARTICLE TYPE: Review Paper
ARTICLE LANGUAGE: English

Abstract:

Forest resource exploitation and the achievement of full forest potential depend on the density and quality of the forest road network. The forest road network has to fulfill multiple functions; it thus has strategic importance in forest management. When planning the forest road network development, decision makers have to consider various technological, economic, social, and environmental factors. A comprehensive and functional approach is needed. A hybrid methodological framework for the formulation of guidelines, within which the strategy for the development of the state-owned forest road network should be defined, is presented in this paper. A fuzzy modification of the A'WOT method is proposed. The model, named FDA'WOT model, is based on an idea to provide a conceptual framework for strategic option selection by combining the fuzzy Delphi technique, the fuzzy SWOT analysis (Strengths, Weaknesses, Opportunities, Threats) and the Analytical Hierarchical Process (AHP). The FDA'WOT model overcomes the problems of a classical SWOT analysis related to the vagueness and uncertainties in assessment of the character, impact and relative importance of strategic factors. It is a frame for a multicriteria approach in decision making which allows analytical prioritization of alternative strategic options and selection of an optimal one. The proposed model is applied to a case study of the strategy selection for the forest road network development in the Republic of Serbia. The presented results have shown that the FDA'WOT model can successfully create conditions for sustainable strategy formulation.

Key words: forest road network, decision making, strategy, FDA'WOT model, fuzzy Delphi, fuzzy SWOT, AHP.

* The article is published in a short form in 1st International Conference on Management, Engineering and Environment - ICMNEE 2017.

Introduction

In the last few decades, the focus in forest management has been shifted from a dominant interest in timber harvesting to the so-called non-extractive uses, such as: recreational uses (hunting, fishing, hiking, camping), wildlife improvement, development of forests, environmental protection, etc. In the case of Serbia, decades of lagging in technical and technological development, numerous institutional weaknesses and slow adaptation to changes, as well as the applied forest management models, were the constraints in the forestry development (Ministry of Agriculture, Forestry and Water Management of the Republic of Serbia, 2006).

The development of the forest road network greatly impacts the achievement of the economic and ecological goals in forest management. Since forest roads are the most important foundation for sustainable forestry operations and represent one of the biggest investments in forest management, it is necessary to have an adequate strategy for the forest road network development for successful forest management. The strategy selection problem has a multidisciplinary character. In practice, the SWOT analysis is a common tool for solving the strategy selection problem, but the traditional SWOT analysis has some shortcomings such as subjectivity, the quantification of factors influences due to their uncertain nature, or the evaluation of strategic alternatives. To overcome these problems, in this paper, we propose a hybrid FDA'WOT model as an analytical approach to strategy formulation. The FDA'WOT model combines the fuzzy Delphi technique, the fuzzy SWOT analysis and the traditional AHP method.

The traditional SWOT analysis is often used in forestry studies. Hoang et al. (2015) used the SWOT analysis to assess the benefits and difficulties of forest management certification from the perspective of groups of smallholders in Vietnam. Hynynen et al. (2014) conducted the SWOT analysis to analyse Finnish forestry sector's operational environment and to define scenarios for the assessment of long-term impacts of alternative forest management strategies on potential resource use (Hynynen et al, 2015). Also, the SWOT analysis was used in the cases of forest management in the Czech Republic and Slovakia (Jarský et al, 2014), Algeria (Meddour-Sahar, 2015), Kyrgyzstan (Jalilova et al, 2012), Bulgaria (Winkel & Sotirov, 2011), Italia (Carbone & Savelli, 2009) and Austria (Rauch, 2007). Very rarely, the objects of the SWOT analysis were management issues regarding forest roads. In those cases, forest roads were analysed mainly from the wider perspective, as

part of forest infrastructure (Meddour-Sahar, 2015), or from the investment perspective (Jarský et al, 2014), but not as a final aim of the SWOT analysis.

The Analytical Hierarchical Process, developed by Saaty (1980), is a multi-criteria decision-making method often used in forestry. For some examples and reviews of the AHP application in forest management issues, we refer the reader to Triantakonstantis et al. (2013) and Diaz-Balteiro and Romero (2008). In some studies, the AHP method was used to solve forest road design, planning and maintainance problems (Hayati et al, 2013), (Pellegrini et al, 2013).

In 2000, Kurttila et al. introduced a new, hybrid A'WOT method. In order to provide quantification and mutual comparison of the influences of the SWOT factors, they conducted the analytical prioritization of the SWOT factors by the AHP. The SWOT analysis, in the A'WOT approach, sets up a formal frame, while the AHP ensures the analytical support to the decision-making process (Kangas et al, 2001). The original or modified A'WOT method has found its application in many areas, especially in natural resources management. The SWOT and AHP combination in forestry management was also used by Stainback et al. (2012), Dwivedi and Alavalapati (2009), etc.

Gerasimov et al. (2013) identified, by the A'WOT, the strategic options for forest energy development and priorities in transferring the Nordic forest energy solutions to the Karelia region in Northwest Russia. Analysing the options, they noticed the forest road network as an important factor for forest energy development. In 2012, Kajanus et al. analysed the possibilities of combining the AHP, the SMART (Simple Multi-Attribute Rating Technique) and the SMAA-O (Stochastic Multicriteria Acceptability Analysis - Ordinal) methods with the SWOT analysis. They concluded, according to four case studies of natural resources management and strategic planning, that the ability to provide different levels of preference information and the required decision support are very important prerequisites for a successful application of hybrid decision-making models, because „too difficult is to consider comparisons of items from different dimensions" of the SWOT matrix. The importance of data for the classification of factors was underlined by Gerasimov et al. (2013), too.They demonstrated that, due to uncertainty and lack of information from the field, it is often not easy to differentiate and categorise identified factors into the given SWOT categories with no doubt. Information uncertainties and ambiguities, inherent to strategic problems, are usually treated with a fuzzy approach, established by Zadeh (1965). Fuzzy techniques have also been applied in forestry

planning and forestry decision making (Zarekar et al, 2012), (Ochoa-Gaona et al, 2010), (Zadnik Stirn, 2006), (Mendoza & Prabhu, 2003).

The fuzzy approach in the application of the SWOT analysis, combined with other methods, such as the Analytical Hierarchical Process, or the Analytical Network Process can be found in areas other than forestry (for example, we refer to Dimić et al. (2016) and Ljubojević et al. (2014). In spite of numerous examples of separate applications of the SWOT and AHP methods in forestry and their more and more intensive combined applications, to the best of our knowledge, the fuzzified A'WOT combined with the fuzzzy Delphi technique has not been used in forest management.

Materials and methods

The proposed FDA'WOT model is a combination of the fuzzy Delphi technique, the fuzzy SWOT analysis and the AHP method. Expert opinions about the influences of the strategic factors are gathered and aggregated by the fuzzy Delphi technique, the strategic options are formulated through the fuzzy SWOT analysis and, finally, they are evaluated and prioritized in the AHP procedure.

As a tool for strategic decision making, the SWOT analysis is widely used, but besides many advantages it also has some disadvantages. The main disadvantages of the traditional SWOT analysis are (Ghazinoory et al, 2007): only qualitative analysis of factors; lack of objective (analytical) prioritization of different factors and strategies; difficult strategy selection in case a lot of factors are involved; and insensitivity to vagueness of the factor influences.

Quantification and prioritization problems can be overtaken by an AHP and SWOT combination. Accordingly, the A'WOT method, proposed by Kangas et al. (2001), solves the problems, but if a lot of factors are considered in the SWOT analysis, there appears a problem of consistency in AHP pairwise comparisons. Kurttila et al. (2000) and Saaty (1977) recommended limiting the number of SWOT factors to ten in order to increase the consistency. As it is axplained in Kurttila et al. (2000), the problem of pairwise comparisons consistency can be solved by grouping factors and introducing an additional level of hierarchy in the AHP model, or using specific techniques for data analysis.

However, the A'WOT model did not solve the problem of treatment and quantification of uncertain nature of the influences of strategic factors. The FDA'WOT model addresses that question. The model consists of six steps:

Step 1: Identify relevant internal and external strategic factors, and use a group of experts to assess the character and the influence of each factor on the forest road network. Do assessment by the fuzzy Delphi technique.

Step 2: Formulate alternative strategic options in the fuzzy SWOT process;

Step 3: Establish the hierarchical structure of the problem of choosing an optimal strategic option, according to the AHP approach;

Step 4: Conduct mutual pairwise comparisons of the factors within each SWOT group of factors (internal and external) and determine their relative priorities;

Step 5: Conduct mutual pairwise comparisons of the SWOT groups of the factors and determine the relative importance of the groups;

Step 6: Use the classic AHP method to evaluate alternatives, in relation to each SWOT group of factors, and to calculate the global priority of the alternatives in accordance with the established hierarchy of choice.

A need for the fuzzy approach in the evaluation of the strategic factors appears when a factor can be viewed as an opportunity and a threat, or a strength and a weakness, at the same time. For example, government support (if it is a strategic factor) is an advantage (opportunity) and a disadvantage (threat) simultaneously. It is an opportunity because of the possibility to use certain funds, but it is also a threat when the government support is denied or the funds are inefficiently used. An appropriate way to evaluate the character of a strategic factor such as this is to represent it as a fuzzy value. Thus, the estimation of the character and the importance of each strategic factor is expressed by a fuzzy number with a membership function which has a free form, in principle. Due to calculation simplicity, according to the recommendations given in (Ghazinoory et al, 2007), it is practical to use triangular fuzzy numbers $A=(a^l,a^m,a^u)$, where: a^l is a lower or pessimistic value, a^m is a medium or the most probable value and a^u is an upper or optimistic value of the factor. The task for the experts involved is to assess and linguistically express the influence of the factors. Their assessments are transformed into triangular fuzzy numbers, according to the adequate fuzzy scale (Figure 1). The average assessment of the group of experts $A_{sr}=(a_{sr}^l,a_{sr}^m,a_{sr}^u)$, for each factor separately, is calculated by aggregating individual assessments into the average value of a set of fuzzy numbers given for a particular factor, according to Eq. (1).

$$A_{sr} = (a_{sr}^{l}, a_{sr}^{m}, a_{sr}^{u}) = (\frac{1}{N} \cdot \sum_{i=1}^{N} a_i^{l}, \frac{1}{N} \cdot \sum_{i=1}^{N} a_i^{m}, \frac{1}{N} \cdot \sum_{i=1}^{N} a_i^{u}) \quad (1)$$

If some experts are more important, there is a possibility to use a weighted approach. In the assessment scale (Figure 1), a negative influence is related to threats or weaknesses, while a positive influence corresponds to opportunities or strengths.

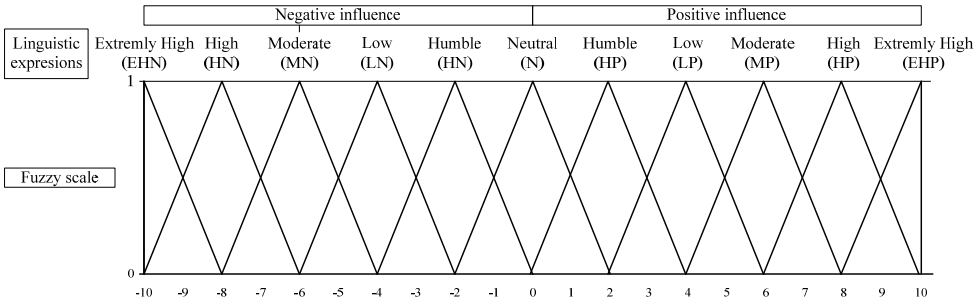


Figure 1 – Linguistic descriptors and a corresponding fuzzy scale for the assessment of the influence of the strategic factors

Рис. 1 – Лингвистические дескрипторы и соответствующая нечёткая шкала для оценки воздействия стратегических факторов

Слика 1 – Лингвистички дескриптори и одговарајућа fuzzy скала за процену утицаја стратегијских фактора

The next activity in the model is factor matching. It is an analysis of the mutual suitability of the factors. After that, the influences of the matched up factors should be mixed and projected into a domain of the adequate strategy type, according to the procedure explained by Ghazinoory et al. (2007). The aggregation and projection of factor influences result in potential ingredients of strategic options. Graphically, the factor combinations are presented as a set of pyramids, formed by a crossing mambership function (see the example in Figure 2).

The selection of factor combinations for the formulation of strategic options depends on the chosen α-cut ($0 \leq \alpha \leq 1$) of the pyramids, the α-cuts projections onto the plane of the bases of the pyramids, and on the fulfillment of the selection criteria.

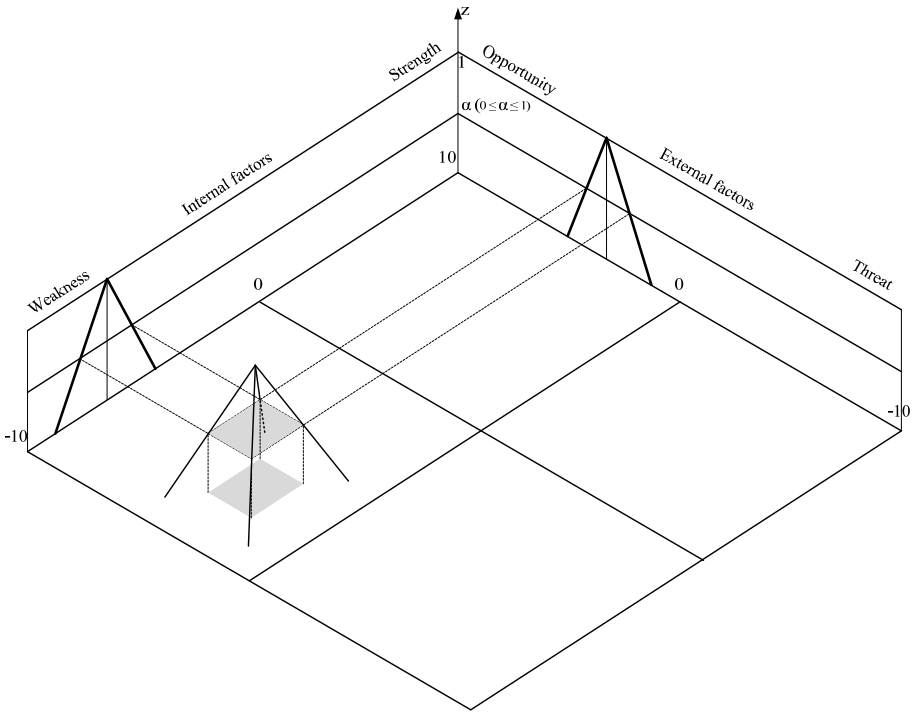


Figure 2 – Example of the aggregation of the membership functions of an internal and an external factor, their α-cut and its projection otno the base
Рис. 2 – Пример агрегации функций принадлежности с одним внутренним и одним внешним фактором, их α-сечения и его проекции на основании
Слика 2 – Пример агрегације функција припадности за један интерни и један екстерни фактор, њиховог α-пресека и његове пројекције на базу

As the selection criterion, Ghazinoory et al. (2007) recommended one of these:

- minimum of the Euklidean distance from the matrix vertices to the nearest edge of the projection area,
- minimum of the distance from the matrix vertices to the centre of gravity of the projection area, or
- maximum of the percentage of the projection area which belongs to a particular quadrant in the matrix.

The strategic options should be based on the combination of factors whose influences are connected and, in the same time, which satisfy the selection criterion. When the strategic options are defined, an AHP hierarchy is set up. Generally, a hierarchy of the selection model can be structured into four levels. At the top level, there is the selection goal –

the optimal strategic option for the forest roads network development. At the second level, there are two SWOT categories of factors - internal factors (strengths and weaknesses) and external factors (opportunities and threats). The identified strategic factors are at the third level while the defined strategic options are at the fourth level.

The presented model is applied to the problem of defining the strategic options in the development of the forest road network in Serbia. The existing forest road network in Serbia was constructed mainly with the view of timber harvest. Considering the contemporary needs of users, interests of stakeholders and forest management policy, an adequate strategy is one of the high priority prerequisites for the development of the forest road network. According to the Bulletin of Statistical Office of the Republic of Serbia (Statistical Office of the Republic of Serbia, 2015), the total length of the state-owned forest roads in Serbia is 25903 km, out of which 386 km are modern roads, 21190 km are rigid roads and 4 km are flexible roads. The assessed density of the forest road network in Serbia is 7.23 m/ha, or 5.24 m/ha if only forest roads paved with gravel are counted in (Danilović & Stojnić, 2014). Additionally, many of the forest roads are in unserviceable condition. A lot of them are unsurfaced „tractor“ roads. This state of the forest road network is not satisfactory. The development of the forest road network depends on many factors. Some of them are limiting. Because of that, a feasible and sustainable strategy should be balanced and based on an appropriate, scientific assessment of an uncertain nature of factors.

Results

Taking into account the contemporary conditions of the forest road network in the observed geographical area, actual management problems, incompleteness of law and management regulations (strategy, policy, development plans, etc.), contemporary and future social needs, as well as forestry needs, a set of internal and external factors with a strategic influence on the forest road network development has been formed. The characters of the identified factors are expressed by fuzzy values (Table 1), based on the expert oppinions gained in the fuzzy Delphy precedure presented in Bojadziev and Bojadziev (2007).

Expert oppinions were collected in 2015 through two rounds of questionnaires. Twenty one experts were involved in the survey (in the second round, 20 experts answered to the questionnaire). All of them are experienced, highly positioned managers in the Ministry of Agriculture,

Forestry and Water Management or in the state enterprise „Srbijašume“, or are eminent professors at the Faculty of Forestry.

The average opinions of the group of experts on the characters of the influencing factors are presented by the triangular fuzzy number $A = (a_{sr}^{l}, a_{sr}^{m}, a_{sr}^{u})$, with the membership function:

$$\mu_A(x) = \begin{cases} 0; & x \le a_{sr}^{l} \\ \dfrac{x - a_{sr}^{l}}{a_{sr}^{m} - a_{sr}^{l}}; & a_{sr}^{l} < x \le a_{sr}^{m} \\ \dfrac{a_{sr}^{u} - x}{a_{sr}^{u} - a_{sr}^{m}}; & a_{sr}^{m} < x < a_{sr}^{u} \\ 0; & x \ge a_{sr}^{u} \end{cases} \quad (2)$$

Table 1 – The expert assessment of the nature of the strategic factors influencing the forest road network development
Таблица 1 – Экспертная оценка характера стратегических факторов, влияющих на развитие сети лесных дорог
Табела 1 – Експертска процена природе стратегијских фактора који утичу на развој мреже шумских путева

INTERNAL FACTORS (Int) - Strengths and Weaknesses		
Int1.	Renewed cooperation with educational institutions	(0, 1, 2)
Int2.	Current cooperation with local government and owners of private forests	(-2,-1, 2)
Int3.	Lack of strategy and policy in the forest road network management	(-1, 0, 2)
Int4.	Implemented Geographic Information System (GIS) provides a detailed map of the forest areas and insight into the existing network of forest roads.	(0, 2, 3)
Int5.	Cooperation with all sectors within the Ministry of Agriculture, Forestry and Water Management	(-2, 1, 2)
Int6.	Availability of the public transport network (rail and road networks)	(-3,-2,1)
Int7.	Density and quality of the existing forest road network	(-5,-4,-1)

EXTERNAL FACTORS (Ext) - Opportunities and Threats		
Ext1.	Legislation and support programs and projects	(0, 2, 3)
Ext2.	Cooperation within the Government of the Republic of Serbia (between different ministries: Ministry of Agriculture and Environmental Protection, Ministry of Civil Engineering, Transport and Infrastructure, etc.)	(0, 1, 3)
Ext3.	Growing interest in the aspects of the use of forests such as recreation, sports, tourism, etc. and potential secondary profit from the development of the forest road network	(1, 3, 5)
Ext4.	Undeveloped and non-standardized communication among stakeholders (administrative bodies, forest owners, transport companies, lumber industry, tourist organizations, etc.)	(-1, 0, 2)
Ext5.	Reconstruction and further development of the lumber industry	(-2, 0, 1)
Ext6.	Build-up rail and road communications on corridor 10 and corridor 11	(-1, 0, 1)
Ext7.	Lack of capital and small investments in the construction and maintenance of the existing forest roads	(-5,-4,0)

The formulation of strategic options for the development of the forest road network was carried out on the basis of the evaluation of the characters of the strategic factors, the correlation of their impacts, the chosen alpha-cut ($\alpha = 0.5$) and the minimum affiliation percentage of the projection of the alpha-cut area to a particular „strategic“ quadrant as the criteria for selecting the factors based on which the strategic options will be formulated (Ghazinoory et al, 2007). The combinations whose projections of the alpha-cut belong to one of the strategic quadrants at least 75% of the total surface were considered as relevant combinations of the factors for the formulation of strategic options (Table 2). The combinations of the factors that also satisfy this condition (and which are indirectly linked through some other factor) are shown in Table 3.

Based on the basic types of the SWOT strategies (SO, ST, WO, and WT strategy) in general, the optimal strategic option is a combination of the characteristics of these types shaped by the impact of situational strategic factors.

In accordance with the combinations of the selected factors relevant for the formulation of strategic options (Figure 3), in the considered case, three strategic options for the development of the forest road network are extracted.

Table 2 – An overview of the combinations of the directly related factors which meet the established criterion
Таблица 2 – Обзор комбинаций непосредственно связанных факторов, которые соответствуют установленным критериям
Табела 2 – Преглед комбинација директно повезаних фактора, које задовољавају постављени критеријум

Factors combination	**Vertices Coordinates (x,y) of the projection surface**				**Percent of the projection surface which belongs to one of the strategic quadrants**
Int1 – Ext1	(0.5, 1)	(1.5, 1)	(1.5, 2.5)	(0.5, 2.5)	100 %
Int1 – Ext3	(0.5, 2)	(1.5, 2)	(1.5, 4)	(0.5, 4)	100 %
Int2 – Ext1	(-1.5, 1)	(0.5, 1)	(0.5, 2.5)	(-1.5, 2.5)	75 %
Int2 – Ext2	(-1.5, 0.5)	(0.5, 0.5)	(0.5, 2)	(-1.5, 2)	75 %
Int2 – Ext3	(-1.5, 2)	(0.5, 2)	(0.5, 4)	(-1.5, 4)	75 %
Int2 – Ext7	(-1.5, -4.5)	(0.5, -4.5)	(0.5, -2)	(-1.5, -2)	75 %
Int4 – Ext1	(1, 1)	(2.5, 1)	(2.5, 2.5)	(1, 2.5)	100 %
Int4 – Ext2	(1, 0.5)	(2.5, 0.5)	(2.5, 2)	(1, 2)	100 %
Int5 – Ext1	(-0.5, 1)	(1.5, 1)	(1.5, 2.5)	(-0.5, 2.5)	75 %
Int5 – Ext3	(-0.5, 2)	(1.5, 2)	(1.5, 4)	(-0.5, 4)	75 %
Int5 – Ext7	(-0.5, -4.5)	(1.5, -4.5)	(1.5, -2)	(-0.5, -2)	75 %
Int6 – Ext2	(-2.5, 0.5)	(-0.5, 0.5)	(-0.5, 2)	(-2.5, 2)	100 %
Int6 – Ext3	(-2.5, 2)	(-0.5, 2)	(-0.5, 4)	(-2.5, 4)	100 %
Int6 – Ext7	(-2.5, -4.5)	(-0.5, -4.5)	(-0.5, -2)	(-2.5, -2)	100 %
Int7 – Ext1	(-4.5, 1)	(-2.5, 1)	(-2.5, 2.5)	(-4.5, 2.5)	100 %
Int7 – Ext3	(-4.5, 2)	(-2.5, 2)	(-2.5, 4)	(-4.5, 4)	100 %
Int7 – Ext7	(-4.5, -4.5)	(-2.5, -4.5)	(-2.5, -2)	(-4.5, -2)	100 %

Tabela 3 – An overview of the combinations of the indirectly related factors which meet the established criterion
Таблица 3 – Обзор комбинаций косвенно связанных факторов, которые соответствуют установленным критериям
Табела 3 – Преглед комбинација индиректно повезаних фактора, које задовољавају постављени критеријум

Factors combination	**Vertices Coordinates (x,y) of the projection surface**				**Percent of the projection surface which belongs to one of the strategic quadrants**
Int1 – Ext2	(0.5, 0.5)	(1.5, 0.5)	(1.5, 2)	(0.5, 2)	100 %
Int1 – Ext7	(0.5, -4.5)	(1.5, -4.5)	(1.5, -2)	(0.5, -2)	100 %

Factors combination	Vertices Coordinates (x,y) of the projection surface				Percent of the projection surface which belongs to one of the strategic quadrants
Int4 – Ext3	(1, 2)	(2.5, 2)	(2.5, 4)	(1, 4)	100 %
Int4 – Ext7	(1, -4.5)	(2.5, -4.5)	(2.5, -2)	(1, -2)	100 %
Int5 – Ext2	(-0.5, 0.5)	(1.5, 0.5)	(1.5, 2)	(-0.5, 2)	75 %
Int6 – Ext1	(-2.5, 1)	(-0.5, 1)	(-0.5, 2.5)	(-2.5, 2.5)	100 %
Int7 – Ext2	(-4.5, 0.5)	(-2.5, 0.5)	(-2.5, 2)	(-4.5, 2)	100 %

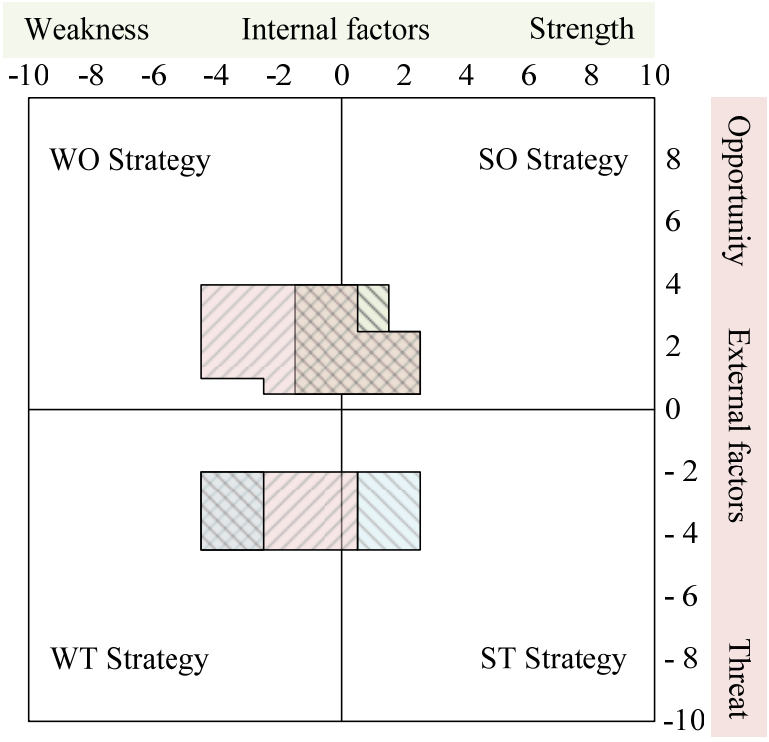


Figure 3 – Surfaces of the alpha-cut projections for the factors which shape the strategic options

Рис. 3 – Площадь α-сечения для факторов, которые образуют стратегические варианты

Слика 3 – Површине пројекција α-пресека за факторе који обликују стратегијске опције

Strategic option 1 is formed on the basis of the combinations of factors: Int 1 with Ext 1 and Ext 3; Int 2 with Ext 1, Ext 2 and Ext 3; and Int 4 with Ext 1 and Ext 2. It can be formulated as follows: *Through intensive cooperation with educational institutions, local government bodies, private forest owners and other stakeholders, based on the existing resources and possible support of the state, enable the efficient exploitation of the existing forest road network in order to achieve extended forest functions and reduce the gap between new needs and current abilities*.

Strategic option 2 is formed on the basis of the combinations of the factors: Int 2 with Ext 1, Ext 2, Ext 3 and Ext 7; Int 4 with Ext 1 and Ext 2; Int 6 with Ext 2, Ext 3 and Ext 7; and Int 7 with Ext 1, Ext 3 and Ext 7. It contains the elements of all four types of strategies (WO-WT-OS-ST). The formulation of strategic option 2 is: *Exploiting the opportunities offered by the programs and support projects to provide funds for the construction of new and maintenance of the existing forest roads, and based on the existing legislation and growing interest of the society for unconventional aspects of forest use, involving all stakeholders and synergistic action at all levels, as well as the achievement of a potential „secondary" profit from forests, establish a sustainable model for the management of the forest road network.*

Strategic option 3 is based on a combination of Factor Int 7 with Factor Ext 7, as well as indirectly linked factors Int 1 and Int 4 with Ext 7. As a mix of the WT and ST strategies, Option 3 can be formulated as: *Due to the lack of capital and insufficient investments, with the help of educational institutions, prepare a framework for analysis, maintenance and (re)construction of the forest roads, determine the priorities for maintenance and (re)construction and create preconditions for preserving the functionality of the existing forest road network*.

After selecting the factors and defining the alternatives, the A'WOT hierarchical model of choosing the guidelines for the long-term development of the forest road network is formed. The model is structured in four levels (Figure 4). The first level represents the selection goal - an optimal strategic option for the development of the forest road network. At the second level, there are two groups of the SWOT factors (internal factors and external factors). Each SWOT group contains perceived strategic factors which make up the third level of the hierarchy, while at the fourth level there are three defined alternatives - strategic options.

In the AHP procedure, by Saaty's scale (Saaty, 1980), decision makers express their own preferences. Transforming the preferences, according to the procedure described by Saaty (Saaty, 1980), the weighting coefficients of the elements in all hierarchical levels are determined. At the end of the procedure, a decision maker has two important pieces of information: 1) information about the significance of the alternatives, and 2) information about the ranking of the alternatives. In the presented case study, the AHP procedure is conducted using the Expert choice 11 software. Based on the pairwise comparison of the factors (the example of factors Ext 6 and Ext 7 is shown in Figure 5) and the pairwise comparison of the alternatives (the example of Strategic option 1 and Strategic option 2 is shown in Figure 6), priorities are defined and the optimal strategic option for the forest road network development is selected.

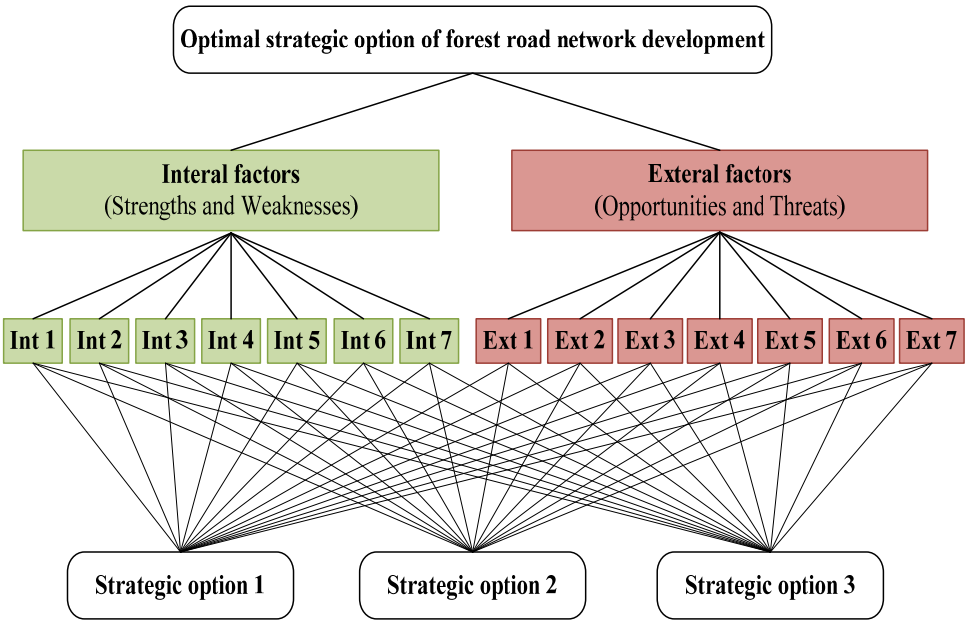


Figure 4 – A'WOT hierarchical model for the selection of the optimal development strategy
Рис. 4 – A'WOT иерархическая модель выбора оптимальной стратегии развития
Слика 4 – A'WOT хијерархијски модел избора оптималне стратегије развоја

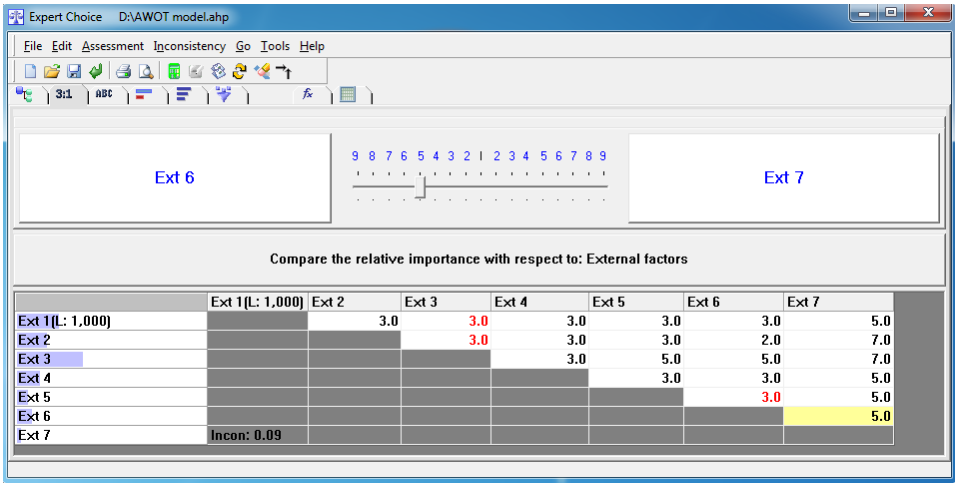


Figure 5 – Pairwise comparison of factors Ext 6 and Ext 7 and the priorities of the external factors
Рис. 5 – Сравнение факторов Ext 6 и Ext 7 и приоритеты внешних факторов
Слика 5 – Међусобно поређење фактора Ext 6 и Ext 7 и приоритети спољашњих фактора

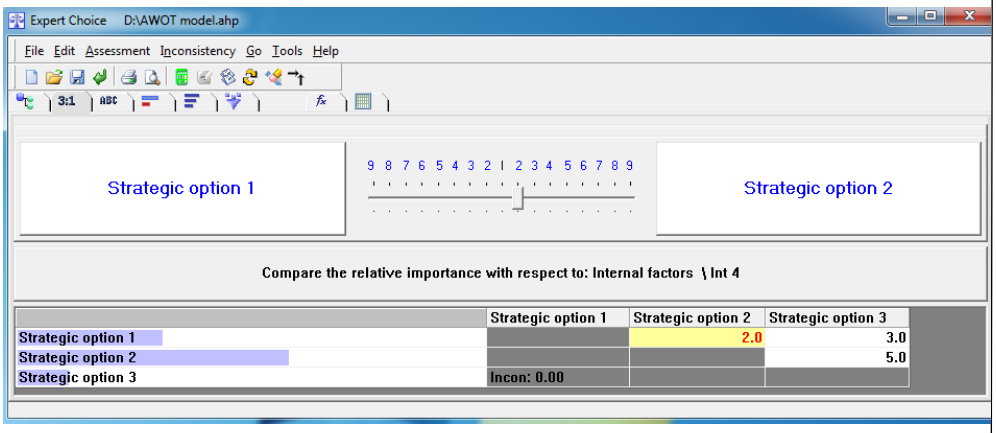


Figure 6 – Pairwise comparison of the alternatives and the relative importance of the alternatives
Рис. 6 – Парное сравнение и относительная важность альтернатив
Слика 6 – Међусобно поређење и релативна важност алтернатива

The final result of ranking the strategic options is shown in Figure 7. According to the results, in the context of the identified internal and external factors, strategic option 2 has the highest priority (its relative importance is the highest - 0.423).

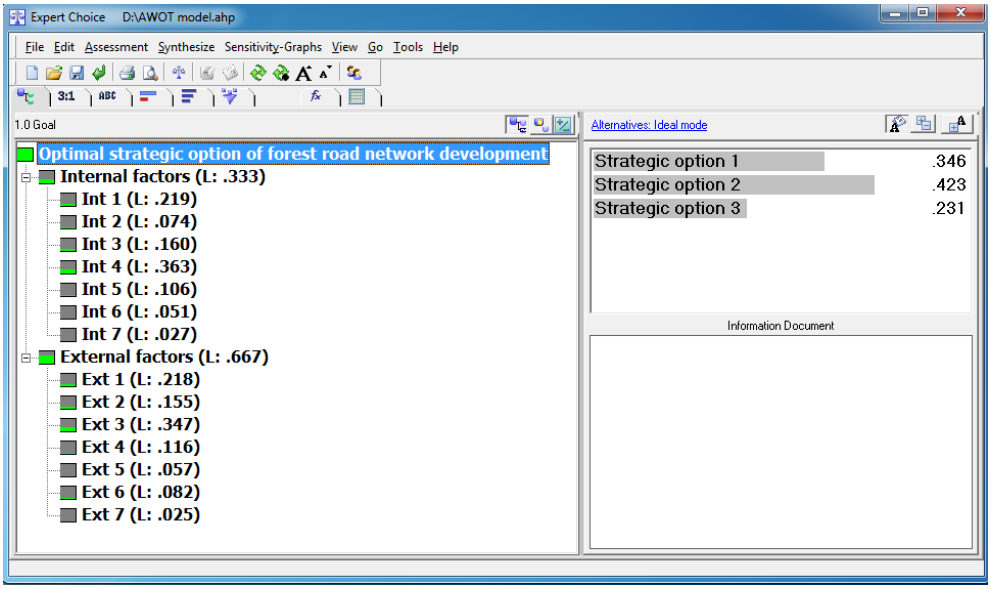


Figure 7 – The strategic options ranking results
Рис. 7 – Результаты ранжирования стратегических вариантов
Слика 7 – Резултати рангирања стратегијских опција

To test the reliability of the results and the sensitivity of the FDA'WOT model, a sensitivity analysis has been conducted. The Expert choice 11 software package enables five types of sensitivity analyses: Dynamic, Performance, Gradient, Head to Head and Two-Dimensional (2D Plot). In this paper, the Performance analysis has been chosen (Figure 8).

The sensitivity analysis is aimed at uderstanding the changes in the ranking order caused by the changes in the factor weighting coefficients. The procedures introduce intentional changes in the factor weighting coefficients to monitor the preferences of the alternatives in a „what-if" manner.

In this case study, the sensitivity analysis has been conducted through four scenarios: *Scenario 1* - Equal importance of the internal and external strategic factors; *Scenario 2* - Internal factors are more important than the external factors; *Scenario 3* - Internal factors are significantly more important than the external factors, and *Scenario 4* - External factors are significantly more important than the internal factors.

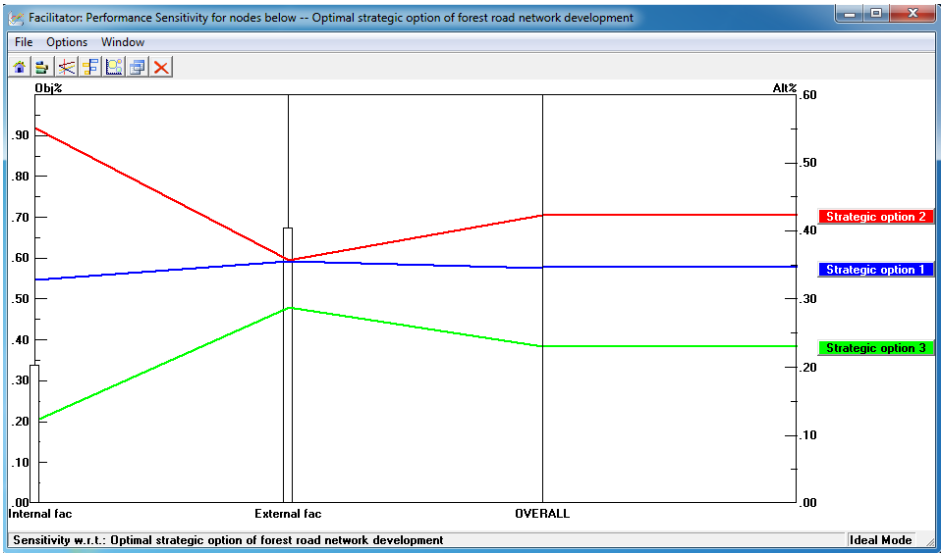


Figure 8 – Sensitivity analysis of the results (Performance analysis screen shot in the case of the dominance of the external factors)
Рис. 8 – Анализ чувствительности (скриншот "Анализ эффективности" в случае преобладания внешних факторов)
Слика 8 – Анализа осетљивости резултата (снимак екрана „Анализе перформанси" у случају доминације екстерних фактора)

The derived conclusions show the stability in the ranks of the alternatives (the ranks stay unchanged and the gaps between the preferences of the alternatives increase) for the first three scenarios. In the fourth scenario, the gaps between the preferences decrease until reaching the equality of strategic option 2 and strategic option 1. Accordingly, the model is sensitive and strategic option 2 is steadily the best option.

Discussion and conclusions

The presented hybrid FDA'WOT model is aimed to set up the guidelines for the selection of a sustainable strategy. The chosen strategy should be based on the current situation analysis and should forecast future trends. The concept of the model consists of the identification of the character of the strategic factors, the strategic options formulation based on the most influential factors, and the evaluation and prioritization of the strategic options in the process of pairwise comparison according to the AHP procedure. Thereby, unlike the classic qualitative approach, fuzzy logic provides a more objective treatment of

imprecise, uncertain and subjective information. Also, in the AHP procedure, factors with indefinite influence are taken into account. It improves the information basis of decision making and quantifies the selection problem.

In the case study, the proposed FA'WOT method was applied to the problem of strategy selection for the development of the forest road network in Serbia.The chosen option provides long-term guidelines for an important aspect of forest management. The strategy defined on this concept should ensure that the road network meets both current and future forest management objectives, and responds to the needs of society, environmental protection requirements, safety requirements, etc. In addition, except for the forest road network long-term planning problem, the FA'WOT method is applicable to any problem of strategic planning.

The areas of possible improvement of the FA'WOT model are: quantification of the involvement of the factors whose influence has a dual character, in different strategic options; selection of the shape of the fuzzy membership functions which, in the most appropriate way, represents the characters of the factors; quantification of the relationships among the factors in order to select ingredients in the strategic options; expansion of the areas of the sensitivity analysis deeper into the model (to analyse the sensitivity of the result when the α value changes, $0 \leq \alpha \leq 1$, to analyse the sensitivity of the result when the selection criteria of factors relevance change, etc.).

References

Bojadziev, G., & Bojadziev, M. 2007. *Fuzzy Logic for Business, Finance and Management*.Singapore: Hackensack. NJ: Word Scientific, pp.71-72.

Carbone, F., & Savelli, S. 2009. Forestry programmes and the contribution of the forestry research community to the Italy experience. *Forest Policy and Economics,* 11(7), pp.508-515. Available at: https://doi.org/10.1016/j.forpol.2009.06.001.

Danilović, M., & Stojnić, D. 2014. Assessment of the state of a forest road network as a basis for making a program of forest management unit opening. *Bulletin of the Faculty of Forestry,* 110, pp.59-71. Available at: https://doi.org/10.2298/gsf1410059d.

Diaz-Balteiro, L., & Romero, C. 2008. Making forestry decisions with multiple criteria: A review and an assessment. *Forest Ecology and Management,* 255(8-9), pp.3222-3241. Available at: https://doi.org/10.1016/j.foreco.2008.01.038.

Dimić, S., Pamučar, D., Ljubojević, S., & Đorović, B. 2016. Strategic Transport Management Models—The Case Study of an Oil Industry. *Sustainability,* 8(9), p.954. Available at: https://doi.org/10.3390/su8090954.

Dwivedi, P., & Alavalapati, J.R.R. 2009. Stakeholders' perceptions on forest biomass-based bioenergy development in the southern US. *Energy Policy,* 37(5), pp.1999-2007. Available at: https://doi.org/10.1016/j.enpol.2009.02.004.

Gerasimov, Y., Senko, S., & Karjalainen, T. 2013. Nordic Forest Energy Solutions in the Republic of Karelia. *Forests,* 4(4), pp.945-967. Available at: https://doi.org/10.3390/f4040945.

Ghazinoory, S., Zadeh, A.E., & Memariani, A. 2007. Fuzzy SWOT analysis. *Journal of Intelligent and Fuzzy Systems,* 18(1), pp.99-108.

Hayati, E., Majnounian, B., Abdi, E., Sessions, J., & Makhdoum, M. 2013. An expert-based approach to forest road network planning by combining Delphi and spatial multi-criteria evaluation. *Environmental Monitoring and Assessment,* 185(2), pp.1767-1776. Available at: https://doi.org/10.1007/s10661-012-2666-1.

Hoang, H.T.N., Hoshino, S., & Hashimoto, S. 2015. Forest stewardship council certificate for a group of planters in Vietnam: SWOT analysis and implications. *Journal of Forest Research,* 20(1), pp.35-42. Available at: https://doi.org/10.1007/s10310-014-0472-z.

Hynynen, J., Salminen, H., Ahtikoski, A., Huuskonen, S., Ojansuu, R., Siipilehto, J., . . . Eerikäinen, K. 2015. Long-term impacts of forest management on biomass supply and forest resource development: a scenario analysis for Finland. *European Journal of Forest Research,* 134(3), pp.415-431. Available at: https://doi.org/10.1007/s10342-014-0860-0.

Hynynen, J., Salminen, H., Huuskonen, S., Ahtikoski, A., Ojansuu, R., Siipilehto, J., . . . Eerikainen, K. 2014. Scenario analysis for the biomass supply potential and the future development of Finnish forest resources. *Working Papers of the Finnish Forest Research Institute,* 302, ISBN 978-951-40-2487-0.

Jalilova, G., Khadka, C., & Vacik, H. 2012. Developing criteria and indicators for evaluating sustainable forest management: A case study in Kyrgyzstan. *Forest Policy and Economics,* 21, pp.32-43. Available at: https://doi.org/10.1016/j.forpol.2012.01.010.

Jarský, V., Sarvašová, Z., Dobšinská, Z., Ventrubová, K., & Sarvaš, M. 2014. Public support for forestry from EU funds – Cases of Czech Republic and Slovak Republic. *Journal of Forest Economics,* 20(4), pp.380-395. Available at: https://doi.org/10.1016/j.jfe.2014.10.004.

Kajanus, M., Leskinen, P., Kurttila, M., & Kangas, J. 2012. Making use of MCDS methods in SWOT analysis—Lessons learnt in strategic natural resources management. *Forest Policy and Economics,* 20, pp.1-9. Available at: https://doi.org/10.1016/j.forpol.2012.03.005.

Kangas, J., Pesonen, M., Kurttila, M., & Kajanus, M. 2001. A'WOT: Integrating the AHP with SWOT Analysis. In *Proceedings of the 6th International Symposium on the Analytic Hierarchy Process - ISAHP 2001.*Bern,Switzerland, pp.189-198.

Kurttila, M., Pesonen, M., Kangas, J., & Kajanus, M. 2000. Utilizing the analytic hierarchy process (AHP) in SWOT analysis — a hybrid method and its application to a forest-certification case. *Forest Policy and Economics,* 1(1), pp.41-52. Available at: https://doi.org/10.1016/s1389-9341(99)00004-0.

Ljubojević, S., Dimić, S., & Luković, N. 2014. An analytical approach to defining strategic options in a case of developing multimodal transport in the Army of Serbia. *Vojnotehnički glasnik / Military Technical Coourier,* 62(2), pp.74-95. Available at: https://doi.org/10.5937/vojtehg62-2068.

Meddour-Sahar, O. 2015. Wildfires in Algeria: problems and challenges. *iForest - Biogeosciences and Forestry,* 8(6), pp.818-826. Available at: https://doi.org/10.3832/ifor1279-007.

Mendoza, G.A., & Prabhu, R. 2004. Fuzzy methods for assessing criteria and indicators of sustainable forest management. *Ecological Indicators,* 3(4), pp.227-236. Available at: https://doi.org/10.1016/j.ecolind.2003.08.001.

-Ministry of Agriculture, Forestry and Water Management of the Republic of Serbia, Directorate for Forests. 2006*. Strategija razvoja šumarstva Republike Srbije.* Belgrade: Ministry of Agriculture, Forestry and Water Management of the Republic of Serbia (in Serbian).

Ochoa-Gaona, S., Kampichler, C., de Jong, B.H.J., Hernández, S., Geissen, V., & Huerta, E. 2010. A multi-criterion index for the evaluation of local tropical forest conditions in Mexico. *Forest Ecology and Management,* 260(5), pp.618-627. Available at: https://doi.org/10.1016/j.foreco.2010.05.018.

Pellegrini, M., Grigolato, S., & Cavalli, R. 2013. Spatial Multi-Criteria Decision Process to Define Maintenance Priorities of Forest Road Network: an Application in the Italian Alpine Region. *Croatian Journal of Forest Engineering,* 34(1), pp.31-42.

Rauch, P. 2007. SWOT analyses and SWOT strategy formulation for forest owner cooperations in Austria. *European Journal of Forest Research,* 126(3), pp.413-420. Available at: https://doi.org/10.1007/s10342-006-0162-2.

Saaty, T.L. 1980. *The Analytic Hierarchy Process*.New York: McGraw-Hill.

Saaty, T.L. 1977. A scaling method for priorities in hierarchical structures. *Journal of Mathematical Psychology,* 15(3), pp.234-281. Available at: https://doi.org/10.1016/0022-2496(77)90033-5.

Stainback, G.A., Masozera, M., Mukuralinda, A., & Dwivedi, P. 2012. Smallholder Agroforestry in Rwanda: A SWOT-AHP Analysis. *Small-scale Forestry,* 11(3), pp.285-300. Available at: https://doi.org/10.1007/s11842-011-9184-9.

-Statistical Office of the Republic of Serbia. 2015. *Šumarstvo u Republici Srbiji, 2014.Bilten,* 596/2015.Belgrade: Statistical Office of the Republic of Serbia (in Serbian).

Triantakonstantis, D.P., Kalivas, D.P., & Kollias, V.J. 2013. Autologistic regression and multicriteria evaluation models for the prediction of forest expansion. *New Forests,* 44(2), pp.163-181. Available at: https://doi.org/10.1007/s11056-012-9308-x.

Zadnik Stirn, L. 2006. Integrating the fuzzy analytic hierarchy process with dynamic programming approach for determining the optimal forest management decisions. *Ecological Modelling,* 194(1-3), pp.296-305. Available at: https://doi.org/10.1016/j.ecolmodel.2005.10.023.

Winkel, G., & Sotirov, M. 2011. An obituary for national forest programmes? Analyzing and learning from the strategic use of "new modes of governance" in Germany and Bulgaria. *Forest Policy and Economics,* 13(2), pp.143-154. Available at: https://doi.org/10.1016/j.forpol.2010.06.005.

Zadeh, L.A. 1965. Fuzzy sets. *Information and Control,* 8(3), pp.338-353. Available at: https://doi.org/10.1016/s0019-9958(65)90241-x.

Zarekar, A., Vahidi, H., Zamani, K.B., Ghorbani, S., & Jafari, H. 2012. Forest Fire Hazard Mapping Using Fuzzy AHP and GIS study area: Gilan province of Iran. *International Journal on Technical and Physical Problems of Engineering,* 12(4), pp.47-55.

МОДЕЛЬ ПРИНЯТИЯ РЕШЕНИЙ В УПРАВЛЕНИИ СЕТЬЮ ЛЕСНЫХ ДОРОГ

Срджан Х. Димич, *Срджан* Д. Любоевич
Университет обороны в г.Белград, Военная академия,
Департамент по логистике, г. Белград, Республика Сербия

ОБЛАСТЬ: движение и транспорт
ВИД СТАТЬИ: обзорная статья
ЯЗЫК СТАТЬИ: английский

Резюме:

Эксплуатация лесных ресурсов и достижение полного потенциала лесного хозяйства зависят от плотности и качества сети лесных дорог. Поскольку сети лесных дорог выполняют не одну, а несколько функций, то их с правом можно считать чрезвычайно значимым стратегическим фактором в управлении лесным хозяйством. При планировании развития сети лесных дорог лица, принимающие решения, должны учитывать многочисленные технологические, экономические, социальные и природно-экологические факторы. При этом необходимо придерживаться комплексного и функционального подхода. В настоящей статье представлена гибридная методологическая основа для разработки принципов, которые помогут определить стратегию развития государственной сети лесных дорог. В данной связи предлагается нечёткая модификация метода A'WOT. Предложенная модель, названная моделью FDA'WOT, основана на идее сочетания нечёткого анализа дельфи, нечёткого SWOT анализа (Силы - Strengths, Слабости - Weaknesses, Шансы - Opportunities, Угрозы - Threats) и Аналитического Иерархического Процесса (AHP), которое формирует концептуальные рамки для

выбора оптимального стратегического варианта. Модель FDA'WOT поможет преодолеть проблему классического SWOT-анализа, связанную с нечёткостью и неопределенностью в оценке характера, воздействия и относительной важности стратегических факторов. Эта модель представляет собой формальную основу для принятия многокритериальных решений, которая позволяет аналитическим способом определить приоритет альтернативных стратегических вариантов и выбрать лучший из них. Предлагаемая модель разработана на примере выбора стратегического варианта при развитии сети лесных дорог в Республике Сербия. Представленные результаты показывают, что модель FDA'WOT создает условия для разработки устойчивой стратегии.

Ключевые слова: сеть лесных дорог, принятие решений, стратегия, модель FDA'WOT, нечёткий метод дельфи, нечёткий SWOT, AHP.

МОДЕЛ ОДЛУЧИВАЊА ПРИ УПРАВЉАЊУ МРЕЖОМ ШУМСКИХ ПУТЕВА

Срђан Х. Димић, *Срђан* Д. Љубојевић
Универзитет одбране у Београду, Војна академија, Катедра логистике, Београд, Република Србија

ОБЛАСТ: саобраћај и транспорт
ВРСТА ЧЛАНКА: прегледни чланак
ЈЕЗИК ЧЛАНКА: енглески

Сажетак:

Експлоатација шумских ресурса и остварење пуног потенцијала шума зависе од густине и квалитета мреже шумских путева. Како треба да задовољи више функција, она има стратегијски значај у управљању шумама. При планирању развоја мреже шумских путева, доносиоци одлука морају да узму у обзир бројне технолошке, економске, друштвене и природне – еколошке факторе, што значи да је неопходан свеобухватан и функционалан приступ. У овом раду приказан је хибридни методолошки оквир за формулисање смерница на којима треба дефинисати стретегију развоја државне мреже шумских путева. У ту свху предложена је fuzzy модификација A'WOT методе. Предложени модел, назван FDA'WOT модел, заснован је на идеји да се кроз комбинацију fuzzy делфи технике, fuzzy SWOT (снаге – Strenghts, слабости – Weaknesses, шансе – Opportunities, претње – Threats) анализе и аналитичког хијерархијског процеса (AHP) обезбеди концептуални оквир за избор оптималне стратегијске опције. FDA'WOT модел омогућава превазилажење проблема класичне SWOT анализе који

се односе на неодређености и неизвесности приликом процене карактера, утицаја и релативне важности стратегијских фактора. Он представља формални оквир за вишекритеријумско одлучивање, који омогућава да се на аналитичан начин одреди приоритет алтернативних стратегијских опција и изабере оптимална. Предложени модел примењен је на примеру избора стратегијске опције развоја мреже шумских путева у Републици Србији, а презентовани резултати показују да FDA'WOT модел ствара услове за формулацију одрживе стратегије.

Кључне речи: мрежа шумских путева, одлучивање, стратегија, FDA'WOT модел, fuzzy делфи, fuzzy SWOT, AHP.

Paperreceivedon / Дата получения работы / Датум пријема чланка: 28.07.2018.
Manuscriptcorrectionssubmittedon / Дата получения исправленной версии работы / Датум достављања исправки рукописа: 24.08.2018.
Paperacceptedfor publishingon / Дата окончательного согласования работы / Датум коначног прихватања чланка за објављивање: 26.08.2018.

СТРУЧНИ ЧЛАНЦИ
ПРОФЕССИОНАЛЬНЫЕ СТАТЬИ
PROFESSIONAL PAPERS

CHARACTERISTICS OF PLASMA SPRAY COATINGS

Mihailo R. Mrdak
Research and Development Center IMTEL Communications a.d.,
Belgrade, Republic of Serbia,
e-mail: drmrdakmihailo@gmail.com,
ORCID iD: http://orcid.org/0000-0003-3983-1605

DOI: 10.5937/vojtehg67-16558; https://doi.org/10.5937/vojtehg67-16558

FIELD: Chemical Technology
ARTICLE TYPE: Professional Paper
ARTICLE LANGUAGE: English

Summary:

The characteristics of plasma spray coatings are directly related to the type of process applied (APS - atmospheric plasma spray, VPS - vacuum plasma spray, and SPS - suspension plasma spray), the characteristics of the powder and the powder deposition parameters. The properties of plasma spray coatings can be changed and adjusted depending on the operating conditions, i.e. the purpose of coatings. Applying the same powder in the deposition process can lead to coatings of different properties, depending on their purpose. If the deposited coating is intended for corrosion protection and biomedical application, it is necessary that the coating is compact. When the coating is deposited for the purpose of thermal insulation, it should be porous. Powder particles in the plasma are spherical liquid drops which, in collision with the substrate, form a lamellar structure of the coating. A higher degree of powder melting and a higher velocity of molten droplets lead to a denser structure of deposited layers. When colliding with the substrate, deposited particles transfer heat to a working part until cooling to ambient temperature. If the working part is cooled by compressed air, molten droplets solidify extremely quickly with columnar crystals in lamellae. The aim of this paper is to describe the influence of temperature and velocity of powder particles on the deformation and hardening of particles defined by the D/d ratio, chemical changes in molten particles as well as porosity, crystal changes, and internal stresses in coatings.

Keywords: APS, VPS and SPS process, adhesion/cohesion, structure, porosity, internal stresses.

ACKNOWLEDGEMENT: The author is thankful for the financial support from the Ministry of Education and Science of the Republic of Serbia (national OI 174004 and TR 34016 projects).

Introduction

The properties of plasma spray coatings depend on: the degree of melting of powder particles, the degree of deformation of individual particles in collision with the substrate, their interaction upon impact on the substrate surface and the interactions of lamellae at the contact during deposition and layer solidification. In the process of deposition, higher temperature and velocity of molten droplets increase coating adhesion, cohesive strength, tensile strength and resistance to friction fatigue, while reducing coating brittleness, which all affects the length of coating service life (Li et al, 2006, pp.1166-1172), (Sobieszczyk, 2010, pp.30-42). The characteristics of deformation and flattening of molten droplets of powder particles during deposition are of utmost importance, defined by the *D/d* (*D* - diameter of a deformed particle, and *d* - diameter of an injected particle) ratio. One of important parameters which affect the coating characteristics is contact temperature (*Tc*) at the interface between the substrate and the deposited layer. An increase in contact temperature (*Tc*) increases the coating – substrate adhesion strength and the density of layers in the coating. Adhesive strength determines the coating quality, while the cohesive strength of layers determines the coating service life (Bull, Rickerby, 2001, pp.181-228). The melting point of powder particles is often higher than the melting temperature of the substrate on which the coating is deposited, so the contact temperature can increase the temperature of the substrate. The increase in the substrate temperature significantly affects the stress state of the substrate / coating interface, which directly reflects on the interface fracture toughness. In some cases, it can cause fatigue in deposited layers, which causes micro and macro cracks in coating layers followed by peeling or separation of coating layers from the substrate surface through coating layers. Also, due to large temperature differences, at some places on the coating surface, segmental micro cracks can occur due to large difference in tensile stress caused by the substrate expansion and shrinkage stress during the solidification of deposited particles (Mrdak, 2016, pp.411-430). In extreme cases, the substrate may be deformed. This can happen during the process of melting and depositing powder particles of refractory metals such as W, Nb, Ta, Mo, Ti, etc. The same phenomenon can occur in the deposition of inorganic bioinert ceramics: TiO_2, Al_2O_3, ZrO_2, $ZrO_2Y_2O_3$, and Cr_2O_3, as well as carbides WC, TC, BC, CrC, etc.

This paper describes the *D/d* ratio of the particles of Al_2O_3 inorganic bioinert ceramics depending on the temperature and velocity of powder particles of different granulation. The aim of this study was to describe the chemical changes in molten particles, the crystal changes in deposited particles, porosity in coatings and its effect on the mechanical properties of the deposited coatings, and stresses in coatings.

Effect of temperature and velocity of powder particles on the D/d ratio

During powder deposition, it is necessary to set parameters so that particles have optimal temperature and velocity (kinetic energy) for a certain type of powder of specific physical characteristics and granulation. The substrate temperature also affects the quality of the coating and during deposition it is necessary to maintain the substrate temperature within certain limits without causing side effects. The contact temperature (*Tc*), which directly influences the *D/d* ratio, depends on the substrate preheating temperature and on the powder melting point, as well as on powder thermal conductivity and cumulativity. The parameters are always set to achieve the highest *D/d* ratio. Ignoring the effect of surface stresses and the assumption that molten particles flatten before solidification has led to the execution of the terms of the *D/d* ratio defined by equation 1 (Sivakumar, Nishiyama, 2004, pp.485-489),

$$D/d = 1{,}29\left(\frac{\rho V d}{\mu}\right)^{0.2} \quad (1)$$

where: is ρ - density of particles μ - viscosity of particles, *Vd* – velocity of particle impact on the substrate. For Al_2O_3 ceramics used in the process of biomedical coatings, temperature and velocity of powder particles are very important. The Al_2O_3 powder particle velocity of 100 m/s - 400 m/s is obtained by the ratio of *D/d* = 3 - 6 (Mishin et al, 1987, p.620). Figure 1 shows the *D/d* ratio for Al_2O_3 powder with a particle surface temperature of 2300 °C depending on particle velocity for the following granulation values: 5, 10, 20, 30 and 35 μm (Vardelle et al, 1993, pp.79-91). For a powder surface temperature of 2300 °C, the *D/d* ratio increases with an increase in particle velocity regardless of the granulation size.

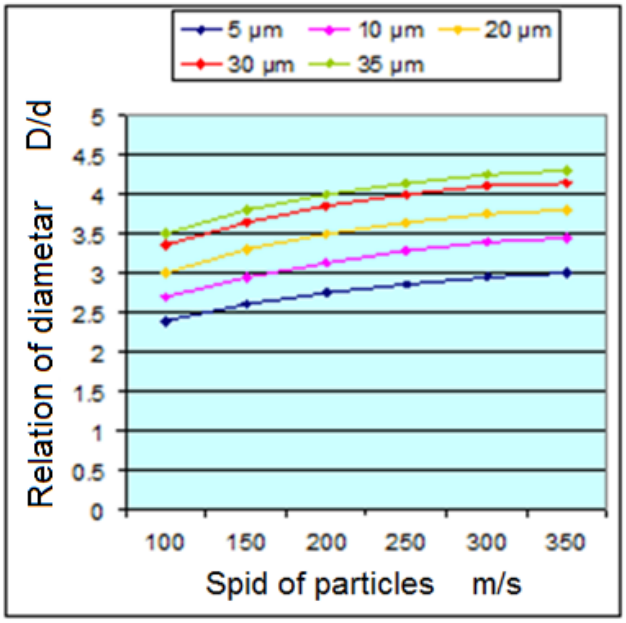


Figure 1 – The D/d ratio depending on the velocity of Al_2O_3 particles
Рис. 1 – Соотношение диаметра D/d в зависимости от скорости частиц Al_2O_3
Слика 1 – Однос пречника D/d у зависности од брзине честица Al_2O_3

With an increase in velocity, the particle kinetic energy increases, which causes a higher degree of flattening of molten particles on the substrate surface. The lowest value of the *D/d* ratio, i.e. 2.4, is found in particles of 5 μm deposited with a velocity of 100 m/s. For particles of 35 μm and a velocity of 100 m/s, this ratio is much higher and amounts to *D/d* = 3.5. For the finest particles with a maximum speed of 350 mm/s, the *D/d* ratio is 3.0 and does not reach the levels of the largest particles with a minimum velocity. The highest *D/d* ratio of 4.3 is achieved with particles of the grain size of 35 μm. Figure 2 gives the *D/d* ratio for Al_2O_3 powder with a particle velocity of 300 m/s depending on the surface temperature of molten particles for the granulation values of 5, 10, 20, 30 and 35 μm. The surface temperature of powder particles has a similar effect on the D/d ratio as the velocity of particles. With an increase in particle surface temperature, particle plasticity increases causing more pronounced flattening of molten droplets on the substrate surface. For the lowest particle surface temperature of 2000 °C, the lowest *D/d* ratio of 2.4 is found in the particles with the smallest size of 5 μm, and the highest *D/d* ratio of 3.5 is found in the biggest particles of 35 μm.

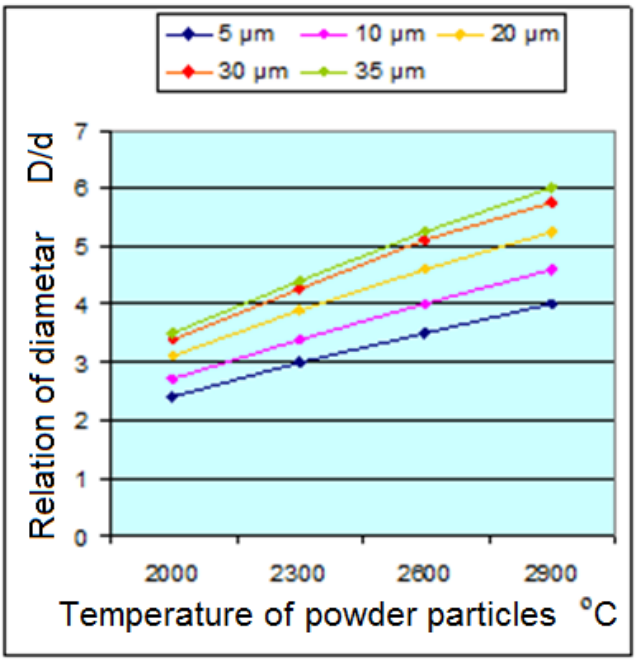


Figure 2 – The D/d ratio depending on the temperature in Al_2O_3 particles
Рис. 2 – Соотношение D/d в зависимости от температуры частиц Al_2O_3
Слика 2 – Однос D/d у зависности од температуре честица Al_2O_3

When temperature increases to 2900 °C, the *D/d* ratio increases to a maximum value. For the 5 μm granulation, the *D/d* ratio is 4.0, and for the granulation of 35 μm, the *D/d* ratio is 6.0. If we compare the effects of particle velocities and the surface temperatures of particles of different sizes on the flattening degree, it is clear that the *D/d* ratio is influenced more by the surface temperature of powder particles (Vardelle et al, 1993, pp.79-91).

Chemical changes in molten particles and crystal changes in coatings

In molten powder particles, chemical changes can occur as a result of the reaction of liquid droplets with the plasma jet. High plasma temperature is suitable for the reactions such as oxidation, reduction and thermal decomposition of the initial powder phases. Many metals absorb a significant amount of oxygen during deposition, oxides lose oxygen and

nitrides lose nitrogen. The chemical reaction is determined by the plasma gas diffusion into the liquid phase of molten particles. When H_2/Ar or He/Ar are used as plasma gases, diffusion is carried out with a fairly low speed of 10^{-3} to 10^{-1}sec in comparison to the particle melting time of 10^{-4}sec. During the deposition of Al_2O_3 powder with a mixture of N_2/Ar as plasma gas, aluminum from the oxide reacts with nitrogen. The result of this reaction is the formation of the AIN phase. Oxidation is a major problem, especially in metals such as tungsten, molybdenum and titanium. Some oxidized particles can be seen in coatings. The oxidation of powder particles is very important and affects porosity as well as cohesion and adhesion strength. The problem is greater in the oxidation of carbides. Oxygen binds carbon from the carbide so that the carbide decomposes. The carbide decomposition is favored by high temperature of plasma. Thermal decomposition of carbides is incomplete due to short time powder particles spend in the plasma jet (Qiao et al, 2003, pp.24-41).

Extremely rapid cooling of the liquid phase of the material deposited may affect the suppression of the crystallization of particular phases. A typical effect was tested with Al_2O_3 particles. The coating is predominantly composed of one or more metastable phases, with the mostly dominant α-Al_2O_3 phase and a smaller share of the γ-Al_2O_3 phase. The formation of metastable phases can be explained by lower free energy for the creation of spinel cells from the liquid phase when the subcooling is below the equilibrium melting temperature due to rapid cooling. The phases are separated by transformation from one to another metastable phase. Different metastable phases are separated depending on the deposition parameters, the size and shape of particles and the substrate temperature. The ratio between substrate and coating cooling during powder deposition is very important. When the substrate is cooled during deposition, the cooling rate of particles is between 10^4 and 10^6 K/s. In order to obtain coatings which contain only the α-Al_2O_3 phase, it is necessary to heat the substrate to a temperature of 1100 °C (Yang et al, 2006, pp.1649-1653). The α-Al_2O_3 phase is always present in the coating with a share of 10% to 25%, because of the incomplete melting of powder particles which serve as centers of crystallization (Friis et al, 2001, p.115).

During deposition, the starting α-Al_2O_3 phase with a density of 3.98 to 4.0 g/cm^3 is transformed into the γ-phase with a density of 3.3 to 3.4 g/cm^3, which is stable up to a temperature of 1050°C (Yang et al, 2006, pp.1649-1653). Due to its lower density, the separated γ-phase increases

porosity and decreases the mechanical properties of the coating. For metals and alloys, the cooling rate of molten particles is higher and ranges from 10^6 to 10^8 K/s (Johnston, 2009, pp.1004-1013). For superalloys with this cooling rate ratio, it is possible to obtain very fine grain sizes from 0.25 to 0.5 μm, which gives very good mechanical properties of the coating. If coatings are overheated at temperatures from 100 to 1200° C, higher density and better mechanical properties are obtained (Mrdak, 2015, pp.337-343). In some coatings, during the deposition of molten droplets, crystals become conveniently directed relative to the substrate surface. This refers primarily to Cr_2O_3 oxide, where the c - axis and the basal planes are conveniently directed relative to the surface, thus giving it high resistance to friction. This also applies to the hexagonal structures of the coatings of W_2C, CoW and CoMo which have a low friction coefficient. These coatings, therefore, have a friction coefficient lower than 0.15 (Hakan et al, 2008, pp.259-265).

Porosity of coatings

Depending on coating purposes, the share and size of pores, together with their distribution through layers, are of key importance for the mechanical properties of the coating (Mrdak et al, 2015, pp.337-343). High porosity in layers reduces the coating strength: it increases the coating brittleness, reduces the brittleness of the interface fracture and friction resistance, as well as resistance to oxidation and corrosion. The cause of pore formation in the coating is the uneven granulation of powder particles injected into the plasma jet which move along different paths through the plasma jet. Porosity is present in the coatings which consist of tough and fully melted powder particles. Substrate surfaces and molten particles may contain air or gas which also causes the formation of pores at the interface, reducing adhesion. If particles have high temperature and high velocity when impinging the substrate, liquid drops of molten particles are sprayed causing high porosity in the coating layers. In the coatings deposited at atmospheric pressure, porosity is in the range from 5 to 20% (Mrdak et al, 2015, pp.337-343).

Materials such as TiO_2, $Al_2O_3TiO_2$, Cr_2O_3, and NiO form coatings with an average porosity below 4%. In Al_2O_3 and ZrO_2 coatings, porosity ranges from 4-8%, while porosity in thermal barriers ($ZrO_2Al_2O_3$, $ZrO_2Y_2O_3$, ZrO_2CaO, ZrO_2MgO, $ZrO_2Y_2O_3CeO_2$, etc.) ranges from 8 to 15 % (Mrdak et al, 2015, pp.337-343), (Mrdak, 2017, pp.30-44). Pore share and size in the coating are directly related to the angle at which the molten particles are deposited and to the tension of deposited particles.

TiO_2 powder particles have half the strength of the Al_2O_3 surface; therefore, TiO_2 coatings have for 2.5% lower porosity compared to Al_2O_3 coatings. Generally, the coating porosity is linked to the size of powder particles, their velocities and temperatures in the moment of impact with the substrate. It is clear that the lowest porosity is obtained with particles that are well melted and have high velocity. Coating layers have a porosity of 23% with Al_2O_3 particles of a granulation of 18 μm deposited on the substrate from a distance of 75 mm. When the distance to the substrate is reduced to 50 mm, powder particles gain maximum velocity and reduce the proportion of pores to 11% (Vardelle et al, 2001, pp.267-284). High-speed plasma jets are suitable for the preparation of coatings with low porosity. High power supply allows for a faster transfer of heat and velocity of plasma particles onto powder particles. The application of a high-power plasma gun is limited; the gun is not used for the deposition of powder with a small coefficient of thermal conductivity because the particle surface vaporizes while the particle core remains unmolten.

Internal stresses in coatings and on the interface

Generally, it can be said that powders of tough materials give tough coatings with low percentage of residual stresses, while ceramic powders produce brittle coatings with a considerable share of residual stresses. The internal stresses in coatings are the result of different temperatures and coefficients of thermal expansion of substrates and coatings. The substrate bond with the ceramic coating is non-metallic; therefore, the bond strength values are lower than the values achieved with metal coatings. The increase in coating thickness leads to the reduction of bond strength. For some ceramic coatings the thickness of which is up to 0.1 mm, the bond strength values range from 30 to 40 MPa. For the thickness values up to 0.3 mm, these values are smaller and range from 5 to 10 Mpa. If the thickness values are over 0.5 mm, strength values reach only 4 MPa (Moridi et al, 2014, pp.449-459). Since coatings consist of several layers, stresses also increase with the coating thickness. In order to reduce stresses caused by the temperature difference and the coefficients of thermal expansion, it is necessary to cool down the substrate and the deposited layers during deposition. Also, if there is a low temperature difference between the substrate and the deposit, this may cause cracking and spalling of the deposit from the substrate. Within individual sections in the coating, micro-cracks can occur, as well as within the entire coating. Micro-cracks in the coating occur as a result of the influence of the substrate on the shrinkage of molten particles during

solidification. The shrinkage of molten powder particles is always limited because of the influence of the substrate. The values of residual stresses mostly depend on the ratio of thermal expansion coefficients and on the elasticity coefficient between the substrate and the coating (Mrdak et al, 2015, pp.337-343). Also, there is the influence of yield and plastic deformation of the coating and the substrate on the value of residual stresses at the interface. Macro cracks may occur In the coating after cooling the coating structure to ambient temperature due to a large temperature gradient between the substrate and the coating layer during deposition, as well as due to differences in the coefficients of thermal expansion (Mrdak, 2017, pp.30-44). High levels of stress at the interface could cause peeling of the coating, while high levels of tensile stresses could cause internal cracks in the deposit. Residual compressive stresses in ceramic coatings could even be beneficial for the increase of fracture strength. In order to reduce stresses in coatings, it is necessary to reduce the temperature gradient between the substrate and the coating. This allows the shrinkage of the coating at lower temperatures during solidification. Therefore, during the deposition of powder particles, coating primary and secondary cooling (after powder deposition) is applied. However, despite cooling both the coating and the substrate, it is extremely difficult to reduce stresses in the coatings with low coefficients of thermal conductivity, especially in the case of thicker coatings. Internal cracks in the deposited layers are formed as a result of lower resistance of layers to tension and compression. In ceramic materials, compressive strength is higher than tensile strength. Residual stresses are usually the result of different coefficients of expansion of the layers α1 and the substrate α2. If α1> α2, the coating will be bent and deformed as shown in Figure 3 or it will be exposed to tensile stresses if the coating is deposited on thicker substrates. When ceramic powders are deposited on metal substrates, the coating will be distorted or subjected to compressive stress, as shown in Figure 4.

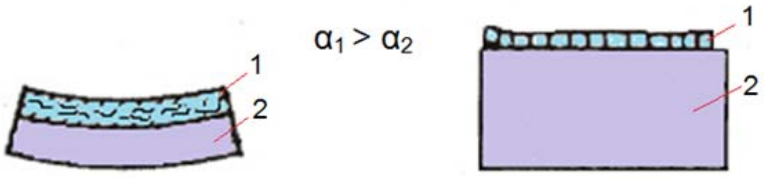


Figure 3 – Stresses in the coating for $\alpha_1 > \alpha_2$
Рис. 3 – Напряжения в покрытии для $\alpha_1 > \alpha_2$
Слика 3 – Напони у превлаци за $\alpha_1 > \alpha_2$

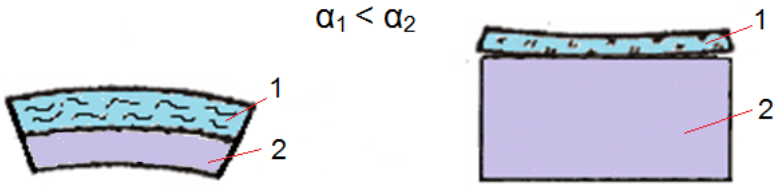


Figure 4 – Stresses in the coating for $\alpha_1 < \alpha_2$
Рис. 4 – Напряжения в покрытии для $\alpha_1 < \alpha_2$
Слика 4 – Напони у превлаци за $\alpha_1 < \alpha_2$

High stresses in layers will be reduced through cracks or through separation of the coating from the substrate. During deposition, controlling layer temperature is of primary importance, especially for materials with a low coefficient of thermal conductivity. If temperature during the deposition process is not under control, a large temperature gradient may appear between the upper and lower surface layers, which is undesirable. In the coatings with changes in volume due to phase transformations, residual stresses are increased. These stresses are also increased during exploitation as a result of cyclic phase transformations. For example, heating the metastable γ - Al_2O_3 phase at temperatures above 1050 °C will transform it into the metastable α - Al_2O_3 phase followed by an increase in volume, which adds to residual stresses (Yang et al, 2006, pp.1649-1653). The same is the case with the metastable tetragonal t - ZrO_2 phase which, at temperatures above 1100 °C under the influence of stress, transforms into the monoclinic phase of m - ZrO_2 accompanied by an increase in volume. Phase transformations occurred in service will further increase stresses in coatings and reduce coating resource. Due to the above, porosity in coatings is preferred in e.g. filters and thermal barriers. Desired porosity levels can be easily obtained in coatings as well as controlled through powder granulation and the location of powder injection into the plasma jet.

Conclusion

This article describes the impact of temperature and velocity of powder particles on the *D/d* ratio, chemical changes in molten particles and crystal changes in coatings, porosity in coatings and internal stresses in coatings and at the interface. Based on the above, the following conclusions can be drawn.

The powder deposition parameters are always adjusted so that the highest *D/d* ratio is obtained for injected particles. The *D/d* ratio increases with increasing particle velocity and temperature regardless of the size of granulation. The comparison of the effect of particle velocity and the effect of the temperature values of particle surfaces of different granulations on the flattening degree has shown that the surface temperature of powder particles has a greater impact on the *D/d* ratio.

In molten powder particles, chemical changes (oxidation, reduction and thermal decomposition of the powder initial starting phase) occur as a result of the reaction of liquid drops with the plasma yet. Extremely rapid cooling of the liquid phase of the depositing material may affect the suppression of crystallization of individual phases. Different metastable phases are separated depending on the deposition parameters, the size and shape of the particles and the substrate temperature. Chemical and crystal changes in the deposited particles significantly affect porosity, cohesion and adhesion strength, fatigue and wear, which is why it is necessary to apply strict control of the coating production process.

Porosity in layers reduceses coating strength, increases coating brittleness, reduces interface fracture brittleness and abrasion resistance as well as resistance to oxidation and corrosion. Pores in coatings are formed due to uneven granulation of powder particles that are injected into the plasma jet and move along different paths through the plasma jet.

The internal stresses in coatings are the result of different temperatures and coefficients of thermal expansion of substrates and coatings. If $\alpha_1 > \alpha_2$, coatings are to be bent and deformed on thicker substrates. If $\alpha_1 < \alpha_2$ when depositing ceramic powders on metal substrates, the coating will be deformed or subjected to compressive stress. High stresses in layers will be reduced through cracks or through separation of the coating from the substrate. In order to reduce stresses caused by the temperature difference between the coefficients of thermal expansion, it is necessary to cool down the substrate and deposited layers during deposition.

The article displayed some of the important parameters affecting the characteristics of plasma spray coatings, which must be taken into consideration when creating a coating for a given purpose.

References

Bull, S.J., & Rickerby, D.S. 2001. Characterization of hard coatings. In R.F. Bunshah Ed., *Handbook of hard coatings*.Park Ridge: Noyes Publications. pp.181-228.

Cetinel, H., Celik, E., & Kusoglu, M.I. 2008. Tribological behavior of Cr2O3 coatings as bearing materials. *Journal of Materials Processing Technology,* 196(1-3), pp.259-265. Available at: https://doi.org/10.1016/j.jmatprotec.2007.05.048.

Friis, M., Persson, C., & Wigren, J. 2001. Influence of particle in-flight characteristics on the microstructure of atmospheric plasma sprayed yttria stabilized ZrO2. *Surface and Coatings Technology,* 141(2-3), pp.115-127. Available at: https://doi.org/10.1016/s0257-8972(01)01239-7.

Johnston, R.E. 2009. The Sensitivity of Abradable Coating Residual Stresses to Varying Material Properties. *Journal of Thermal Spray Technology,* 18(5-6), pp.1004-1013. Available at: https://doi.org/10.1007/s11666-009-9378-2.

Li, C., Yang, G., & Ohmori, A. 2006. Relationship between particle erosion and lamellar microstructure for plasma-sprayed alumina coatings. *Wear,* 260(11-12), pp.1166-1172. Available at: https://doi.org/10.1016/j.wear.2005.07.006.

Mishin, J., Vardelle, M., Lesinski, J., & Fauchais, P. 2000. Two-colour pyrometer for the statistical measurement of the surface temperature of particles under thermal plasma conditions. *Journal of Physics E: Scientific Instruments,* 20(6), pp.620-625. Available at: https://doi.org/10.1088/0022-3735/20/6/008.

Moridi, A., Gangaraj, S.M.H., Vezzu, S., & Guagliano, M. 2014. Number of Passes and Thickness Effect on Mechanical Characteristics of Cold Spray Coating. *Procedia Engineering,* 74, pp.449-459. Available at: https://doi.org/10.1016/j.proeng.2014.06.296.

Mrdak, M., Rakin, M., Medjo, B., & Bajić, N. 2015. Experimental study of insulating properties and behaviour of thermal barrier coating systems in thermo cyclic conditions. *Materials & Design,* 67, pp.337-343. Available at: https://doi.org/10.1016/j.matdes.2014.11.029.

Mrdak, M. 2016. Properties of the ZrO2MgO/MgZrO3NiCr/NiCr triple-layer thermal barrier coating deposited by the atmospheric plasma spray process. *Vojnotehnički glasnik/Military Technical Courier,* 64(2), pp.411-430. Available at: https://doi.org/10.5937/vojtehg64-9612.

Mrdak, M. 2017. Mechanical properties and the microstructure of the plasma-sprayed ZrO2Y2O3 / ZrO2Y2O3CoNiCrAlY/ CoNiCrAlY coating. *Vojnotehnički glasnik/Military Technical Courier,* 65(1), pp.30-44. Available at: https://doi.org/10.5937/vojtehg65-10586.

Qiao, Y., Fischer, T.E., & Dent, A. 2003. The effects of fuel chemistry and feedstock powder structure on the mechanical and tribological properties of HVOF thermal-sprayed WC–Co coatings with very fine structures. *Surface and Coatings Technology,* 172(1), pp.24-41. Available at: https://doi.org/10.1016/s0257-8972(03)00242-1.

Sivakumar, D., & Nishiyama, H. 2004. Analysis of Madejski Splat-Quench Solidification Model With Modified Initial Conditions. *Journal of Heat Transfer,* 126(3), pp.485-489. Available at: https://doi.org/10.1115/1.1738421.

Sobieszczyk, S. 2010. Surface modifications of ti and its alloys. *Advances in Materials Sciences,* 10(1), pp.30-42. Available at: https://doi.org/10.2478/v10077-010-0003-3.

Vardelle, M., Vardelle, A., & Fauchais, P. 1993. Spray parameters and particle behavior relationships during plasma spraying. *Journal of Thermal Spray Technology,* 2(1), pp.79-91. Available at: https://doi.org/10.1007/bf02647426.

Vardelle, M., Vardelle, A., Fauchais, P., Li, K.-., Dussoubs, B., & Themelis, N.J. 2001. Controlling Particle Injection in Plasma Spraying. *Journal of Thermal Spray Technology,* 10(2), pp.267-284. Available at: https://doi.org/10.1361/105996301770349367.

Yang, H., Luan, W., & Tu, S. 2006. Corrosion Behavior and Thermal Conductivity of Plasma Sprayed AlN/Al2O3 Coating. *Materials Transactions,* 47(7), pp.1649-1653. Available at: https://doi.org/10.2320/matertrans.47.1649.

ХАРАКТЕРИСТИКИ ПОКРЫТИЯ, НАНЕСЕННОГО ВОЗДУШНО-ПЛАЗМЕННЫМ НАПЫЛЕНИЕМ

Михаило Р. Мрдак
Центр исследований и развития А.О. «ИМТЕЛ коммуникации»,
г. Белград, Республика Сербия

ОБЛАСТЬ: химические технологии
ВИД СТАТЬИ: профессиональная статья
ЯЗЫК СТАТЬИ: английский

Резюме:

Характеристики покрытий, нанесенных плазменным напылением напрямую взаимосвязаны с видом применяемого процесса (APS - atmospheric plasma spray, VPS - vacuum plasma spray и SPS - suspension plasma spray), свойствами порошка и параметрами осаждения порошка. Свойства покрытий, нанесенных плазменным напылением, могут быть изменены и приспособлены к условиям эксплуатации и их назначению. При использовании одного и того же порошка в процессе осаждения могут быть получены различные свойства покрытий в зависимости от их назначения. Так, например, если покрытие предназначено для антикоррозионной защиты или биомедицинских нужд, то необходимо чтобы оно было как можно более компактным. В то время как при нанесении покрытия для нужд термоизоляции благоприятным свойством будет считаться пористость. Частицы порошка в плазменной струе представляют собой капли жидкости, имеющие сферическую форму, которые при сцеплении с подложкой образуют ламинарную структуру покрытия. Чем выше температура плавления порошка и чем больше скорость капель расплава, тем плотнее будет структура нанесенных слоев. При столкновении с подложкой осажденные частицы передают тепло рабочей поверхности до момента их охлаждения до температуры окружающей среды. В случаях, когда рабочая поверхность охлаждается сжатым воздухом, отверждение капель расплава ускоряется максимально со столбчатыми

кристаллами в ламелях. Целью данной работы являлось описание того, каким образом температура и скорость частиц порошка влияют на образование деформаций и затвердения частиц, которые определяют соотношение D/d, пористость в слоях покрытия, химические реакции в частицах расплава и на кристаллические изменения в слоях покрытия, пористость и внутреннее напряжение покрытия.

Ключевые слова: APS, VPS и SPS процесс, адгезия/когезия, структура, пористость, внутренние напряжения.

КАРАКТЕРИСТИКЕ ПЛАЗМА СПРЕЈ ПРЕВЛАКА

Михаило Р. Мрдак
Истраживачки и развојни центар ИМТЕЛ комуникације а.д., Београд, Република Србија

ОБЛАСТ: хемијске технологије
ВРСТА ЧЛАНКА: стручни чланак
ЈЕЗИК ЧЛАНКА: енглески

Сажетак:

Карактеристике плазма спреј превлака су у директној вези са врстом примењеног процеса (APS – atmospheric plasma spray, VPS – vacuum plasma spray и SPS – suspension plasma spray), карактеристикама праха и параметрима депозиције праха. Својства плазма спреј превлака могу се мењати и подешавати у зависности од радних услова, односно намене превлака. При употреби истог праха у поступку депозиције могу се постићи различита својства превлаке, зависно од намене. Ако се превлака депонује за корозиону заштиту и биомедицинску примену, неопходно је да буде компактна, а када се депонује ради топлотне изолације пожељно је да буде порозна. Честице праха у плазми су течне капи сферног облика које у судару са подлогом формирају ламеларну структуру превлаке. Већи степен топљења праха и већа брзина истопљених капи производи гушће структуре депонованих слојева. На контакту са подлогом депоноване честице преносе топлоту радном делу до хлађења на температуру околине. Ако се радни део хлади компримованим ваздухом, очвршћавање истопљених капи одвија се екстремно брзо са стубастим кристалима у ламелама. Циљ рада јесте да се опишу: утицај температуре и брзине честица праха на деформацију и очвршћавање честица које дефинише однос D/d, порозност у превлакама, хемијске промене у истопљеним честицама и кристалне промене у превлакама, порозност у превлакама и унутрашњи напони превлака.

Кључне речи: APS, VPS и SPS процес, адхезија/кохезија, структура, порозност, унутрашњи напони.

Paper received on / Дата получения работы / Датум пријема чланка: 14.02.2018.
Manuscript corrections submitted on / Дата получения исправленной версии работы / Датум достављања исправки рукописа: 28.02.2018.
Paper accepted for publishing on / Дата окончательного согласования работы / Датум коначног прихватања чланка за објављивање: 02.03.2018.

IMPACT OF THE CURRENT LEVEL IN THE DEVELOPMENT OF THE TELECOMMUNICATION-INFORMATION SYSTEM OF THE SERBIAN ARMED FORCES ON THE DEFENSE OF THE REPUBLIC OF SERBIA

Hatidža A. Beriša[a], *Olga M.* Zorić[b]
University of Defence in Belgrade, School of National Defense, Belgrade, Republic of Serbia
[a] e-mail: hatidza.berisa@mod.gov.rs,
ORCIDiD: http://orcid.org/0000-0002-9432-5273
[b] e-mail: olgazoric@yahoo.com,
ORCIDiD: http://orcid.org/0000-0002-6378-3554

DOI: 10.5937/vojtehg67-19274; https://doi.org/10.5937/vojtehg67-19274

FIELD: Telecommunications
ARTICLE TYPE: Professional Paper
ARTICLE LANGUAGE: English

Abstract:

Information, as one of the important factors of armed conflicts, greatly influences the physiognomy, the direction and the speed of the development of contemporary conflicts. It expresses the availability of knowledge and data necessary for successful command and control at all levels. Its availability reduces the uncertainty in military activity and enables a better assessment of the situation, as well as making relevant decisions in real time. In the paper, the Telecommunications and Information System (TkIS) of the Serbian Armed Forces (SAF) is looked at from several aspects, and the issue of the need for improvement of the existing system, imposed by constant development of information technologies, is being updated. The concept, purpose, structure and level of development of the TkIS are dealt with in the paper, particularly the level of development of the SAF TkIS and its cause-effect relation with the defense of the Republic of Serbia, with a focus on military defense. The aim of this paper is to examine the impact of the Serbian Armed Forces telecommunications and information system on the defense of the Republic of Serbia with the emphasis on military defense, and to point out the need for continuous improvement of the TkIS and continuous education, i.e. adequate and timely training of the personnel for its use for military defense. The importance of the work is in the analyzed state of the Serbian Telecommunications and Information System in relation to the

needs of the military defense of the Republic of Serbia in the context of contemporary security challenges.

Key words: information, telecommunications, Serbian Armed Forces, military defense, satellite networks, fixed networks, internet.

Introduction

In accordance with the security environment and with recognized challenges, risks and threats to the defense, the Republic of Serbia has defined its vital defense interests. Defense interests are an expression of the highest values and needs of the Republic of Serbia that are constantly being realized and improved, and they as such represent the purpose of existence and functioning of the defense system. Creating a unique and efficient defense system of the Republic of Serbia is possible only with a comprehensive and sustainable development of both military and civil defense. The application of the concept of total defense, through the integral engagement of defense entities and defense potential, enables a uniform participation of all parts of society in the preservation and improvement of vital defense interests.

The command and control of military defense is carried out by the President of the Republic, the Minister of Defense and the Chief of the General Staff of the Serbian Armed Forces (SAF) in accordance with the Constitution, their authorizations by law and their competencies. The command and control of civil defense and other entities important for defense is a part of the unified command of the defense system and will be implemented within state bodies, state administration bodies, bodies of autonomous provinces, local self-government bodies, companies and other legal entities in accordance with the law. (Službeni glasnik RS, 88/2009)

Timely, complete and protected data and information for the needs of management, command and control of military and civil defense are provided by telecommunication-information systems in the Republic of Serbia. A TkIS is a set of facilities, devices and equipment that are interconnected in a technical and technological unit enabling the transmission of messages and information from one point to another. These systems have their structures, organizations and boundaries, and, to a certain extent, they are interrelated. All TkISs in the Republic of Serbia form a unified TkIS of the Republic of Serbia.

A telecommunications information system that enables the transmission of messages and information for the needs of military defense is the TkIS of the Serbian Armed Forces. The development of

the SAF TkIS organization is focused on the best-in-depth experiences and the results of the scientific research in the field of telecommunications, information technology and information protection. The compatibility of the TkIS of the Serbian Armed Forces with other TkISs in the Republic of Serbia is one of the essential conditions for the realization of the unified command and control of the military and civil defense of the Republic of Serbia.

The purpose of the SAF TkIS is the telecommunications and information security of the Serbian Armed Forces. It is one of ten security fields in the Serbian Armed Forces and is conducted to collect, process, transfer, exchange and protect data and information in real time. The realization of telecommunications and IT security enables networking in support of visualization of operational environment, decision making process, selection of operation objects, synchronization of combat assets and tools, as well as information management.

As a weapon, information can be used as part of full or partial information superiority of one of the parties in conflict. The enemy will achieve full or partial information superiority over our forces when the telecommunications and information security of the Serbian Armed Forces are not able to provide a safe, continuous, elastic and operational system of command and control of the military defense in the Republic of Serbia.

The focus of the work will be to look at the state of the Serbian Telecommunications and Information System in relation to the needs of the military defense of the Republic of Serbia in the context of contemporary security challenges.

The defense system of the Republic of Serbia

The defense system of the Republic of Serbia is a part of the national security system, which represents a unique, normative, structured and functionally regulated entity, aimed at protecting the sovereignty, independence, territorial integrity and security of the Republic of Serbia from all forms of external and internal threats in peace, state of emergency and war (Službeni glasnik RS, 116/2007, 88/2009 & 10/2015). The Republic of Serbia protects and realizes its vital defense interests through military and civil defense.

The Serbian Armed Forces are the military defense bearer while state bodies, state administration bodies, autonomous provinces bodies, local self-government bodies, companies, public services and other

entities and forces of the defense system participate in civil defense.[1]The Law on the Serbian Armed Forces describes the Serbian Armed Forces as an organized armed force that defends the country against armed threats from outside and performs other missions and tasks in accordance with the Constitution, the law and principles of international law regulating the use of force (Službeni glasnik RS, 116/2007, 88/2009& 10/2015). In accordance with the Constitution, the National Assembly of the Republic of Serbia assigns missions to the Serbian Armed Forces for the protection of vital defense interests. The Serbian Armed Forces implement the stated mission by carrying out tasks (Medija centar „Odbrana“, 2010). The Serbian Armed Forces can realize the assigned missions only if the organization of the Serbian Armed Forces, the content of its preparations, use and security of the Serbian Armed Forces are harmonized and directed to the protection of vital defense interests. Commanding the Serbian Armed Forces is based on the principles of unity, continuity, elasticity, efficiency, operability and security (Medija centar „Odbrana“, 2010). It is organized at the strategic, operational and tactical level. At the strategic level, the Serbian Armed Forces are commanded and run by the President of the Republic of Serbia, the Minister of Defense and the Chief of General Staff of the Serbian Armed Forces. The President of the Republic of Serbia, on the basis of the Constitution and the Law on the Serbian Armed Forces, decides on the use of the Serbian Armed Forces and commands the Serbian Armed Forces in peace and war (Službeni glasnik RS, 98/2006). In accordance with the Law on the Army, the Minister of Defense coordinates and implements the established defense policy and manages the Serbian Armed Forces. Also, based on the Law on the Army and the Guidelines on Responsibilities, the Chief of General Staff of the Serbian Armed Forces commands and controls the Serbian Armed Forces (Figure 1).

At the operational level, command bearers are the commands of the branches and the training command, while at the tactical level, command bearers are the commands of brigades and other same-level commands, the commands of battalions-divisions and the commanders of units (from a company-battery to a team-service- crew). The command and control system in the Serbian Armed Forces will be largely determined by the possession and use of information. For all command levels in the Serbian

[1] "The subjects of the defense system are: citizens, state bodies, companies, other legal entities, entrepreneurs and the Serbian Armed Forces. Defense forces are the human and material potentials of the Republic of Serbia, or the organized structure of the entities of the defense system. " (Službeni glasnik RS, 88/2009, p.14).

Armed Forces, the possession of accurate, timely and relevant information will be enabled by the TkIS of the Serbian Armed Forces, through the realization of telecommunication-information security (TkIOb) at all levels (Medija centar „Odbrana“, 2010).

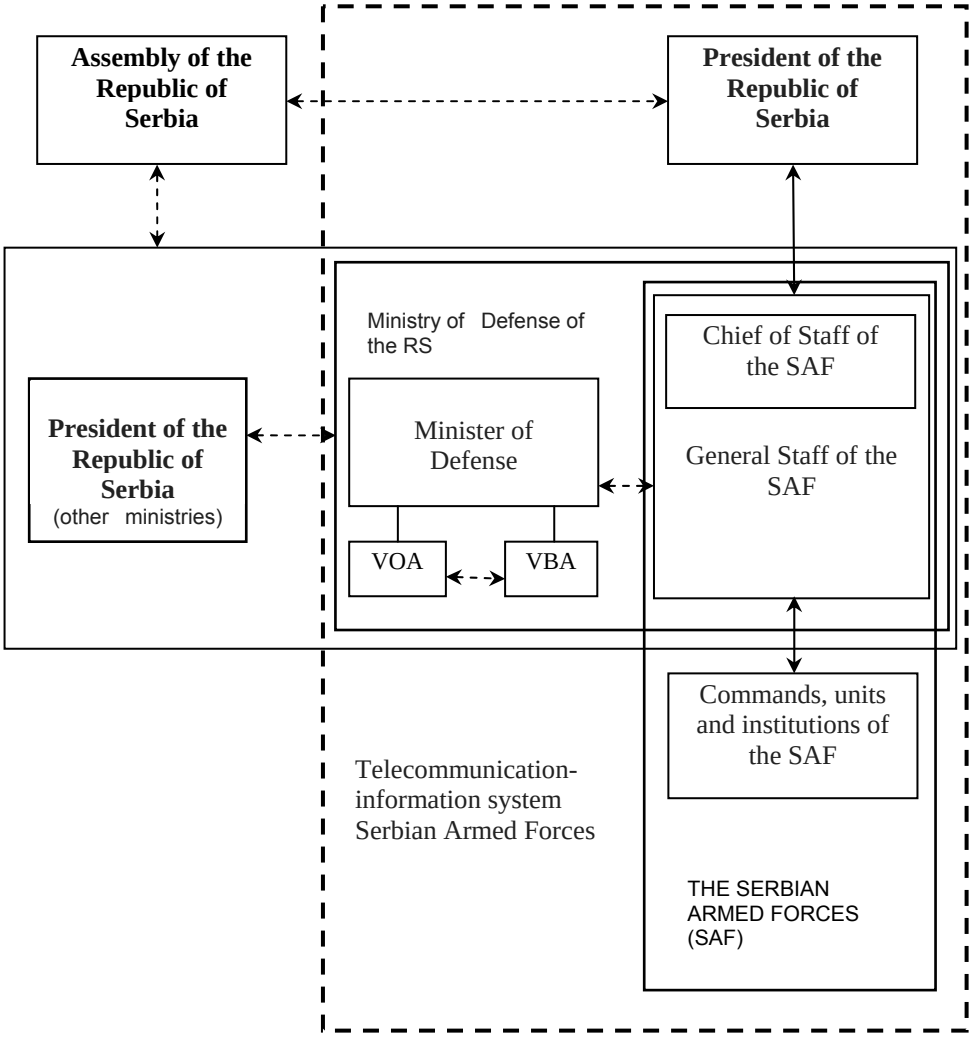


Figure 1 – Command of the Serbian Armed Forces (SAF)
Рис. 1 – Командование Вооруженными силами Республики Сербия
Слика 1 – Командовање Војском Србије

The telecommunication-information security of the military defense is an integral part of the Defense Plan of the Republic of Serbia, which defines the TkIOb of the President of the Republic, the Ministry of Defense and the Serbian Armed Forces (Službeni glasnik RS, 116/2007, 88/2009 & 10/2015). It is important to point out that the dotted arrows indicate interrelationships.

Civil Defense is part of a unified defense system. It is organized at the level of the Republic of Serbia, the autonomous provinces and local self-government units. The Defense Law describes Civil Defense as part of the defense of the Republic of Serbia, which includes a set of measures and activities aimed at: preparing for defense and for the defense of the Republic of Serbia by non-military means; ensuring the successful functioning of state bodies, autonomous provinces and local self-government units, companies and other legal entities, protection and rescue and securing conditions for the life and work of citizens and meeting the needs of the defense forces in the state of emergency and war. Civil defense has assigned missions. (Službeni glasnik RS, 116/2007, 88/2009 & 10/2015)

Civil defense missions are conducted by carrying out its tasks. In addition to the aforementioned missions and tasks, civil defense can also carry out other tasks based on the decisions of the legislative and executive authorities of the Republic, the autonomous provinces and local self-government units.

The command over civil defense and other defense-related entities is part of a unified defense command system and is carried out in accordance with the law. Providing telecommunications and services for the civil defense command is done through the TkIS for special purposes and through the TkIS for general needs (arrows point to interrelationships). The telecommunication-information security of civil defense is an integral part of the Civil Defense Plan of all entities.

Telecommunication-information system of the Serbian Armed Forces

The term *telecommunication-information system* denotes here a set of objects, devices and equipment interconnected in a technical and technological unit that allows the transmission of signals by means of cable, radio, optical or other electromagnetic means, including satellite networks, fixed networks (the Internet and other networks with switching circuits and packets), mobile networks, energy cable systems (in the part used for signal transmission) and networks for the distribution and

broadcasting of media content, intended to enable the transmission of messages and information from one point to another. (Generalštab Vojske Srbije & Medija centar „Odbrana“, 2012)

Concept, purpose and structure of the telecommunication-information system

The Republic of Serbia is a modern state aiming at the harmonization in all areas with the highest European and world standards. Harmonization in the field of telecommunications and IT can be achieved by rational, economical and efficient use of national resources (national radio-frequency spectrum), balanced development of telecommunication-information capacities and development of compatibility and interoperability of systems for their interconnection and utilization in order to obtain a unified technical and technological unit at the national and international level. There is a unified telecommunications and information system at the level of the Republic of Serbia in the field of telecommunications and information.

The unified TkIS of the Republic of Serbia consists of: telecommunication-information systems for general needs, telecommunication-information systems for special purposes and other holders of telecommunication-information assets (Figure 2). The telecommunication-information systems for general needs serve to provide various telecommunication and information services to individuals and legal entities. They represent the mainstay of the other TkISs in the Republic of Serbia. The TkISs for general needs include: TkIS of "Telekom Srbije", TkIS of "PTT Srbija", TkIS of "Radio Television of Serbia", TkIS of "VIP Telekom" and TkIS of "Telenor".

Telecommunication-information systems for special purposes are intended for securing certain organizations and realization of missions and tasks or activities. These systems include: TkIS of the Serbian Armed Forces (VS), TkIS of the Ministry of Internal Affairs (MUP), TkIS of the Ministry of Foreign Affairs (MIP), TkIS of the Security Information Agency (BIA), TkIS of the Serbian Railways (TS), TkIS of Elektroprivreda Srbije (EPS) and TkIS of the authorities responsible for rescue tasks, as well as emergency services.

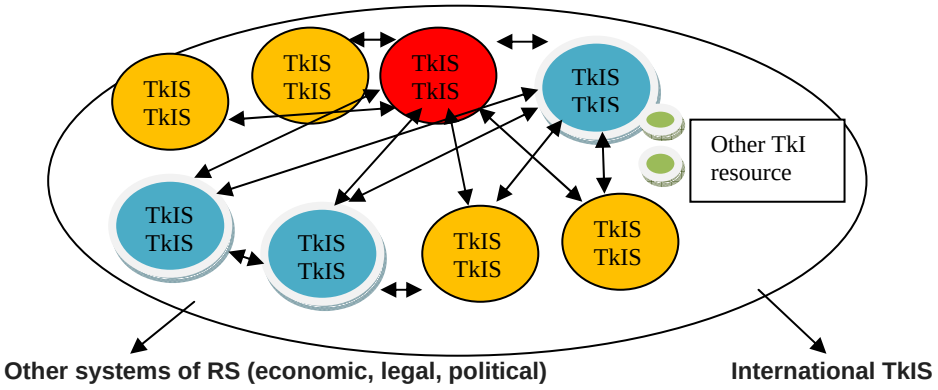


Figure 2 – General model of the telecommunications and information system in the Republic of Serbia (Generalštab Vojske Srbije & Medija centar „Odbrana“, 2012)
Рис. 2 – Общая модель информационной и телекоммуникационно систем в Республике Сербия (Generalštab Vojske Srbije & Medija centar „Odbrana“, 2012)
Слика 2 – Општи модел телекомуникационо-информационог система у Републици Србији (Generalštab Vojske Srbije & Medija centar „Odbrana“, 2012)

The telecommunications and information system of the Serbian Armed Forces belongs to the TkIS group for special purposes. It is intended for the implementation of the TKIOb of the Serbian Armed Forces. Telecommunication-information security is one of the security aspects in the Serbian Armed Forces and is important for ensuring the continuity, timeliness and quality of the functioning of the command and control of the Serbian Armed Forces in all missions and tasks. Telecommunication-information security represents a set of measures, procedures and activities by which the elements of TkIS, ready for operation or already operating in accordance with a certain plan of the TkIOb, are merged into a unified technical-technological entity (Generalštab Vojske Srbije & Medija centar „Odbrana“, 2012). The mentioned system is closely related to the TkIS of "Telekom Srbija" and the TkIS of "PTT Serbia". The use of the capacities of the listed TkISs for the needs of the TkIS of the Serbian Armed Forces is done on the basis of laws, concluded contracts and approved plans of the defense of the Republic of Serbia. Through its elements, the TkIS of the Serbian Armed Forces is connected with other TkISs for special purposes, and also, depending on its needs, with other holders of telecommunications and information resources in the Republic of Serbia. (Politika, 2014)

The telecommunications and information system of the Army has its own structural and functional organization (Generalštab Vojske Srbije &

Medija centar „Odbrana“, 2012). The structural TkIS of the Serbian Armed Forces is divided into a stationary and mobile part, i.e. a stationary telecommunication-information system and a mobile telecommunication-information system (Figure 3). The stationary TkIS of the Serbian Armed Forces is the basis of the TkIS of the Serbian Armed Forces through which the capacities with the other TkISs in the Republic of Serbia are mostly integrated. The mobile TkIS consists of transport and transmission assets of the TkI commands and units capable of operating in field conditions. The functionally mobile TkIS relies (utilizes the capacities) on the stationary TkIS. These systems consist of TkIS elements: stations, centers, nodes and telecommunication pathways.

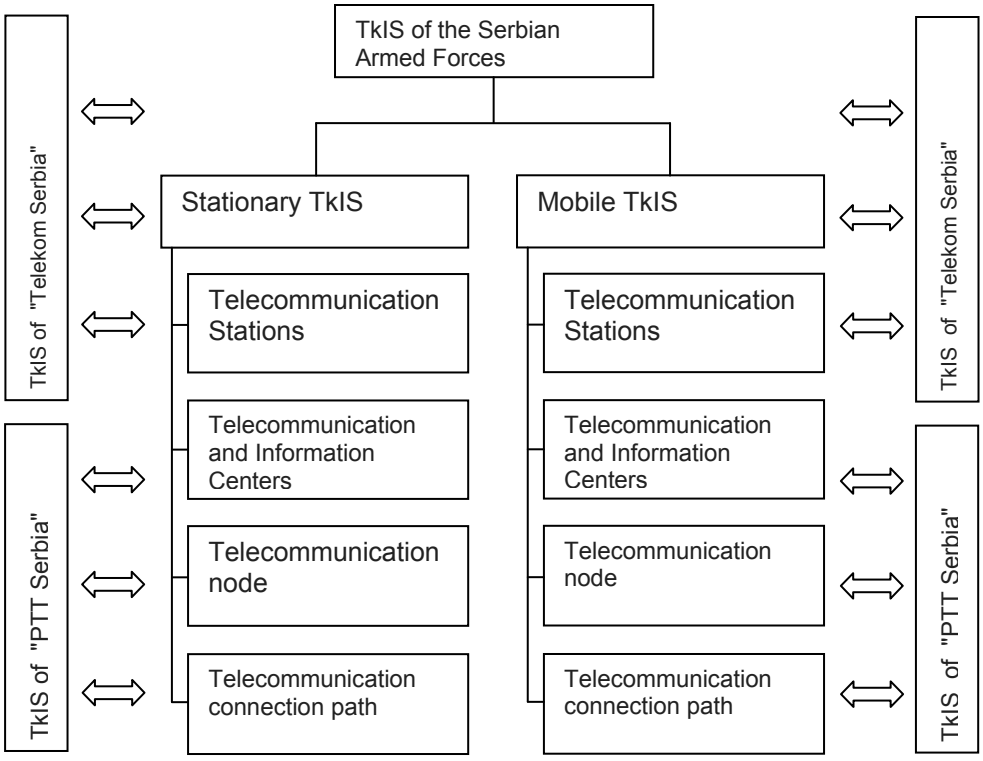


Figure 3 – Structured organization of the TkIS of the Serbian Armed Forces (Generalštab Vojske Srbije & Medija centar „Odbrana“, 2012)
Рис. 3 – Структурная организация ТкИС Вооруженных сил Республики Сербия (Generalštab Vojske Srbije & Medija centar „Odbrana“, 2012)
Слика 3 – Структурна организација ТкИС Војске Србије (Generalštab Vojske Srbije & Medija centar „Odbrana“, 2012)

The Serbian telecommunications and information system is functionally organized from the telecommunication component, the information component and the information protection component. All three components consist of specialized and trained personnel, appropriate equipment and appropriate work documents.

Achieved level of development of the telecommunications and information system of the Serbian Armed Forces

The SAF Telecommunications and Information System has its roots and experiences in the Yugoslav People's Army (JNA) where it had the name of the Armed Forces Communication System (SSNO, Uprava veza GŠ JNA, 1979) The organization and preparation of the Armed Forces Communication System (OS) were based on the experiences of the national liberation war and the concept of the national defense and social self-defense (ONO and DSZ). The experiences of the wars waged around the world at the time were also applied. The organization of the territory and the procurement of modern communication devices were established according to previous plans as well as the training of personnel and the integration of the OS system with the other holders of the Communication System in the SFRY. The usage of the capacities of the holders of the Communication System for general purposes and those of the holders of the Communication System for specific purposes was defined by the highest state acts of the SFR Yugoslavia for the defense of the country. The OS link system used mainly the JPTT capacities in the implementation of the tasks of the defense of the SFR Yugoslavia.[2] (Aksentijević & Rošulj, 1984)

The Communication System in the Yugoslav Army consisted of a stationary part and a movable part. The basic elements of the Communication System were: communication stations, communication centers, communication nodes and communication paths. The planning, preparation, organization and operation of the Communication System were performed by communication organs, communication units and institutions. The communication organs were in the commands of regiments, brigades, divisions, corps, the army, and the General Staff of the Yugoslav Army. The highest communication body in the Yugoslav Army was the Office for Communication and Informatics.

[2] "The Yugoslav Post, Telegraph and Telephone System (JPTT)" communication system serves to meet the needs of society, businesses and individuals in the use of postal, telegraph and telephone services in domestic and international traffic (Aksentijević & Rošulj, 1984, p.45).

During the 1990s war in Bosnia and Herzegovina, the Federal Republic of Yugoslavia was first under partial and later under full economic sanctions in accordance with the resolution of the Security Council.[3] The economic sanctions also concerned trade in weapons and military equipment. Because of the above, the Yugoslav Army Communication System and the other holders of the communication system in the Federal Republic of Yugoslavia could not keep pace with technological and technological development and achievements in the field of telecommunications and informatics in the world. A major challenge for the Yugoslav Army's system of communications was the NATO (NATO, nd) aggression on the FRY lasting for 78 days in 1999 (Pečat, 2010). Some of the NATO priority targets were the command posts and the capacities of the communication system of the Yugoslav Army, but also the capacities of the other holders of the communication system of the Federal Republic of Yugoslavia.[4]Most of the vital facilities of the Yugoslav Army's system of communications were damaged or destroyed. Immediately after the end of the NATO's aggression against the Federal Republic of Yugoslavia, the mitigation of the consequences of the actions on communication system infrastructure facilities began.[5]

After the declaration of independence of Montenegro and the dissolution of the State Union of Serbia and Montenegro, the Republic of Serbia, based on the vision and the decisions of the state leaders, began the reform of the defense system (Medija centar „Odbrana“, 2005). The reform of the entire defense system included the reform of the communication system. The reform of the communication system consisted of the reform of its organization, its equipment and its training system. The reform of the TkIS communication system organization included establishing the TkIS organization, the composition and the locations of the TkIS commands, units and institutions. The Serbian Armed Forces communication system was reformed into the TkIS of the Serbian Armed Forces. Bodies, institutions and units for telecommunications and information technology with equipment and

[3] Sanctions on the Federal Republic of Yugoslavia were imposed on May 30, 1992. by the resolution of the UN Security Council.

[4] Among the numerous facilities were: Tower on Avala, Radio Television Serbia building in Belgrade, radio transmitters of Belgrade and other radio and television stations, "Telekom" in Uzice, the optical and other communication paths of the. "Telekom" and the Serbian Armed Forces on the targeted bridges, the capacities of the MUP of the Republic of Serbia, "Serbian Railways" and "Elektroprivrede Srbije".

[5] The rehabilitation of the most necessary infrastructure facilities for the work of TkIS was completed at the end of the first decade of the 21st century.

infrastructure are incorporated into the TkIS of the Serbian Armed Forces. The telecommunication and IT institutions deal with design, development, introduction and support in the exploitation of information and command and information systems as well as with research and development activities in the field of cryptography. Telecommunication and IT units are intended for the implementation of TKIOb at the tactical, operational and strategic levels. They are organized in communication squads, platoons, companies, batallions and the communication brigade. The composition, size and location of TkI commands, units and institutions are in accordance with the size, composition, distribution of commands, units and institutions of the Serbian Armed Forces and the Ministry of Defense.

The damaged and destroyed facilities of the stationary TkIS of the Serbian Armed Forces were gradually revitalized in order to create the basic conditions for equipping and modernizing the TkIS with modern telecommunication and IT equipment. Equipment supply was carried out in accordance with equipment plans which were made on the basis of multi-year estimates and equipment plans. The stationary TkIS of the Serbian Armed Forces began to be equipped in 2008. The project of the Serbian Army radio-relay network "Saturn 5" foresees the complete replacement of radio-relay devices of the older generation and the connection of stationary nodes and stationary telecommunication-information centers with modern devices characterized by high speed, huge capacity and the possibility of integration with the TkIS holders in the Republic of Serbia. In order to realize the project, the purchase of telecommunication equipment from the manufacturer "NERA" was agreed (Nera Telecom, nd). The mentioned equipment was installed during 2009 and 2010. In addition to the mentioned radio relay network, significant capacities were renewed in the cable transmission system. Telephone exchanges were replaced, optical connecting paths were installed and various types of multichannel devices based on analog technology were replaced. All outdated cable connections and obsolete multi-channel equipment were replaced. The optical transmission system started to be fully operational in the Serbian Armed Forces. The modernization of the stationary TkIS of the Serbian Armed Forces has resulted in stability of the system, increased capacities and increased number of user services that can be offered to the command. The aforementioned equipping harmonized the organizational structure of the communication brigade, the number and the basic equipment for work on the elements of the stationary TkIS of the Serbian Armed Forces, established in 2006.

Equipping the capacities of the mobile TkIS of the Serbian Armed Forces was realized to a much smaller extent than equipping the stationary part of the TkIS. Supply of modern equipment will be realized by importing modern telecommunication and information equipment from the French manufacturer "Tales" and the Israeli manufacturer "Tadiran". Priorities in equipping the TkIS mobile part were given to units sent to international operations, special brigade units, and the training center for informatics and electronic operations. Equipping other commands, units and institutions is carried out in accordance with the approved funds and according to the medium-term plan for equipping the TkI commands and units of the Serbian Armed Forces and the Ministry of Defense.

By creating a new organization of the army, abolishing secondary professional military schools and adopting the decision to start voluntary military service, the Serbian Armed Forces applied a completely new way of recruitment and training (Službeni glasnik RS, 95/2010). The admission of soldiers to volunteer military service and their training for the needs of the telecommunications service is carried out at training centers for a period of six months.[6]The education of non-commissioned staff in place of secondary education was replaced by professional training of professional soldiers - candidates from units who showed above average results at their workplaces in their units in the previous period. The same as in the previous period, training of candidates for officers is carried out at the Military Academy with adapted curricula in accordance with the trends in military management and school requirements.

The coordination and harmonisation of theTkIS organization of other holders in the Republic of Serbia for the purposes of the defense of the Republic of Serbia is carried out by the Telecommunication and IT Administration, in accordance with the powers of the Minister of Defense with the TkIS Administration for General Purposes as well as with special purpose TkIS administration bodies. Coordination and harmonization of activities relate to the acceptance of technical norms for enabling compatibility and interchangeability in TkI capacities by assigning a certain part of TKI capacity for defense needs and aligning the research and development of TkIS elements of individual TkISs with the SAF TkIS and harmonization of joint activities in the realization of tasks of defense of the Republic of Serbia.

[6] Training soldiers in voluntary military service for the information service is not carried out.

The reform of the Communication System in the TkIS of the Serbian Armed Forces covers the period from 2006 to the present. For the mentioned period, the multi-dimensional character of the TkIS of the Serbian Armed Forces reform has been reflected in: revitalization of the damaged TkIS facilities; creation of a new TkIS organization through the composition, size and location of the commands, units and institutions of the telecommunications and information service (and the improvement of the TkIS structural organization and the functional organization of the TkIS of the Serbian Armed Forces); equipping and modernizing the TkIS with modern telecommunication and IT equipment, improving the training of members of the telecommunications and information service and coordinating and harmonising the TkIS organization of other holders in the Republic of Serbia for the needs of the defense.

Analysis of the impact of the current development level of the telecommunication-information system of the Serbian Armed Forces on the defense of the Republic of Serbia

The influence of the achieved level of the development of the TkIS of the Serbian Armed Forces on the defense of the Republic of Serbia is

reflected above all in ensuring the continuity, timeliness and quality of the functioning of command and control in the missions and tasks of the Serbian Armed Forces. Bearing in mind that TkIS of the Serbian Armed Forces is intended to secure the Serbian Armed Forces in the realization of their missions and tasks, the analysis of the achieved level of development of the TkIS Serbian Armed Forces on the defense of the Republic of Serbia will be heavily implemented in military defense. The analysis of the impact of the achieved level of development on the defense of the Republic of Serbia will be based on: analysis of the impact of structural organization TkIS VS (composition, size and location of commands, units and institutions of the telecommunications and information service), analysis of the influence of equipping and modernization of TkIS with modern telecommunication and IT equipment, analysis of the impact of improving the training of members of the telecommunications and information service, and analysis of the impact of coordination and colaboration of the organization of TkIS of other holders of the Republic of Serbia for the defense.

Analysis of the impact of the structural organization of the TkIS of the Serbian Armed Forces on the defense of the Republic of Serbia

Regarding the structure, the telecommunications and information system of the Serbian Armed Forces consists of the stationary part of TkIS and the mobile part of the TkIS of the Serbian Armed Forces. The development of the existing infrastructure of the stationary part of the TkIS of the Serbian Armed Forces is based on real needs of command and control of the Serbian Armed Forces in peace, state of emergency and war. Most of the infrastructure facilities date back to the SFR Yugoslavia and were designed for the needs of the JNA's system of communications. The construction of these facilities was planned for the entire area of the SFRY, and the infrastructure facilities on the territory of the Republic of Serbia were part of the unique JNA system of communications. During the NATO aggression in 1999, most of the mentioned infrastructure facilities of the stationary part of the SAF TkIS were damaged or destroyed. In line with the priorities and economic possibilities, the existing ones were partially repaired and new facilities were built for the needs of the TkIS of the Serbian Armed Forces. Stationary telecommunication nodes (TkČs) are an element of the stationary part of the TkIS of the Serbian Armed Forces (Generalštab Vojske Srbije & Medija centar „Odbrana“, 2012). Their placement, role and purpose make them an important element of the TkIS which enables the integration of command and control systems. By establishing radio-relay communication with the TkČ elements of the mobile part of the TkIS of Serbian Armed Forces, they realize the TkIOb for the needs of the command and units of the Serbian Armed Forces. The distribution of the TkČs in the Republic of Serbia and their interconnection ensures coverage of the majority of the territory of the Republic of Serbia. The analysis of the positions of these TkČs shows that they are relatively unevenly distributed, which is the consequence of the planning and construction of radio-relay facilities in the SFRY. The spatial inequality in the stationary TkČ distribution is more pronounced towards the border areas that represented the border areas in the SFR Yugoslavia with the neighboring countries: the Republic of Hungary, the Republic of Romania and the Republic of Bulgaria. In the other parts of the country, towards the regional borders, the situation in the arrangement of the stationary TkČs is more favorable due to the fact that these areas were not borderlines in the SFRY. After the NATO aggression against the FR Yugoslavia, three TkČs ceased operating in the AP Kosovo and

Metohija, which complicates the implementation of the TkIOb in the southeast and southwestern part of Serbia, due to the size and shape of the territory. Moderately uneven distribution and the number of TkČs do not have a positive influence on the planning, organization and implementation of theTKIOb for military defense in the border regions of the Republic of Serbia.

Stationary telecommunication-information centers (TkICs) are an element of the stationary part of the TkIS of the Serbian Armed Forces. By their location, organization, people and equipment, they provide necessary preconditions for the implementation of TkIOb commands, units and institutions of the Serbian Armed Forces and organizational units of the Ministry of Defense. In most cases, the use of the TkIS capacities for general needs and other TkISs for special purposes is carried out by the Serbian Armed Forces and the Ministry through stationary TkICs. The locations of the stationary TkICs are conditioned by the locations of the Serbian Armed Forces commands, units and institutions and the organizational units of the Ministry of Defense. During the NATO aggression against the FR Yugoslavia in 1999, TkČs and TkICs were NATO targets as well. In line with priorities and economic possibilities, a number of the facilities have been repaired while new ones have been built to a smaller extent. Since 2006, when the reorganization of the Serbian Armed Forces started, some of the facilities have been abandoned due to the disbanding of units (garrisons and garrison sites). The arrangement of stationary TkICs in accordance with the existing organization enables the operation of the command, units and institutions in the Serbian Armed Forces as well as the operation of the organizational units of the Ministry of Defense in the areas of peacetime locations. The complexity of TkIOb commands, units and institutions of the Serbian Armed Forces in the areas outside the peacetime locations has been raised to a higher level in the state of emergency and war. The number, distribution and capacity of the TkICs in the entire territory of the Republic of Serbia have an impact on the defense of the Republic of Serbia and make the SAF TkIS more dependent on the use of the TkC capacities and those of "Telekom Srbija".

Stationary telecommunication paths (TkSPs) are an element of the stationary part of the TkIS of the Serbian Armed Forces. They are mediums for the realization of telecommunications between telecommunication stations (TkSts), TkICs and TkČs. They can be radio, radio-relay, wired and optical coupling paths. In the first decade of the 21st century, modernization of cable communications was carried out, all

outdated cable connections and multiplex equipment were replaced. The optical transmission system is the backbone of communications via permanent cables in the TkIS of the Serbian Armed Forces. Through their locations, capacities and varieties, the stationary telecommunication paths positively affect the planning, organization and realization of the military defense of the Republic of Serbia. Taking into account the locations, distribution, organization, capacities and equipment of the TkČs and TkICs as well as the state of the TkSps, it can be concluded that the achieved level of the development of the stationary TkIS has a favorable effect on the defense of the country.

The mobile TkIS of the Serbian Armed Forces consists of portable and movable telecommunication and IT resources, as well as communication commands and units capable of working in field conditions. It is organized strategically, operatively and tactically. The TkI bodies are intended for planning, organizing, coordinating and controlling telecommunication-information security. The organizational structure of the TkI organs in the commands, units and institutions of the Serbian Armed Forces was made on the basis of the intended and planned tasks to be performed by the TkI organs and directly subordinate units. In the mobile TkIS of the Serbian Armed Forces, TkI units are also organised at the tactical, operational and strategic level in communication squads, platoons, companies, battalions and the brigade.[7]The organizational structure of TkI units is tailored depending on their purposes, tasks and levels of command for which TKIOb is established. In order for a TkI unit to be efficient and functional in the implementation of TKIOb tasks, the organizational structure of the unit must be consistent with the purpose of the unit, the tasks performed by the unit, the composition of the personnel and the technique to be engaged in the implementation of tasks. The TkIOb Implementation Unit in a battalion - division is a communication squad, i.e. platoon. TkI units in battalions - divisions are mostly equipped with TkI equipment of the older generation for the realization of TkIOb. Regardless of the aforementioned problem, the current personnel and TkI equipment in TkI units in TkI battalions - divisions provide a high quality realization of planned telecommunications and services. A TkI unit in a brigade, i.e. a unit of the same rank in the Serbian Armed Forces, is a communication company or platoon. A communication platoon in a Land Army brigade can fully implement the TkIOb at the brigade KM, but due to the above-mentioned organizational

[7] A communication brigade has units of the battalion rank intended for operation in the stationary and mobile TkISs of the Serbian Armed Forces.

solution (a communication platoon instead of a communication company), it is unable to establish a PTkIC at a brigade IKM and/or LoKM in order to provide necessary communications and services for commanding purposes, which negatively affects the organization of the defense of the Republic of Serbia at the tactical level.[8]The reason for planning the existing organization of the communication units should be sought in the existing process of equipping with modern TkISs and devices. Equipping of the TkI units is planned to be carried out in accordance with the Army's Integrated Communication System (ISV) equippment supply program, but due to an unfavorable financial situation it has not been carried out yet. As a transitional solution, some modern devices were installed in the existing communication systems, which improved the operational capabilities of commands and units and enabled the compatibility of the mobile TkIS with the stationary TkIS of the Serbian Armed Forces. At present, the personnel number and the equipment of TkI units in other brigades or units of the rank of the brigade in the Serbian Armed Forces enable the planned telecommunications and services to be realised at a good level of quality. The units for the implementation of TkIOb at the strategic and operational level are a communication battalion of a communication brigade, the 21st communication battalion of the Land Army and the 210th communication battalion of the Air Force and Air Defense (SSNO, Uprava veza GŠ JNA & Vojnoizdavački i novinski centar, 1988). The communication battalion of the communication brigade is intended for the implementation of TkIOb at the strategic level for the needs of the President of the Republic and the General Staff of the Serbian Armed Forces, while the TkIOb needs of the Ministry of Defense (and the President of the Republic to an extent) are dealt with by communication batallions of communication brigades from the stationary part of the TkIS of the Serbian Armed Forces. There is no obligation or jurisdiction of the TkIS of Serbian Armed Forces for the implementation of the TKIOb of other bodies: the Prime Minister of the Republic of Serbia, the Government of the Republic of Serbia, the President of the National Assembly and other state bodies. Telecommunication and information security of the highest state bodies for the purpose of the defense of the Republic of Serbia is defined by the Defense Plan of the Republic of Serbia (Službeni glasnik RS, 116/2007,

[8] The task of the communication company is to set up a communication center at a brigade KM, PKM and IKM (when formed), establish planned communications, maintain the continuity of communications, enable their use, and ensure the security of communications and information (SSNO, Uprava veza GŠ JNA, 1990, p.3).

88/2009 & 10/2015). Telecommunications of the cooperation and colaboration of the Serbian Armed Forces with the other elements are planned to be realized at the strategic, operational and tactical level in accordance with the needs of the defense of the Republic of Serbia and are prescribed by the Defense Plan of the Republic of Serbia (Službeni glasnik RS, 116/2007, 88/2009 & 10/2015). For the realization of the telecommunications of cooperation and colaboration between the Serbian Armed Forces and the other elements of the Defense System, the capacities of TkIS of the Serbian Armed Forces, other TkISs for special purposes (TkIS of the Ministry of Internal Affairs, TkIS of the Ministry of Foreign Affairs, TkIS of the Security Information Agency, TkIS of the Serbian Railways, TkIS of the Elektroprivreda Srbije and TkIS of the authorities responsible for rescue tasks as well as emergency services) and most of TkISs for general needs ("Telekom Srbije" TkIS, "PTT Srbija" TkIS, "Radio-TV Serbia " TkIS, " VIP Telekom " TkIS, and " Telenor" TkIS). The organizational and formation structure of the communication battalion is in line with the purpose and tasks performed by battalions.

The organizational and formation structure of the bodies and units for telecommunications and informatics in the Serbian Armed Forces positively influences the defense of the Republic of Serbia due to the harmonization of the organizational and formation structure of the bodies and units for TkI with the types and scopes of tasks, except for the units of TkI in the Land Army brigades (due to an impossibility to realise some tasks to their full extent).

Analysis of the impact of equipping and modernizing the TkIS with modern telecommunication and IT equipment on the defense of the Republic of Serbia

In the current period (from 2000 to the present), based on the plans for equipping commands, units and institutions of the Serbian Armed Forces with telecommunication and IT equipment and the plans for the adaptation of facilities, infrastructure and capacities for the needs of the defense of the Republic of Serbia regarding the TkIS and TkIOb, a number of facilities have been built and the SAF TkIS elements have been equipped and modernized. Taking into consideration the economic possibilities as well as the estimates based on their importance and TKIOb use for the needs of the defense of the Republic of Serbia, the facilities damaged or destroyed by NATO forces were rebuilt or reconstructed or completely new buildings were built. The construction of

completely new facilities or the repair of the damaged TkIS facilities has eliminated the negative impact of the availability of TkIS infrastructure facilities on the country's defense which was previously caused by reduced TkI capacities and pronounced TkIS dependence on weather conditions, thus creating favorable conditions for proper accommodation of personnel and TkI equipment.

Due to a poor economic situation and the imposed sanctions during the 1990s, modernization of the TkIS of the Serbian Armed Forces was not carried out. These events have led to a disproportion in the technological development of the TkIS of the Serbian Armed Forces and the TkIS of "Telekom Srbija" and there was a real technological inability to use the "Telekom Srbija" TkIS capabilities. By analyzing the existing TkIS capacities at the beginning of the 21st century, it was concluded that the existing TKI equipment with its capacity, quality and technology would not meet the needs of the command and control system at the strategic, operational and tactical level for the defense of the Republic of Serbia. Procurement for the stationary TkIS of the Serbian Armed Forces was carried out in the period from 2008 to 2012. Modernization of the stationary TkIS of the Serbian Armed Forces has resulted in the stability of the system, increase of the capacity and the number of user services that can be offered to the command system, thus ensuring full integration of the SAF TkIS with other TkIS holders in the Republic of Serbia. The mentioned procurement brought in line the organizational structure of the communication brigade, the number of personnel and the basic equipment for work on the elements of the SAF TkIS stationary system established in 2006.

In accordance with the equipment supply plan for the mobile TkIS of the Serbian Armed Forces, the equipment supply was realized to a much smaller extent than the equipping of the stationary part of the TkIS. Priorities in equipping the mobile part of TkIS were given to the units referred to international operations, special brigade units, and the center for training, informatics and electronic operations. All commands, units and institutions are equipped with a certain number of modern devices that ensure the necessary compatibility with the stationary TkIS of the Serbian Armed Forces. Full equipment supply of the commands, units and institutions will be carried out in accordance with the approved funds and according to the medium-term plan for providing commands and units with TkI equipment in the Serbian Armed Forces and the Ministry of Defense. Equipping and modernizing the TkIS with modern telecommunication and IT equipment moderately positively influences the defense of the Republic of Serbia due to incomplete supply of modern

TkI equipment to the commands, units and institutions of the mobile part of the TkIS of the Serbian Armed Forces.

Analysis of the impact of improving the training of members of the telecommunications and information services on the defense of the Republic of Serbia

Improving the skills of the telecommunication service personnel and the information service personnel is achieved through their education, training and professional development as well as through the training of the military reserve members.

Cadets are educated at the Military Academy or at colleges in the country or abroad, as before, and the curricula are adapted to the trends and educational requirements. By studying the content at the Military Academy, officers are prepared for their initial military duties in the telecommunications and information service. This way of training the officers for initial duties positively influences the defense of the Republic of Serbia, because it provides a quality cadre qualified for performing initial duties.

Instead of being educated in secondary schools, NCOs are the result of one-year professional training of professional soldiers - candidates who showed above average results in their workplaces in their units in the previous period. This kind of training for a non-commissioned officer would make sense in the event of a greater flow of personnel, or engagement of non-commissioned officers in the Serbian Armed Forces for a certain period of time. Since the majority of non-commissioned officers obtain employment for an indefinite period after the completion of the course and promotion, after the renewal of the contract, the abolition of the secondary military school becomes unreasonable, and the training of the non-commissioned staff is displaced from the education system into the units. This way of training and teaching non-commissioned officers, in conditions when the inflow of military personnel is reduced and when new NCOs are employed for an indefinite period, does not positively affect the defense of the Republic of Serbia.

The training of soldiers in voluntary military service is carried out in military training centers. The training plan for soldiers includes two periods: the first one is a period of general military training and the second one is a period of vocational-specialist training. Training of soldiers includes all the training content of individual training, including the training of crewmembers. The current way of training soldiers for

voluntary military service has the following disadvantages: training soldiers in voluntary military service does not include a sufficient number of soldiers to fill up war units (it is estimated that currently 1/3 of the required number of soldiers is trained); there is currently no IT specialty for soldiers and, consequently, no training; soldiers who completed voluntary military service did not live and work in units and the period of collective training, which includes unit field exercises, was not realized; and it is not possible to fill vacant posts of professional soldiers by soldiers who voluntarily serve military service, thus violating the age structure of professional soldiers and reducing the percentage of complete units. This kind of training of telecommunication service soldiers negatively influences the defense of the Republic of Serbia for the aforementioned reasons.

Training of individuals, crews, units and commands of the telecommunications and information service is carried out in accordance with the Manual on Conducting the Training in the Serbian Armed Forces and the Training Instructions of the General Staff of the Serbian Armed Forces. This type of training provides freedom and responsibility for the commander to assess the skill levels, to plan and realize the training of individuals, crews, units and commands for the assigned mission. This mode of training positively influences the defense of the Republic of Serbia through cost-effectiveness, efficiency and effectiveness of training and the rationalization of the engagement of the telecommunications and information service staff.

Analysis of the impact of coordination and compatibility of the TkIS organizations of other holders in the Republic of Serbia for defense needs

The coordination and compatibility of the organizations of TkISs of other holders in the Republic of Serbia for the purposes of the defense of the Republic of Serbia are performed by the Telecommunications and IT Administration, in line with the powers of the Ministry of Defense with the Administrative bodies of theTkIS for general needs, as well as with the Administrative bodies of the TkIS for special purposes. Coordination and compatibility of activities relate to the acceptance of technical norms for enabling compatibility and interchangeability in the TkI capacities by assigning a certain part of the TkI capacity for defense needs and aligning the research and development of TkIS elements of individual TkISs with the SAF TkIS and aligning the joint activities in the realization of the defense of the Republic of Serbia. This way of coordination and

compatibility of the organizations of TkISs of other holders in the Republic of Serbia positively influences the defense of the Republic of Serbia.

The achieved level of development of the TkIS of the Serbian Armed Forces in the defense of the Republic of Serbia is positively influenced by the structural organization of the Army TkIS (composition, size and location of the commands, units and institutions of the telecommunications and information service), equipping and modernizing the TkIS of the Serbian Armed Forces with modern equipment, training members of the telecommunications and information service service and coordination and compatibility of the organizations of TkISs of other holders in the Republic of Serbia for the defense needs.

Conclusion

By applying the concept of total defense, the Republic of Serbia enables equal participation of all parts of the society in the preservation and improvement of vital defense interests. The Defense of the Republic of Serbia consists of military defense and civil defense. Military defense is to be commanded and controled by the President of the Republic, the Minister of Defense and the Chief of General Staff of the Serbian Armed Forces in accordance with the Constitution, legal authorizations and their competencies. The bearer of military defense is the Serbian Armed Forces. The command and control of civil defense and other defense entities is to be carried out within state bodies, state administration bodies, autonomous provinces bodies, bodies of local self-government units, companies and other legal entities, in accordance with the law.

Telecommunication-information systems in the Republic of Serbia provide timely, complete and protected data and information for the needs of management, command and control of military and civil defense. With their own organizations and structures, these systems are interrelated, making a single, unified TkIS of the Republic of Serbia. Mutual compatibility of the TkIS for special purposes and the TkIS for general needs in the Republic of Serbia is one of the essential conditions for the realization of unified management, command and control of military and civil defense of the Republic of Serbia.

A telecommunications information system that enables the transmission of messages and information for the needs of military defense is the TkIS of the Serbian Armed Forces. Through its structure and organisation, the telecommunications and information system of the Serbian Armed Forces, according to a plan, realises the TKIOb of the

Serbian Armed Forces. The telecommunications and information security of the Serbian Armed Forces is intended to ensure the continuity, timeliness and quality of the functioning of the command and control of the Serbian Armed Forces in all missions and tasks. The realization of TkIOb enables networking in support of the visualization of the operational environment, the decision making process, the choice of action targets, synchronization of combat assets and tools, as well as information management.

The development of the TkIS of the Serbian Armed Forces has been based so far on the best world experiences and results of scientific and research work in the field of telecommunications, information technology and information protection. The achieved level of development of the TkIS of the Serbian Armed Forces in the defense of the Republic of Serbia is positively influenced by its structural organization (the composition, size and location of the commands, units and institutions of the telecommunications and information service) by its equipping and modernizing with modern equipment, by training members of the telecommunications service and IT services, and by coordination and compatibility of other TkIS organizations in the Republic of Serbia for defense purposes.

In order to improve the state of TkIS of the Serbian Armed Forces and achieve a completely favorable impact of the TkIS of the Serbian Armed Forces on the defense of the Republic of Serbia, it is necessary: to conduct a detailed analysis of the coverage of the entire territory with the signal of radio and radio relay devices from stationary telecommunication nodes and, in accordance with the analysis, to plan possible construction of new capacities at the long-term or medium-term level; to carry out a detailed analysis of the distribution of stationary TkIC centers and the coverage of the territory of the Republic of Serbia and, in accordance with the performed analysis, to plan possible construction or modernisation of the existing capacities; to adjust the organizational structure of TkI units in the Land Army brigades to the scope of tasks; to equip TkI units with modern TkI equipment in accordance with the medium-term equipment supply plan; to plan to provide part of the training of soldiers in voluntary military service in the units of the Serbian Armed Forces in order for to them have collective training and acquire knowledge of the units of the Serbian Armed Forces; to consider a possibility of repealing the Regulation on termination of compulsory military service; to carry out a detailed analysis of the justification of the abolition of secondary military schools for non-commissioned telecommunications and information service officers; and, in order to

support the TkIS of Serbian Armed Forces in the implementation of the TKIOb of the Serbian Armed Forces and the military defense, to conduct a detailed analysis of possible negative impacts of the announced privatization of "Telekom Srbija".

This work has a multifaceted significance which is reflected in: examining the place, role and significance of the TkIS of the Serbian Armed Forces in the defense of the Republic of Serbia, through the practical relationship and interdependence of the TkIS of the Serbian Armed Forces with the other TkISs in the Republic of Serbia and recognizing the importance of uniform technological and spatial development of the TkIS of the Serbian Armed Forces and the TkIS for general purposes for the defense of the Republic of Serbia. This work should serve as a basis for reviewing the state of the TkIS of the Serbian Armed Forces in terms of organization, equipping and modernization of the TkIS of the Serbian Armed Forces, training of members of the telecommunications and information service, and the coordination and compatibility of the organizations of TkISs of other holders in the Republic of Serbia for the defense of the Republic of Serbia.

References

Aksentijević, M., & Rošulj, B. 1984. *Taktika veze*. Belgrade: Vojnoizdavački zavod (in Serbian).

Generalštab Vojske Srbije & Medija centar „Odbrana“. 2012. *Doktrina telekomunikaciono-informatičkog obezbeđenja Vojske Srbije.* Belgrade: Generalštab Vojske Srbije & Medija centar „Odbrana“ (in Serbian).

Medija centar „Odbrana“. 2005. *Bela knjiga odbrane Državne zajednice Srbija i Crna Gora.* Belgrade: Medija centar „Odbrana“ (in Serbian).

Medija centar „Odbrana“. 2010. *Doktrina Vojske Srbije.* Belgrade: Medija centar „Odbrana“ (in Serbian).

-Nera Telecom. [Internet]. Available at:http://www.neratelecom.com. Accessed: 10.10.2018.

-North Atlantic Treaty Organization (NATO). [Internet]. Available at:http://www.nato.int/. Accessed: 10.10.2018.

Pečat. 2010. *Spasoje Smiljanić, kako smo se branili od NATO agresije.* [Internet]. Available at:http://www.pecat.co.rs/2010/03/spasoje-smiljanic-kako-smo-se-branili-od-nato-agresije/. Accessed: 10.10.2018 (in Serbian).

Politika*.* 2014*. Radio-amateri pratili bombardere od Avijana*. [Internet]. Available at: http://www.politika.rs/scc/clanak/288103/Radio-amateri-pratili-bombardere-od-Avijana. Accessed: 10.10.2018 (in Serbian).

Službeni glasnik RS. 98/2006. *Ustav Republike Srbije*. Belgrade: JP „Službeni glasnik“ (in Serbian).

Službeni glasnik RS. 116/2007, 88/2009 & 10/2015. *Zakon o odbrani Republike Srbije.* Belgrade: JP „Službeni glasnik“ (in Serbian).

Službeni glasnik RS. 116/2007, 88/2009 & 10/2015. *Zakon o Vojsci Republike Srbije*. Belgrade: JP „Službeni glasnik“ (in Serbian).

Službeni glasnik RS. 88/2009. *Strategija odbrane Republike Srbije.* Belgrade: JP „Službeni glasnik“ (in Serbian).

Službeni glasnik RS. 95/2010. *Odluka o obustavi obaveze služenja vojnog roka.* Belgrade: JP „Službeni glasnik“ (in Serbian).

SSNO, Uprava veza GŠ JNA. 1979. *Pravilo veze oružanih snaga*. Belgrade: SSNO, Uprava veza GŠ JNA (in Serbian).

SSNO, Uprava veza GŠ JNA. 1990. *Pravilo četa veze*. Belgrade: SSNO, Uprava veza GŠ JNA (in Serbian).

SSNO, Uprava veza GŠ JNA & Vojnoizdavački i novinski centar. 1988. *Pravilo bataljon veze*. Split: SSNO, Uprava veza GŠ JNA &Vojnoizdavački i novinski centar (in Serbian).

ВЛИЯНИЕ ДОСТИГНУТОГО УРОВНЯ РАЗВИТИЯ ИНФОРМАЦИОННОЙ И ТЕЛЕКОММУНИКАЦИОННОЙ СИСТЕМ ВООРУЖЕННЫХ СИЛ РЕСПУБЛИКИ СЕРБИЯ НА ВОЕННУЮ ОБОРОНУ

Хатиджа А. Бериша, *Олга* М. Зорич
Университет обороны в г. Белград, Школа национальной обороны,
г. Белград, Республика Сербия

ОБЛАСТЬ: телекоммуникации
ВИД СТАТЬИ: профессиональная статья
ЯЗЫК СТАТЬИ: английский

Резюме:

Информация, как один из важных факторов войны, оказывает большое влияние на форму, направление и скорость развития современных конфликтов. Она подразумевает владение знаниями и данными, необходимыми для успешного командования и управления на всех уровнях. Владение информацией снижает степень неизвестности в военном деле и способствует лучшей оценке ситуации, а также принятию соответствующих решений в реальном времени. В данной статье с разных аспектов представлена телекоммуникационная система (ТкИС) Вооруженных сил Республики Сербия и открывается вопрос о необходимости совершенствования существующей системы, что в свою очередь требует постоянное развитие информационных технологий. В работе описаны понятие, назначение, применение, структура и достигнутый уровень развития ТкИС. С особым вниманием были проанализированы уровень развития ТкИС ВС РС и причинно-следственные связи с обороной Республики Сербия, с

упором на военную оборону. Цель данной работы заключается в представлении того, каким образом информационная и телекоммуникационная системы Вооруженных сил Республики Сербия могут влиять на оборону Республики Сербия, особенно на военную оборону, нам также хотелось обратить внимание на необходимость постоянного совершенствования и развития ТкИС, то есть, в организации соответствующей и своевременной подготовки персонала для нужд военной обороны. Значимость данной работы заключается в проведенном анализе состояния телекоммуникационной и информационной систем Вооруженных сил Республики Сербия и представлении реальных нужд военной обороны Республики Сербия в контексте современных вызовов безопасности.

Ключевые слова: информация, телекоммуникации, Вооруженные силы Республики Сербия, военная оборона, спутниковые сети, проводные сети, интернет.

УТИЦАЈ ДОСТИГНУТОГ СТЕПЕНА РАЗВОЈА ТЕЛЕКОМУНИКАЦИОНО-ИНФОРМАЦИОНОГ СИСТЕМА ВОЈСКЕ СРБИЈЕ НА ОДБРАНУ РЕПУБЛИКЕ СРБИЈЕ

Хатиџа А. Бериша, *Олга* М. Зорић
Универзитет одбране у Београду, Школа националне одбране,
Београд, Република Србија

ОБЛАСТ: телекомуникације
ВРСТА ЧЛАНКА: стручни чланак
ЈЕЗИК ЧЛАНКА: енглески

Сажетак:

Информација, као један од значајних фактора оружане борбе, у великој мери утиче на физиономију, правац и брзину развоја савремених сукоба. Она изражава расположивост знањима и подацима потребним за успешно командовање и руковођење на свим нивоима. Њеном расположивошћу смањује се неизвесност у војној делатности и омогућава се боља процена ситуације, као и доношење сврсисходних одлука у реалном времену. У раду се са више аспеката сагледава телекомуникационо-информациони систем (ТкИС) Војске Србије и актуелизује питање потребе унапређења постојећег система које намеће непрестани развој информационих технологија. У раду се наводе појам, намена, структура и достигнути степен развоја ТкИС. Детаљно су анализирани степен развоја ТкИС ВС и узрочно-последичне везе са одбраном Републике Србије, са тежиштем на војној одбрани. Циљ рада јесте да се сагледа утицај телекомуникационо-информационог система Војске Србије на одбрану Републике

Србије са тежиштем на војној одбрани, као и да се укаже на потребу непрестаног усавршавања ТкИС и континуиране едукације, односно адекватне и правовремене обуке кадра за њихово коришћење у војноодбрамбене сврхе. Значај рада огледа се у анализи стања телекомуникационо-информационог система Војске Србије у односу на потребе војне одбране Републике Србије у контексту савремених безбедносних изазова.

Кључне речи: информација, телекомуникације, Војска Србије, војна одбрана, сателитске мреже, фиксне мреже, интернет.

Paper received on / Дата получения работы / Датум пријема чланка: 24.10.2018.
Manuscript corrections submitted on / Дата получения исправленной версии работы / Датум достављања исправки рукописа: 05.12.2018.
Paper accepted for publishing on / Дата окончательного согласования работы / Датум коначног прихватања чланка за објављивање: 07.12.2018.

PHYSICAL PROPERTIES OF NANOMATERIALS

Nada M. Čitaković
University of Defence in Belgrade, Military Academy,
Department of natural-mathematical sciences,
Belgrade, Republic of Serbia,
e-mail: nadac@list.ru,
ORCID iD: http://orcid.org/0000-0003-2813-2323

DOI: 10.5937/vojtehg67-18251; https://doi.org/10.5937/vojtehg67-18251

FIELD: Physics of Materials (Physics of Condensed Matter)
ARTICLE TYPE: Professional Paper
ARTICLE LANGUAGE: English

Summary:

Nanotechnology deals with the creation of materials, devices and systems through manipulation of matter at the nanometer length scale. The created object itself does not have to be a nanoscale size object, it might be a micro or macro size object. Significant changes have been observed in physical, chemical, mechanical, electrical, optical, magnetic, and other properties when going down from bulk to nanoscale materials.

Key words: nanotechnology, nanomaterials, nanoparticles, *properties of nanomaterials.*

Introduction

Although the interest in nanotechnology has reached its peak only recently, the concept of nanotechnology itself has been known for more than 50 years. In the article titled “There's Plenty of Room at the Bottom˝(1959), physicist Richard Feynman concluded that according to the existing physics laws, there is no reason why materials could not be “created/manufactured” by manipulating single atoms. Besides Richard Feynman, we need to mention Professor Nori Taniguschi, who first introduced the word “nanotechnology” (1974), as well as the recipients of the Nobel Prize Harold W. Kroto, Richard E. Smalley, and Robert E. Curl, who discovered the fullerene = a .ball-like form of carbon that showed a lot of potential as a building material in manufacturing miniature size objects. An unexpectedly discovered form of carbon, named Buckyballs or Fullerenes after eccentric architect Buckminister Fuller, was declared the molecule of the year by the “Science” magazine in 1991. (Hawkins et al, 1991, pp.312-313)

Progress in the field of nanotechnology was prompted by the development of advanced electron-scanning tunneling microscopes used for observing nano objects. The variety of nanomaterials is vast, just as is the range of their properties and possible applications. We can say that, with nanotechnology, the boundaries between different scientific disciplines are disappearing. Therefore, we can label it as converging technology and we need an interdisciplinary approach to it. Because of its far-reaching and various fields of applications, it is believed that nanotechnology has an enormous potential.

Nanomaterials and Nanoparticles

Nanometer, nanoparticle, ultaramicrosize, nanophase materials are all different terms used for materials with their grain size of the order of a few nanometers (El-Shall & Edelstein, 1996, pp.29-70).

The prefix “nano” comes from a Greek word that means something extremely small. For example, one nanometer equals to 3-5 atoms lined up in a straight line, the diameter of a human hair is about five times that of a nanoparticle, a red blood cell has a diameter ~7000 nm, while a virus has a diameter of 100 nm. Quantum physics/chemistry study atoms and molecules, as well as objects smaller than 1 nm. Physics of condensed matter explores/studies bonded atoms and molecules, i.e. objects ranging from 100 nm to infinity. Empty space is between 1-100 nm i.e. from 10 to 106 atoms per particle. Nanoparticle materials in modern physics of condensed matter are considered to be materials that consist of grains smaller than 100 nm. In the above mentioned region, neither the laws of quantum mechanics nor the laws of classical (Newtonian) physics apply. Because of the limited dimensions, there are changes in the crystalline and zone structure, the number of defects, and the size of the active area. The significance of these changes depends on the particle size. It turns out that all the changes in the characteristics have become very interesting for different applications (nanomania). Their chemical and physical characteristics are important; however, their synthesis is the most important one at this time. Some of the very complex questions/requirements in front of the synthesis are: very narrow particles size distribution without agglomeration, control of defects, specific shape and composition, etc. The classification could be based on: dimensions, phase compositions or synthesis methods (Nass et al, 2004, pp.5-10).

Based on the dimensions:

If 3D is smaller than 100 nm, there are nanoparticles, quantum dots, hollow spheres, etc.

If 2D is smaller than 100 nm, there are nanotubes, nano-fibers, nano-wires, nano-platelets, etc.

If 1D is smaller than 100 nm, there are films, coatings, multilayers, etc.

Based on the phase compositions:

One-phased solid objects are: crystallites, amorphous particles and layers, etc.

Multi-phased solid bodies (objects) are: nanocomposites, coated particles, etc.

Multi-phased systems are: colloids, aerogels, ferrofluids, etc.

Based on synthesis methods:

Reactions from a gas phase are: physical and chemical methods of deposition from a vapor phase, condensation in the atmosphere of inert gases, chemical vapor deposition, etc.

Reactions from a liquid phase are: sol-gel, method of sedimentation, hydrothermal method, etc.

Mechanical methods can be the grinding method, the method of plastic deformation, etc.

From a scientific point of view and for practical application purposes, it is of great importance that the physical characteristics of nanomaterials differ significantly from polycrystalline (bulk) materials of the same chemical composition (Table 1). In some cases, for particular physical parameters, these differences could be a few orders of magnitude. A very important characteristic of nanomaterials is that the values of physical parameters are very sensitive to the size and morphology of nanoparticles (Tadić et al, 2009, pp.839-843), (Tadić et al, 2011, pp.7639-7644), (Tadić et al, 2012, pp.28-33). Some of the examples representing significant difference in the values of some physical parameters are: the melting point, change in the unit-cell parameters, change in the magnetic and optical characteristics, conductivity of the material, etc. The surface to volume ratio is an important parameter that has an impact on new characteristics in comparison to those of bulk materials. The number of atoms on the surface (with regard to the total number of atoms) increases as the particle size gets smaller. As particles get smaller, the surface to volume ratio increases and the influence of the shell on the magnetic properties becomes more significant. For example, 3 nm size iron particles have 50% while 30 nm size iron particles have only 5% atoms on their surface that have a significant impact on their physical characteristics (Sorensen, 2001, pp.37-69).

Table 1 – Some of the common properties of nanomaterials that are significantly different from the properties of the bulk materials with the same chemical composition (Nass et al, 2004, pp.5-10).
Таблица 1 – Некоторые из общих свойств наноматериалов, которые значительно отличаются от свойств сыпучих материалов с одинаковым химическим составом (Nass et al, 2004, pp.5-10).
Табела 1 – Неке од карактеристичних особина наноматеријала које се значајно разликују од особина булк материјала истог хемијског састава

Properties	Examples
Catalytic	Increase in surface activity of particles
Electrical	Increase in electrical conductivity of ceramic materials and magnetic nanocomposites Increase in electrical resistance in metals
Magnetic	Change of the point of magnetic phase transition Increase of coercivity Appearance of super-magnetism
Mechanical	Improvement in firmness and hardness of metals and alloys Appearance of super-elasticity
Optical	Shift in optical absorption and change in fluorescent properties Increase in quantum efficiency of semiconducting crystals

Increase of the surface to volume ratio of particles causes lower melting temperatures, lower magnetization, changes in catalytic activity, etc. A large number of atoms on the surface significantly increase “surface activity” that is very favorable for chemical reactions. However, due to increased activity, nanoparticles have tendency to form aggregates and agglomerates that could cause loss of preferred characteristics. Therefore, it is necessary to stabilize particles with some additional treatment. For example, it is possible to put particles in an adequate matrix or to coat them with a different material even though their characteristics change with this kind of surface modification. The coordination number of atoms on the surface is lower than the one for the atoms inside the particle, which would cause an increase in the surface energy. Therefore, the diffusion of atoms can take place at lower temperatures. For instance, the melting point of gold is 1063 ºC, while nanoparticles of gold with particle diameters under 5 nm have the melting

point of ≈ 300 ºC (Buffat & Borel, 1976, pp.2287-2298). Decreasing the particle size has a significant influence on firmness and hardness of materials (Weertman, Averback,1996, pp.331-353).

Measurements of firmness of copper for crystallite of different sizes have shown that firmness increases as the crystallite size decreases. Firmness of the copper samples with 50 nm size crystallites is 2 times higher, while in the copper samples with 10 nm size crystallites it is 6 times higher than for the bulk. The elasticity limit of copper increases 2 times when crystallites decrease in size form 100 μm to 10 μm (Adams et al, 1989, pp.9479-9484).

One of the characteristics specific for nanomaterials is superplasticity. As opposed to bulk materials, nanomaterials have the ability to withstand the tension beyond the point of fracture. Superplasticity is explained by diffusion of atoms, i.e. moving of dislocations and sliding of the boundaries between particles.

Magnetic properties of nanoparticles

The magnetic properties of nanoparticles can be controlled with a more precise control of size and shape of nanoparticles. Namely, below a certain size, nanoparticles become mono-domain particles because that is energetically preferable and they show super-magnetic behavior that takes place above certain temperatures, so-called blocking temperatures (TB) (Chikazumi, 1999, pp.453-457).

Above blocking temperatures, magnetic moments of particles fluctuate in all directions with the help of thermal activation, similarly to paramagnetic materials, while below this temperature, magnetic moments of particles are locked in the direction of the axis of easy magnetization (Kulal et al, 2011, pp.2567-2571).

The difference from common paramagnetism is that all magnetic moments within a particle rotate coherently creating a super moment that could be of the order of a few thousand Bohr magnetos. The external field tends to align this super magnetic moment in its direction; however, thermal energy disrupts that alignment in the same way as it happens with paramagnetic materials, and that is the reason why this phenomenon was named super-magnetism.

Since the surface effect plays a significant role in investigating the magnetic properties of nanoparticle materials, the “core-shell” model has been used for their description. According to that model, a particle consists of a magnetically aligned nucleus and a non-aligned shell (Fig.1). When temperature decreases, the shell gets aligned.

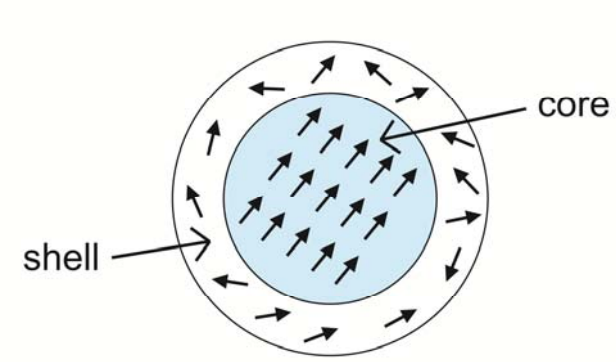


Figure1 – Schematic of the core-shell structure, I.e, the spin alignment of a spherical nanoparticle
Рис.1 – Схема структуры ядра оболочки, т. е. выравнивание спинов сферической наночастицы
Слика 1 – Шематски приказ core-shell структуре, тј. спинско уређење једне сферне наночестице

The particle nucleus keeps the same physical properties of the bulk material, while the shell is responsible for the appearance of new properties. Namely, in the outer shell, magnetic interactions are modified due to the surface effects such as: defects, vacancies, tension, and broken chemical bonds. In addition, these effects are responsible for a decrease in the temperature of a phase change, magnetic saturation and an increase of coercivity in comparison to bulk materials.

The magnetic alignment of a nanoparticle shell is achieved by lowering its temperature (Fig.2).

For super-magnetic systems, the following specific characteristics are noticed: magnetic properties depend on the previous treatment of ZFC (zero - field cooled) and FC (field - cooled) measurements, the existence of a hysteresis loop below the block-temperature (TB) and its appearance above the TB, the appearance of a maximum during ZFC measurements (blocking temperature), and the existence of overlapping magnetization curves at various temperatures above the blocking temperature when magnetization M is shown as a function of H/T (H - magnetic filed strength, T - temperature) (Sorensen, 2001, pp.37-69), (Tadić & Čitaković, 2014, pp.47-64), (Tadić & Čitaković, 2011, pp.91-105).

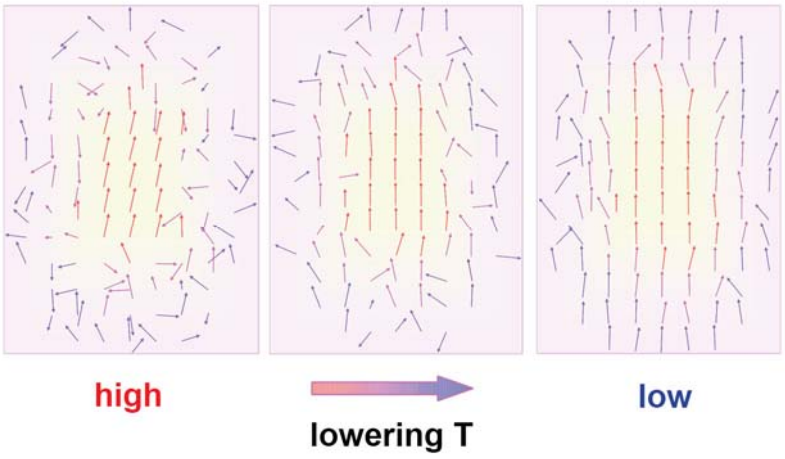


Figure 2 – Schematic of the magnetic alignment of a shell by lowering its temperature
Рис. 2 – Схема магнитного выравнивания оболочки при снижении ее температуры
Слика 2 – Шематски приказ магнетног уређивања shell-а снижавањем температуре

In Figure 3, the strength of a coercive filed is shown as a function of particle size (Pelecky et al, 1996, pp.1770-1783). Above a certain critical particle size characteristic of the material DS (Table 2), a material is composed of many domains (multi-domain structure), while below the critical particle size, a material DS becomes mono-domain.

The figure shows that the coercivity increases as the particle size decreases up to a critical size for a mono-domain particle of a given DS material, beyond which it starts decreasing and, after a certain DSP value, the material becomes super-magnetic, I.e. the coercive field strength goes down to zero. In Figure 3, it could be noticed that, for very high values of the particle diameter D>> DS, the value of the coercive filed strength approaches a constant value, which is a characteristic of the material in its bulk form.

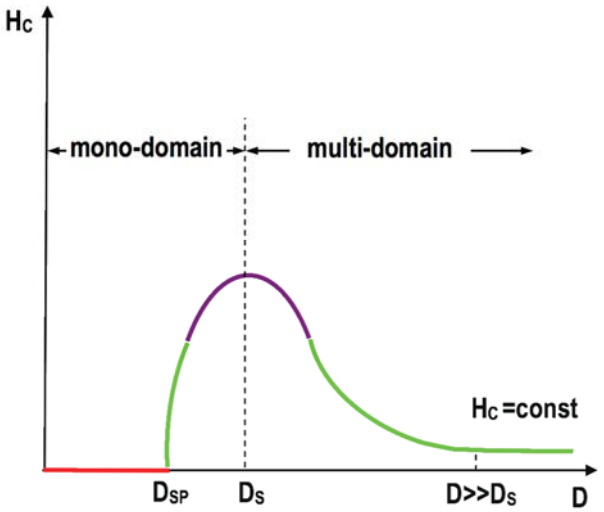


Figure 3 – Coercive field strength as a function of a nanoparticle diameter at a constant temperature. DSP - diameter below which a material shows super-paramagnetic behavior; DS - critical diameter
Рис. 3 – Схема зависимости силы коэрцитивного поля от диаметра наночастиц, при постоянной температуре. DSP - диаметр, ниже которого материал демонстрирует суперпарамагнитное поведение; DS - критический диаметр
Слика 3 – Шематски приказ зависности јачине коерцитивног поља од пречника наночестица при константној температури. DSP – пречник испод којег материјал показује суперпарамагнетно понашање, DS – критични пречник

The critical diameter size for spherical nanoparticles depends on the material type (Table 2 shows the critical diameter values for some materials) (Sorensen, 2001, pp.37-69).

Below the critical diameter-DS, the coercive field strength decreases, according to the following functional relationship:

$$H_C = g - \frac{h}{D^{\frac{3}{2}}}$$

where g and h are constants (Kumar et al, 1994, pp.354-358).

Table 2 – Diameters of the spherical particles of some substances below which they are mono-domain
Таблица 2 – Диаметры сферических частиц некоторых веществ снизу, которые являются монодоменными
Табела 2 – Величине пречника сферних честица неких супстанци испод којих су оне монодоменске

Substance	**D_S (nm)**
Fe	14
α-Fe_2O_3	41
Ni	55
Co	70
Fe_3O_4	128
γ-Fe_2O_3	166

Except the particle size and microstructure, the shape i.e. the elongation of the particle (ratio of the longest dimension and the shortest dimension) also affects the coercive field strength.

(Baibich et al,1986, pp.2472-2475), (Buffat et al, 1976, pp.2287-2298), (Chikazumi, 1999, pp.453-457), (Tadić et al, 2011, pp.7639-7644), (Kulal et al, 2011, pp.2567-2571), (Pelecky et al,1996, pp.1770-1783), (Kumar et al, 1994, pp.354-358), (Zboril et al, 2002, pp.969-982), (Wang, 2000, pp.1-11), (Krill & Birringer, 1998, pp.621-640), (Audebrand et al, 1996, pp.83-87), (Huang et al, 2001, pp.1497-1505), (Gupta et al, 2011, pp.1095-1098).

For example, in the case of the Fe nanoparticle, the increased elongation of ~5 times (from 1 to 5) increases the coercive field strength for ~10 times (Krill et al, 1998, pp.621-640). In general, the coercive field strength increases as elongation increases, i.e. with the increase of the anisotropic shape (Krill & Birringer, 1998, pp.621-640).

The field of magnetic nanoparticle materials still has not been studied enough. One of the reasons is that synthesized nanoparticles have different shapes and sizes so their effects on magnetic properties could not be clearly observed. The basic aim in the process of the

synthesis of nanoparticles is the creation of a desired shape and a size of particles (narrow particles size distribution). Some of the methods used for the synthesis of magnetic nanoparticle materials are: sol-gel, mechanical-chemical, glycerin-nitrate, micro-emulsion, and spray pyrolysis.

Conclusion

Nanotechnology is a growing field of research. During the last decade, interest for nanoparticle materials has been connected to their new and specific physical characteristics and possibilities for their application in all aspects of the human life. It has been noticed that there is a change in the physical characteristics (magnetic, mechanical, and optical properties, as well as in melting temperature, material conductivity, etc.) of nano-particle materials in comparison to bulk materials. In some cases, for some physical parameters, differences are up to a few orders of magnitude and can vary significantly. Nanoparticle materials are objects of intense research, because they represent a significant potential for the development of new materials that can be used/applied in various areas of science and technology. It is expected that nanoparticle materials will soon have a leading role in technology, medicine, etc. and that the production of nanoparticle based materials will be increasing in the near future.

References

Adams, J.B., Wolfer, W.G., & Foiles, S.M. 1989. Elastic properties of grain boundaries in copper and their relationship to bulk elastic constants. *Physical Review B,* 40(14), pp.9479-9484. Available at: https://doi.org/10.1103/physrevb.40.9479.

Audebrand, N., Guillou, N., Auffrédic, J.P., & Louër, D. 1996. The thermal behaviour of ceric ammonium nitrate studied by temperature-dependent X-ray powder diffraction. *Thermochimica Acta,* 286(1), pp.83-87. Available at: https://doi.org/10.1016/0040-6031(96)02944-9.

Baibich, M.N., Broto, J.M., Fert, A., Van, D.F.N., Petroff, F., Etienne, P., . . . Chazelas, J. 1988. Giant Magnetoresistance of (001)Fe/(001)Cr Magnetic Superlattices. *Physical Review Letters,* 61(21), pp.2472-2475. Available at: https://doi.org/10.1103/physrevlett.61.2472.

Buffat, P., & Borel, J.P. 1976. Size effect on the melting temperature of gold particles. *Physical Review A,* 13(6), pp.2287-2298. Available at: https://doi.org/10.1103/physreva.13.2287.

Chikazumi, S. 1999. *Physics of Ferromagnetism*.New York: Oxford University Press.

El-Shall, M.S., & Edelstein, A.S. 1996. Formation of clusters and nanoparticles from a supersaturated vapor and selected properties. In A.S. Edelstein& R.C. Cammarata Eds., *Nanomaterials: Synthesis, Properties and Applications*.Informa UK Limited.

Gupta, R.K., Ghosh, K., Dong, L., & Kahol, P.K. 2011. Structural and magnetic properties of nanostructured iron oxide. *Physica E: Low-dimensional Systems and Nanostructures,* 43(5), pp.1095-1098. Available at: https://doi.org/10.1016/j.physe.2011.01.008.

Huang, J.Y., Zhu, Y.T., Jiang, H., & Lowe, T.C. 2001. Microstructures and dislocation configurations in nanostructured Cu processed by repetitive corrugation and straightening. *Acta Materialia,* 49(9), pp.1497-1505. Available at: https://doi.org/10.1016/s1359-6454(01)00069-6.

Krill, C.E., & Birringer, R. 1998. Estimating grain-size distributions in nanocrystalline materials from X-ray diffraction profile analysis. *Philosophical Magazine A,* 77(3), pp.621-640. Available at: https://doi.org/10.1080/014186198254281.

Kulal, P.M., Dubal, D.P., Lokhande, C.D., & Fulari, V.J. 2011. Chemical synthesis of Fe2O3 thin films for supercapacitor application. *Journal of Alloys and Compounds,* 509(5), pp.2567-2571. Available at: https://doi.org/10.1016/j.jallcom.2010.11.091.

Kumar, P., Borse, P., Rohatgi, V.K., Bhoraskar, S.V., Singh, P., & Sastry, M. 1994. Synthesis and structural characterization of nanocrystalline aluminium oxide. *Materials Chemistry and Physics,* 36(3-4), pp.354-358. Available at: https://doi.org/10.1016/0254-0584(94)90054-x.

Sorensen, C.M. 2001. *Nanoscale Materials in Chemistry*.New York: Wiley-Interscience.

Tadić, M., Kusigerski, V., Marković, D., Čitaković, N., Remškar, M., & Spasojević, V. 2009. Morphological, structural and magnetic properties of α-Fe2O3 nanoparticles in an amorphous alumina matrix obtained by aqueous combustion method. *Journal of Alloys and Compounds,* 486(1-2), pp.839-843. Available at: https://doi.org/10.1016/j.jallcom.2009.07.077.

Tadić, M., Čitaković, N., Panjan, M., Stojanović, Z., Marković, D., & Spasojević, V. 2011. Synthesis, morphology, microstructure and magnetic properties of hematite submicron particles. *Journal of Alloys and Compounds,* 509(28), pp.7639-7644. Available at: https://doi.org/10.1016/j.jallcom.2011.04.117.

Tadić, M., Kusigerski, V., Marković, D., Panjan, M., Milošević, I., Spasojević, V. 2012. Highly crystalline superparamagnetic iron oxide nanoparticles (SPION) in a silica matrix. *J. Alloys. Compd,* 525, pp.28-33. Available at: https://doi.org/10.1016/j.jallcom.2012.02.056.

Tadić, M., & Čitaković, N. 2014. Synthesis, diffraction experiments, transmission electron microscopy and magnetic properties of α-Fe2O3/SiO2 nanocomposite sample. *Vojnotehnički glasnik/Military Technical Courier,* 62(1), pp.47-64. Available at: https://doi.org/10.5937/vojtehg62-4383.

Tadić, M., & Čitakovic, N. 2011. Mechanochemical synthesis and magnetic properties of maghemite. *Vojnotehnički glasnik/Military Technical Courier,* 59(3), pp.91-105. Available at: https://doi.org/10.5937/vojtehg1103091t.

Wang, Z.L., & ed, 2000. *Characterization of Nanophase materials*.Fedaral Republic of Germany: Whiley.

Zboril, R., Mashlan, M., & Petridis, D. 2002. Iron(III) Oxides from Thermal ProcessesSynthesis, Structural and Magnetic Properties, Mössbauer Spectroscopy Characterization, and Applications. *Chemistry of Materials,* 14(3), pp.969-982. Available at: https://doi.org/10.1021/cm0111074.

ФИЗИЧКИЕ СВОЙСТВА НАНОМАТЕРИАЛОВ

Нада М. Читакович
Университет обороны в г. Белград, Военная академия,
Кафедра естественно-математических наук,
г. Белград, Республика Сербия

ОБЛАСТЬ: физика материалов (физика конденсированного состояния)
ВИД СТАТЬИ: профессиональная статья
ЯЗЫК СТАТЬИ: английский

Резюме:

Нанотехнология занимается созданием материалов, устройств и систем путем контролируемого манипулирования веществом на атомном уровне в масштабе нанометров. При этом не обязательно чтобы созданный объект был наноразмерным, он может быть микро или макро размера. Существенные изменения наблюдаются в физических, химических, механических, электрических, оптических, магнитных и других свойствах при переходе от объемных материалов к наноразмерным материалам.

Ключевые слова: нанотехнология, наноматериалы, наночастицы, свойства наноматериалов.

ФИЗИЧКЕ ОСОБИНЕ НАНОМАТЕРИЈАЛА

Нада М. Читаковић
Универзитет одбране у Београду, Војна академија,
Катедра природно-математичких наука, Београд, Република Србија

ОБЛАСТ: физика материјала (физика кондензоване материје)
ВРСТА ЧЛАНКА: стручни чланак
ЈЕЗИК ЧЛАНКА: енглески

Сажетак:

Нанотехнологија бави се стварањем материјала, уређаја и система директном манипулацијом супстанце на нанометарском (атомском) нивоу. Сам креирани објекат не мора да буде нановеличине, већ микро или макровеличине. Постоје значајне промене физичких, хемијских, механичких, електричних, оптичких, магнетних и других карактеристика при прелазу од материјала до наноматеријала.

Кључне речи: нанотехнологија, наноматеријали, наночестице, особине наноматеријала.

Paper received on / Дата получения работы / Датум пријема чланка: 17.07.2018.
Manuscript corrections submitted on / Дата получения исправленной версии работы / Датум достављања исправки рукописа: 26.11.2018.
Paper accepted for publishing on / Дата окончательного согласования работы / Датум коначног прихватања чланка за објављивање: 28.11.2018.

VOJNOTEHNIČKI GLASNIK / MILITARY TECHNICAL COURIER, 2019, Vol. 67, Issue 1

Руски MiG 31: Моћни пресретач који развија брзину од 3 маха[1]

MiG 31

Током последње деценије хладног рата, MiG-31, НАТО ознаке – *Foxhound,* уживао је статус мистичног авиона на Западу. Појављивале су се зрнасте фотографије слабе резолуције и текстови који су више личили на извештаје о НЛО него на озбиљне војне коментаре. Али ни данас, нема прецизнијих анализа овог авиона, које иначе постоје за разне верзије авиона MiG-29 и Su-27.

MiG-31 представља модел старог дизајна који је предвиђао пресретаче који су били намењени за брзо прелажење великих раздаљина и напад на противничке бомбардерске и ракетне снаге. Док је остатак света углавном производио вишенаменске авионе који би били оспособљени за обарање противничких авиона или за нападе типа ваздух-земља, руска војна доктрина и даље заговара потребу за тешким, изузетно брзим пресретачем који би чувао огромна руска пространства.

[1] The National Interest, 2 August 2018

MiG-31 је пројектован као пресретач за заштиту домаћег ваздушног простора и никада није употребљен у борби нити се извозио. Русија и даље одржава велики број ових ловаца као део свог слојевитог система ваздушне одбране, што ће се наставити и у будућности.

Foxhound је настао као покушај унапређења свог, донекле неуспешног, претходника ловца пресретача MiG-25 *Foxbat.* Двомоторни пресретач *Foxbat* је још увек најбржи оперативни ловац на свету, једини који може достићи брзине преко 3 маха на висинама од преко 21.000 метара. Наиме, MiG-25 био је предвиђен за борбу против америчког суперсоничног бомбардера XB-70 *Valkyrie*, који никада није ни ушао у серијску производњу. *Foxbat* је уживао малтене мистичну репутацију на Западу, све док совјетски пилот *Victor Belenko* није пребегао у Јапан 1976. године и омогућио Пентагону да детаљно прегледа авион. Испоставило се да су електронски уређаји на пресретачу били углавном лампашки (што није лоше за дејства након нуклеарне детонације и електромагнетног импулса) што умногоме утиче на брзину обраде информација. Такође, утврђено је да мотори ловца MiG-25 могу достићи, па чак и мало престићи брзину од 3 маха, али по цену уништавања мотора, што се и десило неколицини либијских и ирачких пилота који су на тај начин ипак успели да измакну својим прогонитељима. Авион је могао да одржава суперсоничну брзину само на већим висинама.

Након пребега совјетског пилота и обелодањивања података о авиону почео је и његов извоз, а СССР је започео пројектовање новог пресретача велике брзине, који је имао још један задатак: да пресреће крстареће ракете на малим висинама које би летеле испод радарског видокруга. Нови дизајн предвидео је двосед, с тим да је на задњем седишту седео оператер оружаног система који је управљао новим веома моћним радарским системом, унапређеним ракетама ваздух-ваздух великог домета и новим моторима.

Овакав унапређен *Foxbat* добио је и нови назив – MiG-31. Нови *Foxbat* је, осим места за додатног члана посаде, добио потпуно нови радарски систем Zaslon S-800 са пасивним електронским скенирањем. Нови радар имао је домет до скоро 180 километара и био је опремљен системом „look down, shoot down" који је омогућавао откривање и напад на ниско- летеће циљеве. Осим радара, ловац је био опремљен и инфрацрвеним системом за претрагу и праћење (IRST), што је употпуњавало радарски систем.

Основицу наоружања представљала је нова ракета ваздух-ваздух R-33 великог домета, НАТО кодног назива AA-9 Amos. За ову ракету сматрало се да представља пандан америчкој ракети ваздух-ваздух великог домета AIM-54 *Phoenix* коју је лансирао амерички морнарички ловац F-14. Ове велике ракете са радарским системом вођења биле су монтиране на доњем делу трупа пресретача MiG-31 и биле су намењене за напад на бомбардере на даљинама до 120 километара. Радар ловца омогућавао је лансирање и навођење истовремено на четири авиона. Поред четири ракете великог домета R-33 овај тешки пресретач могао је да

носи на подвесним тачкама испод крила још четири до шест додатних ракета ваздух-ваздух кратког или средњег домета. Поред тога, за разлику од претходника MiG-25, MiG-31 је био наоружан и топом од 23 мм.

MiG-31 је задржао перформансе ловца пресретача MiG-25 у погледу висине лета, али му је максимална брзина ипак била нешто нижа, свега 2,83 маха у односу на 3 маха, што је опет било брже од било ког оперативног западног ловца. Што је још важније, MiG-31 може летети брзином до 1,23 маха на малим висинама – што MiG-25 не може. То га чини много ефикаснијим за лов на крстареће ракете и ловце бомбардере. Упркос томе, MiG-31 нема високу маневарабилност. На пример, не би могао да измане врише америчког ловца F-15 – али његова улога и није таква, јер је намењен само за приближавање непријатељевим летелицама великом брзином, испаљивање ракета и враћање назад.

Ривал Blackbird

Производња ловца пресретача MiG-31 започета је 1979. године, а ушао је у оперативну употребу две године касније. Ловац пресретач MiG-31 употребљен је за лов на амерички шпијунски авион SR-71 *Blackbird* који је на својим извиђачким мисијама могао летети брзинама до 3,3 маха. Поводом тога појавила се прича једног совјетског пилота који је рекао да је на својој мисији лова на амерички SR-71 *Blackbird* успео да „закључа" систем вођења ракете ваздух-ваздух на америчку летелицу. Следећи извештаји указивали су на то да је група од шест пресретача MiG-31 успела да опколи амерички авион у одвојеном инциденту. Међутим, мисије лета америчког авиона *Blackbird*, по наводима Американаца, нису се одвијале над територијом Совјетског Савеза већ дуж њених граница, што објашњава да, иако је могуће да су совјетски пилоти били у могућности да лансирају своје ракете R-33, до тога није дошло, јер је шпијунска летелица била ван граница СССР-а.

Совјетски Савез је током времена унапређивао флоту својих ловаца *Foxhound* производњом авиона за снабдевање горивом у лету типа MiG-31DZ. Касније долази и до увођења новог радарског система и разних хардверских побољшања, након што је совјетски аеронаутички инжињер Adolf Tolkachev открио тајне радарског система авиона америчкој обавештајној служби. Шездесет девет пресретача типа MiG-31B и MiG-31BS добили су нове радарске системе, док су два пресретача, под ознаком MiG-31D, предвиђени за уништавање противничких сателита.

Развијена је и варијанта MiG-31E за извоз, али до тога није дошло, јер је *Foxhound* био превише специјализован и скуп да би привукао стране купце. Једина земља, осим Русије, која располаже ловцима типа MiG-31 је Казахстан који је након распада СССР-а наследио тридесет до педесет ових летелица.

Године 2015. појавиле су се информације да је Сирија купила MiG-31 од Русије, али се испоставило да то није тачно. У сваком случају, Сирија не би имала велике користи од пресретача великих брзина у грађанском рату

који је уследио. У том рату су иначе коришћени пресретачи типа MiG-25 који су се врло лоше показали јер су покушавали да гађају копнене циљеве ракетама ваздух-ваздух.

Будућност пресретача Foxhound

Према расположивим подацима, руско ратно ваздухопловство има 252 ловца MiG-31. Русија је од 2010. године започела модернизацију своје флоте ловаца MiG-31 на стандард MiG-31BM и MiG-31 BSM и планира да модернизује 100 ловаца до 2020. године. Модернизација BM укључује нови систем дисплеја у кокпиту, систем управљања HOTAS и нови радар *Zaslon-M* са максималним дометом откривања циљева до 300 километара. Модернизована летелица употребљава нову генерацију ракета ваздух-ваздух дугог домета, као што су R-33S, R-77 – руски еквивалент америчкој ракети AIM-120 – и ракету врло великог домета R-37, намењену за напад на противничке летеће цистерне и летелице типа AWAC. Осим напада на ваздушне циљеве, нађен је нови начин употребе ових летелица, а то је напад хиперсоничним ракетама ваздух-море „Kinjhal", а процењује се да је 10 до 12 летелица MiG-31K предвиђено за ту сврху.

Процењује се да Русија данас поседује преко 200 оперативних летелица MiG-31, и то око 120 модернизованих MiG-31BM, око 60 MiG-31B, BS и DZ, као и 10 до 12 MiG-31K који су наоружани хиперсоничним ракетама ваздух-земља (море) „Kinjhal". MiG-31 је тренутно најбржи борбени авион на свету и јединствен је због својих одличних висинско-брзинских карактеристика, као и по томе што може дуго летети великом надзвучном брзином са спољним наоружањем које се састоји од различитих комбинација ракета ваздух-ваздух.

Очекује се да и поред тога што је стар 35 година, MiG-31 настави да служи ваздушним снагама Русије до 2030. године. Русије тврди да развија нови тип пресретача за брзине од 4 маха, а наводно се ради о новим пројектима као што су MiG-41 или PAK-DP који би заменили MiG-31 у улози противваздухопловне одбране. То је необично, јер је Русија до сада финансирала производњу само 10 прототипова „невидљивих" ловаца PAK-FA, па се поставља питање да ли је могуће финансирање додатних специјализованих платформи.

MiG-31 је симбол изузетно брзих пресретача који прелазе огромне раздаљине ради уништавања надолазећих бомбардера и ракета. Остатак света је, углавном, прешао на вишенаменске летелице које се могу употребљавати за борбу у режиму ваздух-ваздух, ваздух-земља или ваздух-море. Питање је да ли ће Русија, с обзиром на финансијску ситуацију, и даље моћи да пројектује и набавља уско-специјализоване скупе платформе, као што је, помиње се, наследник ловца MiG-31 – MiG-41, или ће се оријентисати на, можда мање способне, али јефтиније вишенаменске ловце бомбардере.

Драган М. Вучковић (*Dragan* M. Vučković),
e-mail: draganvuckovic@kbcnet.rs,
ORCID iD: http://orcid.org/0000-0003-1620-5601

Актуелно стање немачке морнарице[2]

Тренутно стање немачке морнарице је права срамота за најбогатију земљу Европске уније. Она хитно мора да тражи повећање буџета, јер је иначе ускоро неће ни бити.

Немачка морнарица је до недавно активно учествовала са савезницима у противпиратским операцијама, као што је операција ATALANTA у источном делу Африке, у спасавању избеглица из Средоземног мора, као и у спречавању шверца оружја на обалама Либана. Слике немачких бродова који су учествовали у спасавању очајних избеглица улепшали су слику немачких оружаних снага на начин на који ниједан *Eurofighter* или *Leopard 2* то није могао.

Независно од мишљења јавности, мисија немачке морнарице је испуњавање обавеза према НАТО-у. Нажалост, због лошег планирања и неадекватних одлука, али и због недостатка средстава финансирања, морнарица није у стању да испуни своје обавезе према овом савезу. Уколико се ситуација одмах не промени, способности немачке морнарице ће се додатно срозати. Иако је увек лакше окривити „буџетска кресања", проблеми морнарице су ипак ван домашаја финансија.

Подморница класе Type 212

Немачка морнарица има огромне проблеме са својим основним јединицама: подморницама, површинским бродовима и оним што је преостало од поморске авијације. Она поседује шест подморница типа *Type* 212, од којих ниједна није оперативна. Док немачка индустрија без

[2] The National interest, 23 August 2018

икаквих проблема наставља са продајом сличних подморница свуда по свету, које НАТО партнери употребљавају у многим, па и врло осетљивим мисијама прикупљања обавештајних информација, немачка морнарица, и поред своје дуге традиције развоја и употребе подморница, данас не може да употреби ниједну, а како стоје ствари неће моћи још дуго времена.

На једној од својих првих мисија, нова подморница U-36 налазила се близу Норвешке када је оштетила своје задње управљачке површине „ударцем у стену током рођења", па је морала да буде отпраћена назад до Немачке бродом који је пратио тестно рођење. Иако се овакве несреће дешавају, то је додатно урушило имиџ немачке морнарице која је међу првим земљама употребила подморнице у војне сврхе и то врло успешно. Поред тога, подморница U-31, прва подморница из класе *Type 212*, налази се ван употребе још од 2014. године због незавршених поправки.

Подморница U-32 имала је проблем са акумулаторима средином 2017. Године, па и даље чека поправку. Додуше, U-4 је „скоро па стигла" до првог слободног дока, што значи можда крајем ове године. На срећу, U-33 ће (или је већ) завршити поступак одржавања током 2018. године и биће упућена на тестирање ради поновног увођења у оперативну употребу. Подморница U-35, подморница истог типа као и U-6, завршена је крајем 2017. године, али неће бити у оперативној употреби све до половине или краја 2018. године.

Средства информисања наводе да је проблем у „недостатку резервних делова" и да „Немачка више не може себи дозволити да складишти резервне делова за ове скупе подморнице". Да ли је то могуће? Невероватно је да најбогатија земља Европске уније не може да одржава ни флоту од шест подморница. Ове подморнице су пројектоване за употребу у Балтичком мору и захваљујући својим хидрогенским горивним ћелијама могу остати испод воде и до две недеље. Операције у Балтичком мору и нису тако наивне с обзиром на плитке воде и опасне мисије прикупљања обавештајних података о руским лукама. Подморнице класе *Type 212* пројектоване су за овакву врсту операција, па је велика штета што скоро све у сувим доковима чекају различите врсте резервних делова који би требало да већ постоје у неком складишту. Велико је питање шта би скромна немачка подморничка флота могла урадити уколико би Русија постала агресивнија у односу на Балтичке државе.

Током 2010. године последњи немачки поморски авион типа *Atlantique* отишао је у пензију. Ради његове замене Немачка је одлучила да набави половни холандски авион типа P-3C. Ова одлука је донета иако су се неки с правом питали зашто заменити двомоторни авион, који је врло скуп за одржавање, четворомоторним авионом, још скупљим за одржавање. Поред тога, чини се да нико није приметио да немачки савезници повлаче P-3C и углавном га замењују модернијим авионом за поморско надгледање P-8.

Немачки P-3C

Да ствари буду још горе, ускоро је постало очигледно да су планери испустили из вида чињеницу да је бивши холандски авион имао превише сати налета, па се на крају испоставило да је потребно заменити крила, али и увести нови, модернији тактички систем. Један немачки официр је чак приметио да конструкцију авиона у ствари држи само фарба. Након тога, уместо да се спроведе тендер за спровођење екстензивних радова на структури авиона и модернизацији авионских инструмента и сензора, као што то раде морнарице Америке, Јужне Кореје, Аустралије и Новог Зеланда, Немачка морнарица је применила „једноставнију тактику" и препустила кормило индустријским компанијама. Компанија *Lockheed Martin* је ексклузивно добила уговор од осам година за спровођење модернизације. Програм структурних промена састоји се од осам комплета који укључују крила, централни труп и хоризонталне управљачке структуре. С обзиром на то да данас не постоји ниједан авион типа P3C који је у оперативној употреби, да ли је било могуће, пре ове набавке, извући закључак да је можда ипак било паметније купити нови P-8 или макар спровести тендер за програм модернизације.

Површинска флота је ипак у мало бољем стању. Морнарица има десет фрегата и пет корвета у оперативној употреби. Корвета F-130 је необична, можда поморски еквивалент „товарне мазге". Сувише је мала да би била употребљавана „ван региона" и сувише велика да би била покретна и брза. Изгледа да је корвета представљала компромис између дела командног кадра који је желео нешто мало, брзо и покретно за унутрашње операције у Балтичком мору и другог дела командног кадра који је, ипак, желео брод који би био способан за операције у Атлантском океану. Резултат компромиса је брод носивости до 1800 тона, дужине до 89 метара који нема свој хеликоптер (!), што представља недостатак за било коју мисију од

Балтика до Атлантика. Поред тога, корвета може бити на мору само недељу дана без брода за подршку, што је опет чини некомпатибилном за операције у мору и океану. Она има „самоуништавајуће" мењачке кутије и проблем са самим погонским системом. Треба поменути и то да одржавање овакве корвете немачку морнарицу кошта више него одржавање фрегата типа *Meko* A200, носивости до 3700 тона и дужине до 121 метар, које је Немачка израдила за морнарицу Јужне Африке.

Немачка корвета F-130

На срећу или несрећу, немачка морнарица се задржала само на серији од пет корвета заслугом претходног командујућег официра који је донео такву одлуку. Недавно се и нови морнарички програм фрегата типа F-125 нашао у средишту пажње када нова фрегата од 7000 тона *Baden-Württemberg* није прошла пробна тестирања. Чак се и лист *Wall Street Journal* огласио поводом тога, па је на крају чланка, у којем је набрајао све проблеме фрегате, закључио да „то стварно не ради". Осим проблема са стабилношћу на мору и проблема са софтвером, за које се претпоставља да ће бити решени једног дана, пројектанти су успели да претворе фрегату типа F-125 у авионску мету од 7000 тона, јер су заборавили да уведу противавионски ракетни систем. Сматрали су да ће фрегата бити употребљавана у мировним операцијама, као што су спасавање избеглица и противпиратске операције где се не предвиђа „ваздушна претња".

Овква одлука брањена је изјавом да „уколико буде ваздушних претњи, фрегату ће пратити фрегате типа F-123 или F-124". Када је неко приметио нелогичност овакве изјаве, један од званичних извора је изјавио да „ће фрегата гађати било који противнички авион системом *RAM (Rolling Airframe Missile*) ". Овај систем јесте предвиђен за одбрану од нисколетећих ракета, али како се одбранити од бомби са ласерским навођењем (без активног радара, без зрачења топлоте) које *RAM* не може ни да детектује, које авиони лансирају са даљина на којима *RAM* не може нападати. Овакву фрегату може напасти и авион са обичним „глупим" бомбама које могу оштетити или уништити осетљиву и скупу електронску опрему, што би фрегату учинило потпуно бескорисном.

Немачка фрегата F-125 Baden-Württemberg

Као већина фрегата и фрегата F-125 може искрцати на копно само ојачан вод. Иако располаже одговарајућом ваздушном подршком и даље није јасно шта може урадити један ојачани вод без пратеће технике и како је морнарица која у оперативној употреби има фрегате типа F-123 и F124 и солидне, иако старије, фрегате типа F-122, могла дозволити пројектовање и увођење у оперативну употребу бродова класе K-130 и F-125.

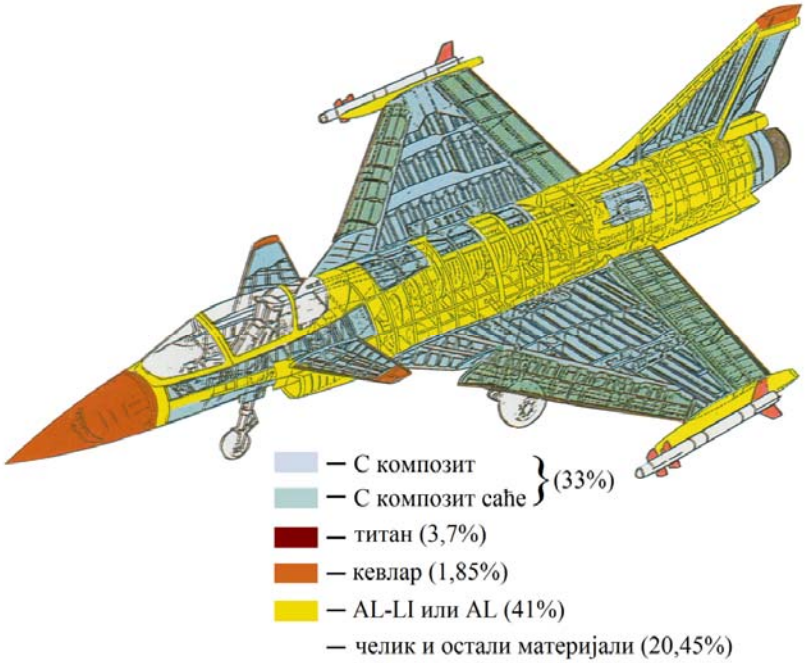
Немачка морнарица била је у сличној ситуацији током пролећа 1941. Године, када је била суочена са проблемом употребе торпеда лансираних са авиона. У писму упућеном својој супрузи, пре првог оперативног изласка бојног брода *Bismarck,* пројектант брода *Heinrich Schlüter* жалио се на глупост морнаричке бирократије која је ограничила оклопни појас брода само на простор изнад површине воде, што је на крају довело до поготка, онеспособљавања *Bismarck-a* и његовог потапања. Несретни пројектант није преживео ограничену бирократију и потонуо је са бродом.

Сада је јасније зашто је амерички председник Трамп толико љут на земље Европске уније и зашто је био нарочито непријатан према немачкој канцеларки Меркел. Немачка јесте најбогатија земља у Европској унији, али је очигледно и на чији рачун. Шта би тек рекао некадашњи главнокомандујући немачке морнарице адмирал Дениц о стању садашње морнарице?

Драган М. Вучковић (*Dragan* M. Vučković),
e-mail: draganvuckovic@kbcnet.rs,
ORCID iD: http://orcid.org/0000-0003-1620-5601

Нови авион: несуђени ловац бомбардер бивше СФРЈ[3]

Током осамдесетих година војно руководство Социјалистичке Федеративне Републике Југославије (СФРЈ) закључило је да постоји потреба за новим лаким ловцем који би заменио застарелу флоту ловаца MiG-21. Убрзо започиње домаћи пројекат под називом *Нови авион* чији је циљ развој домаћег лаког вишенаменског ловцабомбардера.



Југословенска аеронаутичка индустрија није била без искуства у развоју млазних борбених авиона с обзиром на развој и производњу неколико типова авиона, као што су тренажни авион G-2 Galeb, његова наоружана верзија Jastreb, лаки бомбардер J-22 Orao и тренажно-јуришни авион G-4 Super Galeb, али је развој супersoничног ловца ипак била друга прича. С тим у вези, СФРЈ се обратила захтевом за техничку помоћ различитим страним аеронаутичким компанијама, укључујући израелске, француске и британске.

Пошто је одабрана француска компанија Dassault Aviation, пројекат новог авиона био је под великим утицајем решења употребљених за развој новог ловца *Rafale,* француске компаније *Dassault Aviation,* који је развијан за потребе француског ратног ваздухопловства.

Нови авион југословенске авијације имао би нову технологију *fly-by-wire,* која омогућује већу маневарабилност аеродинамички нестабилном

[3] The National Interest 9 July 2018

Vučković, D., SAVREMENO NAORUŽANJE I VOJNA OPREMA / MODERN WEAPONS AND MILITARY EQUIPMENT, pp.172-183

авиону, а којом су били опремљени амерички F-16, совјетски Su-27 и француски *Mirage* 2000. Ради потпуног савладавања те технологије један J-22 *Orao* био је опремљен поменутим системом.

Конструкција авиона такође је била врло модерна. Већи део крила требало је да буде израђен од композитних материјала, а кључни структурни елементи од титанијума, челика и алуминијумских легура. Французи су ове материјале већ употребљавали у пројекту ловца *Rafale,* тако да је у то представљало велику уштеду у времену и новцу.

Слична сарадња постојала је и у погледу авионских инструмената и сензора. Авионски компјутер био је пројектован тако да је пилот могао брзо променити постојеће задатке и репрогамирати нову мисију током лета. Навигација је предвиђала употребу система INS/GPS, као и ограничену употребу гласовних команди.

Проток података требало је да буде по НАТО стандарду MIL-STD-1553, што би омогућило једноставнија унапређења и компатибилност са западним радарским уређајима.

Систем наоружања ваздух-ваздух директно је преузет са ловца *Rafale*. Предвиђена је и интерна уградња авионског топа 30 мм компаније GIAT. Сходно томе, наоружање ловца би се састојало од ракета ваздух-ваздух кратког домета *Magic II* и ракета средњег и дугог домета типа *Super Matra* и *MICA*. Ракета дугог домета *MICA* имала је активно радарско навођење.

У погледу мисија земља-ваздух, *Нови авион* требало је да буде оспособљен за ношење већег броја различитог подвесног наоружања, као што су вођене и невођене бомбе и ракете. Вероватно је да би било омогућено ношење ракете ваздух-земља типа AGM-65 *Maverick,* али и домаће верзије те ракете *Grom*, која је тада такође била у развоју. У том погледу почели су и преговори са Француском у вези с набавком крстареће ракете *MBDA Apache.* За *Нови авион* била је предвиђена уградња француског мотора *Snecma* M88Y који би му омогућавао да развије брзину до 1,88 маха, док су брзине на нивоу мора биле око 1,1 маха. (Понуђени су били и амерички мотор *General Electric* F404, *Pratt & Whitney* PW1120 и *Turbo-Union* RB.199)

Први лет новог авиона био је предвиђен за период између 1991. и 1993. године, а увођење у оперативну употребу око 1995. године. Југославија је предвиђала куповину до 150, односно 200 ловаца (неки извештаји су наводили чак и до 250), а постојале су неке пројекције да би извоз на светском тржишту достигао чак 600 до 700 ових летелица.

Пројекат *Нови авион* је заустављен због недостатка средстава током 1991. године, у тренутку када је пројектни посао био скоро готов, али су ретке откривене фотографије кокпита, на којима се могао видети само мали број потребних авионских инструмената, ипак указивале на то да је могућност првог лета 1992. године била нереална.

Током осамдесетих година многе земље су започеле развој сличних лаких вишенаменских ловаца: израелски *Lavi* (чији је развој зауставила америчка војна аеронаутичка индустрија), индијски лаки борбени авион

(*LCA* – који ни до данас није у потпуности развијен али је то типично за индијску војну индустрију), као и шведски JAS-39 *Gripen* који је данас доживео и E серију. Осамдесете године означиле су и почетак развоја јапанског ловца F-2, као и јужно-афричког ловца *Cava* и румунског ловца IAR 95. Тих година започет је и пројекат француског вишенаменског ловца *Rafale,* чије је технологије требало да користи *Нови авион.* Као и развој тенка *вихор,* тако је и пројекат *Новог авиона* могао итекако засметати западној војној индустрији, нарочито ако су пројекције у вези с потенцијалом извоза биле тачне.

Драган М. Вучковић (*Dragan* M. Vučković),
e-mail: draganvuckovic@kbcnet.rs,
ORCID iD: http://orcid.org/0000-0003-1620-5601

Карактеристике модерних борбених патика

Војничка чизма један је од традиционалних симбола војничког позива. У питању је веома важан елемент опреме коју службена лица, запослени у сектору приватне безбедности и други, користе скоро свакодневно у веома различитим условима и, по правилу, у дужем периоду. Управо су ове околности довеле до растуће потребе да се конструкција модерних тактичких чизама, односно борбених патика, значајно усаврши и прилагоди захтевима данашњих корисника.

Differentia specifica

Међу експертима и ентузијастима се водирасправа не само о етимологији појма *војничка чизма,* него и о тражењу скупа одређујућих карактеристика модерних модела и њиховом правилном појмовном одређивању. Управо зато је данас у употреби више термина, као што су војничка чизма, борбена чизма, тактичка чизма, односно борбена/тактичка патика. Хронолошки посматрано, изрази борбена или тактичка патика су новији, а вероватно су уведени у употребу ради истицања разлика у конструкцији у односу на старије, традиционалније чизме. Додатно, треба имати и у виду и језичке баријере, посебно када су у питању енглеске синтагме „tactical boot", или „combat boot", које је много правилније превести уз употребу речи *чизма,* а не *патика.* По обичају, развој тржишта, а првенствено нови захтеви корисника, развој технике и технологије, утицали су и на конструкцијски развој модерних тактичких, или борбених патика, које су данас веома популарне међу оператерима елитних војних и полицијских јединица за специјалне намене.

Са планине у касарне

Модерни модели тактичких чизама, односно борбених патика, у ствари представљају адаптацију обуће за планинарење и друге „outdoor" активности, првенствено услед релативно мале масе ове категорије обуће, одличне стабилизације и потпоре чланака, робустности и, наравно, удобности при пролонгираном ношењу.

Робујући демагогији да један модел чизме може да се употребљава универзално, овај део тржишта је дуго стагнирао. Основни захтев истицан произвођачима односио се на што израженију робустност модела, а ови су одговарали углавном габаритним, масивним, кожним, једнобојним моделима, са изузетно крутим, високим и тврдим ђоновима. Срећом, постало је јасно (али још увек не и општеприхваћено) да, као што не постоји тактичка униформа која би одговарала свим окружењима, нити универзалан пушчани систем који би одговарао свим тактичким задацима, тако не постоји ни универзална борбена или тактичка чизма која може подједнако добро да задовољи очекивања у различитим теренско-климатским условима.

Напуштањем традиционалне одбојности према новитетима и нерационалних потреба за једнообразношћу и других крутих правила, руководиоци и оператери у војним[1] и полицијским јединицама почињу да користе „outdoor" обућу приликом обављања службених задатака, послова и радњи. Насупрот габаритним, масивним и крутим чизмама ове „outdoor" дубоке и плитке патике знатно су пријатније за ношење, што се посебно примећује при дужим активностима које се често изводе и под додатним тежинским оптерећењем. Водећи светски произвођачи су врло брзо препознали ову новину у понашању њихових потенцијалних корисника, па тржиште, које је до недавно било прилично монотоно, доживљава велику промену и почиње да се развија у новом правцу.

Карактеристике

Ходање као способност и волјна активност је веома значајна за сваког човека, при чему стопало, са више од сто различитих мишића, 26 костију и 33 зглоба, има важну улогу.. То су само неке од очигледних чињеница које таутолошки показују зашто су стопала, али и њихово здравље, веома важни за активног и здравог човека. Здравље стопала у великој мери зависи и од квалитета обуће коју свакодневно носимо, што је посебно важно за оне појединце који свакодневно обављају физички веома захтевне, па и стресне покрете, на различитом (и често тешком) терену и у различитим климатским условима.

Оператер из састава „Кобри" носи модел „LOWA Zephyr GTX Mid TF". Фото: Милош Јевтић

[1] Сматра се да су такву обућу први користили амерички војни специјалци.

Јасно је да није свака чизма, односно патика, борбена или тактичка. Као најупечатљивију карактеристику треба истаћи да су тактичке чизме/патике оне које су примарно намењене оператерима војних и полицијских јединица[2]. Ова обућа је конструисана тако да носиоцу омогући удобност и заштиту при обављању веома стресних физичких активности у различитим окружењима, као што су вода, блато, песак, камење, бетон, али и у различитим климатским условима, попут екстремно ниских и високих температура, велике влажности ваздуха и слично.

Иако је наивно говорити о универзалном моделу, квалитетна тактичка чизма или патика ипак треба да обједини више карактеристика. Максимална уштеда на маси обуће необично је важна и долази до изражаја при обављању пролонгираних физичких активности. Последње што оператер у том случају жели јесте утисак да је на стопала закачио тегове. Прихватљива, правилно распоређена маса обуће прија и зглобовима и мишићима стопала и ногу, али и оних у лумбалном делу људског тела. Такође, позитивно се одражава и на брзину и гипкост вољног покрета. С обзиром на то да оператери обућу, по правилу, носе у вишечасовном периоду, без паузе, оптимално вентилирање стопала и заштита од климатских услова изузетно су значајни. Томе могу допринети посебно осмишљени системи у конструкцији обуће[3], као и материјали[4] који се користе у изради. Многи произвођачи данас употребљавају *Gore- Tex (GTX),* синтетички материјал са мноштвом микроотвора, изузетне водоотпорности.

Природна кожа је и даље веома заступљен материјал који, поред осталог, увећава и масу и крајњу цену производа на тржишту, што је један од разлога употребе синтетичких материјала у изради. Синтетички материјали, као на пример, полиестер, најлон и др. по правилу су лакши, брже се суше, обарају крајњу цену, али се по питању трајности не могу мерити са кожом. Ђонови треба да буду поуздани, флексибилни, релативно лагани, да омогућавају сигурно и тихо кретање. Када су у питању тактичке чизме или патике, ђонови се често израђују од гумених материјала, а карбонска ојачања сеумећу ради додатног учвршћивања. Многи произвођачи одлучују се за *vibram* ђонове који се добро понашају на клизавој површини, лагани су и трајни.

[2] Листа корисника је у пракси, наравно, знатно дужа, обухватајући и лица из сектора приватне безбедности, различитих спасилачких служби, ентузијасте из цивилства и друге.

[3] На пример, реномирани амерички произвођач „LALO" је серију „Shadow Amphibian" развио за потребе јединица за специјалне операције, у сарадњи са „SEAL" оператерима. Серију, поред осталог, карактерише и пасивни систем дренаже воде, осмишљен тако да олакша проток воде у и из чизме и патике, што је веома значајно приликом кретања у води или пливања.

[4] Одабир материјала, наравно, утиче и на укупну масу, трајност, робустност, водоотпорност и друге карактеристике.

Не мање важан захтев који квалитетна обуће ове врсте треба да испуни је поуздана стабилизација и потпора чланака.

Детаљ са приказа оперативних капацитета „Кобри", у оквиру вежбе „Век победника 1918–2018". Фото: Милош Јевтић

Стабилизација било ког зглоба при извођењу неког вољној покрета знатно умањује могућност повређивања, а истовремено јача и самопоуздање појединца у извођењу покрета. Уколико чланци нису објективно заштићени, оператери су, логично, изложени незгодним повредама. Додатно, на субјективном плану, уколико оператер нема поверења у своју опрему, ни његове перформансе неће бити на максимуму, што свакако није пожељно стање.

Нове борбене патике за службена лица у Републици Србији

У 2018. години Министарство унутрашњих послова Републике Србије реализовало је неколико набавки, поред осталих и борбених патика „LOWA Zephyr GTX Mid TF", са дупло бризганим „LOWA Cross" ђоновима, у дистрибуцији фирме „Хорус д.о.о". Реч је о веома квалитетним, вишенаменским, водоотпорним моделима[5] атрактивног дизајна, који су примарно намењени за средњетешке терене, а за потребе јединица министарства набављени су у црној боји.

[5] Маса једног пара у величини 42 износи 1120 грама.

Модел „LOWA Zephyr GTX Mid TF" припадника СПЈ Жандармерије. Фото: Милош Јевтић

У оквиру Министарства одбране војна лица из састава Батаљона војне полиције специјалне намене „Кобре" Војске Србије дуже исти модел, али у „sage" боји, тј. светлијој нијанси зелене боје. Треба нагласити да су ове набавке део једног доброг тренда, који код нас, нажалост, касни, али свакако има потенцијала.

Милош М. Јевтић (*Miloš* M. Jevtić), уредник сајта specijalne-jedinice.com,
e-mail: info@specijalne-jedinice.com,
ORCID iD: http://orcid.org/0000-0002-1305-7618

ПОЗИВ И УПУТСТВО АУТОРИМА
ПРИГЛАШЕНИЕ И ИНСТРУКЦИЯ ДЛЯ АВТОРОВ РАБОТ
CALL FOR PAPERS AND INSTRUCTIONS FOR AUTHORS

ПОЗИВ И УПУТСТВО АУТОРИМА О НАЧИНУ ПРИПРЕМЕ ЧЛАНКА

Упутство ауторима о начину припреме чланка за објављивање у *Војнотехничком гласнику* урађено је на основу Акта о уређивању научних часописа, Министарства за науку и технолошки развој Републике Србије, евиденциони број 110-00-17/2009-01, од 09. 07. 2009. године. Примена овог Акта првенствено служи унапређењу квалитета домаћих часописа и њиховог потпунијег укључивања у међународни систем размене научних информација. Засновано је на међународним стандардима ISO 4, ISO 8, ISO 18, ISO 215, ISO 214, ISO 18, ISO 690, ISO 690-2, ISO 999 и ISO 5122, односно одговарајућим домаћим стандардима.

Војнотехнички гласник / Vojnotehnički glasnik / Military Technical Courier (втг.мо.упр.срб, www.vtg.mod.gov.rs, ISSN 0042-8469 – штампано издање, e-ISSN 2217-4753 – online, UDC 623+355/359) јесте мултидисциплинарни научни часопис Министарства одбране Републике Србије, који објављује научне и стручне чланке, као и техничке информације о савременим системима наоружања и савременим војним технологијама. Часопис прати јединствену интервидовску техничку подршку Војске на принципу логистичке системске подршке, области основних, примењених и развојних истраживања, као и производњу и употребу средстава наоружања и војне опреме, те остала теоријска и практична достигнућа која доприносе усавршавању свих припадника српске, регионалне и међународне академске заједнице, а посебно припадника Министарства одбране и Војске Србије.

Министарство просвете, науке и технолошког развоја Републике Србије, сагласно одлуци из члана 27. став 1. тачка 4), а по прибављеном мишљењу из члана 25. став 1. тачка 5) Закона о научноистраживачкој делатности („Службени гласник РС”, бр. 110/05, 50/06-испр. и 18/10), утврдило је категоризацију Војнотехничког гласника, за 2018. годину:

за област технолошки развој:

– на листи часописа за материјале и хемијске технологије:

категорија водећи научни часопис националног значаја **(М51)**,

– на листи часописа за машинство:

категорија научни часопис националног значаја **(М52)**,

– на листи часописа за електронику, телекомуникације и информационе технологије:

категорија научни часопис **(М53)**,

за област основна истраживања:

– на листи часописа за математику, рачунарске науке и механику:

категорија научни часопис **(М53)**.

Усвојене листе домаћих часописа за 2018. годину могу се видети на сајту Војнотехничког гласника, страница *Категоризација часописа* (Министарство просвете, науке и технолошког развоја Републике Србије још увек није објавило званичну категоризацију научних часописа за 2019. годину).

Детаљније информације могу се пронаћи и на сајту Министарства просвете, науке и технолошког развоја Републике Србије.

Подаци о категоризацији могу се пратити и на сајту КОБСОН-а (Конзорцијум библиотека Србије за обједињену набавку).

Категоризација часописа извршена је према Правилнику о поступку и начину вредновања и квантитативном исказивању научноистраживачких резултата истраживача, који је прописао Национални савет за научни и технолошки развој (Службени гласник РС, број 38/2008).

У складу са овим правилником и табелом о врсти и квантификацији индивидуалних научноистраживачких резултата (у саставу Правилника), објављени рад у Војнотехничком гласнику вреднује се са 2 бода (категорија М51), 1,5 бод (категорија М52) и 1 бод (категорија М53).

Часопис се прати у контексту Српског цитатног индекса – СЦИндекс (база података домаћих научних часописа) и Руског индекса научног цитирања (РИНЦ). Подвргнут је сталном вредновању (мониторингу) у зависности од утицајности (импакта) у самим базама и, посредно, у међународним (Clarivate Analytics) цитатним индексима. Детаљи о индексирању могу се видети на сајту Војнотехничког гласника, страница *Индексирање часописа*.

Војнотехнички гласник омогућава и примењује Creative Commons (CC BY) одредбе о ауторским правима. Детаљи о ауторским правима могу се видети на сајту часописа, страница *Ауторска права и политика самоархивирања*.

Радови се предају путем онлајн система за електронско уређивање АСИСТЕНТ, који је развио Центар за евалуацију у образовању и науци (ЦЕОН).

Приступ и регистрација за сервис врше се на сајту www.vtg.mod.gov.rs, преко странице *АСИСТЕНТ* или *СЦИНДЕКС*, односно директно на линку aseestant.ceon.rs/index.php/vtg.

Детаљно упутство о регистрацији и пријави за сервис налази се на сајту www.vtg.mod.gov.rs, страница *Упутство за е-Ур: Електронско уређивање – АСИСТЕНТ*.

Потребно је да се сви аутори који подносе рукопис за објављивање у Војнотехничком гласнику региструју у регистар ORCID (Open Researcher and Contributor ID), према упутству на страници сајта *Регистрација за добијање ORCID идентификационе шифре*.

Војнотехнички гласник објављује чланке на српском, руском и енглеском језику (arial, српска ћирилица или српска латиница, величина слова 11 pt, проред Single).

Поступак припреме, писања и уређивања чланка треба да буде у сагласности са *Изјавом о етичком поступању* (http://www.vtg.mod.gov.rs/izjava-o-etickom-postupanju.html).

Чланак треба да садржи сажетак са кључним речима, увод, разраду, закључак, литературу и резимеа са кључним речима на енглеском и руском језику (без нумерације наслова и поднаслова). Обим чланка треба да буде око једног ауторског табака (16 страница формата А4 са проредом Single), а највише 24 странице.

Чланак треба да буде написан на обрасцу за писање чланка, који се у електронској форми може преузети са сајта на страници *Образац за писање чланка*.

Наслов

Наслов треба да одражава тему чланка. У интересу је часописа и аутора да се користе речи прикладне за индексирање и претраживање. Ако таквих речи нема у наслову, пожељно је да се придода и поднаслов. Наслов треба да буде преведен и на енглески и руски језик.

Ови наслови исписују се испред сажетка на одговарајућем језику.

Текући наслов

Текући наслов се исписује са стране сваке странице чланка ради лакше идентификације, посебно копија чланака у електронском облику. Садржи презиме и иницијал имена аутора (ако аутора има више, преостали се означавају са „et al.“ или „и др.“), наслове рада и часописа и колацију (година, волумен, свеска, почетна и завршна страница). Наслови часописа и чланка могу се дати у скраћеном облику.

Име аутора

Наводи се пуно име и презиме (свих) аутора. Веома је пожељно да се наведу и средња слова аутора. Имена и презимена домаћих аутора увек се исписују у оригиналном облику (са српским дијакритичким знаковима), независно од језика на којем је написан рад.

Назив установе аутора (афилијација)

Наводи се пун (званични) назив и седиште установе у којој је аутор запослен, а евентуално и назив установе у којој је аутор обавио истраживање. У сложеним организацијама наводи се укупна хијерархија (нпр. Универзитет одбране у Београду, Војна академија, Катедра природно-математичких наука). Бар једна организација у хијерархији мора бити правно лице. Ако аутора има више, а неки потичу из исте установе, мора се, посебним ознакама или на други начин, назначити из које од наведених установа потиче сваки од наведених аутора. Афилијација се исписује непосредно након имена аутора. Функција и звање аутора се не наводе.

Контакт подаци

Адреса или е-адреса свих аутора даје се поред имена и презимена аутора.

Категорија (тип) чланка

Категоризација чланака обавеза је уредништва и од посебне је важности. Категорију чланка могу предлагати рецензенти и чланови уредништва, односно уредници рубрика, али одговорност за категоризацију сноси искључиво главни уредник.

Чланци у часописима се разврставају у следеће категорије:

Научни чланци:

1. оригиналан научни чланак (рад у којем се износе претходно необјављивани резултати сопствених истраживања научним методом);

2. прегледни чланак (рад који садржи оригиналан, детаљан и критички приказ истраживачког проблема или подручја у којем је аутор остварио одређени допринос, видљив на основу аутоцитата);

3. кратко или претходно саопштење (оригинални научни рад пуног формата, али мањег обима или прелиминарног карактера);

4. научна критика, односно полемика (расправа на одређену научну тему, заснована искључиво на научној аргументацији) и осврти.

Изузетно, у неким областима, научни рад у часопису може имати облик монографске студије, као и критичког издања научне грађе (историјско-архивске, лексикографске, библиографске, прегледа података и сл.) – дотад непознате или недовољно приступачне за научна истраживања.

Радови класификовани као научни морају имати бар две позитивне рецензије.

Ако се у часопису објављују и прилози ваннаучног карактера, научни чланци треба да буду груписани и јасно издвојени у првом делу свеске.

Стручни чланци:

1. стручни чланак (прилог у којем се нуде искуства корисна за унапређење професионалне праксе, али која нису нужно заснована на научном методу);

2. информативни прилог (уводник, коментар и сл.);

3. приказ (књиге, рачунарског програма, случаја, научног догађаја, и сл.).

Језик рада

Језик рада може бити српски, руски или енглески.

Текст мора бити језички и стилски дотеран, систематизован, без скраћеница (осим стандардних). Све физичке величине морају бити изражене у Међународном систему мерних јединица – SI. Редослед образаца (формула) означава се редним бројевима, са десне стране у округлим заградама.

Сажетак (апстракт) и резиме

Сажетак (апстракт) јесте кратак информативан приказ садржаја чланка који читаоцу омогућава да брзо и тачно оцени његову релевантност. У интересу је уредништава и аутора да сажетак садржи термине који се често користе за индексирање и претрагу чланака. Саставни делови сажетка су циљ истраживања, методи, резултати и закључак. Сажетак треба да има од 100 до 250 речи и треба да се налази између заглавља (наслов, имена аутора и др.) и кључних речи, након којих следи текст чланка. Ако је рад написан на српском или руском језику, пожељно је да се, поред сажетка на српском и руском, даје и сажетак у проширеном облику на енглеском језику – као тзв. резиме (summary). Овакав резиме треба да буде на крају чланка, након одељка Литература. Важно је да резиме буде у структурираном облику, а његова дужина може бити до 1/10 дужине чланка (опширнији је од сажетка са почетка чланка). Почетак овог резимеа може бити преведени сажетак (са почетка чланка), а затим треба да следе преведени главни наслови, поднаслови и основе закључка чланка (литература се не преводи). Потребно је да се у структурираном резимеу преведе и део текста испод наслова и поднаслова, водећи рачуна да он буде пропорционалан њиховој величини, а да одражава суштину. Након резимеа на енглеском језику (проширеног сажетка) додаје се његов превод на српском, да би редакција извршила проверу и лектуру.

Кључне речи

Кључне речи су термини или фразе које адекватно представљају садржај чланка за потребе индексирања и претраживања. Треба их додељивати ослањајући се на неки међународни извор (попис, речник или тезаурус) који је најшире прихваћен или унутар дате научне области. За нпр. науку уопште, то је листа кључних речи Web of Science. Број кључних речи не може бити већи од 10, а у интересу је уредништва и аутора да учесталост њихове употребе буде што већа. Кључне речи дају се на језику на којем је написан чланак (сажетак) и на енглеском језику. У чланку се пишу непосредно након сажетка, односно након резимеа.

Систем АСИСТЕНТ у ту сврху користи специјалну алатку KWASS: аутоматско екстраховање кључних речи из дисциплинарних тезауруса/речника по избору и рутине за њихов одабир, тј. прихватање односно одбацивање од стране аутора и/или уредника.

Датум прихватања чланка

Датум када је уредништво примило чланак, датум када је уредништво коначно прихватило чланак за објављивање, као и датуми када су у међувремену

достављене евентуалне исправке рукописа наводе се хронолошким редоследом, на сталном месту, по правилу на крају чланка.

Захвалница

Назив и број пројекта, односно назив програма у оквиру којег је чланак настао, као и назив институције која је финансирала пројекат или програм, наводи се у посебној напомени на сталном месту, по правилу при дну прве стране чланка.

Претходне верзије рада

Ако је чланак у претходној верзији био изложен на скупу у виду усменог саопштења (под истим или сличним насловом), податак о томе треба да буде наведен у посебној напомени, по правилу при дну прве стране чланка. Рад који је већ објављен у неком часопису не може се објавити у Војнотехничком гласнику (прештампати), ни под сличним насловом и измењеном облику.

Табеларни и графички прикази

Пожељно је да наслови свих приказа, а по могућству и текстуални садржај, буду дати двојезично, на језику рада и на енглеском језику.

Табеле се пишу на исти начин као и текст, а означавају се редним бројевима са горње стране. Фотографије и цртежи треба да буду јасни, прегледни и погодни за репродукцију. Цртеже треба радити у програму word или corel. Фотографије и цртеже треба поставити на жељено место у тексту.

За слике и графиконе не сме се користити снимак са екрана рачунара програма за прикупљање података. У самом тексту чланка препоручује се употреба слика и графикона непосредно из програма за анализу података (као што су Excel, Matlab, Origin, SigmaPlot и други).

Навођење (цитирање) у тексту

Начин позивања на изворе у оквиру чланка мора бити једнообразан.

Војнотехнички гласник за референцирање (цитирање и навођење литературе) примењује Харвардски систем референци, односно Харвардски приручник за стил (Harvard Referencing System, Harvard Style Manual). У самом тексту, у обичним заградама, на месту на којем се врши позивање, односно цитирање литературе набројане на крају чланка, обавезно у обичној загради написати презиме цитираног аутора, годину издања публикације из које цитирате и, евентуално, број страница. Нпр. (Petrović, 2012, pp.10–12).

Детаљно упутство о начину цитирања, са примерима, дато је на страници сајта *Упутство за Харвардски приручник за стил*. Потребно је да се позивање на литературу у тексту уради у складу са поменутим упутством.

Систем АСИСТЕНТ у сврху контроле навођења (цитирања) у тексту користи специјалну алатку CiteMatcher: откривање изостављених цитата у тексту рада и у попису референци.

Напомене (фусноте)

Напомене се дају при дну стране на којој се налази текст на који се односе. Могу садржати мање важне детаље, допунска објашњења, назнаке о коришћеним изворима (на пример, научној грађи, приручницима), али не могу бити замена за цитирану литературу.

Листа референци (литература)

Цитирана литература обухвата, по правилу, библиографске изворе (чланке, монографије и сл.) и даје се искључиво у засебном одељку чланка, у виду листе референци. Референце се не преводе на језик рада и набрајају се у посебном одељку на крају чланка.

Војнотехнички гласник, као начин исписа литературе, примењује Харвардски систем референци, односно Харвардски приручник за стил (Harvard Referencing System, Harvard Style Manual).

Литература се обавезно пише на латиничном писму и набраја по абецедном редоследу, наводећи најпре презимена аутора, без нумерације.

Детаљно упутство о начину пописа референци, са примерима, дато је на страници сајта *Упутство за Харвардски приручник за стил*. Потребно је да се попис литературе на крају чланка уради у складу са поменутим упутством.

Нестандардно, непотпуно или недоследно навођење литературе у системима вредновања часописа сматра се довољним разлогом за оспоравање научног статуса часописа.

Систем АСИСТЕНТ у сврху контроле правилног исписа листе референци користи специјалну алатку RefFormatter: контрола обликовања референци у складу са Харвардским приручником за стил.

Пропратно писмо (само за ауторе из Републике Србије и по посебном захтеву уредника)

Поред чланка доставља се пропратно писмо у којем треба истаћи о којој врсти чланка се ради, који су графички прилози (фотографије и цртежи) оригинални, а који позајмљени.

У пропратном писму наводе се и подаци аутора: име, средње слово, презиме, чин, звање, е-маил, адреса послодавца (ВП), кућна адреса, телефон на радном месту и кућни (мобилни) телефон, рачун и назив банке, СО места становања, број личне карте и ЈМБ грађана.

Сви радови подлежу стручној рецензији.

Списак рецензената Војнотехничког гласника може се видети на страници сајта *Списак рецензената*. Процес рецензирања објашњен је на страници сајта *Рецензентски поступак*.

Адреса редакције:
Војнотехнички гласник
Генерала Павла Јуришића Штурма 1
11040 Београд,
e-mail: vojnotehnicki.glasnik@mod.gov.rs.

Главни и одговорни уредник
мр *Небојша* Гаћеша, дипл. инж.
nebojsa.gacesa@mod.gov.rs,
http://orcid.org/0000-0003-3217-6513,
тел.: војни 40-260 (011/3603-260),
066/8700-123

ПРИГЛАШЕНИЕ И ИНСТРУКЦИЯ ДЛЯ АВТОРОВ О ПОРЯДКЕ ПОДГОТОВКИ СТАТЬИ

Инструкция для авторов о порядке подготовки статьи к опубликованию в журнале «Военно-технический вестник» разработана в соответствии с Актом о редактировании научных журналов Министерства науки и технологического развития Республики Сербия, № 110-00-17/2009-01 от 09.07.2009 г. Применение этого Акта способствует повышению качества отечественных журналов и их более полному вовлечению в международную систему обмена научной информацией. Инструкция соответствует международным стандартам ISO 4, ISO 8, ISO 18, ISO 215, ISO 214, ISO 18, ISO 690, ISO 690-2, ISO 999, ISO 5122 и соответствующим стандартам Республики Сербия.

Военно-технический вестник (**Vojnotehnički glasnik / Military Technical Courier**), втг.мо.упр.срб, www.vtg.mod.gov.rs/index-ru.html, ISSN 0042-8469 – печатное издание, e-ISSN 2217-4753 – online, UDK 623+355/359, является мультидисциплинарным научным журналом Министерства обороны Республики Сербия, который публикует научные и профессиональные статьи, а также техническую информацию о современных системах вооружения и современных военных технологиях. Журнал следит за единой межвидовой технической поддержкой вооруженных сил, основанной на принципах системной логистики, за прикладными и инновационными научными исследованиями, в том числе, в области производства вооружения и военной техники, и за прочими теоретическими и практическими достижениями, которые способствуют профессиональному росту представителей сербского, регионального и международного академического сообщества, и особенно военнослужащих Министерства Обороны и Вооружённых сил Республики Сербия.

Министерство образования, науки и технологического развития Республики Сербия, согласно решению принятому в соотвествии со ст. 27 абзац 1, пункт 4 и на основании толкования ст. 25 абзац 1 пункт 5 Закона о научно-исследовательской деятельности («Службени гласник РС», № 110/05, утвердило категоризацию «Военно-технического вестника» за 2018 год:

Категории в области технологического развития:

– Область материалов и химической технологии:

ведущий научный журнал национального значения **(M51)**,

– Область механики:

научный журнал национального значения **(M52)**,

– Область электроники, телекоммуникаций и информационных технологий:

научный журнал **(M53).**

Категории в области основных исследований:

– Область математика, компьютерные науки, технические науки:

научный журнал **(M53)**.

С информацией относительно категоризации за 2018 год можно ознакомиться на странице сайта «Военно-технического вестника» *Категоризация Вестника* (Министерством просвещения, науки и технологического развития Республики Сербия пока не произведено официального ранжирования научных журналов за 2019 год).

Более подробную информацию можно найти на сайте Министерства образования, науки и технологического развития Республики Сербия.

С информацией о категоризации можно ознакомиться и на сайте КОБСОН (Консорциум библиотек Республики Сербия по вопросам объединения закупок).

Категоризация Вестника проведена согласно Положению о порядке и способе категоризации научно-исследовательских результатов, утверждённого Национальным комитетом по науке и технологиям (Службени гласник РС, № 38/2008).

В соответствии с вышеуказанным Положением и таблицей с показателями классификации и категоризации индивидуальных научно-исследовательских результатов, являющейся неотъемлемой частью Положения, научная статья, опубликованная в «Военно-техническом вестнике», оценивается следующим способом: 2 балла (категория М51), 1,5 балла (категория М52) и 1,5 балл (категория М53).

Журнал соответствует стандартам Сербского индекса научного цитирования (СЦИндекс/SCIndeks) – наукометрической базы данных научных журналов Республики Сербия, а также Российского индекса научного цитирования (РИНЦ). Журнал постоянно подвергается мониторингу и оценивается количественными наукометрическими показателями, отражающими его научную ценность, в т.ч. опосредованно в международных индексах цитирования (Clarivate Analytics).

С информацией об индексировании можно ознакомиться на странице сайта журнала *Индексирование Вестника*.

«Военно-технический Вестник» обеспечивает читателям возможность открытого доступа, в соответствии с положениями об авторских правах, утверждёнными Creative Commons (CC BY). С инструкцией об авторских правах можно ознакомиться на странице *Авторские права и политика самоархивирования*, перейдя по ссылке http://www.vtg.mod.gov.rs/index-ru.html.

Рукописи статей направляются в редакцию журнала с использованием online системы е-Ур: Электронное издательство – ASSISTANT, запущенной Центром поддержи развития образования и науки (ЦПРОН).

Регистрация в системе и оформление прав доступа выполняется по адресу http://www.vtg.mod.gov.rs/index-ru.html, через страницу *ASSISTANT* или *СЦИНДЕКС* (aseestant.ceon.rs/index.php/vtg).

С инструкцией по регистрации и правам доступа можно ознакомиться по адресу http://www.vtg.mod.gov.rs/index-ru.html, на странице *Инструкция по е-Ур: Электронное издательство ASSISTANT*.

Все авторы, предоставляющие свои рукописи для публикации в редакцию журнала «Военно-технический вестник» должны пройти предварительную регистрацию в реестре ORCID (Open Researcher and Contributor ID). Эта процедура осуществляется в соответствии с инструкцией, размещенной на странице сайта *Регистрация в реестре ORCID для присвоения идентификационного кода*.

«Военно-технический вестник» публикует статьи на сербском, русском или английском языках (Arial, шрифт 11 pt, пробел Single).

Процесс подготовки, написания и редактирования статьи должен осуществляться в соответствии с принципами *Этического кодекса* (http://www.vtg.mod.gov.rs/etichyeskiy-kodyeks.html).

Статья должна содержать аннотацию с ключевыми словами, введение, основную часть, выводы, список использованной литературы и резюме с ключевыми словами на английском языке (без нумерации заголовков и

подзаголовков). Объём статьи не должен превышать один авторский лист (16 страниц формата А4 с пробелом Single).

Статья должна быть набрана на компьютере с использованием специально подготовленного редакцией макета, который можно скачать на странице сайта *Правила и образец составления статьи*.

Заголовок

Заголовок должен отражать тему статьи. В интересах журнала и автора необходимо использовать слова и словосочетания, удобные для индексации и поиска. Если такие слова не содержатся в заголовке, то желательно их добавить в подзаголовок. Заголовок должен быть переведён на английский язык. Название заголовка (подзаголовка) пишется перед аннотацией на соответствующем языке.

Текущий заголовок

Текущий заголовок пишется в титуле каждой страницы статьи с целью упрощения процесса идентификации, в первую очередь копий статьей в электронном виде.
Заголовок содержит в себе фамилию и инициал имени автора (в случае если авторов несколько, остальные обозначаются с «et al.» или «и др.»), название работы и журнала (год, том, выпуск, начальная и заключительная страница). Заголовок статьи и название журнала могут быть приведены в сокращенном виде.

ФИО автора

Приводятся полная фамилия и полное имя (всех) авторов. Желательно, чтобы были указаны инициалы отчеств авторов. Фамилия и имя авторов из Республики Сербия всегда пишутся в оригинальном виде (с сербскими диакритическими знаками), независимо от языка, на котором написана работа.

Наименование учреждения автора (аффилиация)

Приводится полное (официальное) наименование и местонахождение учреждения, в котором работает автор, а также наименование учреждения, в котором автор провёл исследование. В случае организаций со сложной структурой приводится их иерархическая соподчинённость (напр. Военная академия, кафедра военных электронных систем, г. Белград). По крайней мере, одна из организаций в иерархии должна иметь статус юридического лица. В случае если указано несколько авторов, и если некоторые из них работают в одном учреждении, нужно отдельными обозначениями или каким-либо другим способом указать в каком из приведённых учреждений работает каждый из авторов. Аффилиация пишется непосредственно после ФИО автора. Должность и специальность по диплому не указываются.

Контактные данные

Электронный адрес автора указываются рядом с его именем на первой страницы статьи.

Категория (тип) статьи

Категоризация статьей является обязанностью редакции и имеет особое значение. Категорию статьи могут предлагать рецензенты и члены редакции, т.е. редакторы рубрик, но ответственность за категоризацию несет исключительно главный редактор. Статьи в журнале распределяются по следующим категориям:

Научные статьи:

1. оригинальная научная статья (работа, в которой приводятся ранее неопубликованные результаты собственных исследований, полученных научным методом);

2. обзорная статья (работа, содержащая оригинальный, детальный и критический обзор исследуемой проблемы или области, в который автор внёс определённый вклад, видимый на основе автоцитат);

3. краткое сообщение (оригинальная научная работа полного формата, но меньшего объёма или имеющая предварительный характер);

4. научная критическая статья (дискуссия-полемика на определённую научную тему, основанная исключительно на научной аргументации) и научный комментарий.

Однако, в некоторых областях знаний научная работа в журнале может иметь форму монографического исследования, а также критического обсуждения научного материала (историко-архивного, лексикографического, библиографического, обзора данных и т.п.) – до сих пор неизвестного или недостаточно доступного для научных исследований. Работы, классифицированные в качестве научных, должны иметь, по меньшей мере, две положительные рецензии.

В случае если в журнале объявляются и приложения, не имеющие научный характер, научные статьи должны быть сгруппированы и четко выделены в первой части номера.

Профессиональные статьи:

1. профессиональная работа (приложения, в которых предлагаются опыты, полезные для совершенствования профессиональной практики, но которые не должны в обязательном порядке быть обоснованы на научном методе);

2. информативное приложение (передовая статья, комментарий и т.п.);

3. обзор (книги, компьютерной программы, случая, научного события и т.п.).

Язык работы

Работа может быть написана на сербском, русском или английском языке.

Текст должен быть в лингвистическом и стилистическом смысле упорядочен, систематизирован, без сокращений (за исключением стандартных). Все физические величины должны соответствовать Международной системе единиц измерения – СИ. Очередность формул обозначается порядковыми номерами, проставляемыми с правой стороны в круглых скобках.

Аннотация (абстракт) и резюме

Аннотация (абстракт) является кратким информативным обзором содержания статьи, обеспечивающим читателю быстроту и точность оценки её релевантности. В интересах редакции и авторов, чтобы аннотация содержала термины, часто используемые для индексирования и поиска статьей. Составными частями аннотации являются цель исследования, методы и заключение. В аннотации должно быть от 100 до 250 слов, и она должна находится между титулами (заголовок, ФИО авторов и др.) и ключевыми словами, за которыми следует текст статьи. Если работа написана на сербском или русском языке, желательно, чтобы кроме аннотации на сербском и русском, была бы предоставлена и аннотация в расширенном виде на английском языке – в качестве т.н. резюме (summary). Такое резюме должно находиться в конце статьи, после раздела Литература. Важно, чтобы резюме было в структурированном виде, и его длина может составлять до

1/10 длины статьи (оно более обширно, чем аннотация из начала статьи). Началом данного резюме может быть переведенная аннотация (из начала статьи), а затем должны следовать переведенные главные заголовки, подзаголовки и основы заключения статьи (литература не переводится). В структурированном резюме нужно перевести часть текста под заголовком и заголовком, принимая во внимание, чтобы оно было пропорционально их размеру и в то же время отражала суть.

Ключевые слова

Ключевыми словами являются термины или фразы, адекватно представляющие содержание статьи, необходимые для индексирования и поиска. Ключевые слова необходимо выбирать, опираясь при этом на какой-либо международный источник (регистр, словарь, тезаурус), наиболее используемый внутри данной научной области. Число ключевых слов не может превышать 10. В интересах редакции и авторов, чтобы частота их встречи в статье была как можно большей. Ключевые слова даются на языке, на котором написана статья (аннотация), и на английском языке. В статье они пишутся непосредственно после аннотации (в начале) и после резюме (в конце).

Программа ASSISTANT предоставляет возможность использования сервиса KWASS, автоматически фиксирующего ключевые слова из источников/словарей по выбору автора/редактора.

Дата получения статьи

Дата, когда редакция получила статью; дата, когда редакция окончательно приняла статью к публикации; а также дата, когда были предоставлены необходимые исправления рукописи, приводятся в хронологическом порядке, как правило, в конце статьи.

Выражение благодарности

Наименование и номер проекта, т.е. название программы благодаря которой статья возникла, совместно с наименованием учреждения, которое финансировало проект или программу, приводятся в отдельном примечании, как правило, внизу первой страницы статьи.

Предыдущие версии работы

В случае если статья в предыдущей версии была изложена устно (под одинаковым или похожим названием, например, в виде доклада на научной конференции), сведения об этом должны быть указаны в отдельном примечании, как правило, внизу первой страницы статьи. Работа, которая уже была опубликована в каком-либо из журналов, не может быть напечатана в «Военно-техническом вестнике» ни под похожим названием, ни в изменённом виде.

Нумерация и название таблиц и графиков

Желательно, чтобы нумерация и название таблиц и графиков были исполнены на двух языках (на языке оригинала и на английском). Таблицы подписываются таким же способом как и текст и обозначаются порядковым номером с верхней стороны. Фотографии и рисунки должны быть понятны, наглядны и удобны для репродукции. Рисунки необходимо делать в программах Word или Corel. Фотографии и рисунки надо поставить на желаемое место в тексте. Для создания изображений и графиков использование функции снимка с экрана (скриншота) не допускается. В самом тексте статьи рекомендуется применение изображений и графиков, обработанных такими компьютерными программами, как: Excel, Matlab, Origin, SigmaPlot и др.

Ссылки (цитирование) в тексте

Оформление ссылок на источники в рамках статьи должно быть однообразным. «Военно-технический вестник» для оформления ссылок, цитат и списка использованной литературы применяет Гарвардскую систему (Harvard Referencing System, Harvard Style Manual). В тексте в скобках приводится фамилия цитируемого автора (или фамилия первого автора, если авторов несколько), год издания и по необходимости номер страницы. Например: (Petrović, 2010, pp.10-20). Рекомендации о способе цитирования размещены на странице сайта *Инструкция по использованию Гарвардского стиля*. При оформлении ссылок, цитат и списка использованной литературы необходимо придерживаться установленных норм. Программа ASSISTANT предоставляет при цитировании возможность использования сервиса CiteMatcher, фиксирующего пропущенные цитаты в работе и в списке литературы.

Примечания (сноски)

Примечания (сноски) к тексту указываются внизу страницы, к которой они относятся. Примечания могут содержать менее важные детали, дополнительные объяснения, указания об использованных источниках (напр. научном материале, справочниках), но не могут быть заменой процедуры цитирования литературы.

Литература (референции)

Цитированной литературой охватываются, как правило, такие библиографические источники как статьи, монографии и т.п. Вся используемая литература в виде референций размещается в отдельном разделе статьи.

Названия литературных источников не переводятся на язык работы.

«Военно-технический вестник» для оформления списка использованной литературы применяет Гарвардскую систему (Harvard Style Manual). В списке литературы источники указываются в алфавитном порядке фамилий авторов или редакторов. Рекомендации о способе цитирования размещены на странице сайта *Инструкция по использованию Гарвардского стиля*. При оформлении списка использованной литературы необходимо придерживаться установленных норм.

При оформлении списка литературы программа ASSISTANT предоставляет возможность использования сервиса RefFormatter, осуществляющего контроль оформления списка литературы в соответствии со стандартами Гарвардского стиля.

Нестандартное, неполное и непоследовательное приведение литературы в системах оценки журнала считается достаточной причиной для оспаривания научного статуса журнала.

Все рукописи статей подлежат профессиональному рецензированию.

Список рецензентов журнала «Военно-технический вестник» размещён на странице сайта *Список рецензентов*. Процесс рецензирования описан в разделе *Правила рецензирования*.

Почтовый адрес редакции:
«Војнотехнички гласник»
ул. Генерала Павла Юришича Штурма 1
11040 Белград, Республика Сербия
e-mail: vojnotehnicki.glasnik@mod.gov.rs.

Главный и ответственный редактор
Кандидат технических наук *Небойша* Гачеша
nebojsa.gacesa@mod.gov.rs
http://orcid.org/0000-0003-3217-6513
тел: +381 11 3603 260, +381 66 8700 123

CALL FOR PAPERS AND ARTICLE FORMATTING INSTRUCTIONS

The instructions to authors about the article preparation for publication in the *Military Technical Courier* are based on the Act on scientific journal editing of the Ministry of Science and Technological Development of the Republic of Serbia, No 110-00-17/2009-01 of 9th July 2009. This Act aims at improving the quality of national journals and raising the level of their compliance with the international system of scientific information exchange. It is based on international standards ISO 4, ISO 8, ISO 18, ISO 215, ISO 214, ISO 18, ISO 690, ISO 690-2, ISO 999 and ISO 5122 and their national equivalents.

The Military Technical Courier / Vojnotehnički glasnik (www.vtg.mod.gov.rs/index-e.html, втг.мо.упр.срб, ISSN 0042-8469 – print issue, e-ISSN 2217-4753 – online, UDC 623+355/359) is a multidisciplinary scientific journal of the Ministry of Defence of the Republic of Serbia. It publishes scientific and professional papers as well as technical data on modern weapon systems and military technologies. The journal covers inter-service technical support to the Army on the principle of logistic system support; fundamental, applied and development research; production and use of weapons and military equipment as well as other theoretical and practical achievements leading to professional development of all members of Serbian, regional and international academic communities, members of the Ministry of Defence and the Army of Serbia in particular.

Pursuant to the decision given in Article 27, paragraph 1, point 4, and in accordance with the acquired opinion given in Article 25, paragraph 1, point 5 of the Act on Scientific and Research Activities (Official Gazette of the Republic of Serbia, No 110/05, 50/06-cor and 18/10), the Ministry of Education, Science and Technological Development of the Republic of Serbia classified the Military Technical Courier for the year 2017

in the field technological development:
– on the list of periodicals for materials and chemical technology,
category: leading scientific periodical of national interest **(M51)**,
– on the list of periodicals for mechanical engineering,
category: scientific periodical of national interest **(M52)**,
– on the list of periodicals for electronics, telecommunications and IT,
category: scientific periodical **(M53)**,
in the field fundamental research:
– on the list of periodicals for mathematics, computer sciences and mechanics,
category: scientific periodical **(M53)**.

The approved lists of national periodicals for the year 2018 can be viewed on the website of the Military Technical Courier, page *Journal categorization* (The Ministry of Education, Science and Technological Development of the Republic of Serbia has not yet published the official evaluation of scientific journals for 2019).

More detailed information can be found on the website of the Ministry of Education, Science and Technological Development of the Republic of Serbia.

The information on the categorization can be also found on the website of KOBSON (Consortium of Libraries of Serbia for Unified Acquisition).

The periodical is categorized in compliance with the Regulations on the procedure and method of evaluation and quantitative formulation of scientific and research results of researchers, stipulated by the National Council for Scientific and Technological Development (*Official Gazette of RS*, No 38/2008). More detailed information can be found on the website of the Ministry of Education, Science and Technological Development.

In accordance with the Regulations and the table about types and quantification of individual scientific and research results (as a part of the Regulations), a paper published in the *Military Technical Courier* scores 2 (two) points (category M51), 1,5 (one and a half) point (category M52) and 1 (one) point (category M53).

The journal is in the Serbian Citation Index – SCIndex (data base of national scientific journals), in the Russian Index of Science Citation/Российский индекс научного цитирования (RINC/РИНЦ) and is constantly monitored depending on the impact within the bases themselves and indirectly in the international (e.g. Clarivate Analytics) citation indexes. More detailed information can be viewed on the website of the Military Technical Courier, page *Journal indexing*.

Military Technical Courier enables open access and applies the Creative Commons Attribution (CC BY) licence provisions on copyright. The copyright details can be found on the *Copyright notice and Self-archiving policy* page of the journal's website.

Manuscripts are submitted online, through the electronic editing system ASSISTANT, developed by the Center for Evaluation in Education and Science – CEON.

The access and the registration are through the Military Technical Courier site http://www.vtg.mod.gov.rs/index-e.html, on the page *ASSISTANT* or the page *SCINDEKS* or directly through the link (aseestant.ceon.rs/index.php/vtg).

The detailed instructions about the registration for the service are on the website http://www.vtg.mod.gov.rs/index-e.html, on the page *Instructions for e-Ur: Electronic Editing - ASSISTANT*.

All authors submitting a manuscript for publishing in the Military Technical Courier should register for an ORCID ID following the instructions on the web page *Registration for an ORCID identifier*.

The Military Technical Courier publishes articles in Serbian, Russian or English, using Arial and a font size of 11pt with Single Spacing.

The procedures of article preparation, writing and editing should be in accordance with the *Publication ethics statement* (http://www.vtg.mod.gov.rs/publication-ethics-statement.html).

The article should contain the abstract with keywords, introduction, body, conclusion, references and the summary in English language (without heading and subheading enumeration). The article length should not exceed 24 pages of A4 paper format.

The article should be formatted following the instructions in the Article Form which can be downloaded from website page *Article form*.

Title

The title should be informative. It is in both Journal's and author's best interest to use terms suitable for indexing and word search. If there are no such terms in the title, the author is strongly advised to add a subtitle. The title should be given in English as well.

The titles precede the abstract and the summary in an appropriate language.

Letterhead title

The letterhead title is given at a top of each page for easier identification of article copies in an electronic form in particular. It contains the author's surname and first name initial (for multiple authors add "et al"), article title, journal title and collation (year, volume, issue, first and last page). The journal and article titles can be given in a shortened form.

Author's name

Full name(s) of author(s) should be used. It is advisable to give the middle initial. Names are given in their original form (with diacritic signs if in Serbian).

Author's affiliation

The full official name and seat of the author's affiliation is given, possibly with the name of the institution where the research was carried out. For organizations with complex structures, give the whole hierarchy (for example, University of Defence in Belgrade, Military Academy, Department for Military Electronic Systems). At least one organization in the hierarchy must be a legal entity. When some of multiple authors have the same affiliation, it must be clearly stated, by special signs or in other way, which department exactly they are affiliated with. The affiliation follows the author's name. The function and title are not given.

Contact details

The postal addresses or the e-mail addresses of the authors are given in the first page.

Type of articles

Classification of articles is a duty of the editorial staff and is of special importance. Referees and the members of the editorial staff, or section editors, can propose a category, but the editor-in-chief has the sole responsibility for their classification.

Journal articles are classified as follows:

Scientific articles:

1. Original scientific paper (giving the previously unpublished results of the author's own research based on scientific methods);

2. Survey paper (giving an original, detailed and critical view of a research problem or an area to which the author has made a contribution visible through his self-citation);

3. Short or preliminary communication (original scientific paper of full format but of a smaller extent or of a preliminary character);

4. Scientific critique or forum (discussion on a particular scientific topic, based exclusively on scientific argumentation) and commentaries.

Exceptionally, in particular areas, a scientific paper in the Journal can be in a form of a monograph or a critical edition of scientific data (historical, archival, lexicographic, bibliographic, data survey, etc.) which were unknown or hardly accessible for scientific research.

Papers classified as scientific must have at least two positive reviews.

If the journal contains non-scientific contributions as well, the section with scientific papers should be clearly denoted in the first part of the Journal.

Professional articles:

1. Professional paper (contribution offering experience useful for improvement of professional practice but not necessarily based on scientific methods);

2. Informative contribution (editorial, commentary, etc.);

3. Review (of a book, software, case study, scientific event, etc.)

Language

The article can be in Serbian, Russian or English.

The grammar and style of the article should be of good quality. The systematized text should be without abbreviations (except standard ones). All measurements must be in SI units. The sequence of formulae is denoted in Arabic numerals in parentheses on the right-hand side.

Abstract and summary

An abstract is a concise informative presentation of the article content for fast and accurate evaluation of its relevance. It is both in the Editorial Office's and the author's best interest for an abstract to contain terms often used for indexing and article search. The abstract describes the purpose of the study and the methods, outlines the findings and state the conclusions. A 100- to 250- word abstract should be placed between the title and the keywords with the body text to follow. Besides an abstract in Serbian and Russian, articles in Serbian and Russian are advised to have a summary in English, at the end of the article, after the Reference list. The summary should be structured and long up to 1/10 of the article length (it is more extensive than the abstract). It can start with the translated Serbian or Russian abstract from the beginning of the article with translated main headings, subheadings and major conclusions to follow (Reference list is not translated). The structured summary should also contain the proportional informative parts of the text below the headings and subheadings.

Keywords

Keywords are terms or phrases showing adequately the article content for indexing and search purposes. They should be allocated heaving in mind widely accepted international sources (index, dictionary or thesaurus), such as the Web of Science keyword list for science in general. The higher their usage frequency is, the better. Up to 10 keywords immediately follow the abstract and the summary, in respective languages.

For this purpose, the ASSISTANT system uses a special tool KWASS for the automatic extraction of key words from disciplinary thesauruses/dictionaries by choice and the routine for their selection, i.e. acceptance or rejection by author and/or editor.

Article acceptance date

The date of the reception of the article, the dates of submitted corrections in the manuscript (optional) and the date when the Editorial Board accepted the article for publication are all given in a chronological order at the end of the article.

Acknowledgements

The name and the number of the project or programme within which the article was realised is given in a separate note at the bottom of the first page together with the name of the institution which financially supported the project or programme.

Article preliminary version

If an article preliminary version has appeared previously at a meeting in a form of an oral presentation (under the same or similar title), this should be stated in a separate note at the bottom of the first page. An article published previously cannot be published in the *Military Technical Courier* even under a similar title or in a changed form.

Tables and illustrations

All the captions should be in the original language as well as in English, together with the texts in illustrations if possible. Tables are typed in the same style as the text and are denoted by Arabic numerals at the top. Photographs and drawings, placed

appropriately in the text, should be clear, precise and suitable for reproduction. Drawings should be created in Word or Corel.

For figures and graphs, proper data plot is recommended i.e. using a data analysis program such as Excel, Matlab, Origin, SigmaPlot, etc. It is not recommended to use a screen capture of a data acquisition program as a figure or a graph.

Citation in the text

Citation in the text must be uniform. The Military Technical Courier applies the Harvard Referencing System given in the Harvard Style Manual. When citing sources within your paper, i.e. for in-text references of the works listed at the end of the paper, place the year of publication of the work in parentheses and optionally the number of the page(s) after the author's name, e.g. (Petrovic, 2012, pp.10-12). A detailed guide on citing, with examples, can be found on Military Technical Courier website on the page *Instructions for Harvard Style Manual*. In-text citations should follow its guidelines.

For checking in-text citations, the ASSISTANT system uses a special tool CiteMatcher to find out quotes left out within papers and in reference lists.

Footnotes

Footnotes are given at the bottom of the page with the text they refer to. They can contain less relevant details, additional explanations or used sources (e.g. scientific material, manuals). They cannot replace the cited literature.

Reference list (Literature)

The cited literature encompasses bibliographic sources such as articles and monographs and is given in a separate section in a form of a reference list.

References are not translated to the language of the article.

In compiling the reference list and bibliography, the Military Technical Courier applies the Harvard System – Harvard Style Manual. All bibliography items should be listed alphabetically by author's name, without numeration. A detailed guide for listing references, with examples, can be found on Military Technical Courier website on the page *Instructions for Harvard Style Manual*. Reference lists at the end of papers should follow its guidelines.

In journal evaluation systems, non-standard, insufficient or inconsequent citation is considered to be a sufficient cause for denying the scientific status to a journal.

All articles are peer reviewed.

The list of referees of the Military Technical Courier can be viewed at website page *List of referees*. The article review process is described on the *Peer Review Process* page of the website.

Address of the Editorial Office:
Vojnotehnički glasnik / Military Technical Courier
Generala Pavla Jurišića Šturma 1
11040 Belgrade, Republic of Serbia,
e-mail: vojnotehnicki.glasnik@mod.gov.rs.

Editor in chief
Nebojša Gaćeša MSc
nebojsa.gacesa@mod.gov.rs
http://orcid.org/0000-0003-3217-6513
tel.: +381 11 3603 260, +381 66 8700 123

ОБАВЕШТЕЊА САРАДНИЦИМА И ЧИТАОЦИМА
СООБЩЕНИЯ ДЛЯ АВТОРОВ И ЧИТАТЕЛЕЙ
INFORMATION FOR CONTRIBUTORS AND READERS

Министарство просвете, науке и технолошког развоја Републике Србије објавило категоризацију „Војнотехничког гласника" за 2018. годину

Министарство просвете, науке и технолошког развоја Републике Србије, сагласно одлуци из члана 27. став 1. тачка 4), а по прибављеном мишљењу из члана 25. став 1. тачка 5) Закона о научноистраживачкој делатности („Службени гласник РС" бр. 110/05, 50/06-испр. и 18/10), утврдило је категоризацију „Војнотехничког гласника" за 2018. годину:

за област технолошки развој:

– на листи часописа за материјале и хемијске технологије: категорија водећи научни часопис од националног значаја (М51),
– на листи часописа за машинство: категорија научни часопис од националног значаја (М52),
– на листи часописа за електронику, телекомуникације и информационе технологије: категорија научни часопис (М53);

за област основна истраживања:

– на листи часописа за математику, рачунарске науке и механику: категорија научни часопис (М53).

Усвојене листе домаћих часописа за 2018. годину могу се видети на страници сајта *Категоризација часописа* (http://www.vtg.mod.gov.rs/kategorizacija-casopisa.html).

Детаљније информације могу се пронаћи и на сајту Министарства просвете, науке и технолошког развоја Републике Србије.

Категоризација часописа извршена је према Правилнику о поступку и начину вредновања и квантитативном исказивању научноистраживачких резултата истраживача, који је прописао Национални савет за научни и технолошки развој (Службени гласник РС, број 38/2008).

У складу са овим правилником и табелом о врсти и квантификацији индивидуалних научноистраживачких резултата (у саставу Правилника), објављени рад у Војнотехничком гласнику вреднује се са 2 бода (категорија М51), 1,5 бод (категорија М52) и 1 бод (категорија М53).

Министерство образования, науки и технологического развития Республики Сербия утвердило категоризацию журнала «Военно-технический вестник» за 2018 год

Министерством образования, науки и технологического развития Республики Сербия согласно решению по ст. 27 абзац 1, пункт 4 и по полученному толкованию ст. 25 абзац 1 пункт 5 Закона о научно-исследовательской деятельности («Службени гласник РС» № 110/05, 50/06-испр. и 18/10) утверждена категоризация журнала «Военно-технический вестник» за 2018 год:

Категории в области технологического развития:

– Область материалов и химической технологии: ведущий научный журнал национального значения (М51),
– Область механики: научный журнал национального значения (М52),

– Область электроники, телекоммуникаций и информационных технологий: научный журнал (М53).

Категории в области основных исследований:

Область математика, компьютерные науки, технические науки: научный журнал (М53).

С информацией о категоризации за 2018 год можно ознакомиться на странице *Категоризация вестника* (http://www.vtg.mod.gov.rs/kategorizacia-vestnika.html).

Более подробно с информацией можно ознакомиться на сайте Министерства образования, науки и технологического развития Республики Сербия.

Категоризация журнала проведена в соответствии с Регламентом о порядке и методах категоризации научно-исследовательских результатов, утвержденного Национальным комитетом по науке и технологиям (Службени гласник РС, № 38/2008).

В соответствии с вышеуказанными положениями Регламента и таблицей по классификации и категоризации индивидуальных научно-исследовательских результатов (являющихся неотъемлемой частью Регламента), работа, опубликованная в журнале «Военно-технический вестник», оценивается следующим образом: 2 балла (категория М51), 1,5 баллов (категория М52) и 1 балл (категория М53).

Ministry of Education, Science and Technological Development of the Republic of Serbia classified the Military Technical Courier for the year 2018

Pursuant to the decision given in Article 27, paragraph 1, point 4, and in accordance with the acquired opinion given in Article 25, paragraph 1, point 5 of the Act on Scientific and Research Activities (Official Gazette of the Republic of Serbia, No 110/05, 50/06-cor and 18/10), the Ministry of Education, Science and Technological Development of the Republic of Serbia classified the Military Technical Courier for the year 2018

in the field Technological Development:

– on the list of periodicals for materials and chemical technology, category: leading scientific periodical of national interest (M51),
– on the list of periodicals for mechanical engineering, category: scientific periodical of national interest (M52),
– on the list of periodicals for electronics, telecommunications and IT, category: scientific periodical (M53),

in the field Fundamental Research:

– on the list of periodicals for mathematics, computer sciences and mechanics: category: scientific periodical (M53).

The approved lists of national periodicals for the year 2018 can be viewed on the web page *Journal categorization* (http://www.vtg.mod.gov.rs/journal-categorisation-1.html).

More detailed information can be found on the website of the Ministry of Education, Science and Technological Development of the Republic of Serbia. The periodical is categorized in compliance with the Regulations on the procedure and method of evaluation and quantitative formulation of scientific and research results of researchers, stipulated by the National Council for Scientific and Technological Development (Official Gazette of RS, No 38/2008).

In accordance with the Regulations and the table about types and quantification of individual scientific and research results (as a part of the Regulations), a paper published in the Military Technical Courier scores 2 (two) points (category M51), 1.5 (one and a half) point (category M52) and 1 (one) point (category M53).

Индексирани чланци „Војнотехничког гласника” од 1990. до 1999. године у Српском цитатном индексу

Захваљујући удруженим напорима Центра за евалуацију у образовању и науци (ЦЕОН) и редакције „Војнотехничког гласника”, на страницама Српског цитатног индекса индексирани су сви чланци објављени у „Војнотехничком гласнику” од 1990. до 1999. године, поред до сада индексираних чланака који су објављени после 2000. године. И ови чланци индексирани су у пуном формату, са додељеним ДОИ бројем и доступним целокупним текстом чланка у ПДФ формату, на страници https://scindeks.ceon.rs/issue.aspx?issue=14095&lang=sr. Редакција се захваљује ЦЕОН-у на овом важном доприносу у дигитализацији „Војнотехничког гласника”.

Статьи журнала «Военно-технический вестник» с 1990 по 1999 год прошли индексацию в Сербском индексе научного цитирования

Благодаря совместным усилиям Центра оценки образования и науки (CEON) и редакции журнала «Военно-технический вестник», в Сербском индексе научного цитирования проиндексированы статьи журнала «Военно-технический вестник» с 1990 по 1999 год, помимо статей с 2000 года, которые ранее уже прошли индексацию. Данные статьи размещены в полном формате, и их можно найти под присвоенным DOI номером, в формате PDF на странице https://scindeks.ceon.rs/issue.aspx?issue=14095&lang=en. Редакция благодарит CEON за важный вклад в оцифровку журнала «Военно-технический вестник».

Serbian Citation Index has indexed the Military Technical Courier articles from 1990 to 1999

Thanks to the joint efforts of the Center for Evaluation in Education and Science (CEON) and the editorial team of the Military Technical Courier, the Serbian Citation Index has indexed all articles published in the Military Technical Courier from 1990 to 1999, in addition to the already indexed articles published since 2000. These articles are indexed in full format, with the assigned DOI number and available in full text of the article in the PDF format, at https://scindeks.ceon.rs/issue.aspx?issue=14095&lang=en. The editorial team thanks the CEON for this important contribution to the digitization of the Military Technical Courier.

СПИСАК РЕЦЕНЗЕНАТА ВОЈНОТЕХНИЧКОГ ГЛАСНИКА
СПИСОК РЕЦЕНЗЕНТОВ ЖУРНАЛА «ВОЕННО-ТЕХНИЧЕСКИЙ ВЕСТНИК»
LIST OF REFEREES OF THE MILITARY TECHNICAL COURIER

СПИСАК РЕЦЕНЗЕНАТА *ВОЈНОТЕХНИЧКОГ ГЛАСНИКА*

Име, средње слово и презиме	**Област компетенције (научног интересовања)**	**ORCID iD**	**Publons identifier**
Марко Д. Андрејић	логистика	https://orcid.org/0000-0002-6753-9786	https://publons.com/a/1597995
Миленко С. Андрић	дигитална обрада сигнала, препознавање облика и класификација, сигнали и системи, стохастички процеси у телекомуникацијама и радарским системима, временско-фреквенцијска обрада сигнала, фази логички системи	https://orcid.org/0000-0001-9038-0876	https://publons.com/a/1615557
Милош Ж. Арсић	логистички менаџмент	https://orcid.org/0000-0001-7853-0819	https://publons.com/a/1604531
Саша Т. Бакрач	заштита животне средине, процена еколошких ризика, екоменаџмент	https://orcid.org/0000-0003-0211-3765	https://publons.com/a/1597282
Војислав Ј. Батинић	опште машинске конструкције	https://orcid.org/0000-0001-6786-7846	https://publons.com/a/1643029
Стеван М. Бербер	телекомуникације, бежичне комуникације, CDMA, OFDM системи, сензорске мреже, рачунарски системи у реалном времену, обрада стохастичких сигнала	https://orcid.org/0000-0002-2432-3088	https://publons.com/a/1610900
Драгана Бечејски-Вујаклија	пословни информациони системи, пословна интелигенција, ERP, IT менаџмент	https://orcid.org/0000-0002-9615-3620	https://publons.com/a/1623502
Дарко И. Божанић	вишекритеријумско одлучивање, менаџмент у одбрани	https://orcid.org/0000-0002-9657-0889	https://publons.com/a/1524010
Бобан П. Бонџулић	дигитална обрада слике, дигитална обрада сигнала и њене примене, сједињавање слика, процена квалитета слике и видео сигнала	https://orcid.org/0000-0002-8850-9842	https://publons.com/a/1603131

Име, средње слово и презиме	Област компетенције (научног интересовања)	ORCID iD	Publons identifier
Мирко А. Борисов	геодетско инжењерство, геоматика, географски информациони системи, дигитални модели терена, картографија, геодезија, мултимедијална картографија, веб картографија	https://orcid.org/0000-0002-7234-6372	https://publons.com/a/1613254
Угљеша С. Бугарић	операциона истраживања, масовно опслуживање, теротехнологија-одржавање, транспортни и складишни системи	https://orcid.org/0000-0003-2459-2656	https://publons.com/a/1596666
Славиша И. Влачић	ваздушни саобраћај, системска контрола; аутоматска контрола; навигација возила; морнарички борбени и навигациони системи; симулација	https://orcid.org/0000-0001-9336-0512	https://publons.com/a/1604062
Драгољуб А. Вујић	примењена механика, дијагностика, софистицирани системи одржавања техничких система	https://orcid.org/0000-0001-6999-6828	https://publons.com/a/1627346
Иван Б. Вулић	информациони системи, географски информациони системи	https://orcid.org/0000-0002-5161-5422	https://publons.com/a/1606268
Младен М. Вуруна	војно-хемијско инжењерство (погонска средства, токсиколошка средства, заштита од НХБ оружја, заштита животне средине)	https://orcid.org/0000-0002-3558-4312	https://publons.com/a/1626384
Љубомир Ј Гиговић	географија, географски информациони систем, геопросторна анализа	https://orcid.org/0000-0002-8388-3624	https://publons.com/a/1418283
Миро Ј. Говедарица	геоинформатика	https://orcid.org/0000-0003-1698-0800	https://publons.com/a/1539597

Име, средње слово и презиме	Област компетенције (научног интересовања)	ORCID iD	Publons identifier
Горан Д. Дикић	системи аутоматског управљања, праћење циљева, системи вођења и управљања ракета	https://orcid.org/0000-0002-0858-1415	https://publons.com/a/1634756
Снежана М. Драгићевић	енергетска ефикасност, машинство, соларна енергија, термоинжењеринг	https://orcid.org/0000-0002-6244-0111	https://publons.com/a/1604121
Чедомир В. Дубока	мотори, моторна возила	https://orcid.org/0000-0003-2944-2278	https://publons.com/a/1627827
Бобан Д. Ђоровић	процеси и методе у саобраћају и транспорту, транспортне мреже, организација транспорта	https://orcid.org/0000-0001-8133-2389	https://publons.com/a/1633020
Владо П. Ђурковић	примењена механика крутог и деформабилног тела	https://orcid.org/0000-0002-5064-4117	https://publons.com/a/1622194
Жељко М. Ђуровић	обрада сигнала, управљање системима, препознавање облика	https://orcid.org/0000-0002-6076-442X	/
Бојан М. Зрнић	сензорски системи, стратегијско планирање	https://orcid.org/0000-0002-0961-993X	/
Дамир Д. Јерковић	наоружање, нумеричка анализа, CFD симулација, спољна балистика, балистика, балистика на циљу, интеграција наоружања	https://orcid.org/0000-0001-5182-7057	https://publons.com/a/1500127
Вукица М. Јовановић	машинство	https://orcid.org/0000-0002-8626-903X	https://publons.com/a/1656683
Митар Т. Јоцановић	трибологија и теорија подмазивања, одржавање технолошких система, хидраулички системи	https://orcid.org/0000-0003-1088-5028	https://publons.com/a/1596778
Радован М. Каркалић	хемијске технологије (нуклеарно-хемијско-биолошка заштита, детекција, идентификација и деконтаминација)	https://orcid.org/0000-0002-8074-7264	https://publons.com/a/1602667

Име, средње слово и презиме	Област компетенције (научног интересовања)	ORCID iD	Publons identifier
Владимир А. Катић	енергетска електроника, електричне машине, електромоторни погони, квалитет електричне енергије, обновљиви извори електричне енергије	https://orcid.org/0000-0002-0138-8807	https://publons.com/a/1318533
Мирко С. Козић	механика флуида, нумеричка динамика флуида, аеродинамичка оптерећења	https://orcid.org/0000-0002-7287-0780	https://publons.com/a/1627334
Сања Љ. Корица	физика	https://orcid.org/0000-0002-7915-9430	https://publons.com/a/1595795
Ана И. Костов	материјали, хемијске технологије, металургија	https://orcid.org/0000-0000-0001-6436-9091	https://publons.com/a/1609813
Комлен Г. Лаловић	информационе технологије, програмирање, заштита података	https://orcid.org/0000-0000-0002-4590-2185	https://publons.com/a/1610913
Славољуб С. Лекић	битехнологија	https://orcid.org/0000-0002-4834-3550	https://publons.com/a/1600615
Марија З. Малнар	електротехника – телекомуникације	https://orcid.org/0000-0003-1416-8253	https://publons.com/a/1605030
Василије М. Мановић	заштита животне средине, хемијско инжењерство	https://orcid.org/0000-0002-8377-7717	/
Јаромир Марес	логистика, логистичка подршка, заштита животне средине, заштита на раду, процена ризика	https://orcid.org/0000-0002-1337-3821	https://publons.com/a/1658858
Бојан Ч. Милановић	микроталасна техника, антене	https://orcid.org/0000-0003-0683-4500	https://publons.com/a/1604390
Зоран Ђ. Миљковић	технологија машинске обраде, роботика, вештачка интелигенција, аутономни системи и машинско учење, вештачке неуронске мреже, интелигентни технолошки системи и процеси, методе одлучивања	https://orcid.org/0000-0001-9706-6134	https://publons.com/a/1410489

Име, средње слово и презиме	Област компетенције (научног интересовања)	ORCID iD	Publons identifier
Надица С. Миљковић	биомедицинска обрада сигнала, е-здравље, електротехника, биомедицински инжењеринг, електрофизиологија	https://orcid.org/0000-0002-3933-6076	https://publons.com/a/1628814
Срђан Т. Митровић	мобилни роботи, управљање у реалном времену, фази логика, фази управљање, микропроцесорски системи, управљање системима (аутоматика), алгоритми навигације возила, бродски борбени и навигациони системи	https://orcid.org/0000-0002-1287-2792	https://publons.com/a/1467408
Дејан М. Мицковић	конструкција класичног наоружања, аутоматска оружја, унутрашња балистика	/	/
Драган Д. Младеновић	информациона безбедност, сајбер безбедност, сајбер сукоби, сајбер ратовање, информационе технологије, међународно право, нове технологије	https://orcid.org/0000-0003-4530-633X	https://publons.com/a/1604465
Славко Р. Муждека	моторна возила, борбена возила	https://orcid.org/0000-0002-6189-9473	https://publons.com/a/1599773
Бобан З. Павловић	телекомуникационе мреже, квалитет сервиса, телекомуникациони саобраћај	https://orcid.org/0000-0002-5476-7894	https://publons.com/a/1606407
Драган С. Памучар	саобраћајно инжењерство, операциона истраживања	https://orcid.org/0000-0001-8522-1942	https://publons.com/a/1239906
Сретен Р. Перић	машинство	https://orcid.org/0000-0002-7270-5187	https://publons.com/a/1620400

Име, средње слово и презиме	Област компетенције (научног интересовања)	ORCID iD	Publons identifier
Славко Ј. Покорни	поузданост, расположивост и одржавање техничких система (хардвер, софтвер, човек); инфрацрвено зрачење; информационе и комуникационе технологије	https://orcid.org/0000-0002-3173-597X	https://publons.com/a/1557795
Мирослав В. Поповић	рачунарска техника	https://orcid.org/0000-0002-1118-6491	https://publons.com/a/1558230
Стојан Н. Раденовић	математика	https://orcid.org/0000-0001-8254-6688	https://publons.com/a/1596168
Југослав Р. Радуловић	муниција, менаџмент, квалитет	https://orcid.org/0000-0002-4003-7209	https://publons.com/a/1611389
Андреја Б. Самчовић	мултимедија, компресија сигнала и слике, безбедност информација	https://orcid.org/0000-0001-6432-2816	https://publons.com/a/1597639
Влада С. Соколовић	одржавање, техничка подршка, интегрисани навигацијски системи, GPS, GNSS, сателитски системи, логистика	https://orcid.org/0000-0003-0782-0506	https://publons.com/a/1559198
Срећко С. Стопић	хидрометалургија, нанотехнологија, хемијске синтезе, рециклирање, заштита животне средине	https://orcid.org/0000-0002-1752-5378	https://publons.com/a/1597645
Љубиша К. Танчић	унутрашња балистика, наоружање	https://orcid.org/0000-0003-1242-9333	https://publons.com/a/1623091
Иван А. Тот	базе података, информациони системи, заштита информационих система	https://orcid.org/0000-0002-5862-9042	https://publons.com/a/1558155
Вадим Л. Хајков	унутрашња и спољна балистика, рачунарска математика	https: //orcid.org/0000-0003-1433-3562	https://publons.com/a/1655562
Обрад Т. Чабаркапа	индустријска својина, заштита интелектуалне и индустријске својине, патентна заштита, управљање пројектима, машинство, наоружање, пројект менаџмент	https://orcid.org/0000-0002-3949-8227	https://publons.com/a/1600393

Име, средње слово и презиме	Област компетенције (научног интересовања)	ORCID iD	Publons identifier
Нада М. Читаковић	физика	https://orcid.org/0000-0003-2813-2323	https://publons.com/a/1601584
Томислав Б. Шекара	управљање процесима са концентрисаним и распоређеним параметрима; оптимални индустријски регулатори; фракциони закони управљања са применом у индустрији; карактеризација процеса; адекватна дискретизација и обрада сигнала; сензори и актуатори; компензација и уштеда електричне енергије у дистрибутивним електроенергетским системима	https://orcid.org/0000-0001-8031-3135	https://publons.com/a/1596795
Горан П. Шимић	информациони системи, рачунарство, програмирање, базе података, вештачка интелигенција	https://orcid.org/0000-0002-7563-699X	https://publons.com/a/1600386

СПИСОК РЕЦЕНЗЕНТОВ ЖУРНАЛА *«ВОЕННО-ТЕХНИЧЕСКИЙ ВЕСТНИК»*

ФИО	Области научной деятельности	ORCID iD	Publons identifier
Марко Д. Андреич	логистика	https://orcid.org/0000-0002-6753-9786	https://publons.com/a/1597995
Миленко С. Андрич	цифровая обработка сигналов, распознавание и классификация форм, сигналы и системы, случайные процессы в телекоммуникационных и радиолокационных системах, частотно-временная обработка сигналов, фазовые логические системы	https://orcid.org/0000-0001-9038-0876	https://publons.com/a/1615557
Милош Ж. Арсич	управление логистикой	https://orcid.org/0000-0001-7853-0819	https://publons.com/a/1604531
Саша Т. Бакрач	охрана окружающей среды, оценка экологических рисков, экологический менеджмент	https://orcid.org/0000-0003-0211-3765	https://publons.com/a/1597282
Воислав Й. Батинич	общие машиностроительные конструкции	https://orcid.org/0000-0001-6786-7846	https://publons.com/a/1643029
Стеван М. Бербер	телекоммуникации, беспроводные сети, CDMA, OFDM системы, сенсорные сети, вычислительные системы реального времени, обработка стохастических сигналов	https://orcid.org/0000-0002-2432-3088	https://publons.com/a/1610900
Драгана Бечейски-Вуяклия	бизнес-информационные системы, бизнес-аналитика, ERP, управление ИТ	https://orcid.org/0000-0002-9615-3620	https://publons.com/a/1623502
Дарко И. Божанич	принятие многокритериальных решений, управление в области обороны	https://orcid.org/0000-0002-9657-0889	https://publons.com/a/1524010
Бобан П. Бонджулич	цифровая обработка изображений, обработка цифрового сигнала и его приложения, оценка качества изображения и видео, слияние изображений	https://orcid.org/0000-0002-8850-9842	https://publons.com/a/1603131

ФИО	Области научной деятельности	ORCID iD	Publons identifier
Мирко А. Борисов	геодезическая инженерия, геоматика, геоинформационные системы, цифровые модели местности, картография, геодезия, мультимедийная картография, веб-картография	https://orcid.org/0000-0002-7234-6372	https://publons.com/a/1613254
Углеша С. Бугарич	исследование операций, теория массового обслуживания, теротехнология обслуживания, транспортно-складские системы	https://orcid.org/0000-0003-2459-2656	https://publons.com/a/1596666
Славиша И. Влачич	воздушное движение, управление системой; автоматическое управление; автомобильная навигация; морские боевые и навигационные системы; моделирование	https://orcid.org/0000-0001-9336-0512	https://publons.com/a/1604062
Драголюб А. Вуич	прикладная механика, диагностика, сложные системы технического обслуживания	https://orcid.org/0000-0001-6999-6828	https://publons.com/a/1627346
Иван Б. Вулич	информационные системы, географические информационные системы	https://orcid.org/0000-0002-5161-5422	https://publons.com/a/1606268
Младен М. Вуруна	военно-химическая инженерия (топлива, токсикология, РХБ защита, охрана окружающей среды)	https://orcid.org/0000-0002-3558-4312	https://publons.com/a/1626384
Любомир Й. Гигович	география, географическая информационная система, геопространственный анализ	https://orcid.org/0000-0002-8388-3624	https://publons.com/a/1418283
Миро Й. Говедарица	геоинформатика	https://orcid.org/0000-0003-1698-0800	https://publons.com/a/1539597
Бобан Д. Джорович	транспортные процессы и методы, транспортные сети, организация транспорта	https://orcid.org/0000-0001-8133-2389	https://publons.com/a/1633020

ФИО	Области научной деятельности	ORCID iD	Publons identifier
Владо П. Джуркович	прикладная механика твердых и деформируемых тел	https://orcid.org/0000-0002-5064-4117	https://publons.com/a/1622194
Желько М. Джурович	обработка сигналов, управление системой, распознавание формата	https://orcid.org/0000-0002-6076-442X	/
Горан Д. Дикич	системы автоматического управления, прицеливания, системы наведения и телеуправления ракет	https://orcid.org/0000-0002-0858-1415	https://publons.com/a/1634756
Снежана М. Драгичевич	энергоэффективность, машиностроение, солнечная энергия, теплотехника термоинженерия	https://orcid.org/0000-0002-6244-0111	https://publons.com/a/1604121
Чедомир В. Дубока	двигатели, автомобили	https://orcid.org/0000-0003-2944-2278	https://publons.com/a/1627827
Дамир Д. Еркович	вооружение, численный анализ, CFD вычислительная гидродинамика, внешняя баллистика, баллистика, терминальная баллистика, интегрирование вооружения	https://orcid.org/0000-0001-5182-7057	https://publons.com/a/1500127
Боян М. Зрнич	сенсорные системы, стратегическое планирование	https://orcid.org/0000-0002-0961-993X	/
Вукица М. Йованович	машиностроение	https://orcid.org/0000-0002-8626-903X	https://publons.com/a/1656683
Митар Т. Йоцанович	трибология и теория смазки, техническое обслуживание технологических систем, гидравлических систем	https://orcid.org/0000-0003-1088-5028	https://publons.com/a/1596778
Радован М. Каркалич	химическая технология (ядерно-химическая-биологическая защита, обнаружение, идентификация и дезактивация)	https://orcid.org/0000-0002-8074-7264	https://publons.com/a/1602667

ФИО	Области научной деятельности	ORCID iD	Publons identifier
Владимир А. Катич	силовая электроника, электрические машины, электрические приводы, качество электроэнергии, возобновляемые источники энергии	https://orcid.org/0000-0002-0138-8807	https://publons.com/a/1318533
Мирко С. Козич	механика жидкостей, вычислительная динамика жидкостей, аэродинамические нагрузки	https://orcid.org/0000-0002-7287-0780	https://publons.com/a/1627334
Саня Л. Корица	физика	https://orcid.org/0000-0002-7915-9430	https://publons.com/a/1595795
Ана И. Костов	материалы, химические технологии, металлургия	https://orcid.org/0000-0000-0001-6436-9091	https://publons.com/a/1609813
Комлен Г. Лалович	информационные технологии, программирование, защита данных	https://orcid.org/0000-0000-0002-4590-2185	https://publons.com/a/1610913
Славолюб С. Лекич	биотехнология	https://orcid.org/0000-0002-4834-3550	https://publons.com/a/1600615
Мария З. Малнар	электротехника – телекоммуникации	https://orcid.org/0000-0003-1416-8253	https://publons.com/a/1605030
Василие М. Манович	охрана окружающей среды, химическая инженерия	https://orcid.org/0000-0002-8377-7717	/
Яромир Марес	логистика, логистическая поддержка, охрана окружающей среды, охрана труда, оценка рисков	https://orcid.org/0000-0002-1337-3821	https://publons.com/a/1658858
Боян Ч. Миланович	микроволновая техника, антенны	https://orcid.org/0000-0003-0683-4500	https://publons.com/a/1604390
Зоран Дж. Милькович	технология производства, процессы обработки, робототехника, искусственный интеллект, автономные системы и машинное обучение, искусственные нейронные сети, интеллектуальные производственные системы и процессы, принятие решений	https://orcid.org/0000-0001-9706-6134	https://publons.com/a/1410489

ФИО	Области научной деятельности	ORCID iD	Publons identifier
Надица С. Милкович	обработка биомедицинских сигналов, электронное здравоохранение, электротехника, биомедицинская инженерия, электрофизиология	https://orcid.org/0000-0002-3933-6076	https://publons.com/a/1628814
Срджан Т. Митрович	мобильные роботы, управление в реальном времени, нечеткая логика, нечеткое управление, микропроцессорные системы, управление системами автоматики, алгоритмы навигации транспорта, навигационные системы для судов и боевого транспорта	https://orcid.org/0000-0002-1287-2792	https://publons.com/a/1467408
Деян М. Мицкович	конструкция классического конвенционального вооружения, автоматическое оружие, внутренняя баллистика	/	/
Драган, Д. Младенович	информационная безопасность, кибербезопасность, кибер-конфликт, кибер-война, информационные технологии, международное право, новые технологии	https://orcid.org/0000-0003-4530-633X	https://publons.com/a/1604465
Славко Р. Муждека	транспортные средства, боевые транспортные средства	https://orcid.org/0000-0002-6189-9473	https://publons.com/a/1599773
Бобан З. Павлович	телекоммуникационные сети, качество обслуживания, телекоммуникационный трафик	https://orcid.org/0000-0002-5476-7894	https://publons.com/a/1606407
Драган С. Памучар	транспортная инженерия, оперативные исследования	https://orcid.org/0000-0001-8522-1942	https://publons.com/a/1239906
Сретен Р. Перич	машиностроение	https://orcid.org/0000-0002-7270-5187	https://publons.com/a/1620400

ФИО	Области научной деятельности	ORCID iD	Publons identifier
Славко Й. Покорни	надежность, доступность и техническое обслуживание технических систем (аппаратное обеспечение, программное обеспечение, человек); инфракрасное излучение; информационно-коммуникационные технологии	https://orcid.org/0000-0002-3173-597X	https://publons.com/a/1557795
Мирослав В. Попович	компьютерная инженерия	https://orcid.org/0000-0002-1118-6491	https://publons.com/a/1558230
Стоян Н. Раденович	математика	https://orcid.org/0000-0001-8254-6688	https://publons.com/a/1596168
Югослав Р. Радулович	боеприпасы, менеджмент, качество	https://orcid.org/0000-0002-4003-7209	https://publons.com/a/1611389
Андрея Б. Самчович	мультимедиа, сжатие сигнала и изображений, информационная безопасность	https://orcid.org/0000-0001-6432-2816	https://publons.com/a/1597639
Влада С. Соколович	техническое обслуживание, техническая поддержка, интегрированные навигационные системы, GPS, GNSS, спутниковые системы, логистика	https://orcid.org/0000-0003-0782-0506	https://publons.com/a/1559198
Сречко С. Стопич	гидрометаллургия, нанотехнологии, химический синтез, рециклирование, охрана окружающей среды	https://orcid.org/0000-0002-1752-5378	https://publons.com/a/1597645
Любиша К. Танчич	внутренняя баллистика, вооружение	https://orcid.org/0000-0003-1242-9333	https://publons.com/a/1623091
Иван А. Тот	базы данных, информационные системы, защита информационных систем	https://orcid.org/0000-0002-5862-9042	https://publons.com/a/1558155
Вадим Л. Хайков	внутренняя и внешняя баллистика, компьютерная математика	https: //orcid.org/0000-0003-1433-3562	https://publons.com/a/1655562

ФИО	Области научной деятельности	ORCID iD	Publons identifier
Обрад Т. Чабаркапа	промышленная собственность, защита интеллектуальной и промышленной собственности, патентная защита, управление проектами, машиностроение, вооружение, управление проектами	https://orcid.org/0000-0002-3949-8227	https://publons.com/a/1600393
Нада М. Читакович	физика	https://orcid.org/0000-0003-2813-2323	https://publons.com/a/1601584
Томислав Б. Шекара	управление процессами концентрированных и распределенных параметров, оптимальные промышленные регуляторы, фракционные методы управления в промышленном секторе, характеризация процессов, соответствующая дискретизация и обработка сигналов, сенсоры и актуаторы, компенсация и сбережение электроэнергии в распределительных электроэнергетических системах	https://orcid.org/0000-0001-8031-3135	https://publons.com/a/1596795
Горан П. Шимич	информационные системы, информатика, программирование, базы данных, искусственный интеллект	https://orcid.org/0000-0002-7563-699X	https://publons.com/a/1600386

LIST OF REFEREES OF THE MILITARY TECHNICAL COURIER

Name, middle initial and surname	Scientific research competence area	ORCID iD	Publons identifier
Marko D. Andrejić	logistics	https://orcid.org/0000-0002-6753-9786	https://publons.com/a/1597995
Milenko S. Andrić	digital signal processing, pattern recognition and classification, signals and systems, stochastic processes in telecommunications and radar systems, time-frequency signal processing, phase logic systems	https://orcid.org/0000-0001-9038-0876	https://publons.com/a/1615557
Miloš Ž. Arsić	logistics management	https://orcid.org/0000-0001-7853-0819	https://publons.com/a/1604531
Saša T. Bakrač	environmental protection, environmental risk assessment, eco-management	https://orcid.org/0000-0003-0211-3765	https://publons.com/a/1597282
Vojislav J. Batinić	general mechanical engineering constructions	https://orcid.org/0000-0001-6786-7846	https://publons.com/a/1643029
Dragana Bečejski-Vujaklija	business information systems, business intelligence, ERP, IT management	https://orcid.org/0000-0002-9615-3620	https://publons.com/a/1623502
Stevan M. Berber	telecommunications, wireless communications, CDMA, OFDM systems, sensor network, computer systems in real time, processing of stochastic signals	https://orcid.org/0000-0002-2432-3088	https://publons.com/a/1610900
Boban P. Bondžulić	digital image processing, digital signal processing and its applications, image and video quality assessment, image fusion	https://orcid.org/0000-0002-8850-9842	https://publons.com/a/1603131
Mirko A. Borisov	geodetic engineering, geomatics, geographic information systems, digital terrain models, cartography, geodesy, multimedia cartography, web mapping	https://orcid.org/0000-0002-7234-6372	https://publons.com/a/1613254
Darko I. Božanić	multi-criteria decision making, management in defense	https://orcid.org/0000-0002-9657-0889	https://publons.com/a/1524010

Name, middle initial and surname	Scientific research competence area	ORCID iD	Publons identifier
Uglješa S. Bugarić	operational research, mass service, terotechnology – maintenance, transportation and storage systems	https://orcid.org/0000-0003-2459-2656	https://publons.com/a/1596666
Obrad T. Čabarkapa	industrial property, protection of intellectual and industrial property, patent protection, project management, mechanical engineering, armaments, project management	https://orcid.org/0000-0002-3949-8227	https://publons.com/a/1600393
Nada M. Čitaković	physics	https://orcid.org/0000-0003-2813-2323	https://publons.com/a/1601584
Goran D. Dikić	automatic control systems, target tracking, missile guidance and control systems	https://orcid.org/0000-0002-0858-1415	https://publons.com/a/1634756
Snežana M. Dragićević	energy efficiency, mechanical engineering, solar energy, thermal engineering	https://orcid.org/0000-0002-6244-0111	https://publons.com/a/1604121
Čedomir V. Duboka	engines, motor vehicles	https://orcid.org/0000-0003-2944-2278	https://publons.com/a/1627827
Boban D. Đorović	processes and methods in traffic and transportation, transportation networks, transport organization	https://orcid.org/0000-0001-8133-2389	https://publons.com/a/1633020
Vlado P. Đurković	applied mechanics of rigid and deformable bodies	https://orcid.org/0000-0002-5064-4117	https://publons.com/a/1622194
Željko M. Đurović	signal processing, systems control, pattern recognition	https://orcid.org/0000-0002-6076-442X	
Ljubomir J. Gigović	geography, geographic information system, geospatial analysis	https://orcid.org/0000-0002-8388-3624	https://publons.com/a/1418283
Miro J. Govedarica	geoinformatics	https://orcid.org/0000-0003-1698-0800	https://publons.com/a/1539597
Damir D. Jerković	weapons, numerical analysis, CFD simulation, external ballistics, ballistics, terminal ballistics, weapons integration	https://orcid.org/0000-0001-5182-7057	https://publons.com/a/1500127
Mitar T. Jocanović	tribology and theory of lubrication, maintenance of technological systems, hydraulic systems	https://orcid.org/0000-0003-1088-5028	https://publons.com/a/1596778
Vukica M. Jovanović	mechanical engineering	https://orcid.org/0000-0002-8626-903X	https://publons.com/a/1656683

Name, middle initial and surname	Scientific research competence area	ORCID iD	Publons identifier
Radovan M. Karkalić	chemical technology (nuclear-chemical-biological protection, detection, identification and decontamination)	https://orcid.org/0000-0002-8074-7264	https://publons.com/a/1602667
Vladimir A. Katić	power electronics, electric machines, electric power systems and stations, electric power quality, renewable energy sources	https://orcid.org/0000-0002-0138-8807	https://publons.com/a/1318533
Vadim L. Khaikov	internal and external ballistics, computer mathematics	https://orcid.org/0000-0003-1433-3562	https://publons.com/a/1655562
Sanja Lj. Korica	physics	https://orcid.org/0000-0002-7915-9430	https://publons.com/a/1595795
Ana I. Kostov	materials science, chemical technologies, metallurgy	https://orcid.org/0000-0000-0001-6436-9091	https://publons.com/a/1609813
Mirko S. Kozić	mechanics of fluids, computational fluid dynamics, aerodynamic load	https://orcid.org/0000-0002-7287-0780	https://publons.com/a/1627334
Komlen G. Lalović	information technology, programming, data protection	https://orcid.org/0000-0000-0002-4590-2185	https://publons.com/a/1610913
Slavoljub S Lekić	biotechnology	https://orcid.org/0000-0002-4834-3550	https://publons.com/a/1600615
Marija Z. Malnar	electrical engineering - telecommunications	https://orcid.org/0000-0003-1416-8253	https://publons.com/a/1605030
Vasilije M. Manović	environmental protection, chemical engineering	https://orcid.org/0000-0002-8377-7717	/
Jaromir Mares	logistics, logistic support,environmental protection, protection at work, risk assessment	https://orcid.org/0000-0002-1337-3821	https://publons.com/a/1658858
Dejan M. Micković	construction of classic weapons, automatic weapons, internal ballistics	/	/
Bojan Č. Milanović	microwave engineering, antennas	https://orcid.org/0000-0003-0683-4500	https://publons.com/a/1604390
Nadica S. Miljković	biomedical signal processing, e-health, electrical engineering, biomedical engineering, electrophysiology	https://orcid.org/0000-0002-3933-6076	https://publons.com/a/1628814

Name, middle initial and surname	Scientific research competence area	ORCID iD	Publons identifier
Zoran Đ. Miljković	manufacturing technology, machining processes, robotics, artificial intelligence, autonomous systems and machine learning, artificial neural networks, intelligent manufacturing systems and processes, decision-making methods	https://orcid.org/0000-0001-9706-6134	https://publons.com/a/1410489
Srđan T. Mitrović	mobile robots, real time control, fuzzy logic, fuzzy control, microprocessing systems, system control (automation), vehicle navigation algorithms, naval combat and navigation systems	https://orcid.org/0000-0002-1287-2792	https://publons.com/a/1467408
Dragan D. Mladenović	information security, cyber security, cyber conflict, cyber warfare, information technology, international law, emerging technologies	https://orcid.org/0000-0003-4530-633X	https://publons.com/a/1604465
Slavko R. Muždeka	motor vehicles, combat vehicles	https://orcid.org/0000-0002-6189-9473	https://publons.com/a/1599773
Dragan S. Pamučar	traffic engineering, operational research	https://orcid.org/0000-0001-8522-1942	https://publons.com/a/1239906
Boban Z. Pavlović	telecommunication networks, quality of service, telecommunication traffic	https://orcid.org/0000-0002-5476-7894	https://publons.com/a/1606407
Sreten R. Perić	mechanical engineering	https://orcid.org/0000-0002-7270-5187	https://publons.com/a/1620400
Slavko, J. Pokorni	reliability, maintainability and system maintenance (hardware, software, human), infrared radiation, information and communication technologies	https://orcid.org/0000-0002-3173-597X	https://publons.com/a/1557795
Miroslav V. Popović	computer engineering	https://orcid.org/0000-0002-1118-6491	https://publons.com/a/1558230
Stojan N. Radenović	mathematics	https://orcid.org/0000-0001-8254-6688	https://publons.com/a/1596168
Jugoslav R. Radulović	ammunition, management, quality	https://orcid.org/0000-0002-4003-7209	https://publons.com/a/1611389

Name, middle initial and surname	Scientific research competence area	ORCID iD	Publons identifier
Andreja B. Samčović	multimedia, image and signal compression, information security	https://orcid.org/0000-0001-6432-2816	https://publons.com/a/1597639
Vlada S. Sokolović	maintenance, technical support, integrated navigation systems, GPS, GNSS, satellite systems, logistics	https://orcid.org/0000-0003-0782-0506	https://publons.com/a/1559198
Srećko S. Stopić	hydrometallurgy, nanotechnology, chemical synthesis, recycling, environmental protection	https://orcid.org/0000-0002-1752-5378	https://publons.com/a/1597645
Tomislav B. Šekara	control of processes with concentrated and distributed parameters, industrial regulators with optimum performance, fraction laws of control in industrial application, process characterisation, adequate signal discretisation and processing, sensors and actuators, electric energy compensation and saving in electric energy distribution systems	https://orcid.org/0000-0001-8031-3135	https://publons.com/a/1596795
Goran P. Šimić	Inform. systems, computer science, programming, databases, artificial intelligence	https://orcid.org/0000-0002-7563-699X	https://publons.com/a/1600386
Ljubiša K. Tančić	internal ballistics, armaments	https://orcid.org/0000-0003-1242-9333	https://publons.com/a/1623091
Ivan A. Tot	databases, inform.systems, information system security	https://orcid.org/0000-0002-5862-9042	https://publons.com/a/1558155
Slaviša I. Vlačić	air traffic, system control, automatic control, vehicle navigation, naval combat and navigation systems, simulation	https://orcid.org/0000-0001-9336-0512	https://publons.com/a/1604062
Dragoljub A. Vujić	applied mechanics, diagnostics, sofisticated systems for technical system maintenance	https://orcid.org/0000-0001-6999-6828	https://publons.com/a/1627346
Ivan B. Vulić	information systems, geographic information systems	https://orcid.org/0000-0002-5161-5422	https://publons.com/a/1606268
Mladen M. Vuruna	military-chemical engineering (propulsion agents, toxicological agents, protection against NHB weapons, environmental protection)	https://orcid.org/0000-0002-3558-4312	https://publons.com/a/1626384
Bojan M. Zrnić	sensor systems, strategic planning	https://orcid.org/0000-0002-0961-993X	/

ИЗЈАВА О ЕТИЧКОМ ПОСТУПАЊУ
ЭТИЧЕСКИЙ КОДЕКС
PUBLICATION ETHICS STATEMENT

ИЗЈАВА ВОЈНОТЕХНИЧКОГ ГЛАСНИКА О ЕТИЧКОМ ПОСТУПАЊУ

Објављивање чланака након стручне рецензије основна је делатност научног часописа *Војнотехнички гласник*. Неопходно је постићи сагласност о етичким начелима у поступцима свих учесника приликом објављивања чланака, од аутора, Редакције часописа и стручних рецензената до издавача.

Обавезе Редакције *Војнотехничког гласника*

Уредништво *Војнотехничког гласника* не тражи од аутора плаћање накнаде за аплицирање чланка за објављивање. Читав поступак уређивања и објављивања чланка за ауторе је потпуно бесплатан.

Редакција *Војнотехничког гласника* одговорна је за доношење одлуке који ће од приспелих чланака бити одабран за објављивање. Уредник не сме имати сукоб интереса у вези са рукописима које разматрају. Ако такав сукоб интереса постоји, о избору рецензената и судбини рукописа одлучује уредништво. Чланови уређивачког одбора код којих постоји сукоб интереса дужни су да се повуку из процедуре.

Редакција треба да поступа у складу с политиком Уређивачког одбора *Војнотехничког гласника* као и у складу са законским прописима који се односе на клевету, кршење ауторских права и плагијате. Редакција може да се консултује са члановима Уређивачког одбора или рецензентима при доношењу одлуке.

Редакција процењује садржај рукописа независно од расе, пола, полне оријентације, религијских уверења, етничког порекла, политичких уверења и државне припадности аутора.

У свом раду, према препоруци Центра за евалуацију у образовању и науци (ЦЕОН), Редакција користи електронски систем уређивања АСИСТЕНТ, који омогућава транспарентност и јавност рада, подразумевајући пуну одговорност за прихватање и објављивање чланка.

Пре слања на рецензију Редакција проверава да ли је садржај рукописа плагијат, коришћењем сервиса iThenticate (CrossRef и CrossCheck). Према стандардима које часопис примењује, плагирање, односно преузимање туђих идеја, речи или других облика креативног израза и представљање као својих, представља грубо кршење научне и издавачке етике. Плагирање може да укључује и кршење ауторских права, што је законом кажњиво. Плагијат обухвата: дословно или готово дословно преузимање или смишљено парафразирање (у циљу прикривања плагијата) делова текстова других аутора без јасног указивања на извор или обележавање копираних фрагмената (на пример, коришћењем наводника); копирање слика или табела из туђих радова без правилног навођења извора и/или без дозволе аутора или носилаца ауторских права. Рукописи код којих постоје јасне индиције да се ради о плагијату биће аутоматски одбијени.

Часопис примењује „двоструки слепи поступак рецензије“ чланака, који подразумева да аутори не знају ко су им рецензенти, нити су рецензентима познати аутори.

Нико из уређивачке куће не сме да открије ниједну информацију о пристиглом рукопису икоме, осим аутору, рецензентима, потенцијалним рецензентима, другим саветницима уређивачке куће и издавачу, према потреби.

Необјављен материјал из пристиглих рукописа не сме да се користи за истраживачки рад уређивача, осим са изричитим писменим одобрењем аутора.

Редакција се обавезује да ће повући већ објављени чланак у случају накнадног откривања следећих околности у вези рада:

– плагијаризам,

– аутоплагијаризам,

– рад је већ објављен у другом часопису или некој другој публикацији,

– нетачни подаци о ауторству (присвајање туђег рада, навођење аутора који нису учествовали у писању рада, изостављање аутора који су учествовали у писању рада),

– сукоб интереса,

– лажирање или фабриковање резултата,

– недозвољене техничке интервенције на сликама,

– озбиљнија техничка грешка, као што је изостављање делова текста, грешка у репродукцији илустративног материјала.

Стандарди за разрешавање ситуација када мора доћи до повлачења рада дефинисани су од стране библиотека и научних тела, а иста пракса је усвојена и од стране часописа: у електронској верзији изворног чланка (оног који се повлачи) успоставља се веза (HTML линк) са обавештењем о повлачењу. Повучени чланак се чува у изворној форми, али са воденим жигом на PDF документу, на свакој страници, који указује да је чланак повучен (RETRACTED).

Опозиви и исправке се публикују према захтевима ЦЕОН-а (http://www.ceon.rs/pdf/postupanje_s_nelegitimnim_radovima.pdf) као издавача националног цитатног индекса где се метаподаци опозива и опзваних радова морају означити одговарајућим упозорењима и међусобно повезати унакрсним линковима.

Обавезе рецензената

Рецензенти су дужни да стручно, аргументовано, непристрасно и у задатим роковима доставе уреднику оцену научне вредности рукописа. Рецензенти евалуирају радове у односу на усклађеност теме рада са профилом часописа, релевантност истраживане области и примењених метода, оригиналност и научну релевантност података изнесених у рукопису, стил научног излагања и опремљеност текста научним апаратом.

Стручни рецензент помаже Редакцији у доношењу одлуке, а посредством контаката са ауторима преко Редакције може да помаже и ауторима на побољшавању текста рада.

Уколико изабрани рецензент сматра да није довољно квалификована да изврши рецензију истраживања у рукопису или је пак спречен да заврши и достави рецензију у договореном року, о томе треба благовремено да обавести Редакцију.

Сваки рукопис прихваћен на рецензију мора да се третирати као поверљив документ. Не сме се показивати трећим лицима нити дискутовати са њима, осим када то одобри Редакција.

Рецензија треба да буде објективна. Неприхватљива је лична критика аутора. Рецензенти треба јасно да образложе своје ставове и поткрепе их аргументима.

Рецензенти треба да идентификују релевантне постојеће радове које аутор није цитирао. Свака претходно јавно саопштена тврдња или аргумент треба да буду

пропраћени одговарајућим цитатом. Дужност рецензента је да скрене пажњу уреднику на значајна поклапања или сличност рукописа са већ објављеним радом, уколико о томе има лична сазнања.

Информације и идеје до којих се дошло стручном рецензијом поверљивог су карактера и не смеју се користити за сопствене потребе. Рецензенти не би требало да примају рукописе који их доводе у сукоб интереса на основу конкуренције, заједничког рада или других односа с било којим аутором, компанијом или институцијом повезаним с радом.

Обавезе аутора

Аутори гарантују да рукопис представља њихов оригиналан допринос, да није објављен раније и да се не разматра за објављивање на другом месту. Истовремено предавање истог рукописа у више часописа представља кршење етичких стандарда. Такав рукопис се моментално искључује из даљег разматрања.

Када аутори пишу о оригиналном истраживању треба прецизно да прикажу обављени рад и да објективно изложе његов значај. Подаци треба да буду прецизно наведени. Чланак треба да садржи довољно детаља и референци да би могао да се репродукује. Лажне или намерно нетачне тврдње представљају неетичко поступање и неприхватљиве су.

Аутори треба да обезбеде необрађене податке у вези са чланком и пруже их на увид Редакцији, као и јавни приступ тим подацима, ако је то могуће, и да, у сваком случају, буду спремни да сачувају те податке у разумном року после објављивања.

Аутори треба да напишу потпуно оригиналне радове, а ако су користили радове и/или формулације других, онда то треба да наведу на одговарајући начин.

У принципу, аутори би требало да објаве рукопис који се суштински бави истим истраживањем само у једном часопису или примарној публикацији. Слање истог рукописа у више редакција часописа у исто време представља неетичко понашање и неприхватљиво је.

Обавезно је да аутор наведе радове које је користио у писању рукописа, као и да цитира публикације које су утицале на његов рад.

Ауторство треба да буде ограничено на оне који су значајно допринели идеји, њеном обликовању, извођењу или интерпретацији у датом истраживању. Сви који су значајно допринели раду треба да буду наведени као коаутори. Ако су појединци били битни у појединим аспектима истраживачког пројекта, треба им у захвалници одати признање за допринос.

Аутор треба да се постара да сви коаутори буду наведени као такви, као и да међу наведеним нема оних који то не заслужују. Ауторова дужност је да сви коаутори виде и одобре финалну верзију рада, као и да одобре његово објављивање.

Ако се у истраживању појављују хемијска једињења, поступци или опрема који су опасни по здравље људи или животиња, аутор то мора јасно да назначи у рукопису.

Сваки аутор треба да наведе у рукопису све врсте финансијских и осталих значајних конфликата интереса који би могли да утичу на резултате или интерпретацију његовог рада. Сви извори финансијске подршке треба да буду такође наведени.

Када аутор открије материјалну грешку или нетачност у свом објављеном раду, његова је дужност да одмах обавести Редакцију часописа или издавача и да сарађује са Редакцијом при повлачењу или кориговању рада.

Разрешавање спорних ситуација

Сваки појединац или институција могу у било ком тренутку да уреднику и/или уредништву пријаве сазнања о кршењу етичких стандарда и другим неправилностима и да о томе доставе неопходне информације/доказе. Поступак провере изнесених доказа одвијаће се у складу са следећим принципима: уредништво ће донети одлуку о покретању поступка који има за циљ проверу изнесених навода и доказа; током тог поступка сви изнесени докази сматраће се поверљивим материјалом и биће предочени само оним лицима која су директно укључена у поступак; лицима за која се сумња да су прекршила етичке стандарде биће дата могућност да одговоре на оптужбе изнесене против њих; ако се установи да је заиста дошло до неправилности, процениће се да ли их треба окарактерисати ако мањи прекршај или грубо кршење етичких стандарда. Ситуације окарактерисане као мањи прекршај решаваће се у директној комуникацији са лицима која су прекршај учинила, без укључивања трећих лица, нпр.: обавештавањем аутора/рецензената да је дошло до мањег прекршаја који је проистекао из неразумевања или погрешне примене академских стандарда; слањем упозорења аутору/рецензенту који је учинио мањи прекршај. У случају грубог кршења етичких стандарда, уредништво доноси одлуке о даљим акцијама. Мере које ће предузети могу бити следеће (и могу се примењивати појединачно или истовремено): објављивање саопштења или уводника у ком се описује случај кршења етичких стандарда; слање службеног обавештења руководиоцима или послодавцима аутора/рецензента; повлачење објављеног рада у складу са процедуром описаном под Повлачење већ објављених радова; ауторима ће бити забрањено да током одређеног периода шаљу радове у часопис; упознавање релевантних стручних организација или надлежних органа са случајем како би могли да предузму одговарајуће мере. Приликом разрешавања спорних ситуација редакција часописа редакција се руководи смерницама и препорукама Одбора за етику у издаваштву (Committee on Publication Ethics – COPE): http://publicationethics.org/resources/.

Одрицање одговорности

Изнесени ставови у објављеним радовима не изражавају ставове уредника и чланова редакције часописа. Аутори преузимају правну и моралну одговорност за идеје изнесене у својим радовима. Издавач неће сносити никакву одговорност у случају испостављања било каквих захтева за накнаду штете.

Рекламирање

Није дозвољено рекламирање у *Војнотехничком гласнику*.

КОДЕКС ПРОФЕССИОНАЛЬНОЙ ЭТИКИ ЖУРНАЛА *«ВОЕННО-ТЕХНИЧЕСКИЙ ВЕСТНИК»*

Публикация статьей после их профессиональной рецензии является основной деятельностью научного журнала «*Военно-технический вестник*». В первую очередь необходимо достичь договоренности об этических нормах и принципах, применяемых ко всем участникам в процессе выпуска журнала, начиная с автора, Редакционной коллегии, профессиональных рецензентов до издателя.

Обязанности редакторов «***Военно-технического вестника***»

Редакция журнала «*Военно-технический вестник*» сообщает, что не взымает с авторов плату за публикацию их статей, то есть, все действия, связанные с редактированием и размещением статей в Вестнике являются абсолютно бесплатными.

Редакция «*Военно-технического вестника*» несет ответственность за принятие решений о публикации представленных в адрес журнала статей. При наличии конфликта интересов редактор не принимает участия в процессе рассмотрения рукописи. В таком случае решение о выборе рецензента и публикации рукописи принимает редколлегия. При наличии конфликта интересов члены редколлегии не принимают участия в процессе рассмотрения рукописи.

Редакция обязана соблюдать политику Редакционной коллегии *«Военно-технического вестника*», а также положения действующего законодательства, регулирующие вопросы распространения заведомо ложных сведений, порочащих честь и достоинство другого лица или подрывающих его репутацию и несоблюдения авторских прав. Редакция имеет право проконсультироваться с Редакционной коллегией или рецензентами относительно принятия решений о публикации статьи.

Редакция отбирает и оценивает материалы независимо от пола, религии, расы, национальности, политических убеждений автора.

По рекомендациям Центра поддержки развития образования и науки (ЦПРОН), редакция журнала в своей работе пользуется электронной системой редактирования ASSISTANT, обеспечивающей транспарентность и доступность информации о текущем соотоянии рукописи, а также подразумевает полную ответственность за принятие решения о её публикации.

Путём использоваия системы iThenticate (CrossRef и CrossCheck) редакция до момента представления статьи рецензентам проверяет её содержание на плагиат. В соответствии со стандартами журнала, плагиат, то есть присвоение чужих идей, высказываний либо другой формы творческого выражения и представление их как своих собственных представляет собой грубое нарушение научной и редакционной этики. Плагиат является уголовно наказуемым нарушением авторских прав. С точки зрения редакции, плагиатом является: дословное копирование работы другого лица, либо цитирование работы другого лица без указания его авторства, ссылки на источник; некорректное перефразирование произведения другого лица без ссылки на источник; использование элементов работы (рисунков, таблиц, графиков, диаграмм) другого лица без указания авторства, ссылки на источник; авторы должны получить разрешение владельца авторских прав на использование элементов его работы. В случае возникновения обоснованного сомнения в том, что работа является плагиатом, редакция отказывает автору в публикации.

Редакция журнала проводит конфиденциальное рецензирование, применяя «двойной слепой метод». Авторы статьи и рецензенты не знают друг друга.

Никто из работников издательской компании не имеет право раскрывать любые сведения о представленной научной статье, за исключением случаев, если они по мере потребности нужны автору, рецензентам, возможным рецензентам и другим советникам редакторов и издателя.

Неопубликованными материалами нельзя воспользоваться для исследовательских работ без согласия автора.

Редакция обязуется исключить из публикации принятую статью, в случае следующих нарушений:

– плагиат,

– автоплагиат,

– повторная публикация в данном или другом издании,

– неверные данные об авторе (присвоение чужой работы, указание автора не принимавшего участия в написании работы),

– конфликт интересов,

– фальсификация результатов исследования,

– неправильно оформленные рисунки (графики, иллюстрации) и таблицы,

– крупные технические ошибки в оформлении текста, на-пример, пропуск частей текста.

Стандарты регламентирующие процедуру снятия опубликованной работы с публикации, которые применяет «Военно-технический вестник» предписаны Национальной библиотекой Сербии (НБС) и другими научными учреждениями. За статьей (определённой к снятию) в электронном формате закрепляют HTML ссылку с уведомлением о её снятии с публикации. Изъятая статья хранится в исходном виде, но каждая страница ПДФ формата визируется печатью, свидетельствующей о снятии статьи с публикации (RETRACTED).

Отзывы и исправления публикуются в соответствии с требованиями ЦПРОН – Сербского индекса научного цитирования (СЦИндекс/SCIndex) (http://www.ceon.rs/pdf/postupanje_s_nelegitimnim_radovima.pdf), при этом метаданные отозванных и снятых с публикации статей должны быть обозначены соответствующим предупреждением и соединены между собой ссылками.

Обязанности рецензентов

Рецензенты должны профессионально и объективно аргументировать свою позицию и в указанный срок предоставить редактору оценку научной ценности рукописи.

Рецензенты, рассматривая работы оценивают соответствие темы работы с профилем журнала, релевантность исследуемой области и примененных методов, оригинальность и научную значимость результатов, представленных в рукописи, стиль научного изложения, а также использование в тексте научного аппарата.

Профессиональный рецензент оказывает поддержку Редакции при принятии решений о публикации статьей, а также, оказывает содействие авторам в целях улучшения качества их работы. Взаимодействие рецензента с авторами осуществляется путём контактов с ними через Редакцию.

В случае если рецензент считает, что он в достаточной степени не обладает качествами, необходимыми для осуществления профессиональной рецензии работы, или не сможет её осуществить во время, то ему необходимо об этом проинформировать Редакцию.

Любая работа, представленная на рецензию, является конфиденциальным документом и её нельзя показывать третьим лицам без одобрения Редакции.

Рецензия должна базироваться на объективных условиях. Не допускается личная критика автора. Рецензенты должны обосновать и доказать свои позиции по отношению к статье.

Рецензенты обязаны идентифицировать релевантные существующие работы, которые автор не цитировал. По любому общему сведению или аргументу приведенным в работе должны быть указаны соответствующие цитаты. Рецензент обязан обратить внимание редактору на эвентуальные сходства работы с другими опубликованными работами, в случае если такое будет обнаружено.

Мнение и выводы о рукописи статьи, к которым пришли рецензенты является конфиденциальной информацией и ей нельзя воспользоваться для личных потребностей. Рецензентам рекомендуется не рецензировать работы, которые могут вызвать коллизию интересов (конкуренты, совместная работа, или иные другие отношения с автором, компанией или учреждением связанными с работой).

Обязанности авторов

В своей исследовательской работе авторы должны придерживаться принципов четкости, разборчивости, понятности с целью объективного растолкования значения данной работы. Факты и показатели должны быть четко указаны. Работа должна содержать в достаточной степени фактов и деталей, чтобы она могла репродуцироваться. Неправильные или неточные утверждения являются примером неэтического поведения и не будут приняты.

Авторы должны обеспечит Редакцию первичными, необработанными данными, относящимися к работе, и представить их на рассмотрение Редакции, и обеспечить к ним доступ всем заинтересованным лицам, если это является возможным. Также, авторы должны после публикации статьи хранить в разумные сроки полученные результаты.

Авторы должны в своих работах заниматься полностью оригинальными вопросами. В случае если они в своей работе использовали данные или факты других авторов, то об этом необходимо указать в работе.

Также, авторы должны свои работы публиковать только в одном научном журнале, или размещать публикации на сайте с прямыми ссылками. Публикация одной и той же работы в нескольких научных журналах считается неэтичным поведением и является недопустимой.

Авторы работ обязаны указать в своих работах все материалы, которыми они воспользовались при исследовании, в том числе все публикации, которые повлияли на результаты их исследований.

Авторство должно быть ограничено только теми лицами, которые в значительной степени участвовали в процессе исследования и получения результатов работы. Имена, отчества, фамилии всех лиц, участвующих в значительной степени в процессе исследования и получения результатов работы, должны быть указаны в работе в качестве соавторов, и их необходимо поблагодарить за содействие.

Автор должен обеспечить условия, чтобы имена, отчества, фамилии всех соавторов, действительно участвующих в процессе исследования и содействующих получению результатов, были указаны в работе. Также, обязанностью автора является предоставление окончательной версии работы соавторам на согласование.

В случае появления в процессе исследования необходимости контакта с опасными веществами, т.е. веществами, обладающими потенциальной опасностью в отношении человека, животных и окружающей среды, то автор об этом должен четко указать в работе.

Каждый автор обязан в работе указать на все виды потенциальных финансовых или других конфликтов интересов, которые могли бы повлиять на результаты исследования или их интерпретацию. Все источники финансовой поддержки должны быть указаны в работе.

В случае обнаружения автором в работе существенные ошибки или какие-либо неточности, он обязан об этом незамедлительно сообщить Редакции журнала или издателю, также оказать содействие в их исправлении.

Разрешение спорных ситуаций

Любое лицо, либо учреждение вправе в любой момент предъявить претензию редактору или редколлегии в связи с нарушением этических стандартов и авторских прав, подкрепив ее достоверными доказательствами.

По получении претензии, подкрепленной доказательствами, редакционная комиссия проведет расследование, в соответствии со следующими принципами: редколлегия принимает решение о проведении проверки по поводу выдвинутых жалоб и доказательств о нарушении редакционной этики; в процессе рассмотрения доказательств, все материалы считаются конфиденциальными и будут предоставлены только тем лицам, которые непосредственно причастны к процессу проверки; подозреваемым лицам в нарушении этических норм будет предоставлена возможность ответить на выдвинутое против них обвинение; в случае выявления нарушения, характеризуется его степень, как грубого или негрубого нарушения этических норм.

В случае негрубого нарушения, редакция напрямую, без содействия третьих лиц, обращается к нарушителю, следующим образом: путем уведомления автора/рецензента о наличии негрубого нарушения, произошедшего вследствие недопонимания, либо несоответственного применения академических стандартов; путем предупреждения автора/рецензента, допустившего негрубое нарушение.

В случае грубого нарушения этических норм, редакция принимает решение о дальнейших мерах. Редакция вправе предпринять следующие меры (одновременно, поочередно или в отдельности): обнародование сообщения, в котором описывается случай нарушения этических стандартов; официальное уведомление руководителей или работодателей автора/рецензента; снятие опубликованной статьи с публикации, в соответствии с предписаниями; авторы-нарушители определенный период времени не будут допускаться к публикации в журнале; уведомление релевантных профессиональных организаций и соответствующих учреждений о случае, в целях привлечения нарушителя к ответственности.

При разрешении спорных ситуаций редакция журнала соблюдает предписания и инструкции Руководства Комитета по этике научных публикаций (Committee on Publication Ethics – COPE): http://publicationethics.org/resources/.

Отказ от ответственности

Вынесенные позиции в опубликованных работах не обязательно отражают точку зрения редколлегии журнала. Авторы несут полную юридическую и моральную ответственность за представленные в своих работах идеи. Редакция не несет никакой ответственности в случае возникновения требований по возмещению материального или морального вреда.

Реклама

Реклама в журнале *«Военно-технический вестник»* не допускается.

PUBLICATION ETHICS STATEMENT

The publication of an article in this peer reviewed journal is an essential model for the scientific journal *Military Technical Courier*. It is necessary to agree upon standards of expected ethical behavior for all parties involved in the act of publishing: the author, the journal editor, the peer reviewer and the publisher.

Duties of the *Military Technical Courier* editor

There are no APCs (author processing charges) or submission charges for the articles submitted to the *Military Technical Courier*. The whole process of article editing and publishing is entirely free of charge for authors.

The editor of the *Military Technical Courier* is responsible for deciding which of the articles submitted to the journal should be published. The Editor must hold no conflict of interest with regard to the articles he/she considers for publication. If an Editor feels that there is likely to be a perception of a conflict of interest in relation to their handling of a submission, the selection of reviewers and all decisions on the paper shall be made by the Editorial Board. If any member of the Editorial Board feels that there is likely to be a perception of a conflict of interest in relation to their handling of a submission, they shall withdraw from the editorial process.

The editor should be guided by the policies of the journal's editorial board and constrained by such legal requirements as shall then be in force regarding libel, copyright infringement and plagiarism. The editor may confer with the members of the editorial board or reviewers in making this decision.

The editor should evaluate manuscripts for their intellectual content without regard to race, gender, sexual orientation, religious belief, ethnic origin, citizenship, or political philosophy of the authors.

Following the recommendations of the CEON Centre for Evaluation in Education and Science (CEON/CEES), the editor applies the electronic editing system ASSISTANT which enables transparency and public access to work and accepts a full responsibility for the acceptance and publishing of articles.

Before sending articles for peer reviews, the editor checks the content of the submitted manuscripts for plagiarism using the iThenticate service (CrossRef and CrossCheck). According to the standards applied by the journal, plagiarism, where someone assumes another's ideas, words, or other creative expression as one's own, is a clear violation of scientific ethics. Plagiarism may also involve a violation of copyright law, punishable by legal action. Plagiarism includes the following: word for word, or almost word for word copying, or purposely paraphrasing portions of another author's work without clearly indicating the source or marking the copied fragment (for example, using quotation marks); copying equations, figures or tables from someone else's paper without properly citing the source and/or without permission from the original author or the copyright holder. Any manuscript which shows obvious signs of plagiarism will be automatically rejected.

Journal applies a „double blind peer review process“ for papers. Authors and reviewers are anonymous to each other in the process of review.

The editor and any editorial staff must not disclose any information about a submitted manuscript to anyone other than the corresponding author, reviewers, potential reviewers, other editorial advisers, and the publisher, as appropriate.

Unpublished materials disclosed in a submitted manuscript must not be used in an editor's own research without the express written consent of the author.

The Editorial Office has pledged to remove an already published article in case of the following, subsequently discovered facts regarding the article in question:

– plagiarism,

– self-plagiarism,

– article already published in some other journal or publication,

– inaccurate data on authorship (fake claim of authorship, listing authors who did not participate in the article's creation or omitting authors who did participate),

– conflict of interests,

– fraudulent use of data or fabrication of results,

– unauthorised technical interventions on figures,

– substantial technical error such as omitting parts of the text or an error in reproducing illustrations.

Standards for dealing with retractions have been developed by a number of library and scholarly bodies, and this practice has been adopted for article retraction by our journal: in the electronic version of the retraction note, a link is made to the original article. In the electronic version of the original article, a link is made to the retraction note where it is clearly stated that the article has been retracted. The original article is retained unchanged, save for a watermark on the PDF indicating on each page that it is “RETRACTED”.

Retractions and corrections are published according to the requirements set up by CEON/CEES (http://www.ceon.rs/pdf/postupanje_s_nelegitimnim_radovima.pdf) as the publisher of national citation index, where metadata of retractions and retracted papers have to be marked by appropriate warnings and cross-links.

Duties of reviewers

Reviewers are required to provide written, competent and unbiased feedback in a timely manner on the scholarly merits and the scientific value of the manuscript.

The reviewers assess manuscript for the compliance with the profile of the journal, the relevance of the investigated topic and applied methods, the originality and scientific relevance of information presented in the manuscript, the presentation style and scholarly apparatus.

A peer reviewer assists the editor in making editorial decisions and through the editorial communications with the author may also assist the author in improving the paper.

Any selected referee who feels unqualified to review the research reported in a manuscript or knows that its prompt review will be impossible should notify the editor and excuse himself from the review process.

Any manuscripts received for review must be treated as confidential documents. They must not be shown to or discussed with others except as authorized by the editor.

Reviews should be conducted objectively. Personal criticism of the author is inappropriate. Referees should express their views clearly with supporting arguments.

Reviewers should identify relevant published work that has not been cited by the authors. Any statement that an observation, derivation, or argument had been previously reported should be accompanied by the relevant citation. A reviewer should also call to the editor's attention any substantial similarity or overlap between the manuscript under consideration and any other published paper of which they have personal knowledge.

Unpublished materials disclosed in a submitted manuscript must not be used in a reviewer’s own research without the express written consent of the author. Privileged information or ideas obtained through peer review must be kept confidential and not used for personal advantage. Reviewers should not consider manuscripts in which they have

conflicts of interest resulting from competitive, collaborative, or other relationships or connections with any of the authors, companies, or institutions connected to the papers.

Duties of authors

Authors warrant that their manuscript is their original work, that it has not been published before and is not under consideration for publication elsewhere. Parallel submission of the same paper to another journal constitutes a misconduct and eliminates the manuscript from consideration by the journal.

The reviewers assess manuscript for the compliance with the profile of the journal, the relevance of the investigated topic and applied methods, the originality and scientific relevance of information presented in the manuscript, the presentation style and scholarly apparatus.

Authors of reports of original research should present an accurate account of the work performed as well as an objective discussion of its significance. Underlying data should be represented accurately in the paper. A paper should contain sufficient detail and references to permit others to replicate the work. Fraudulent or knowingly inaccurate statements constitute unethical behavior and are unacceptable.

Authors may be asked to provide the raw data in connection with a paper for editorial review, and should be prepared to provide public access to such data if practicable, and should in any event be prepared to retain such data for a reasonable time after publication.

The authors should ensure that they have written entirely original works, and if the authors have used the work and/or words of others, that this has been appropriately cited or quoted.

An author should not in general publish manuscripts describing essentially the same research in more than one journal or primary publication. Submitting the same manuscript to more than one journal concurrently constitutes unethical publishing behavior and is unacceptable.

Proper acknowledgment of the work of others must always be given. Authors should cite publications that have been influential in determining the nature of the reported work.

Authorship should be limited to those who have made a significant contribution to the conception, design, execution, or interpretation of the reported study. All those who have made significant contributions should be listed as co-authors. Where there are others who have participated in certain substantive aspects of the research project, they should be acknowledged or listed as contributors.

The corresponding author should ensure that all appropriate co-authors and no inappropriate co-authors are included on the paper, and that all co-authors have seen and approved the final version of the paper and have agreed to its submission for publication.

If the work involves chemicals, procedures or equipment that have any unusual hazards inherent in their use, the author must clearly identify these in the manuscript.

All authors should disclose in their manuscript any financial or other substantive conflict of interest that might be construed to influence the results or interpretation of their manuscript. All sources of financial support for the project should be disclosed.

When an author discovers a significant error or inaccuracy in his/her own published work, it is the author's obligation to promptly notify the journal editor or publisher and cooperate with the editor to retract or correct the paper.

Procedures for dealing with unethical behaviour

Anyone may inform the editors and/or Editorial Staff at any time of suspected unethical behaviour or any type of misconduct by giving the necessary information/evidence to start an investigation. The investigation shall conform to the following principles: the Editorial Staff will initiate an investigation; during an investigation, any evidence should be treated as strictly confidential and only made available to those strictly involved in investigating; the accused will always be given the chance to respond to any charges made against them; if it is judged at the end of the investigation that misconduct has occurred, then it will be classified as either minor or serious/major. Minor misconduct will be dealt directly with those involved without involving any other parties, e.g.: communicating to authors/reviewers whenever a minor issue involving misunderstanding or misapplication of academic standards has occurred, or a warning letter to an author or reviewer regarding fairly minor misconduct. In case of major misconduct, the Editorial Staff should make decisions regarding the course of action to be taken using the evidence available. The possible outcomes are as follows (these can be used separately or jointly): publication of a formal announcement or editorial describing the misconduct; informing the author's (or reviewer's) head of department or employer of any misconduct by means of a formal letter, the formal, announced retraction of publications from the journal in accordance with the Retraction Policy (see below); a ban on submissions from an individual for a defined period; referring a case to a professional organization or legal authority for further investigation and action. When dealing with unethical behaviour, the Editorial Staff will rely on the guidelines and recommendations provided by the Committee on Publication Ethics (COPE): http://publicationethics.org/resources/.)

Disclaimer

The views expressed in the published works do not express the views of the Editors and Editorial Staff. The authors take legal and moral responsibility for the ideas expressed in the articles. Publisher shall have no liability in the event of issuance of any claims for damages. The Publisher will not be held legally responsible should there be any claims for compensation.

Advertising

Advertising in the *Military Technical Courier* is not permitted.

Ликовно-графички уредник
мр *Небојша* Кујунџић,
e-mail: nebojsa.kujundzic@mod.gov.rs

Техничко уређење
мр *Небојша* Гаћеша, e-mail: nebojsa.gacesa@mod.gov.rs,
http://orcid.org/0000-0003-3217-6513

Лектор
Добрила Милетић, професор,
e-mail: dobrila.miletic@mod.gov.rs

Превод на енглески
Јасна Вишњић, професор,
e-mail: jasnavisnjic@yahoo.com, http://orcid.org/0000-0003-1728-4743

Превод на руски
др Карина Авагјан,
e-mail: karinka2576@mail.ru

Превод на немачки
Гордана Богдановић
e-mail: gordana.bogdanovic@yahoo.com

Превод на француски
Драган Вучковић,
e-mail: draganvuckovic@kbcnet.rs, http://orcid.org/0000-0003-1620-5601

ЦИП – Каталогизација у публикацији:
Народна библиотека Србије, Београд

623+355 / 359
355 / 359

ВОЈНОТЕХНИЧКИ гласник : научни часопис Министарства одбране Републике Србије = Military Technical Courier : scientific periodical of the Ministry of Defence of the Republic of Serbia / одговорни уредник Небојша Гаћеша. - Год. 1, бр. 1 (1953) - - Београд (Браће Југовића 19) : Министарство одбране Републике Србије, 1953- (Београд : Војна штампарија). - 24 cm

Доступно и на: http://www.vtg.mod.gov.rs
Тромесечно. - Друго издање на другом медијуму: Vojnotehnički glasnik (Online) = ISSN 2217-4753
ISSN 0042-8469 = Војнотехнички гласник
COBISS.SR-ID 4423938

Цена: 350,00 динара,
Тираж: 100 примерака

На основу мишљења Министарства за науку, технологију и развој Републике Србије, број 413-00-1201/2001-01 од 12. 9. 2001. године,
часопис „Војнотехнички гласник“ је публикација од посебног интереса за науку.

УДК: Народна библиотека Србије, Београд

Художественный редактор
Магистр дизайна, *Небойша* Куюнджич,
e-mail: nebojsa.kujundzic@mod.gov.rs

Технический редактор
Кандидат технических наук *Небойша* Гачеша, e-mail: nebojsa.gacesa@mod.gov.rs,
http://orcid.org/0000-0003-3217-6513

Корректор
Добрила Милетич,
e-mail: dobrila.miletic@mod.gov.rs

Перевод на английский язык
Ясна Вишнич,
e-mail: jasnavisnjic@yahoo.com, http://orcid.org/0000-0003-1728-4743

Перевод на русский язык
Д.филол.н. *Карина* Кареновна Авагян,
e-mail: karinka2576@mail.ru

Перевод на немецкий язык
Гордана Богданович,
e-mail: gordana.bogdanovic@yahoo.com

Перевод на французский язык
Драган Вучкович,
e-mail: draganvuckovic@kbcnet.com, http://orcid.org/0000-0003-1620-5601

CIP – Каталогизация в публикации: Национальная библиотека Сербии, г. Белград

623+355 / 359
355 / 359

ВОЕННО-ТЕХНИЧЕСКИЙ вестник: научный журнал
Министерства обороны Республики Сербия=
Military Technical Courier : scientific
periodical of the Ministry of Defence of the
Republic of Serbia / главный редактор
Небойша Гачеша. – Первый выпуск (1953) –
г. Белград (ул. Браче Юговича, д. 19): Министерство
обороны Республики Сербия, 1953- (Белград:
Военная типография). - 24 см
Размещено на сайте:
http://www.vtg.mod.gov.rs
Ежеквартально - Издание в электронном виде:
Военно-технический вестник (Online) = ISSN2217-4753
ISSN 0042-8469 = Военно-технический вестник
COBISS.SR-ID 4423938

Цена: 350,00 динаров
Тираж: 100 экземпляров

На основании решения Министерства науки и технологий Республики Сербия,
№ 413-00-1201/2001-01 от 12. 9. 2001 года, журнал «Военно-технический вестник»
объявлен изданием, имеющим особое значение для науки.

УДК: Национальная библиотека Сербии, г. Белград

Graphic design editor
Nebojša Kujundžić MA,
e-mail: nebojsa.kujundzic@mod.gov.rs

Copy editing
Nebojša Gaćeša MSc, e-mail: nebojsa.gacesa@mod.gov.rs,
http://orcid.org/0000-0003-3217-6513

Proofreader
Dobrila Miletić BA,
e-mail: dobrila.miletic@mod.gov.rs

English translation and polishing
Jasna Višnjić BA,
e-mail: jasnavisnjic@yahoo.com, http://orcid.org/0000-0003-1728-4743

Russian translation and polishing
Karina Avagyan PhD,
e-mail: karinka2576@mail.ru

German translation and polishing
Gordana Bogdanović,
e-mail: gordana.bogdanovic@yahoo.com

French translation and polishing
Dragan Vučković,
e-mail: draganvuckovic@kbcnet.rs, http://orcid.org/0000-0003-1620-5601

CIP – Catalogisation in the publication: National Library of Serbia, Belgrade

623+355 / 359
355 / 359

ВОЈНОТЕХНИЧКИ гласник : научни часопис Министарства одбране Републике Србије = Military Technical Courier : scientific periodical of the Ministry of Defence of the Republic of Serbia / одговорни уредник Небојша Гаћеша. - Год. 1, бр. 1 (1953) - - Београд (Браће Југовића 19) : Министарство одбране Републике Србије, 1953-(Београд : Војна штампарија). - 24 cm

Доступно и на:
http://www.vtg.mod.gov.rs
Тромесечно. - Друго издање на другом медијуму:
Vojnotehnički glasnik (Online) = ISSN 2217-4753
ISSN 0042-8469 = Војнотехнички гласник
COBISS.SR-ID 4423938

Price: 350.00 RSD
Printed in 100 copies

According to the Opinion of the Ministry of Science and Technological Development No 413-00-1201/2001-01 of 12th September 2001, the *Military Technical Courier* is a publication of special interest for science.

UDC: National Library of Serbia, Belgrade