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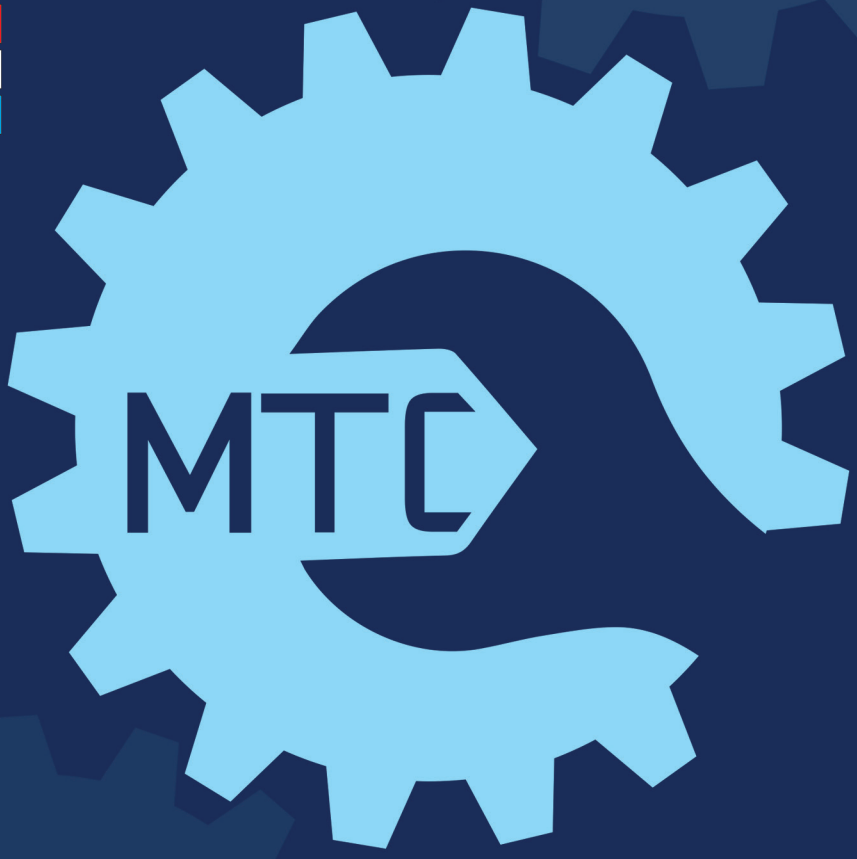

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мр Небојша Гаћеша, потпуковник
e-mail: nebojsa.gacesa@mod.gov.rs, tel.: 011/3603-260, 066/87-00-123, http://orcid.org/0000-0003-3217-6513

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ОРИГИНАЛЬНЫЕ НАУЧНЫЕ СТАТЬИ

ORIGINAL SCIENTIFIC PAPERS

SOME FIXED POINT THEOREMS IN b_2-METRIC SPACES

Poom Kumam[a], *Zoran* D. Mitrović[b], *Mirjana* V. Pavlović[c]

[a] King Mongkut's University of Technology Thonburi, Faculty of Science, KMUTT-Fixed Point Theory and Applications Research Group, Theoretical and Computational Science Center (TaCS), Science Laboratory Building, Bangkok, Kingdom of Thailand, e-mail: poom.kumam@mail.kmutt.ac.th, ORCID iD: http://orcid.org/0000-0002-5463-4581

[b] University of Banja Luka, Faculty of Electrical Engineering, Banja Luka, Republic of Srpska, Bosnia and Herzegovina, e-mail: zoran.mitrovic@etf.unibl.org, ORCID iD: http://orcid.org/0000-0001-9993-9082

[c] 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

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Abstract:

In this paper, we first prove a result that gives a sufficient condition for the convergence of the sequences in the b_2-metric space. Next, we give some fixed point theorems in the b_2-metric space. Some of our results are the corresponding generalizations of the known results in the b_2-metric space, which is confirmed by some examples.

Keywords: fixed points, common fixed points, 2-metric space, b_2-metric space.

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Introduction and Preliminaries

The applications of fixed point theorems are very important in diverse disciplines of mathematics, engineering and economics. The origin of the fixed theory is dated to the last quarter of the nineteenth century. The work of S. Banach in 1922 known as the Banach contraction principle is the starting point of the metric fixed point theory.

More on fixed point results and contractive conditions, the reader can find in (Ćirić, 2003), (Agarwal et al, 2015), (Kirk & Shahzad, 2014).

Theorem 1.1 (Banach contraction principle) Let (X,d) be a complete metric space. Let T be a contractive mapping on X, that is, one for which there is a $\lambda \in [0,1)$ satisfying

$$d(Tx,Ty) \le \lambda d(x,y)$$

for all $x, y \in X$. Then, there exists a unique fixed point $x \in X$ of T.

This theorem is a forceful tool in the nonlinear analysis. It has many applications and has been extended by a great number of authors. Although the famous Banach contraction principle was proved in the metric space, after 1990 many new modifications of the definition of the metric space appeared.

From now on, R and N will denote the set of real numbers and natural numbers, respectively. Let us recall the definitions of the b-metric spaces, the rectangular b-metric spaces, the 2-metric spaces, and the b_2-metric spaces.

In the papers of Bakhtin (Bakhtin, 1989, pp.26-37) and Czerwik (Czerwik, 1993, pp.5-11), the notion of the b-metric space was introduced and some fixed point theorems for single-valued and multi-valued mappings in the b-metric spaces were proved.

Definition 1.2 Let X be a nonempty set and $s \ge 1$ a given real number. The function $d : X \times X \to [0,\infty)$ is said to be a b-metric if for all $x, y, z \in X$ the following conditions are satisfied:

- $d(x,y) = 0$ if and only if $x = y$;
- $d(x,y) = d(y,x)$;
- $d(x,z) \le s[d(x,y) + d(y,z)]$.

A triplet (X,d,s) is called a b-metric space with the coefficient s.

In the paper (George et al, 2015, pp.1005-1013), the authors introduced the concept of a rectangular b-metric space, which is not necessarily Hausdorff and which generalizes the concept of the metric space, the rectangular metric space (RMS) and the b-metric space.

Definition 1.3 (George et al, 2015, pp.1005-1013) Let X be a nonempty set and $s \geq 1$ a given real number. The function $d : X \times X \to [0, \infty)$ is said to be a rectangular b-metric if the following conditions are satisfied:

(RbM1) $d(x, y) = 0$ if and only if $x = y$;

(RbM2) $d(x, y) = d(y, x)$ for all $x, y \in X$;

(RbM3) $d(x, y) \leq s[d(x, u) + d(u, v) + d(v, y)]$ for all $x, y \in X$ and all distinct points $u, v \in X \setminus \{x, y\}$.

A triplet (X, d, s) is called a rectangular b-metric space with the coefficient s (in short RbMS).

Also in (George et al, 2015, pp.1005-1013), the concept of convergence in such spaces is similar to that of standard metric spaces.

In the paper (Gähler, 1963, pp.115-118), Gähler introduced the concept of the 2-metric space.

Definition 1.4 (Gähler, 1963, pp.115-118) Let X be a nonempty set and the mapping $d : X \times X \times X \to$ R satisfies:

(1) For every pair of distinct points $x, y \in X$, there exists a point $z \in X$ such that $d(x, y, z) \neq 0$.

(2) If at least two of three points x, y, z are the same, then $d(x, y, z) = 0$

(3) The symmetry:

$d(x, y, z) = d(x, z, y) = d(y, x, z) = d(y, z, x) = d(z, x, y) = d(z, y, x)$

for all $x, y, z \in X$.

(4) The rectangle inequality:

$d(x, y, z) \leq d(x, y, t) + d(y, z, t) + d(z, x, t)$ for all $x, y, z, t \in X$.

Then d is called a 2-metric on X and (X, d) is called a 2-metric space.

Many generalizations of the concept of metric spaces are established, and several papers are published on the topic of the b-metric spaces (see (Aleksić et al, 2018), (Aydi, 2016, pp.2417-2433), (Czerwik, 1993, pp.5-11), (Czerwik, 1998, pp.263-276), (Dung & Le Hang, 2016, pp.267-284), (Miculescu & Mihail, 2017, pp.2153-2163) and others), of the rectangular b-metric spaces, see (George et al, 2015, pp.1005-1013), (Mitrović & Radenović, 2017, pp.3087-3095), (Mitrović & Radenović, 2017, pp.401-407) and others) and of the 2-metric spaces, see (Ahmed, 2009, pp.2914-2920), (Aliouche & Simpson, 2012, pp.668-690), (Deshpande & Chouhan, 2011,

pp.37-55), (Dung & Le Hang, 2013), (Fadail et al, 2015, pp.533-548), (Freese et al, 1992, pp.391-400), (Gähler, 1963, pp.115-118), (Iseki, 1975, 133-136), (Iseki, 1976, pp.127-135), (Lahiri et al, 2011, pp.337-352), (Lal & Singh, 1978, pp.137-143), (Naidu & Prasad, 1986, pp.974-993), (Popa et al, 2010, pp.105-120) and others).

In the paper (Mustafa et al, 2014), the notion of the b_2-metric space was introduced and some fixed point theorems in the b_2-metric spaces proved.

Definition 1.5 (Mustafa et al, 2014) Let X be a nonempty set, $s \geq 1$ be a real number and let $d : X \times X \times X \to \mathrm{R}$ satisfies:

(1) For every pair of distinct points $x, y \in X$, there exists a point $z \in X$ such that $d(x, y, z) \neq 0$.

(2) If at least two of three points x, y, z are the same, then $d(x, y, z) = 0$.

(3) The symmetry:

$$d(x, y, z) = d(x, z, y) = d(y, x, z) = d(y, z, x) = d(z, x, y) = d(z, y, x)$$

for all $x, y, z \in X$.

(4) The rectangle inequality:

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

for all $x, y, z, t \in X$.

Then d is called a b_2-metric on X and (X, d, s) is called a b_2-metric space.

Remark 1.6 Note that, $d(x, y, z) \geq 0$ for all $x, y, z \in X$. Applying the rectangle inequality, we get

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

By (2) and the symmetry of d, we obtain $d(x, y, z) \geq 0$.

Note that a 2-metric space is included in the class of the b_2-metric spaces with the coefficient $s = 1$.

Example 1 (Mustafa et al, 2014)

1. Let $X = [0, +\infty)$ and $d(x, y, z) = (xy + yz + zx)^p$ if $x \neq y \neq z \neq x$, and otherwise $d(x, y, z) = 0$, where $p \geq 1$ is a real number.

From convexity of the function $f(x) = x^p$ for $x \geq 0$, then by Jensen inequality we have

$$(a + b + c)^p \leq 3^{p-1}(a^p + b^p + c^p).$$

So, (X, d, s) is a b_2-metric space with $s \leq 3^{p-1}$.

2. Let a mapping $d : \mathrm{R}^3 \to [0, +\infty)$ be defined by

$$d(x, y, z) = \min\{|x - y|, |y - z|, |z - x|\}.$$

Then d is a b_2-metric on R, i.e., the following inequality holds:

$$d(x, y, z) \leq d(x, y, t) + d(y, z, t) + d(z, x, t),$$

for all $x, y, z, t \in \mathrm{R}$. From the convexity of the function $f(x) = x^p$ on $[0, +\infty)$ for $p \geq 1$, we obtain that

$$d^p(x, y, z) = \min\{|x - y|, |y - z|, |z - x|\}^p$$

is a b_2-metric on R with $s \leq 3^{p-1}$.

Definition 1.7 (Mustafa et al, 2014) Let $\{x_n\}$ be a sequence in a b_2-metric space (X, d, s).

1. $\{x_n\}$ is said to be b_2-convergent to $x \in X$, written as $\lim_{n\to\infty} x_n = x$, if for all $a \in X, \lim_{n\to\infty} d(x_n, x, a) = 0$.

2. $\{x_n\}$ is said to be a b_2-Cauchy sequence in X if for all $a \in X, \lim_{n,m\to\infty} d(x_n, x_m, a) = 0$.

3. (X, d) is said to be b_2-complete if every b_2-Cauchy sequence is a b_2-convergent sequence.

Definition 1.8 (Mustafa et al, 2014) Let (X, d, s) be a b_2-metric spaces and let $f : X \to X$ be a mapping. Then f is said to be b_2-continuous at a point $z \in X$ if for a given $\varepsilon > 0$, there exists $\delta > 0$ such that $x \in X$ and $d(z, x, a) < \delta$ for all $a \in X$ imply that $d(fz, fx, a) < \varepsilon$. The mapping f is b_2-continuous on X if it is b_2-continuous at all $z \in X$.

Remark 1.9 Let (X, d) be b_2-metric spaces. Then a mapping $f : X \to X$ is b_2-continuous at a point $x \in X$ if and only if it is b_2-sequentially continuous at x, that is, whenever $\{x_n\}$ is b_2-convergent to x, $\{fx_n\}$ is b_2-convergent to $f(x)$.

This paper is to derive theorems of Banach, Reich and Jungck in the b_2-metric spaces. Also, we obtain some results in partially ordered b_2-metric spaces.

One sequence convergence test in the b_2-metric space

The inequality given in the next Lemma 2.1 is key to proving our main results.

Lemma 2.1 Let (X,d,s) be a b_2-metric space and $\{x_n\}$ a sequence in X. Suppose that $\lambda \in (0,1)$ and let c be a real nonnegative number such that

$$d(x_m, x_n, a) \le \lambda d(x_{m-1}, x_{n-1}, a) + c(\lambda^m + \lambda^n) \tag{2.1}$$

for all $m,n \in \mathbb{N}$ and $a \in X$. Then $\{x_n\}$ is a b_2-Cauchy sequence in X.

Proof. Let $m,n \in \mathbb{N}$, $a \in X$ and $p \in \mathbb{N}$ fixed such that $p > -2\log_\lambda s$. From (2.1) we have that

$$d(x_{m+k}, x_{n+k}, a) \le \lambda^k d(x_m, x_n, a) + ck\lambda^k(\lambda^m + \lambda^n) \tag{2.2}$$

for all $m,n,k \in \mathbb{N}$ and $a \in X$. We have

$$\begin{aligned}
d(x_m, x_n, a) &\le s[\, d(x_{m+p}, x_n, a) + d(x_m, x_{m+p}, a) + d(x_m, x_n, x_{m+p}) \,] \\
&\le s[\, d(x_{m+p}, x_n, a) + \lambda^m d(x_0, x_p, a) \\
&+ cm\lambda^m(1+\lambda^p) + \lambda^m d(x_0, x_n, x_p) + cm\lambda^m(1+\lambda^p) \,] \\
&\le s[\, d(x_{m+p}, x_n, a) + \lambda^m d(x_0, x_p, a) + \lambda^m d(x_0, x_n, x_p) \,] \\
&+ 4scm\lambda^m.
\end{aligned}$$

Next, as it is

$$\begin{aligned}
d(x_0, x_n, x_p) &\le s[\, d(x_{n+p}, x_n, x_p) + d(x_0, x_{n+p}, x_p) + d(x_0, x_n, x_{n+p}) \,] \\
&\le s[\, \lambda^n d(x_p, x_0, x_p) + cn\lambda^n(\lambda^p + 1) + \lambda^p d(x_0, x_n, x_0) \\
&+ cp\lambda^p(1+\lambda^n) + \lambda^n d(x_0, x_0, x_p) + cn\lambda^n(1+\lambda^p) \,] \\
&\le 2cs(2n\lambda^n + p),
\end{aligned}$$

and

$$\begin{aligned}
d(x_{m+p}, x_n, a) &\le s[\, d(x_{n+p}, x_n, a) + d(x_{m+p}, x_{n+p}, a) + d(x_{m+p}, x_n, x_{n+p}) \,] \\
&\le s[\, \lambda^n d(x_p, x_0, a) + cn\lambda^n(1+\lambda^p) + \lambda^p d(x_m, x_n, a) \\
&+ cp\lambda^p(\lambda^m + \lambda^n) + \lambda^p d(x_m, x_n, x_n) + cp\lambda^p(\lambda^m + \lambda^n) \,] \\
&\le s[\, \lambda^n d(x_p, x_0, a) + \lambda^p d(x_m, x_n, a) \,] \\
&+ 2cs[\, p(\lambda^m + \lambda^n) + n\lambda^n \,],
\end{aligned}$$

we obtain the following

$$d(x_m, x_n, a) \le s^2\left[\ \lambda^n d(x_p, x_0, a) + \lambda^p d(x_m, x_n, a) + s\lambda^m d(x_0, x_p, a)\ \right]$$
$$+ 2cs^2\left[\ p(\lambda^m + \lambda^n) + n\lambda^n\ \right] + 2s^2 c\lambda^m\left(2n\lambda^n + p\right).$$

So,

$$\left(1 - s^2\lambda^p\right)d(x_m, x_n, a) \le s^2\lambda^n d\left(x_p, x_0, a\right) + s\lambda^m d\left(x_0, x_p, a\right) \qquad (2.3)$$
$$+ 2cs^2\left[\ 2p\lambda^m + (p+n)\lambda^n + 2n\lambda^{m+n}\ \right], \qquad (2.4)$$

how is it $p > -2\log_\lambda s$ we have $1 - s^2\lambda^p > 0$, therefore, we obtain that $\{x_n\}$ is a b_2-Cauchy.

Lemma 2.2 Let (X, d, s) be a b_2-metric space and $\{x_n\}$ a sequence in X. Suppose that $\lambda \in [0,1)$ such that

$d(x_m, x_n, a) \le \lambda d(x_{m-1}, x_{n-1}, a)$ for all $m, n \in \mathbb{N}$, $a \in X$.

Then

$$d(x_m, x_n, a) \le \frac{s^2\left(\lambda^m + \lambda^n\right)}{1 - s^2 p} d\left(x_0, x_p, a\right), \qquad (2.5)$$

for all $m, n, p \in \mathbb{N}$, $p > -2\log_\lambda s$ and $a \in X$.

Proof. It follows directly from Lemma 2.1, if we put $c = 0$, see (2.4).

Remark 2.3 Note that both Lemma 2.1 and Lemma 2.2 improve the result of Lemma 1.6. in (Fadail et al, 2015, pp.533-548).

A Theorem of Jungck in the b_2-metric space

The following Theorem is the version of the Theorem of Jungck (Jungck, 1976, pp.261-263) in b_2-metric spaces.

Theorem 3.1 Let T and I be commuting mappings of a b_2-complete b_2-metric space (X, d, s) into itself satisfying the inequality

$$d(Tx, Ty, a) \le \lambda d(Ix, Iy, a) \qquad (3.1)$$

for all $x, y, a \in X$, where $0 < \lambda < 1$. If the range of I contains the range of T and if I is b_2-continuous, then T and I have a unique common fixed point.

Proof. Let $x_0 \in X$ be arbitrary. Then Tx_0 and Ix_0 are well defined. Since $Tx_0 \in I(X)$, there is any $x_1 \in X$ such that $Ix_1 = Tx_0$. In general, if x_n is chosen, then we choose a point x_{n+1} in X such that $Ix_{n+1} = Tx_n$. We show that $\{Ix_n\}$ is a b_2-Cauchy sequence. From (3.1) we have

$$d(Ix_m, Ix_n, a) = d(Tx_{m-1}, Tx_{n-1}, a) \le \lambda d(Ix_{m-1}, Ix_{n-1}, a).$$

So,

$$d(Ix_m, Ix_n, a) \le \lambda d(Ix_{m-1}, Ix_{n-1}, a), \text{ for all } m, n \in \mathbb{N},\ a \in X. \qquad (3.2)$$

From Lemma 2.2 we obtain

$$d(Ix_m, Ix_n, a) \le \frac{s^2(\lambda^m + \lambda^n)}{1 - s^2 p} d(Ix_0, Ix_p, a), \qquad (3.3)$$

for all $m, n \in \mathbb{N}$, $a \in X$ and for some $p \in \mathbb{N}$ such that it is $p > -2\log_\lambda s$. Thus, we obtain that $\{Ix_n\}$ is a b_2-Cauchy sequence in X. By the b_2-completeness of X, there exists $u \in X$ such that

$$\lim_{n\to\infty} Ix_n = \lim_{n\to\infty} Tx_{n-1} = u.$$

Now, since I is b_2-continuous, (3.1) implies that both I and T are b_2-continuous. Since T and I commute, we obtain

$$Iu = I\left(\lim_{n\to\infty} Tx_n\right) = \lim_{n\to\infty} ITx_n = \lim_{n\to\infty} TIx_n = T\left(\lim_{n\to\infty} Ix_n\right) = Tu.$$

Let $v = Iu = Tu$. We get $Tv = TIu = ITu = Iv$. If $Tu \ne Tv$, from (3.1) we obtain

$$d(Tu, Tv, a) \le \lambda d(Iu, Iv, a) = \lambda d(Tu, Tv, a) < d(Tu, Tv, a),$$

a contradiction. So we have $Tu = Tv$, and finally we obtain $Tv = Iv = v$ i.e. v is a common fixed point for T and I. Condition (3.1) implies that v is the unique common fixed point.

Theorem 3.2 Let T and I be commuting mappings of a complete 2-metric space (X, d, s) into itself satisfying the inequality

$$d(Tx,Ty,a) \le \lambda d(Ix,Iy,a) \tag{3.4}$$

for all $x, y, a \in X$, where $0 < \lambda < 1$. If the range of I contains the range of T and I is continuous, then T and I have a unique common fixed point.

From Theorem 3.1, we obtain the following variant of the Banach theorem in b_2-metric spaces.

Theorem 3.3 Let (X,d,s) be a b_2-complete b_2-metric space and $T : X \to X$ a mapping satisfying:

$$d(Tx,Ty,a) \le \alpha d(x,y,a) \tag{3.5}$$

for all $x, y, a \in X$, where $\alpha \in [0,1)$. Then T has a unique fixed point.

Proof. Put $I(x) = x, x \in X$ in Theorem 3.1.

We obtain the following result as a consequence of Theorem 3.1 if we put $K = \frac{1}{\lambda}$ and T to be the identity map, i.e. $T(x) = x, x \in X$.

Theorem 3.4 Let I be a continuous onto mapping of a b_2-complete b_2-metric space (X,d,s). If there exists $K > 1$ such that

$$d(Ix,Iy,a) \ge Kd(x,y,a)$$

for all $x, y, a \in X$, then I has a unique fixed point.

The Reich theorem in b_2-metric spaces

The following theorem is the analogue of the Reich contraction principle (Reich, 1971, pp.121-124) in the b_2-metric space.

Theorem 4.1 Let (X,d,s) be a b_2-complete b_2-metric space and $T : X \to X$ be a mapping satisfying:

$$d(Tx,Ty,a) \le \alpha d(x,y,a) + \beta d(x,Tx,a) + \gamma d(y,Ty,a) \tag{4.1}$$

for all $x, y, a \in X$, where α, β, γ are nonnegative constants with $\alpha + \beta + \gamma < 1$ and $\min\{\beta, \gamma\} < \frac{1}{s}$. Then T has a unique fixed point.

Proof. Let $x_0 \in X$ be arbitrary. Define the sequence $\{x_n\}$ by $x_{n+1} = Tx_n$ for all $n \geq 0$. From condition (4.1) we have that

$$d(x_{n+1}, x_n, a) \leq \alpha d(x_n, x_{n-1}, a) + \beta d(x_n, x_{n+1}, a) + \gamma d(x_{n-1}, x_n, a).$$

Therefore,

$$d(x_{n+1}, x_n, a) \leq \frac{\alpha + \gamma}{1 - \beta} d(x_n, x_{n-1}, a). \tag{4.2}$$

Put $r = \frac{\alpha + \gamma}{1 - \beta}$. We have that $r \in [0,1)$. It follows from (4.2) that

$$d(x_{n+1}, x_n, a) \leq r^n d(x_1, x_0, a) \text{ for all } n \geq 1. \tag{4.3}$$

From conditions (4.1) and (4.3), we obtain

$$\begin{aligned} d(x_m, x_n, a) &\leq \alpha d(x_{m-1}, x_{n-1}, a) + \beta d(x_{m-1}, x_m, a) + \gamma d(x_{n-1}, x_n, a) \\ &\leq \alpha d(x_{m-1}, x_{n-1}, a) + \beta r^{m-1} d(x_{0,}, x_1, a) + \gamma r^{n-1} d(x_{0,}, x_1, a) \\ &= \alpha d(x_{m-1}, x_{n-1}, a) + (\beta r^{m-1} + \gamma r^{n-1}) d(x_{0,}, x_1, a) \end{aligned}$$

From this, together with Lemma 2.1 (we can put

$$\lambda = \alpha, c = \max\{\beta, \gamma\} d(x_0, x_1, a)$$

for all $m, n \in \mathbb{N}$, note that if $r = 0$ then the proof is trivial) we conclude that $\{x_n\}$ is Cauchy. By the b_2-completeness of (X, d, s) there exists $x^* \in X$ such that

$$\lim_{n \to \infty} x_n = x^*. \tag{4.4}$$

Now we obtain that x^* is the unique fixed point of T. Namely, we have

$$d(x^*, Tx^*, a) \le s\left[d(x_{n+1}, Tx^*, a) + d(x^*, x_{n+1}, a) + d(x^*, Tx^*, x_{n+1})\right]$$
$$= s\left[d(Tx_n, Tx^*, a) + d(x^*, x_{n+1}, a) + d(x^*, Tx^*, Tx_n)\right]$$
$$\le s\left[\alpha d(x_n, x^*, a) + \beta d(x_n, x_{n+1}, a) + \gamma d(x^*, Tx^*, a)\right.$$
$$+ d(x^*, x_{n+1}, a) + \alpha d(x^*, x^*, x_n) + \beta d(x^*, x^*, Tx^*)$$
$$\left. + \gamma d(x^*, x_n, x_{n+1})\right]$$

and

$$d(Tx^*, x^*, a) \le s\left[d(x_{n+1}, x^*, a) + d(Tx^*, x_{n+1}, a) + d(Tx^*, x^*, x_{n+1})\right]$$
$$= s\left[d(x_{n+1}, x^*, a) + d(Tx^*, Tx_n, a) + d(Tx^*, x^*, Tx_n)\right]$$
$$\le s\left[d(x_{n+1}, x^*, a) + \alpha d(x^*, x_n, a) + \beta d(x^*, Tx^*, a)\right.$$
$$+ \gamma d(x_n, x_{n+1}, a) + \alpha d(x^*, x^*, x_n) + \beta d(x^*, x^*, Tx^*)$$
$$\left. + \gamma d(x^*, x_n, x_{n+1})\right].$$

Since $\lim_{n\to\infty} d(x^*, x_n, a) = 0$, $\lim_{n\to\infty} d(x_n, x_{n+1}, a) = 0$, $\lim_{n\to\infty} d(x_n, x_{n+1}, x^*) = 0$ and $\min(\beta, \gamma) < \frac{1}{s}$, we have $d(x^*, Tx^*, a) = 0$ for all $a \in X$ i. e., $Tx^* = x^*$ (Axiom (1) in Definition 1.5).

For uniqueness, let y^* be another fixed point of T. Then it follows from (4.1) that

$$d(x^*, y^*, a) = d(Tx^*, Ty^*, a) \le \alpha d(x^*, y^*, a) + \beta d(x^*, Tx^*, a) + \gamma d(y^*, Ty^*, a)$$
$$= \alpha d(x^*, y^*, a) < d(x^*, y^*, a)$$

is a contradiction. Therefore, we must have $d(x^*, y^*, a) = 0$, i.e., $x^* = y^*$.

From Theorem 4.1, we obtain the following variant of the Kannan theorem (Kannan, 1968, pp.71-76) in b_2-metric spaces.

Theorem 4.2 Let (X, d, s) be a b_2-complete b_2-metric space and $T : X \to X$ be a mapping satisfying:

$$d(Tx, Ty, a) \le \beta d(x, Tx, a) + \gamma d(y, Ty, a) \qquad (4.5)$$

for all $x, y, a \in X$, where β, y nonnegative constants with $\beta + \gamma < 1$ and $\min\{\beta, \gamma\} < \frac{1}{s}$. Then T has a unique fixed point.

A result in partial order b_2-metric space

Let F_s denote the class of all functions $\beta : [0, \infty) \to \left[0, \frac{1}{s}\right)$ satisfying the following condition:

$$\beta(t_n) \to \frac{1}{s} \text{ as } n \to \infty \text{ implies } t_n \to 0 \text{ as } n \to \infty.$$

In the paper (Mustafa et al, 2014), Mustafa et al. obtain the following result in partially ordered b_2-metric spaces.

Theorem 5.1 (Mustafa et al, 2014, Theorem 1) Let $(X, \preceq)$ be a partially ordered set and suppose that there exists a b_2-metric d on X such that (X, d, s) is a b_2-complete b_2-metric space. Let $f : X \to X$ be an increasing mapping with respect to $\preceq$ such that there exists an element $x_0 \in X$ with $x_0 \preceq f x_0$. Suppose that

$$sd(fx, fy, a) \le \beta(d(x, y, a))M(x, y, a) \tag{5.1}$$

for all $a \in X$ and for all comparable elements $x, y \in X$, where

$$M(x, y, a) = \max\left\{d(x, y, a), \frac{d(x, fx, a)d(y, fy, a)}{1 + d(fx, fy, a)}\right\}.$$

If f is b_2-continuous, then f has a fixed point. Moreover, the set of fixed points of f is well ordered if and only if f has one and only one fixed point.

In the further, we consider that $M(x, y, a)$ is given as in Theorem 5.1.

In the paper (Fadail et al, 2015, pp.533-548), Fadail et al. generalize, complement and improve Theorem 5.1 in several directions.

Theorem 5.2 (Fadail et al, 2015, pp.533-548, Theorem 2.1) Let $(X, \preceq)$ be a partially ordered set and suppose that there exists a b_2-metric d on X such that (X, d, s) is a b_2-complete b_2-metric space with $s > 1$. Let $f : X \to X$ be an increasing mapping with respect to $\preceq$ such that there exists an element $x_0 \in X$ with $x_0 \preceq f x_0$. Suppose that

$$s^{\varepsilon} d(fx, fy, a) \le \beta(d(x, y, a)) M(x, y, a) \tag{5.2}$$

for all $a \in X$ and for all comparable elements $x, y \in X$, where $\varepsilon \in (0,1]$. If f is b_2-contuniuous then f has a fixed point. Moreover, the set of fixed points of f is well ordered if and only if f has one and only one fixed point.

Using Lemma 2.1, we get the following result.

Theorem 5.3 Let $(X, \preceq)$ be a partially ordered set and suppose that there exists a b_2-metric d on X such that (X, d, s) is a b_2-complete b_2-metric space with $s > 1$. Let $f : X \to X$ be an increasing mapping with respect to $\preceq$ such that there exists an element $x_0 \in X$ with $x_0 \preceq fx_0$. Suppose that exists $\lambda \in (0,1]$ such that

$$d(fx, fy, a) \le \lambda M(x, y, a), \tag{5.3}$$

for all $a \in X$ and for all comparable elements $x, y \in X$. If f is b_2-continuous, then f has a fixed point. Moreover, the set of the fixed points of f is well ordered if and only if f has one and only one fixed point.

Proof. Since $x_0 \preceq fx_0$ and f is an increasing function, we obtain that

$$x_0 \preceq fx_0 \preceq f^2 x_0 \preceq \cdots \preceq f^n x_0 \preceq f^{n+1} x_0 \preceq \cdots.$$

Since $x_n \preceq x_{n+1}$, where $x_{n+1} = fx_n, n \in \mathbb{N}$, from (5.3) we obtain

$$d(x_n, x_{n+1}, a) \le \lambda \max\left\{ d(x_{n-1}, x_n, a), \frac{d(x_{n-1}, x_n, a) d(x_n, x_{n+1}, a)}{1 + d(x_n, x_{n+1}, a)} \right\}$$

$$\le \lambda d(x_{n-1}, x_n, a).$$

Using induction, we conclude that

$$d(x_n, x_{n+1}, a) \le \lambda^n d(x_0, x_1, a), \tag{5.4}$$

for all $n \in \mathbb{N}$, $a \in X$. Further from conditions (5.3), we have

$$d(x_m, x_n, a) \le \lambda \max\left\{ d(x_{m-1}, x_{n-1}, a), \frac{d(x_{m-1}, x_m, a) d(x_{n-1}, x_n, a)}{1 + d(x_m, x_n, a)} \right\}$$

$$\le \lambda \max\{ d(x_{m-1}, x_{n-1}, a), d(x_{m-1}, x_m, a) d(x_{n-1}, x_n, a) \}.$$

Now, from inequality (5.4), it follows

$$d(x_m, x_n, a) \le \lambda \max\{d(x_{m-1}, x_{n-1}, a), \lambda^{m-1} d(x_0, x_1, a) \lambda^{n-1} d(x_0, x_1, a)\}$$
$$\le \lambda d(x_{m-1}, x_{n-1}, a) + \lambda^{m+n-1} d^2(x_0, x_1, a)$$
$$\le \lambda d(x_{m-1}, x_{n-1}, a) + (\lambda^m + \lambda^n) d^2(x_0, x_1, a)$$
$$= \lambda d(x_{m-1}, x_{n-1}, a) + c(\lambda^m + \lambda^n),$$

where $c = d^2(x_0, x_1, a)$. Now, because of Lemma 2.1, we get that $\{x_n\}$ is a b_2-Cauchy sequence in (X, d). The rest of the proof is the same as in (Mustafa et al, 2014) (Steps IV and V).

Note that condition (5.1) implies (5.2) and condition (5.2) implies (5.3).

Example 2 Let $X = \{(a,0): a \in [0,+\infty)\} \cup \{(0,2)\}$ and let $d(x, y, z)$ denote the square of the area of a triangle with the vertices $x, y, z \in X$, e.g.,

$$d((a,0),(b,0),(0,2)) = (a-b)^2.$$

Then d is a b_2-metric with the parameter $s = 2$. Introduce an order in X by

$$(a,0) \preceq (b,0) \Leftrightarrow a \ge b,$$

with all other pairs of distinct points in X incomparable.

Consider the mapping $f : X \to X$ given by

$$f(a,0) = (\lambda a, 0) \text{ for } a \in [0,+\infty) \text{ and } f(0,2) = (0,2),$$

and the function $\beta \in F_2$ given as

$$\beta(t) = \frac{1+t}{2+4t} \text{ for } t \in [0,+\infty).$$

Then f is an increasing mapping with $(a,0) \preceq f(a,0)$ for each $a \ge 0$.

1. If $\lambda = \frac{1}{3}$ then the assumptions of Teoreme 5.1 are satisfied (Mustafa et al, 2014, Example 3).

2. If $\lambda = \frac{1}{2}$ then the assumptions of Theorem 5.2 are satisfied (Fadail et al, 2015, pp.533-548, Example 2.6), but we cannot apply Theorem 5.1.

3. If $\lambda \in \left(\frac{1}{2}, 1\right)$ then the assumptions of Theorem 5.3 are satisfied, but we cannot apply Theorem 5.2.

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НЕКОТОРЫЕ ТЕОРЕМЫ О НЕПОДВИЖНЫХ ТОЧКАХ В b_2-МЕТРИЧЕСКИХ ПРОСТРАНСТВАХ

Пум Кумам[а], *Зоран* Д. Митрович[б], *Мирьяна* В. Павлович[в]

[а] Технологический университет короля Монгкута в Тхонбури, Естественно-математический факультет, Исследовательская группа по теории неподвижных точек и их применению, Центр теоретических и вычислительных наук, Здание научной лаборатории, г. Бангкок, Королевство Таиланд

[б] Университет в г. Баня-Лука, Электротехнический факультет, г. Баня-Лука, Республика Сербская, Босния и Герцеговина

[в] Университет в г. Крагуевац, Естественно-математический факультет, г. Крагуевац, Республика Сербия

РУБРИКА ГРНТИ: 27.00.00 МАТЕМАТИКА;
27.39.27 Нелинейный функциональный анализ
ВИД СТАТЬИ: оригинальная научная статья
ЯЗЫК СТАТЬИ: английский

Резюме:

Во введении данной статьи мы доказали результат, который является достаточным условием для сходимости последовательностей в b_2-метрическом пространстве. Далее представлены некоторые теоремы о неподвижной точке в b_2-метрическом пространстве. Некоторые из наших результатов представляют собой соответствующие обобщения известных результатов в b_2-метрическом пространстве, в качестве доказательства приведены примеры.

Ключевые слова: неподвижные точки, обобщенные неподвижные точки, 2-метрическое пространство, b_2-метрическое пространство.

НЕКЕ ТЕОРЕМЕ О ФИКСНОЈ ТАЧКИ У b_2-МЕТРИЧКИМ ПРОСТОРИМА

Пум Кумам[а], *Зоран* Д. Митровић[б], *Мирјана* В. Павловић[в]

[а] Технолошки универзитет Краља Монгкаста у Тонбурију, Природно-математички факултет, Истраживачка група теорије и примене фиксних тачака, Центар за теоријске и рачунске науке, Зграда научне лабораторије, Бангкок, Краљевина Тајланд

[б] Универзитет у Бањој Луци, Електротехнички факултет, Бања Лука, Република Српска, Босна и Херцеговина

[в] Универзитет у Крагујевцу, Природно-математички факултет, Крагујевац, Република Србија

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

Сажетак:

У овом раду прво је доказан резултат који даје довољан услов за конвергенцију низова у b_2-метричком простору. Такође, наведене су неке теореме о фиксној тачки у b_2-метричком простору. Неки резултати представљају одговарајуће генерализације познатих резултата у b_2-метричком простору, а примери су презентирани да то потврде.

Кључне речи: фиксне тачке, заједничке фиксне тачке, 2-метрички простор, b_2-метрички простор.

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ANALYSIS AND SYNTHESIS OF SILHOUETTES OF FRONTAL - AND FLANK-ATTACKING SHOOTING TARGETS USING GRAPHS

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

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Abstract:

The goal of this contribution is to reveal the analytical framework and synthesis guidelines for frontal-attacking targets (FRATs) and flank-attacking targets (FLATs) from the point of view of a graph as a mathematical object. The final outcome of this study are three graph models that in many ways describe the shooting targets under consideration. The first graph model characterizes the structure of connections between the vertices using an undirected graph. The model showed that the complexity of silhouettes leads to an increase of the path in the graph and growth of the complexity of its internal structure. The second graph model allows the analysis of the connectivity of the graph vertices. In this case, a bipartite graph is used. As a result, the reviewed FRATs and FLATs are described by the same graph. The second model showed its indifference to the types of the used graphic primitives (GPs). The third graph model was developed for the analysis of the common borders of the neighboring GPs and it uses a bipartite graph. It is also indifferent to the types of the used GPs, but it takes into account the length of the common borders. The third model describes FRATs/FLATs groups in the same way. When using I-III models, one can design GPs and carry out the synthesis of new targets. A full group of flank-attacking targets consisting of five silhouettes and their GPs is offered.

Key words: shooting target, geometric primitive, graph, adjacency matrix, Mathcad.

Introduction

The availability of various shooting targets in training processes makes it possible to reproduce necessary combat situations for operators of military special operations units as well as for radio-operators of robotized ground combat systems with remote operating control. Since shooting at selected targets is carried out only after the detection, classification and aiming stages, the process of developing a mathematical description of human-like silhouettes is actually a scientific field.

Despite a diversity of plane shooting targets (PSTs), target design as a generation of combatants' silhouettes is not widespread in scientific literature. A generally accepted point of view is that it is a phenomenon of human creativity which has a complex formal description.

Graphs are widely used for modeling different processes in physics, chemistry, engineering, information systems (Bondy & Murty, 1982), (Kennedy & Quintas, 1988), (Xu, 2003), and for image processing (Lézoray & Grady, 2012). Military applications also often apply the graph theory in: military geography and geodesy (Talevski & Temjanovski, 2003), military planning systems (Boukhtouta et al, 2011), (Hocker, 2012), and combat modeling (Tolk, 2012).

Based on the graph theory in (Khaikov, 2019), there is a description of a geometric similarity between the silhouettes of PSTs used in the Swiss Confederation (Wikipedia Contributors, 2012) and in the USSR/Collective Security Treaty Organization (Tarchishnikov, 2011). However, the considered two groups of PSTs belonged to the same target type, namely to frontal-attacking silhouettes. This study is a continuation of the previous paper (Khaikov, 2019). This new contribution attempts to widen the methods of the graph theory for the analysis of frontal-attacking shooting targets (FRATs) to flank-attacking shooting targets (FLATs). The goal of this work is to determine the principles of construction, analysis and synthesis of the methods for the FRAT/FLAT geometry from the point of view of a graph as the prime object of discrete mathematics. The computer algebra system Mathcad is used for graphic visualization of these sets of problems.

Description of a single PST and a group of PSTs in terms of graphs

Depending on the direction of displacement relative to an observer, an infantryman can move forward/backward and from left to right (or vice

versa). On the other hand, regardless of the direction of movement, an observer can see only a head of an infantryman, a head and a chest together or a full-size figure. If a real human silhouette is replaced by a set of abstract shapes, then this group of targets must be controled by some discretely variable parameter. The total area of a human-like silhouette visible to an observer can be recognized as such. Therefore, if the direction of an infantryman's displacement is considered as a classification criterion, and if an independent observer sees only a certain part of an infantryman's silhouette, one can create frontal-attacking and flank-attacking shooting targets.

In Fig. 1, we consider five Soviet/Russian FRATs and two (outside of the rectangle) FLATs (Tarchishnikov, 2011). The target geometry will be useful for deeper understanding and further reasoning.

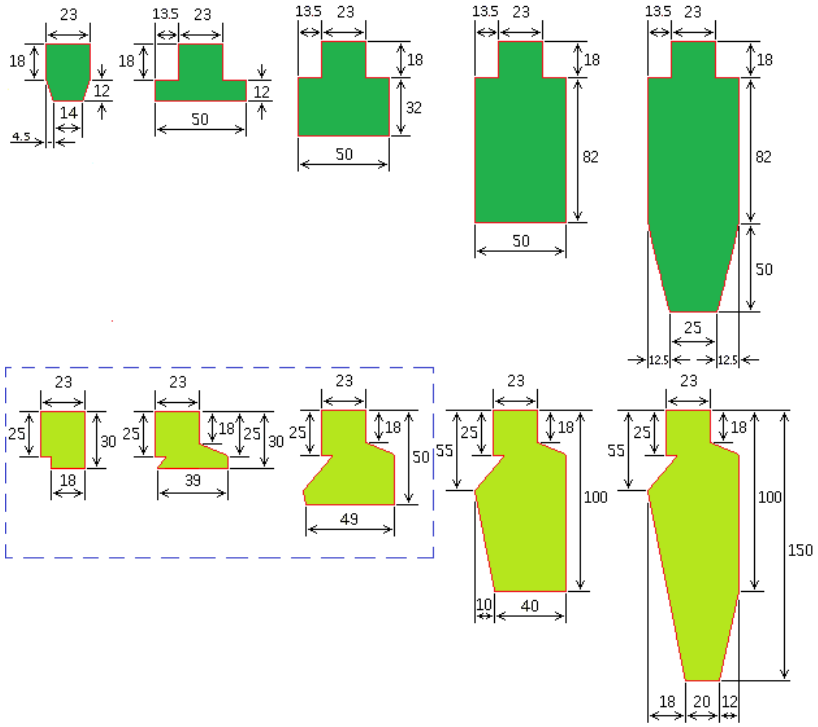


Figure 1 – Silhouettes of five FRATs (top row) and five FLATs (bottom row)
Рис. 1 – Силуэты пяти фронтально атакующих (верхний ряд) и флангово-атакующих плоских мишеней (нижний ряд)
Слика 1 – Силуете пет фронталних мета за гађање (горњи ред) и пет бочних мета за гађање (доњи ред)

The dimensions of all silhouettes shown in Fig. 1 are given in centimeters. Three figures in the bottom row are drawn inside a rectangle (its perimeter is depicted by a dotted line). It should be mentioned that these images are missing in (Tarchishnikov, 2011) and that they are the result of a synthesis process conducted using I-III graph models, developed below.

Five FRATs have the following designations (from left to right): the head target; the head and shoulders target; the upper torso target; the torso target; and full-sized target. The designations of the two FLATs are: the side view of the torso target; the man-sized target (side view). All FLATs move from right to left. If the movement is carried out from left to right, the targets of the lower row must be rotated horizontally.

Plane shooting targets consist of geometrical primitives (GPs) which are plane figures of elementary shapes. In addition, a single GP can be represented as a polygon. An important feature of GPs is the fact that a PST is built from them like a mosaic. The area of two contiguous GPs increases due to the existence of a common border between them.

Each PST from the FRAT group can consist of a maximum of five GPs (Fig. 2 a). There are «head», «shoulders (left / right)», «bottom of the chest», «bottom of the torso», and «legs» GPs. The minimum number of primitives required to generate a target's shape is one.

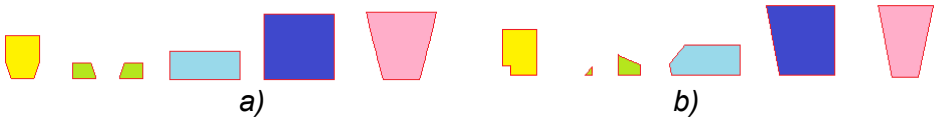


Figure 2 – Geometric primitives as constituent elements of PSTs
a) FRATs; b) FLATs;
Рис. 2 – Геометрические примитивы как составляющие элементы
а) фронтально атакующих мишеней; б) флангово-атакующих мишеней;
Слика 2 – Основне геометријске фигуре као конститутивни елементи
а) фронталних мета за гађање, б) бочних мета за гађање

The GPs of the FRAT group are obtained by overlaying a GP shape with a smaller area on a shape with a larger area. For example, if the silhouette «the torso target» is placed over the silhouette «full-sized target», we obtain the GP named «the leg». Further, if the «the upper torso target» silhouette is put on the «the torso target» silhouette, one can obtain the GP with the designation «the bottom of the torso», and so on.

Applying the principle of splitting the silhouette for the FLAT group, five GPs were obtained (Fig. 2 b). There are side projections for «the

head», «the chest / the back», «the bottom of the chest», «the bottom of the torso», and «the leg». The GPs forming the FLAT group do not have axial symmetry; however, the GPs of the FRAT group are symmetric by the vertical OY axis. It should be noted that the shapes of the GPs for the FLATs are more complex than the GPs for the FRATs. In order to compare them more easily, the GPs for the FRATs and the FLATs groups have the same numbers (1-5 from left to right) and identical colors (Fig. 2). The GPs with number 2 for the FRATs and the FLATs groups consist of two areas (light green color).

The first graph-model

The vertices of the first graph-model (Fig. 3, 4) are geometric primitives and the edges of the graph are the connecting lines between the adjacent GPs. The designations «No. I-V» shows the number of the graph in the group of 6-, 10-, 10-, 12-, 14-vertex graphs.

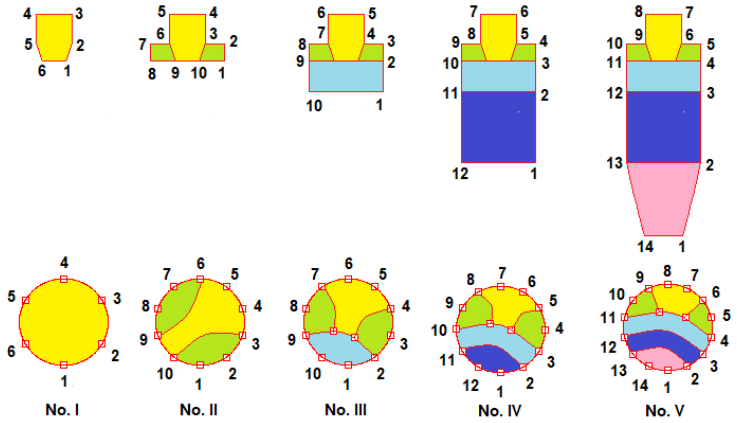


Figure 3 – The graphic visualization of the first graph model for five (I-V) frontal-attacking plane shooting targets
Рис. 3 – Реализация первой граф-модели для пяти (I-V) фронтально атакующих плоских стрелковых мишеней
Слика 3 – Графички приказ првог модела графа за пет (I-V) фронталних дводимензионалних мета за гађање

The graph with No. I is a classical circle graph. The vertices of the polygon are numbered counterclockwise. The starting vertex is at the bottom right. The vertices of the graph are not only the vertices of the external polygon (vertices 1-8 for No.2), but also the points of the sides formed by the intersections of the vertices which belong to different GPs (points 9, 10 for No.2).

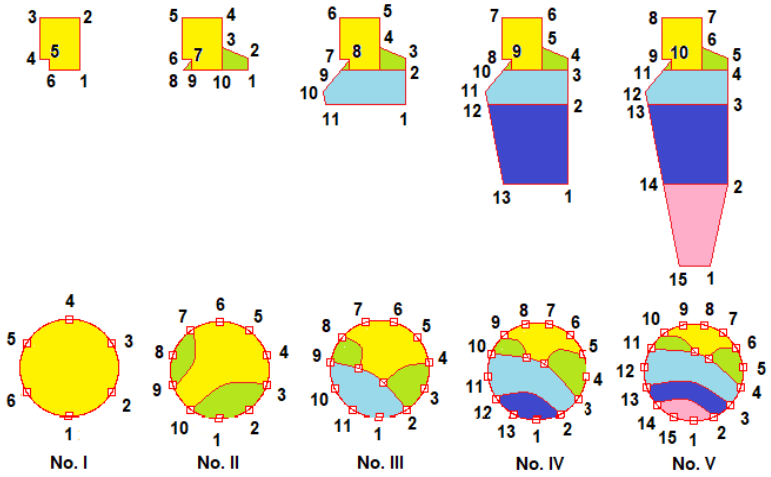


Figure 4 – The graphic visualization of the first graph model for five (I-V) flank-attacking plane shooting targets
Рис. 4 – Реализация первой граф-модели для пяти (I-V) фланго-атакующих плоских стрелковых мишеней
Слика 4 – Графички приказ првог модела графа за пет (I-V) бочних дводимензионалних мета за гађање

The idea of analyzing the graph structure is to isolate the external contour as a set of interconnected vertices and to transform them into a circle. Regardless of the size of the target area in a group, the area of the circle for all graphs is constant (Fig. 3, 4, I-V graphs). Then any connection between the vertices of the external contour can be represented as one or more edges inside the circle. The number of such edges will characterize the complexity of the graph adjacency matrix. The colors of the areas correspond to the colors of the geometric primitives which form a group of targets. In Figures 3 and 4, the ratio of the areas between the geometric primitives that make up the plane shooting targets is not preserved.

A disappearance of target symmetry is detected when an odd number of vertices appears in a circle-graph. In Fig. 3, each of the five circle-graphs has an even number of vertices, i.e. 6, 10, 10, 12, and 14. By comparing the areas with the same color (Fig. 4), we can notice an unequal number of vertices in the adjacent areas inside the circle. The light green areas of the graphs with III-V number (Fig. 3) have the same number of vertices, but by transition to Fig. 4, these ratios change.

In this way, the undirected circle-graph with a constant area has provided a study of the internal connections in both silhouettes: a single PST as well as a group of PSTs.

The second graph-model

Although the second model was already formulated in (Khaikov, 2019), its application here contributes to the FRATs/FLATs comparison. The second graph-model consists of 10 vertices and 15 edges (Fig. 5).

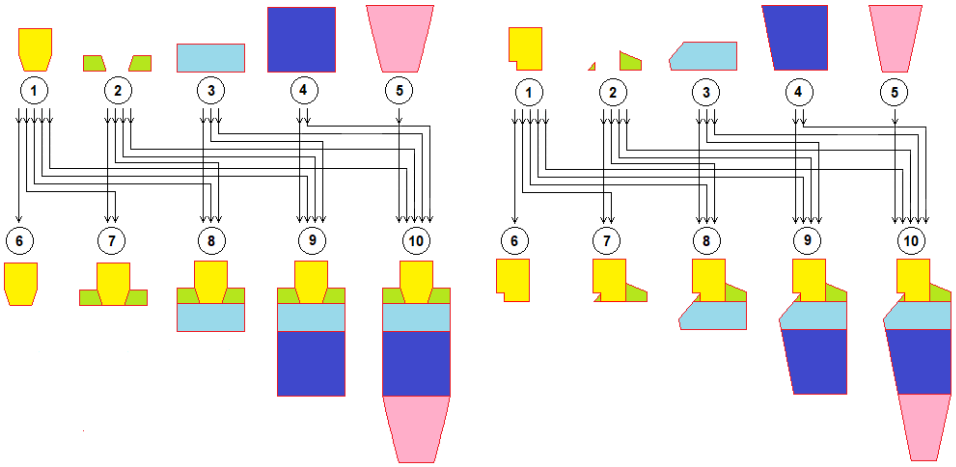


Figure 5 – Target design system for the FRATs (a) and the FLATs (b) groups
Рис. 5 – Две системы построения мишеней: а) фронтально атакующих мишеней; б) флангово-атакующих мишеней
Слика 5 – Систем пројектовања мета за групе фронталних (а) и бочних (б) мета за гађање

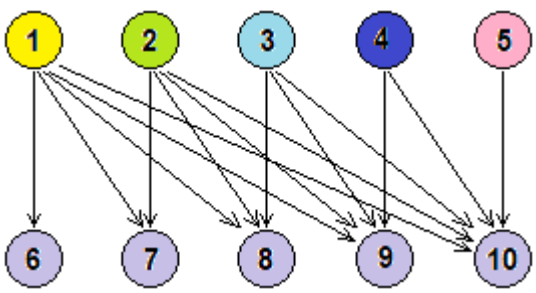
Vertices numbered 1-5 are GPs. Numbers 6–10 are the vertices of the graph characterizing one of the frontal-attacking (or flank-attacking) targets. The arrows (edges of the graph) show the relationship between the GPs and the silhouettes. The colors of the graphic primitives (the vertices of the graph) are identical to the colors in Fig. 2. The two structures in Fig. 5 represent a target design system (TDS) (Khaikov, 2019). The left TDS (Fig. 5 a) is that of the FRATs group, while the system on the right (Fig. 5 b) can be used for FLAT group generation. Let us draw attention to the fact that the structures of the FRAT/FLAT schemes (Fig. 5 a, b) are the same. The difference is only in the sets of

the used primitives which are assigned in advance. By rebuilding these schemes, we obtain a bipartite graph (Fig. 6 a)

$$G_2 = (V, E) = (10, 15),$$

where $|V|$ – number of vertices (or nodes) (graph order);
$|E|$ – number of edges (links, arcs) (graph size).

In a directed bipartite graph (Fig. 6), the edges are classically drawn as arrows that indicate the direction. The G_2 graph does not have loops and multiple edges.



a)

	1	2	3	4	5	6	7	8	9	10
1	0	0	0	0	0	1	1	1	1	1
2	0	0	0	0	0	0	1	1	1	1
3	0	0	0	0	0	0	0	1	1	1
4	0	0	0	0	0	0	0	0	1	1
5	0	0	0	0	0	0	0	0	0	1
6	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0

b)

Figure 6 – The bipartite graph of FRATs/FLATs groups (a) and its adjacency matrix (b)
Рис. 6 – Двудольный граф (биграф) фронтально / флангово-атакующих мишеней (а) и их матрица связи (б)
Слика 6 – Бипартитан граф група фронталних и бочних мета за гађање (а) и његова матрица повезаности (б)

For the bipartite graph $G_2=(V(G_2), E(G_2))$ and the vertex $(x_1, x_2, x_3, x_4, x_5) \in V(G_2)$, the out-degree of any vertex from the set $(x_1, x_2, x_3, x_4, x_5)$ refers to the number of edges-arrows directed away from the selected vertex. The in-degree of $(x_6, x_7, x_8, x_9, x_{10}) \in V(G_2)$ refers to the number of edges-arrows directed towards the vertex from the set $(x_6, x_7, x_8, x_9, x_{10})$.

Therefore, the out-degree indicates how many times the GPs with numbers 1-5 in the FRATs/FLATs groups are used. The in-degree shows how many GPs are included in the targets with numbers from 6 to 10. Accordingly, this graph-model is a formal description of the target construction method from a set of GPs. By using it, one can obtain not

only the Swiss/Soviet frontal targets (Khaikov, 2019), but also the flank targets.

On the basis of the two targets shown in Fig. 1 (bottom row) and their frontal images (top row of Fig. 1), it is possible to develop new geometric primitives and synthesize a full group of flanking-attacking targets. Therefore, the field of using the second graph-model has expanded.

The adjacency matrix (Fig. 6 b) is a clear and unambiguous description of the graph G_2. This same matrix will correspond to both front-attacking and flank-attacking targets. This matrix has a size of 10×10. The colors of vertices 1-5 correspond to the colors of the geometric primitives in Fig. 2, and the resulting targets 6-10 are shown in purple. Since the adjacency matrix is a sparse matrix, the single elements of the matrix are shown in light brown.

The sparsity of the adjacency matrix (Fig. 7 b) is 85%, and its matrix density – 15%. All nonzero-valued elements form a special upper triangular matrix with four diagonals parallel to the main diagonal. The adjacency matrix is singular.

The graph-model of the second type is indifferent to the type, but not to the number of the used GPs that make up the target. The model does not take into account the position of common boundaries in the resulting target. Thus, the 10×10 matrix is a mathematical description for both the FRATs and FLATs groups, and the shape of the targets depends on the forms of the five geometric primitives used to generate them.

The third graph-model

The third graph model (Fig. 7) uses an oriented graph in which the vertices of the graph are the GPs and edges of the graph - the existence of common borders between the GPs. Two areas in GP No. 2 (see Fig. 2, light green designation) are considered as a coherent whole.

Two groups of targets, their decomposition to a set of GPs, and the graphs of FRATs and FLATs are presented in Fig. 7. The arrows in the forward (and reverse) directions indicate that the common borders between the GPs can be crossed in the forward and reverse directions. The designations «No. I-V» show the number of the graph. The colors of the GPs are identical to those in Fig. 2. Each FRAT/FLAT group includes 5 graphs with the formulas: G3-(I-V) = (V, E): G3-I = (1, 0); G3-II = (2, 2); G3-III = (3, 6); G3-IV = (4, 8); and G3-V = (5, 10). The graph-model of building targets for FRATs and FLATs groups is the same.

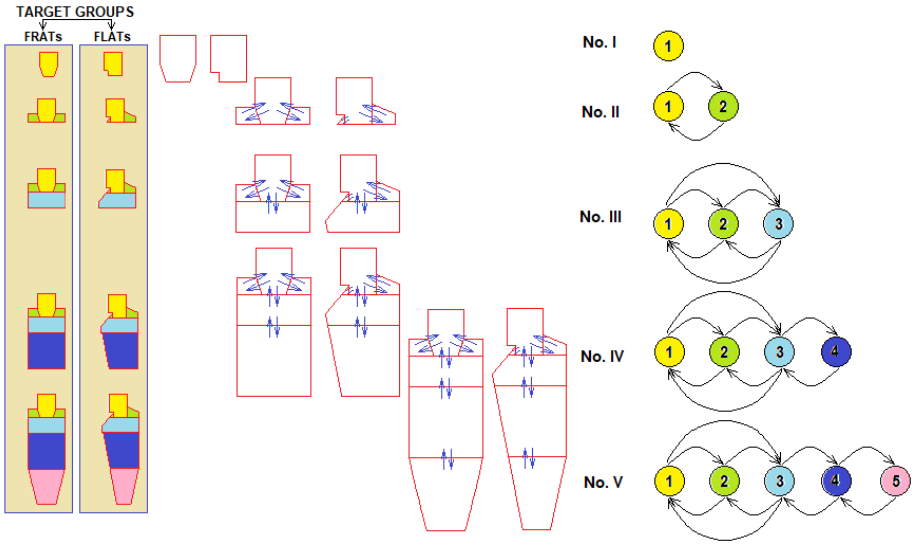


Figure 7 – The implementation of the third graph-model for five FRATs and five FLATs
Рис. 7 – Реализация третьей граф-модели для пяти фронтальных и пяти фланговo-атакующих стрелковых мишеней
Слика 7 – Примена трећег модела графа за пет фронталних и пет бочних мета за гађање

The indifference (non-sensitivity) of the graph to the type of geometric primitives confirmed by the use different sets of GPs, but the same graph-structure. In this case one can generate both a frontal-attacking targets and a flank-attacking targets. On the left, near each of the I-V graphs, a FRAT/FLAT silhouette is represented.

Similarly to the model of the second type, the graph-model of the third type is indifferent to the used GPs, but unlike the previous, it is able to take into account the features of the common borders between the GPs (for example, their length).

Conclusions

The basis of an individual description of a target in the form of a graph is a set of vertices and edges connecting them (I model). Using additional information about the number of geometric primitives and their location in the silhouette, one can investigate the complexity of a certain target.

The basis of the description of a set of targets is a group of geometric primitives. They describe the target either formally (II model) taking into account only the number of primitives in the target, or with additional consideration of the common boundaries between them (III model).

The combination of the I-III developed models makes it possible to describe silhouettes and their groups and to characterize the process of modifying the shape of the target inside the selected group. Knowledge of the shape modifying rules allows the synthesis of new targets.

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АНАЛИЗ И СИНТЕЗ СИЛУЭТОВ ФРОНТАЛЬНЫХ И ФЛАНГОВО-АТАКУЮЩИХ СТРЕЛКОВЫХ МИШЕНЕЙ С ИСПОЛЬЗОВАНИЕМ ГРАФОВ

Вадим Л. Хайков

независимый исследователь, г. Краснодар, Российская Федерация

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Резюме:

Целью данной статьи является раскрытие принципов анализа и методов синтеза фронтальных и флангово-атакующих мишеней, с точки зрения графов как математических инструментов. Основными задачами исследования являются разработка математического описания силуэтов мишени. В качестве окончательного результата были предложены три граф-модели. Первая граф-модель характеризует структуру связей между вершинами и использует неориентированный граф. Модель показала, что усложнение силуэта мишени приводит к увеличению пути графа и сложности его внутренней структуры. Вторая граф-модель позволяет анализировать связность вершин графа. В этом случае используется ориентированный граф. В результате группа фронтальных и флангово-атакующих мишеней описывается одним общим графом. Модель показала свою индифферентность к используемым графическим примитивам (ГП). Третья графовая модель позволяет анализировать общие границы между ГП. Она также индифферентна к используемым примитивам (учитывает только длины их общей границы). Вторая модель, так же как и третья, описывает две выбранные группы мишеней одинаково. I-III модели позволяют исследователю проектировать ГП и выполнить синтез новых стрелковых мишеней. Используя ранее известные стрелковые мишени была предложена группа флангово-атакующих мишеней и их пять ГП.

Ключевые слова: стрелковая мишень, геометрический примитив, математический граф, матрица смежности, Mathcad.

АНАЛИЗА И СИНТЕЗА СИЛУЕТА ФРОНТАЛНИХ И БОЧНИХ МЕТА ЗА ГАЂАЊЕ ПОМОЋУ ГРАФОВА

Вадим Л. Хајков

самостални истраживач, Краснодар, Руска Федерација

ОБЛАСТ: примењена математика (балистика, теорија гађања)
ВРСТА ЧЛАНКА: оригинални научни рад
ЈЕЗИК ЧЛАНКА: енглески

Сажетак:

У раду су представљени аналитички оквир и смернице за синтезу фронталних и бочних мета за гађање са становишта графа као математичког објекта. Крајњи резултат ове студије су три модела графа који на различите начине описују разматране мете за гађање. Први модел графа карактерише структуру веза између чворова помоћу неусмереног графа. Показао је да сложеност силуета доводи до повећања пута у графу и пораста сложености његове унутрашње структуре. Други модел графа омогућава анализу повезаности чворова графа, при чему се користи бипартитни граф који описује обе групе разматраних мета – и фронталне и бочне. Други модел је показао индиферентност према типовима коришћених геометријских фигура. Трећи модел графа развијен је за анализу заједничких страница суседних геометријских фигура помоћу бипартитног графа. И он је индиферентан према типовима коришћених геометријских фигура, али узима у обзир дужину заједничких страница. Трећи модел на исти начин описује групе фронталних и бочних мета за гађање. Помоћу ових модела могуће је пројектовати основне геометријске фигуре и синтетизовати нове мете. Представљена је целокупна група бочних мета за гађање која се састоји од пет силуета и њихових основних геомерijских фигура.

Кључне речи: мета за гађање, основна геометријска фигура, граф, матрица повезаности, Mathcad.

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STATISTICAL APPROACH TO SELECTING THE OPTIMAL PARAMETERS FOR DIAGNOSIS OF SOME CONNECTIVE TISSUE DISEASES

Mira J. Paskota[a], *Sanvila* S. Rašković[b], *Aleksandra* Ž. Perić-Popadić[c], *Vojislav* D. Đurić[d], *Žikica* M. Jovičić[e], *Aleksandar* M. Perović[f]

[a] Universtiy of Belgrade, Faculty of Transport and Traffic Engineering, Belgrade, Republic of Serbia,
e-mail: m.paskota@sf.bg.ac.rs,
ORCID iD: http://orcid.org/0000-0002-7625-6155

[b] Universtiy of Belgrade, School of Medicine, Clinical Center of Serbia, Clinic of Allergolorgy and Immunology, Belgrade, Republic of Serbia,
e-mail: sanvila.raskovic@kcs.ac.rs,
ORCID iD: http://orcid.org/0000-0002-4625-5485

[c] Universtiy of Belgrade, School of Medicine, Clinical Center of Serbia, Clinic of Allergolorgy and Immunology, Belgrade, Republic of Serbia,
e-mail: aleksandra.popadic@kcs.ac.rs,
ORCID iD: http://orcid.org/0000-0001-9718-2688

[d] Universtiy of Belgrade, School of Medicine, Clinical Center of Serbia, Clinic of Allergolorgy and Immunology, Belgrade, Republic of Serbia,
e-mail: vojislav.djuric@kcs.ac.rs,
ORCID iD: http://orcid.org/0000-0002-7544-8307

[e] Universtiy of Belgrade, School of Medicine, Clinical Center of Serbia, Clinic of Allergolorgy and Immunology, Belgrade, Republic of Serbia,
e-mail: zikica.jovicic@kcs.ac.rs,
ORCID iD: http://orcid.org/0000-0002-8805-8391

[f] Universtiy of Belgrade, Faculty of Transport and Traffic Engineering, Belgrade, Republic of Serbia,
e-mail: pera@sf.bg.ac.rs,
ORCID iD: http://orcid.org/0000-0002-8326-8007

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Abstract:

In order to choose the optimal parameters for easier diagnosis of systemic autoimmune diseases, the authors focused on data dimensionality reduction, using both feature selection and feature extraction.

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The Multiple Correspondence Analysis was used as a feature extraction method, with the aim of exploring the underlying data structure and detecting the crucial latent variables. The obtained latent variables were used as an input for the Discriminant Analysis which correctly classified 86.5% of all analyzed cases. The high rate of correctly classified objects indicates that it would be possible to automate diagnostic processes, which would lead towards the development of decision support systems in this area of medicine. In addition to their knowledge and experience, clinical experts would have further help in decision support systems. That can allow easier learning, faster checking of diagnostic steps, lower rates of misdiagnosed cases and easier communication with experts from other medical centers.

Key words: multiple correspondence analysis, dimensionality reduction, discriminant analysis, connective tussue diseases, autoimmunity, diagnosis.

Introduction

Autoimmune systemic diseases like systemic lupus erythematosus, progressive systemic sclerosis and Sjögren's syndrome can be very difficult to diagnose in practice. Doctors at the primary and secondary level of a typical health care system are usually not qualified enough to recognize connective tissue diseases. Even for specialists at clinics it can be a challenge. The additional problem lies in the fact that many autoimmune diseases patients suffer from more than one condition at the same time. This is why a great number of different parameters are typically needed for the correct diagnosis of these diseases.

In practice, various variables are used for the identification and classification of patients with systemic connective tissue diseases (Hoogen et al, 2013), (Shiboski et al, 2012). For the purpose of research, the American College of Rheumatology developed the Classification criteria for systemic lupus erythematosus in 1982. In 1997, these criteria were revised. The Systemic Lupus International Collaborating Clinics (SLICC) proposed new classification criteria in 2012 (Petri et al, 2012). The SLICC variables were selected after the statistical analysis of patients' medical records by experts, using logistic regression analyses. These variables were then used for the recursive partitioning analysis. The final selection of the variables was performed by the committee of medical experts, but it was strongly influenced by the statistical analysis. Thus, both expert opinion and statistical methods were used in attempts to classify systemic connective tissues diseases (Nadashkevich et al, 2004), (Vitali et al, 2002).

Even though we could not find any application of the Multiple Correspondence Analysis (MCA) in the research of the connective tissue or autoimmune diseases, the applications of the correspondence analysis in medicine are not new. Crichton and Hinde in (Crichton & Hinde, 1989) used a simple Correspondence Analysis (CA) to help diagnose patients with chest pain and acute abdominal pain. Greenacre in (Greenacre, 1992) gives several applications of the CA in different fields of medicine. The same author also gives an example of the application of the MCA in medicine. In (Almeida et al, 2009) the authors are using the MCA in building a logistic model for the predictor selection in living-donor kidney transplant data.

Concerning the other statistical methods applied in the study of autoimmune diseases, we refer the reader to (Armañanzas et al, 2009), where a combination a multivariate correlation and certain machine learning techniques are used for the application of the microarray analysis in study of SLE and PAPS (primary antiphospholipid syndrome).

The rest of the paper is organized as follows: Section 2 gives a short description of the analyzed data set and the available variables. In Section 3, we describe the statistical methods used for the analysis of the data set. Section 4 presents and discusses the results, while the concluding remarks are given in Section 5.

The data set and variables description

The data set consists of 37 patients treated at the Clinic of Allergology and Immunology in Belgrade in the period 2012/2013. Among them, eleven were diagnosed as systemic lupus erythematosus (SLE), fourteen as Sjögren's syndrome (Sy Sjögren), nine as progressive systemic sclerosis (PSS) and three had both SLE and Sy Sjögren. The patients were diagnosed according to the ARA criteria (Hochberg, 1997).

The connective tissue diseases are relatively difficult to diagnose, requiring a broad picture of the patient's medical history, usually assessed through a large number of variables. All the subjects from our study were evaluated using 87 different variables belonging to three different groups, classified according to their 'availability' and 'cost'. The first group consists of 33 variables relatively easy to obtain, and consequentially considered to be 'cheap' (variables 1 to 33, Table 1). These were the variables obtained during the anamnesis and clinical examination of the patients. The second group of 37 variables (variables 34 to 70, Table 1) were the laboratory results of different blood tests, while the 17 variables from the third group (71 to 87, Table 1) are the

results of more invasive diagnostic procedures such as salivary gland histopathology or kidney histopathology, and therefore the most 'expensive' to obtain. It is important to note that the final diagnosis was not included in the data set in any way.

The diagnostics process typically varies among individual patients depending on their condition, so not all of the mentioned diagnostics procedures were needed for all patients and there are some missing cases in the data set.

Methods

A short description of the multivariate correspondence analysis and the discriminant analysis is given in order to familiarize the reader with them and make the text and the results easier to follow and understand.

Multivariate Correspondence Analysis

The MCA is an exploratory statistical technique suitable for analyzing nominal variables, usually applied with the aim of learning something previously unknown about the analyzed data. By the results researchers can get from it and the field of application, the MCA is considered to be the equivalent of the principal component analysis (PCA) for nominal variables. The main features of the MCA are the possibilities of underlying structure exploration/detection and dimension reduction, usually resulting in a set of latent variables. The MCA is a generalization of the Simple Correspondence Analysis (CA), a very popular method for the analysis of contingency tables (Benzécri, 1973), (Greenacre, 1984). While the CA is suitable for the analysis of only two nominal variables, the MCA can be used for the simultaneous analysis of any number of nominal variables. Since the MCA is basically an optimal scaling method, it can also been used for the quantification of nominal variables. Good and detailed descriptions of the MCA, its characteristics and examples of application can be found in the literature, see for instance (Gifi, 1990), (Greenacre & Blasius, 2006), (Le Roux & Rouanet, 2004).

Discriminant analysis

The important results of the MCA are object scores, coefficients of all objects regarding virtual dimensions of the solution. Since these coefficients are numerical, as opposed to original variables being categorical, it is possible to think of the MCA as of a method of quantification. However, it is important to mention that a one to one

relationship between the original and quantified variables does not exist, because object scores are virtual variables, in many ways equivalent to principal components. Keeping that in mind, it is possible to apply any statistical method suitable for the analysis of numerical data on such virtual variables. In this study, the discriminant analysis was used to control the validity of classification.

As usually explained in the literature (Klecka, 1980), (McLachlan, 1992), the discriminant analysis in practice has two main purposes: to find a linear combination of the variables which separate the elements in the best possible way, and to allocate the sample elements into previously defined groups using these linear combinations, usually called discriminant functions. The first and necessary step, finding the discriminant functions, is also a form of data reduction. In some applications, the functions are used as a linear classifier for the allocation of the elements to the previously defined groups. In this research, the discriminant analysis was used with that purpose.

Results and the discussion

The analysis of frequencies, as a necessary first step in every statistical analysis of nominal variables, showed that out of 87 total variables, 29 had too many missing cases to be useful in the analysis. The list of all variables showing if they are included in the analysis and the reasons for the exclusion is given in Table 1. That left 58 variables in the initial set; all were included in the preliminary analysis.

Table 1 – List of all variables
Таблица 1 – Список всех переменных
Табела 1 – Листа свих променљивих

* LF (low frequency)
** HF (high frequency)
*** LC (low contribution)

No	Variable (number of categories)	Step 1		Steps 2 & 3	
		Included	Missing cases	Included	Reason for exclusion
1	Sex (2)	Yes		No	LF* (3/37)
2	Age (4)	Yes		Yes	
3	Malar rash (2)	Yes		Yes	
4	Discoid rash (2)	Yes		No	LF (3/37)
5	Photosensitivity (2)	Yes		Yes	
6	Oral ulcers (2)	Yes		No	LC***

No	Variable (number of categories)	Step 1		Steps 2 & 3	
		Included	Missing cases	Included	Reason for exclusion
7	Dryness of the mouth (2)	Yes		Yes	
8	Arthralgia (2)	Yes		No	HF**(34/37)
9	Arthritis (3)	Yes		No	LC
10	Dryness of eyes (2)	Yes		Yes	
11	Proximal scleroderma (2)	Yes		Yes	
12	Sclerodactyly (2)	Yes		Yes	
13	Digital ulcers (2)	Yes		Yes	
14	Raynaud phenomenon (2)	Yes		No	LC
15	Livedo reticularis (2)	Yes		No	LF (4/37)
16	Dysphagia (2)	Yes		Yes	
17	Teleangiectasia (2)	Yes		No	LC
18	Fever (2)	Yes		No	LC
19	Weight loss (2)	Yes		No	LC
20	Malaise (2)	Yes		No	LC
21	Hair loss (2)	Yes		No	LC
22	Lymphadenopathy (2)	Yes		No	LF (4/37)
23	Epilepsy (2)	Yes		No	LC
24	Psychiatric (2)	Yes		No	LC
25	Psychologic (2)	Yes		No	LC
26	Cerebrovascular disease (2)	Yes		No	LF (2/37)
27	Miscarriage (2)	Yes		No	LC
28	Thrombosis (2)	Yes		No	LF (4/37)
29	Embolism (2)	Yes		No	LF (1/37)
30	Pleural effusion (2)	Yes		Yes	
31	Pulmonary fibrosis (2)	Yes		Yes	
32	Calcinosis (2)	Yes		No	LF (2/37)
33	Blood pressure (3)	Yes		No	LC
34	Erythrocyte sedimentation rate (4)	Yes		No	LC
35	Fibrinogen (3)	Yes		No	LC
36	Anemia (3)	Yes		No	LC
37	Leucopenia (3)	Yes		No	LC
38	Lymphopenia (3)	Yes		Yes	
39	Thrombocytopenia (3)	Yes		No	LC
40	Iron (3)	No	7		
41	Erythrocyturia (3)	Yes		No	LC
42	Cylindruria (2)	Yes		No	LF (4/37)

No	Variable (number of categories)	Step 1		Steps 2 & 3	
		Included	Missing cases	Included	Reason for exclusion
43	Proteinuria (4)	Yes		Yes	
44	Leukocyturia (2)	Yes		Yes	
45	Coombs test (2)	No	5		
46	RF (2)	No	8		
47	CRP (3)	No	5		
48	ANA (3)	Yes		Yes	
49	HEp-2 ANA (2)	No	12		
50	Anticentromere antibody (2)	No	23		
51	ANCA (2)	No	15		
52	MPO (2)	No	32		
53	PR3 (2)	No	33		
54	Anti Sm (2)	No	30		
55	RNP (2)	No	19		
56	Anti ds DNA (3)	Yes		Yes	
57	SSA (3)	No	14		
58	SSB (2)	No	24		
59	SCl 70 (2)	Yes		Yes	
60	AclA IgG (2)	No	13		
61	AclA IgM (2)	No	13		
62	B2GPI IgG (2)	No	31		
63	B2GPI IgM (2)	No	31	No	
64	LA (2)	No	32		
65	VDRL (2)	No	25		
66	KCT (2)	No	18		
67	Lowered complement (2)	Yes		No	LC
68	Elevated IgG IgM (3)	Yes		Yes	
69	Cryoglobulins (2)	No	16		
70	Paraprotein (2)	Yes		No	LC
71	Keratoconjunctivitis sicca (2)	Yes		Yes	
72	Funduscopic abnormalities (2)	No	12		
73	Other eye symptoms (2)	No	9		
74	Capillaroscopy (2)	Yes		Yes	
75	Diffusing capacity (2)	Yes		Yes	
76	Pericardial effusion (2)	Yes		Yes	
77	Pulmonary hypertension (2)	Yes		Yes	
78	Pulmonary scintigraphy (2)	No	32		

No	Variable (number of categories)	Step 1		Steps 2 & 3	
		Included	Missing cases	Included	Reason for exclusion
79	Salivary scintigraphy (4)	No	27		
80	Endocranial NMR (3)	No	22		
81	Chest x ray (2)	Yes		Yes	
82	Hand x ray (2)	No	30		
83	Esophageal dysfunction (2)	Yes		Yes	
84	Lupus band test (2)	No	33		
85	Labial salivary gland histopathology (4)	Yes		Yes	
86	Kidney histopathology (3)	Yes		Yes	
87	Electroneuromyography (3)	No	30		

Two-dimensional solution

Table 2 presents the results of the MCA in the two-dimensional space. Cronbach's alpha is very high for both dimensions, confirming their validity and importance for the interpretation. The first dimension explains 30.698% of the total variability, while the second one explains 25.603%. In the two-dimensional space, the total of 56.301% of the variance is explained. Even though more than 40% of the variability is not explained in this solution, reducing the dimensionality from 27 (number of variables entered in the final analysis) to only two is a very good result and worth further discussion and interpretation.

Table 2 – 2D results of the MCA
Таблица 2 – Результаты 2Д анализа множественной корреспонденции
Табела 2 – Резултати 2Д мултикореспонденционе анализе

Dimension		Variance Accounted For		
	Cronbach's Alpha	Inertia	% of Variance	Total
1	.913	8.289	.307	30.698
2	.888	6.913	.256	25.603
Total		15.201	.563	56.301

The object scores represent positioning of the patients in the two-dimensional space, the objects are labeled by the diagnosis. Figure 1 plots the objects (in our case, they are the patients with the connective tissue disease diagnosis), using their scores along the first two dimensions. At the first glance, it is obvious that the first dimension separates PSS on the right (higher values of the scores) from other

patients, positioned at the left (lower score values). The separation is very clean along the line of x approximately equal to 0.5. The grouping along the second dimension is also very interesting, although the separation is not so clean. Positioned high are PSS, Sy Sjögren, the cases with both Sy Sjögren and SLE and several of the SLE cases. Most of the SLE cases are positioned lower. The second dimension shows both that the SLE cases are more heterogonous than the PSS or Sy Sjögren cases, and that the separation between SLE and Sy Sjögren is not clean.

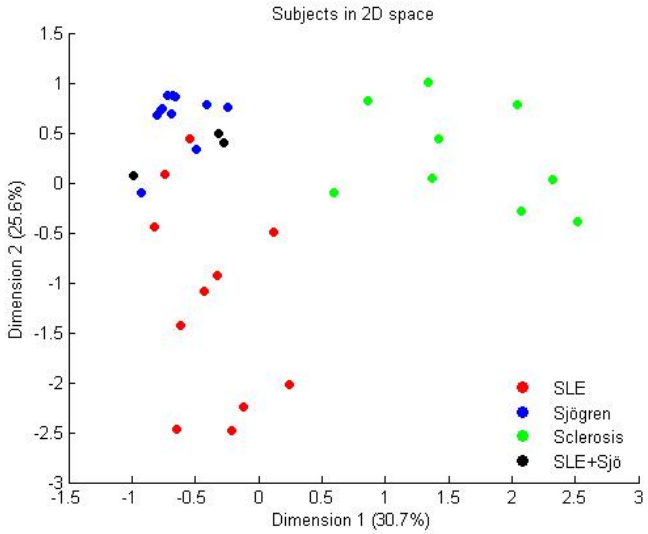

Figure 1 – 2D objects plot
Рис. 1 – 2 Д изображение объектов на участке
Слика 1 – Приказ објеката у равни

The clinical medical experience is in accordance with this result. The PSS patients are usually easy to distinguish by their characteristics from the SLE or Sy Sjögren patients, who are more similar regarding their clinical and biochemical characteristics.

In order to better understand the first two virtual dimensions, we are going to analyze the discrimination measures of all 27 variables (Table 3). The discrimination measures are the squared component loadings along the two virtual axes, and have the meaning of the variance of the quantified variables. As previously explained, in the last step of the variables selection, all variables with the mean discrimination measure in the 2D solution less than 0.1 were excluded from the final analysis.

Table 3 – Discrimination measures of the variables, 2D solution
Таблица 3 – Дискриминативные значения переменных, 2Д решение
Табела 3 – Дискриминационе мере променљивих, 2Д решење

	Dimension		Mean
	1	2	
Age	.064	.466	.265
Malar rash	.106	.137	.122
Photosensitivity	.178	.122	.150
Dryness of the mouth	.208	.506	.357
Dryness of the eyes	.152	.616	.384
Proximal scleroderma	.674	.002	.338
Sclerodactyly	.840	.026	.433
Digital ulcers	.468	.004	.236
Dysphagia	.507	.052	.280
Pleural effusion	.027	.408	.218
Pulmonary fibrosis	.488	.011	.249
Lymphopenia	.030	.434	.232
Proteinuria	.034	.719	.376
Leukocyturia	.572	.176	.374
ANA	.097	.275	.186
Anti ds DNA	.044	.746	.395
Scl-70	.512	.001	.256
Elevated IgG IgM	.114	.338	.226
Keratoconjunctivitis sicca	.131	.545	.338
Capillaroscopy	.472	.052	.262
Diffusing capacity	.601	.065	.333
Pericardial effusion	.139	.205	.172
Pulmonary hypertension	.507	.012	.260
Chest x ray	.254	.117	.185
Esophageal dysfunction	.673	.036	.354
Labial salivary gland histopathology	.376	.316	.346
Kidney histopathology	.018	.526	.272
Active Total	8.289	6.913	7.601
% of Variance	30.698	25.603	28.150

The discrimination measure can take values between 0 and 1. The discrimination measure plot (Figure 2) is very helpful in the interpretation of the virtual space.

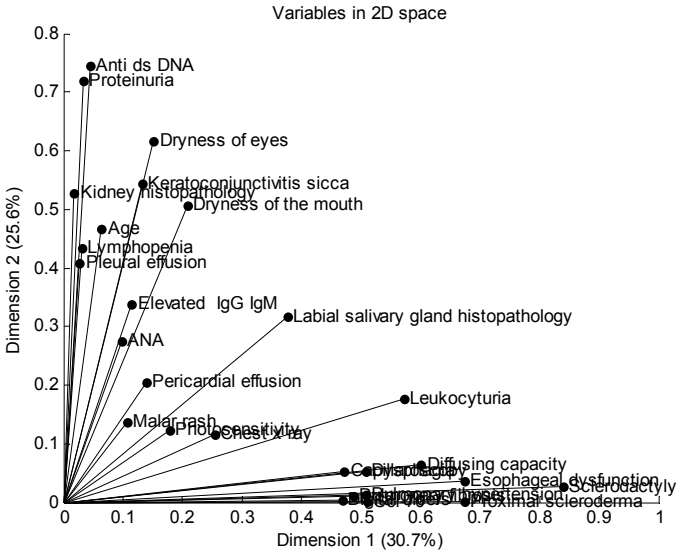

Figure 2 – Discrimination measure plot, 2D solution
Рис. 2 – Изображение 2Д решения, при применении дискриминативных значений
Слика 2 – Приказ 2Д решења применом дискриминационе мере

There are a number of variables with a relatively high value of the discrimination measure along the first, but very low value along the second virtual dimension. In Figure 2, they are positioned very low, close to the x axis. The variables from this group are Diffusing capacity, Esophageal dysfunction, Proximal scleroderma, Sclerodactyly, Digital ulcers, Dysphagia, Pulmonary fibrosis, Scl-70, Capillaroscopy, and Pulmonary hypertension and they can be used to explain the role of the first virtual dimension in the solution. These variables are typical for the PSS patients; some of them like Proximal scleroderma and Esophageal dysfunction are used as the diagnostic criteria for PSS. Therefore, the first dimension was named ‘Sclerosis’.

There are also several variables with relatively low values of the discrimination measure along the first, but quite high values along the second virtual dimension. In the discrimination measure plot (Figure 2), they are positioned very close to the y axis. Kidney histopathology, Proteinuria, Anti ds DNA, Pleural effusion and Lymphopenia are in this

group. These are the variables important for the diagnosis of SLE and lupus nephritis. The variables characteristic for Sy Sjögren (Dryness of eyes, Dryness of mouth, keratoconjunctivitis sicca) are also positioned relatively high and close to the y axis, but not as close as the SLE group of the variables. Some of the variables are characteristic for both SLE and Sy Sjögren (Elevated IgG i IgM, ANA). They are also leaning towards the y axis, but have lower discrimination measures. The second dimension was accordingly named 'SLE and/or Sy Sjögren'.

The rest of the variables have similar contributions towards both virtual dimensions. Most of the variables in the middle, especially the ones with relatively low discrimination measures, are typically seen in both SLE and Sy Sjögren. The variables like Malar rash, Photosensitivity and ANA are positioned closer to the coordinate center and not too close to any of the axes,since they can be observed in both SLE and Sy Sjögren, as is known from the clinical practice.

It is important to understand that the 2D solution explains only 56.301% of the total variability contained in the data, and that it is quite likely that some of these variables highly contribute towards the third (or a higher ranked) dimension, which would not be shown in the 2D representation. In order to better understand the role and importance of different variables for the connective tissue disease diagnosis, we are also going to look at the three-dimensional solution.

Three-dimensional solution

The three-dimensional solution keeps the first two dimensions described in Section 4.1 and adds one more dimension to the preexisting two-dimensional solution. The third dimension also has a relatively high value of Cronbach's Alpha (0.696) and adds 11.221% to the explained variability (Table 4). The first three dimensions together explain 67.522% of the total variance.

Table 4 – 3D results of the MCA
Таблица 4 – 3Д результаты применения анализа множественной корреспонденции
Табела 4 – 3Д резултати примене мултикорепонденционе анализе

Dimension		Variance Accounted For		
	Cronbach's Alpha	Inertia	% of Variance	Total
1	.913	8.289	.307	30.698
2	.888	6.913	.256	25.603
3	.696	3.030	.112	11.221
Total		18.231	.675	67.522

The positions of the objects in the 3D space (Figure 3) are revealing that the PSS patients are clearly separated from others, while the SLE and Sy Sjögren patients are not clearly separated from each other. However, the patients with both diagnoses (SLE and Sy Sjögren) are correctly positioned in the area where the two diagnoses are overlapping. It is also noticeable that the PSS and Sy Sjögren patients do not vary much along the third dimension. The SLE cases, however, are showing significant heterogeneity along the third dimension, as well as along the second dimension. As it was mentioned in the previous discussion, the SLE patients tend to be more different between them and more heterogonous, while the PSS and Sy Sjögren patients are more homogenous in their groups. The third dimension may give more insight in the causes of the SLE heterogeneity.

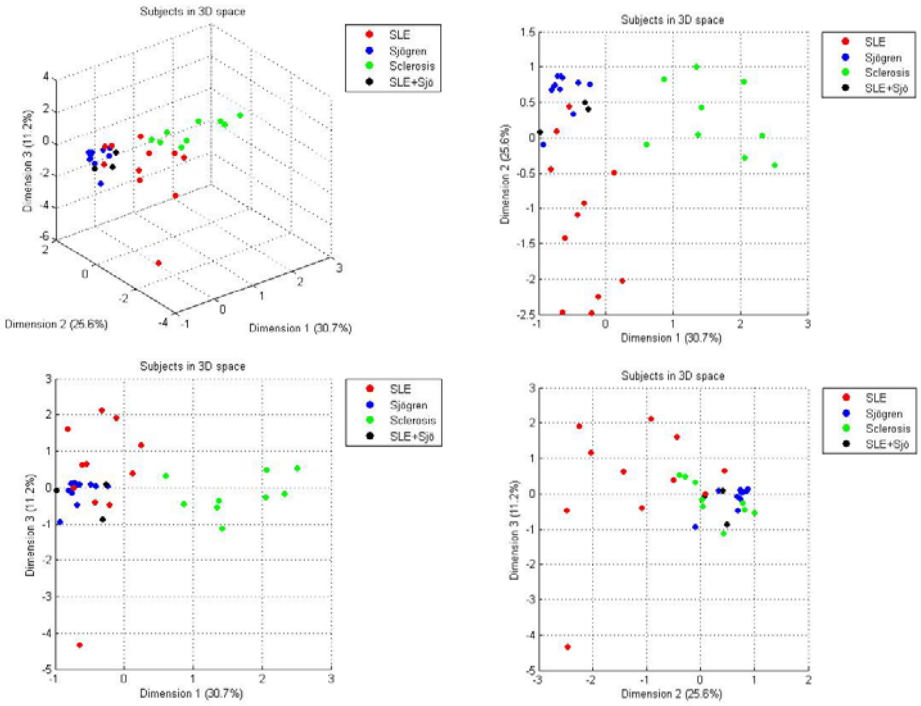

Figure 3 – 3D objects plot
Рис. 3 – 3Д изображение объектов
Слика 3 – 3Д приказ објеката

The variables with very high values of the discrimination measure along the third dimension are Age, Kidney histopathology and

Leukocyturia, while the values of Proteinuria, Anti ds DNA are also relatively high. These variables are responsible for the variations among the SLE cases, and are indicating some level of the kidney dysfunction. This is why the third dimension was named 'Renal Impairment'.

Lupus is a chronic inflammatory autoimmune disease which can affect any organ system, but mainly involves the skin, joints, kidneys and the nervous system (Ching et al, 2012), (Edworthy, 2005), (Hahn et al, 2005), (Hahn et al, 2012), (Muscal & Brey, 2010). SLE has a multitude of presentations ranging from mild, localized disease to severe multi-organ involvement abruptly or sequentially over the course of months to even years. Some patients can have only 4 diagnostic criteria, but many of patients can have more, between 4 and all 11 criteria. This poses a challenge to practitioners as SLE can be a great mimicker of many diseases.

One of the first steps in evaluating a patient with lupus is to recognize that there are various subtypes of lupus (Arbuckle et al, 2009), (Melba & Ovalle, 2013). Autoantibodies alone would not be sufficient to diagnose SLE because these autoantibodies are also present in other rheumatologic diseases (Arbuckle et al, 2009), (Shiboski et al, 2012), (Heaton, 1959), (Tan et al, 2005), (Manoussakis et al, 2004). Sy Sjogren and SLE do have similarities. Their autoantibody profiles are similar. They effect women more than men and have similar HLA haplotypes and autoantibodies. Most likely this is not a coincidence, but it may not be clinically relevant (Manoussakis et al, 2004), (Scheinfeld, 2006).

Sjögren's syndrome may occur in patients with systemic lupus erythematosus (SLE). The subset of patients with SLE and SY Sjögren has a distinct clinical and laboratory phenotype, with a higher frequency among older white women with photosensitivity, oral ulcers, Raynaud's phenomenon, anti-Ro antibodies, anti-La antibodies and a lower frequency of renal disease, anti-dsDNA antibodies and anti-RNP antibodies.

Classification using the Discriminant Analysis

As it was already mentioned, the diagnosis of the patients was never used during the MCA analysis. Since the positions of the objects in the virtual space (Figure 1) indicate that there is a natural grouping of the patients with the same diagnosis, it was necessary to check if that grouping is good enough to be used for the purpose of diagnosis, learning and automated separation of the objects. To accomplish that, the linear discriminant analysis was used.

The object scores from the two-dimensional MCA were used as an input to the discriminant analysis. The grouping variable was the diagnosis, consisting of four different classes: SLE, PSS, Sy Sjögren and SLE + Sy Sjögren. The number of predictors (virtual numerical variables obtained as the result of the MCA analysis) was two, so the number of discriminant functions was also two - equal to the min(number of classes – 1, number of predictors).

Table 5
Таблица 5
Табела 5

Diagnosis	Object scores, dimension 1			Object scores, dimension 2		
	Mean	Std. Deviation	Valid N	Mean	Std. Deviation	Valid N
SLE	-.372118	.3471989	11	-1.188039	1.0299628	11
Sjögren	-.635476	.1850666	14	.695795	.2670113	14
PSS	1.617873	.6588988	9	.260829	.5162426	9
SLE+Sjö	-.523629	.3994424	3	.326613	.2201460	3
Total	.000000	1.0137938	37	.000000	1.0137938	37

Table 5 presents the group means of both variables, while the results of the equality of means test are given in Table 6. The low values of Wilk's Lambda indicate that both variables are very important for the classification and are significantly contributing towards the objects separation (the significance asymptotically converging towards zero in both tests).

Table 6
Таблица 6
Табела 6

	Wilks' Lambda	F	df1	df2	Sig.
Object scores dimension 1	.147	63.775	3	33	.000
Object scores dimension 2	.372	18.570	3	33	.000

The eigenvalues of both discriminant functions with their corresponding canonical correlations are given in Table 7; the first function explains 79.9%, and the second 20.1% of the total variability.

Table 7
Таблица 7
Табела 7

Function	Eigenvalue	% of Variance	Cumulative %	Canonical Correlation
1	6.392(a)	79.9	79.9	.930
2	1.605(a)	20.1	100.0	.785

Based on the MCA virtual dimensions, the DA algorithm was very successful in predicting the group membership (Table 8). 86.5% of the cases were classified correctly. All of the PSS and SLE+Sy Sjögren patients were correctly classified. The only misclassifications were 3 of the SLE and 2 of the Sy Sjögren cases, all predicted as being SLE+Sy Sjögren patients.

Table 8
Таблица 8
Табела 8

Diagnosis	Predicted group membership				Total
	SLE	Sy Sjögren	PSS	SLE+Sjö	SLE
SLE	8	0	0	3	11
Sy Sjögren	0	12	0	2	14
PSS	0	0	9	0	9
SLE+Sjö	0	0	0	3	3
SLE	72.7	.0	.0	27.3	100.0
Sy Sjögren	.0	85.7	.0	14.3	100.0
PSS	.0	.0	100.0	.0	100.0
SLE+Sjö	.0	.0	.0	100.0	100.0

The explanation could be that SLE and Sy Sjögren are frequently overlapping diseases; at the moment we see the patients for the first time it might not be obvious that they can have a mixed form of the disease, named the overlap syndrome. Also, patients with diagnoses of SLE can have some characteristics of Sy Sjögren, (such as dryness of mouth and eyes), but without enough criteria for both diagnoses. A number of patients who seem to have only Sy Sjögren can develop some

manifestations of SLE (eg lymphopenia, ds DNA). The border between the diagnoses of SLE and Sy Sjögren is very subtle, and could be the explanation of the aforementioned misclassifications. Figures 4 and 5 show the corresponding discrimination measure plot for the 3D solution.

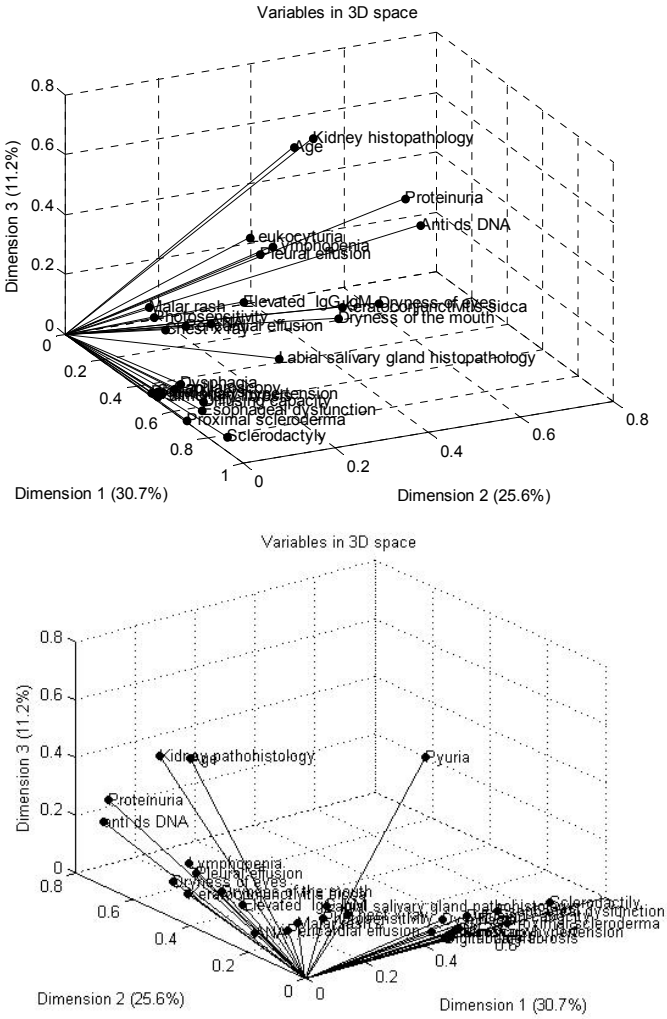

Figure 4
Рис. 4
Слика 4

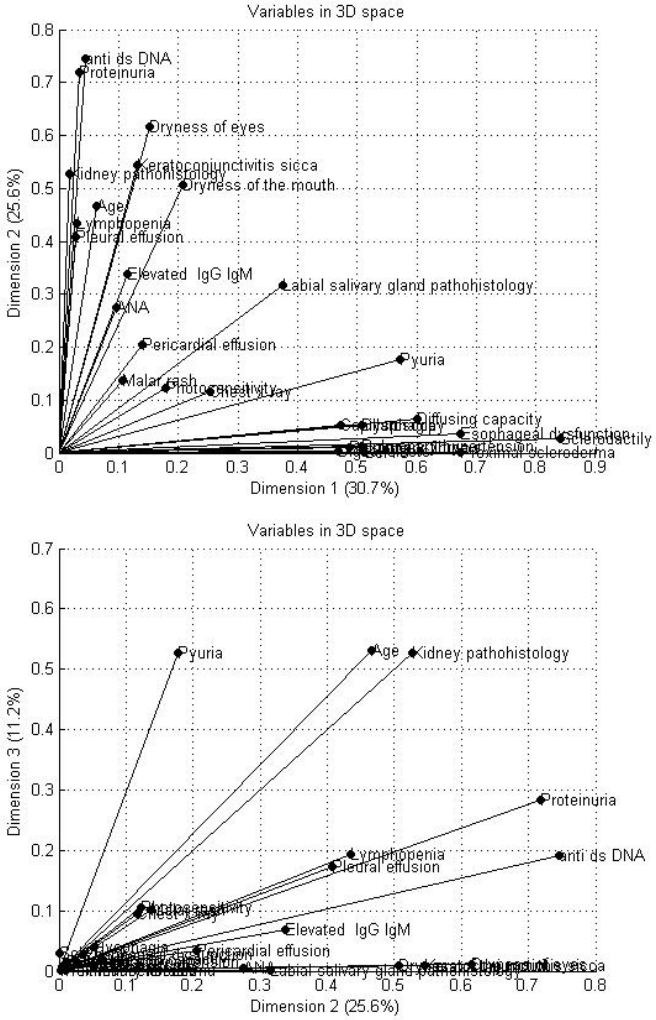

Figure 5
Рис. 5
Слика 5

Conclusion

This study has demonstrated that it is possible to significantly lower the number of parameters needed to diagnose the connective tissue diseases. Out of 87 available variables, 60 were discarded in the three-step eliminatory process. The remaining 27 variables were analyzed

using the multiple correspondence analysis. The three-dimensional solution was enough to identify the most important parameters related to different diseases and clearly separate the cases. Even the two-dimensional solution was enough to give a significant insight into the relationships among the variables and spatial positioning of the patients. The close proximity of some of the variables in the three-dimensional solution might indicate that a further dimension reduction is possible, which can be the subject of a separate study.

The importance of the results is in a possible successful application of the methods of advanced statistics in the medical practice, especially in the process of learning. The discriminant analysis classification was based on the two-dimensional MCA solution. The high rate of correctly classified objects indicates that it would be possible to automate the diagnostic processes, which would lead towards development of decision support systems in this area of medicine. In addition to their knowledge and experience, clinical experts would have further help in decision support systems. Thist can allow easier learning, faster checking of the diagnostic steps, lower rates of misdiagnosed cases, and easier communication with experts from other medical centers.

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СТАТИСТИЧЕСКИЙ МЕТОД ВЫБОРА ОПТИМАЛЬНЫХ ПАРАМЕТРОВ ДЛЯ ДИАГНОСТИКИ НЕКОТОРЫХ ЗАБОЛЕВАНИЙ СОЕДИНИТЕЛЬНОЙ ТКАНИ

Мира Й. Паскота[а], *Санвила* С. Рашкович[б],
Александра Ж. Перич-Попадич[б], *Воислав* Д. Джурич[б],
Жикица М. Йовичич[б], *Александар* М. Перович[а]

[а] Белградский университет, Факультет транспорта и связи, г. Белград, Республика Сербия

[б] Белградский университет, Медицинский факультет, Клинический центр Республики Сербия, Клиника аллергологии и иммунологии, г. Белград, Республика Сербия

РУБРИКА ГРНТИ: 27.00.00 МАТЕМАТИКА;
27.43.17 Математическая статистика
ВИД СТАТЬИ: оригинальная научная статья
ЯЗЫК СТАТЬИ: английский

Резюме:

В данной работе представлена так называемая редукция размерности данных, проведенная методом селекции и экстракции характерных атрибутов, с целью выбора оптимальных параметров для диагностики заболеваний иммунной системы. Анализ множественной корреспонденции проведен не только при экстракции, но и при исследовании самой структуры данных, а также при диагностике латентных переменных. Благодаря проведенному анализу множественной корреспонденции на материале экстрагированных латентных переменных с максимальной точностью было классифицировано 86,5% наблюдаемых случаев. Высокий уровень точно классифицированных заболеваний свидетельствует о реальных возможностях автоматизации диагностических процессов, которая поможет в усовершенствовании системы поддержки диагностики системных заболеваний соединительной ткани. Данные системы отличаются надежностью и скоростью диагностики, они легко осваиваются и облегчают коммуникацию специалистов из различных медицинских учреждений.

Ключевые слова: анализ множественной корреспонденции, редукция размерности, дискриминативный анализ, заболевания соединительной ткани, автоиммунные заболевания, диагностика.

СТАТИСТИЧКИ ПРИСТУП ИЗБОРУ ОПТИМАЛНИХ ПАРАМЕТАРА У ДИЈАГНОСТИЦИ НЕКИХ БОЛЕСТИ ВЕЗИВНОГ ТКИВА

Мира Ј. Паскота[а], *Санвила* С. Рашковић[б],
Александра Ж. Перић-Попадић[б], *Војислав* Д. Ђурић[б],
Жикица М. Јовичић[б], *Александар* М. Перовић[а]

[а] Универзитет у Београду, Саобраћајни факултет,
Београд, Република Србија
[б] Универзитет у Београду, Медицински факултет, Клинички центар
Србије, Клиника за алергологију и имунологију,
Београд, Република Србија

ОБЛАСТ: математика
ВРСТА ЧЛАНКА: оригинални научни рад
ЈЕЗИК ЧЛАНКА: енглески

Сажетак:

Ради избора оптималних параметара у дијагностици системских аутоимуних болести, аутори су се у овом раду фокусирали на тзв. редуцкију димензионалности података употребом метода селекције и екстракције карактеристичних атрибута. Вишеструка анализа кореспонденције коришћена је не само за екстракцију, већ и за испитивање саме структуре података, као и за детекцију кључних латентних променљивих. На екстраховане латентне променљиве је, применом дискриминантне анализе, коректно класификовано 86,5% посматраних случајева. Висока успешност класификације упућује на реалне могућности аутоматизације дијагностичког процеса, што би резултирало развојем система за подршку у дијагностици системских болести везивног ткива. Овакви системи омогућују лакше учење, бржу и поузданију дијагностику и лакшу комуникацију са експертима из других медицинских центара.

Кључне речи: вишеструка анализа кореспонденције, редукција димензионалности, дискриминантна анализа, болести везивног ткива, аутоимуне болести, дијагностика.

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LEACHING OF RARE EARTH ELEMENTS FROM BASTNASITE ORE (THIRD PART)

Srećko R. Stopić[a], *Bernd* G. Friedrich[b]
RWTH Aachen University, IME Process Metallurgy and Metal Recycling, Aachen, Federal Republic of Germany
[a] e-mail: sstopic@ime-aachen.de,
ORCID iD: http://orcid.org/0000-0002-1752-5378
[b] e-mail: bfriedrich@ime-aachen.de,
ORCID iD: http://orcid.org/0000-0002-2934-2034

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Summary:

Sulfuric acid dissolution of rare earth elements from bastnasite ore was studied after reductive smelting with carbon as a reducing agent at 1600°C. The two-step strategy: 1.carbothermic reduction, and 2.dissolution with sulfuric acid at 70°C was applied under atmospheric pressure aiming at an increased selective extraction of rare earth elements from slag containing rare earth elements.

Key words: rare earth elements, smelting, leaching, acid.

Introduction

Rare earth elements are a group of metallic elements of the periodic table, often overlooked, but very significant in today's industrial landscape and modern lifestyle. Like other metals, rare earths are silvery-gray, malleable, ductile, and they conduct electricity. They appear in nature in the form of oxides and other compounds, but with one particularity – the chemical similarity between all of them is so astounding that they all occur together in their bearing minerals, substituting one

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another at the molecular level (Gupta & Krishnamurthy, 2005), (Castor & Hedrick, 2006, pp.769-772). Bastnasite (La,Ce)CO_3F is fluororcarbonate of the cerium group found in ore deposits, metamorphic zones and pegmatites. In average, it contains 70% rare earth oxides, most of them belonging to the light fraction and in particular lanthanum, cerium and neodymium (Stopić & Friedrich, 2018, pp.757-770). The sulfuric acid leaching process was studied for the processing of roasted ore of Dechang bastnasite in Sichuan, China, in order to obtain rare earth elements (Feng et al, 2013, pp.849-854). With a particle size of 0.074-0.100mm, 1.5 mol/L sulfuric acid concentration, a liquid to solid mass ratio of 8 and a stirring speed of 500 rpm, the reaction rate of the leaching process can be controlled by diffusion through the product/ash layer, as described by the shrinking-core model, and the calculated activation energy of 9.97 kJ/mol, which is typical for the diffusion controlled process.

A stepwise carbochlorination-chemical vapor-transport-oxidation process was developed for the green rare earth extraction from a bastnasite concentrate using carbon as a reductant, chlorine gas as a chlorination agent, gas as a defluorination agent, aluminium chloride as a vapor complex former and a mixture from oxygen and hydrogen as an oxidant (Zhang et al, 2004, pp.217-221). After carbochlorination for an efficient rare earth extraction and thorium free volatile by–product release, thorium was removed by chemical vapor transport at 800°C for 0.5 hours in the chlorine-, silicium chloride-, and aluminium chloride atmosphere and alkaline earths were separated from rare earth by oxidation at 700°C to 1000°C in the mixture of oxygen and water atmosphere for 0.5 hours, followed by water leaching at room temperature. Their proposed treatment reached a clean and efficient rare earth extraction from the bastnasite concentrate.

A process for rare earth recovery from the Baotou bastnasite concentrate was developed by fixing fluorine and chlorinating with ammonium chloride in the ore (Shi et al, 2003, pp.438-442). The optimum conditions were determined as follows: the MgO/ore ratio of 3 at 600 °C; chlorinating the fixed fluorine calcine in 80 min, with ammonium chloride/ore ratio of 2 at 500°C.

The main equations concerning a dissolution of rare earth elements from bastnasite ore in sulfuric acid are described as:

$$2REFCO_3 + 3H_2SO_4 \rightarrow RE_2(SO_4)_3 + 2HF + 2H_2CO_3 \quad (1)$$

$$CaCO_3 + H_2SO_4 \rightarrow CaSO_4 + H_2CO_3 \quad (2)$$

$$Fe_2O_3 + 3H_2SO_4 \rightarrow Fe_2(SO_4)_3 + 3H_2O \quad (3)$$

$$MnO + H_2SO_4 \rightarrow MnSO_4 + H_2O \quad (4)$$

According to the “Recovery behavior of rare earth from Bayan Obo Complex Iron ore” (Ding et al, 2013, pp.28-36) a two step strategy with a carbothermic reduction in an electric furnace and a subsequent sulfuric acid leaching of the formed slag was proposed. As already mentioned, the rare earth elements such as Ce and La which are more fully crystallized when the cooling rate of the liquid slag is decreased, were leached by hydrochloric acid to evaluate the relations between the leaching efficiency of rare earth elements and the cooling conditions. This method would allow a separation of the produced iron and the formed slag containing REE. Once smelted, the slag should contain a high fraction of rare earth elements together with other compounds that normally appear in slags. Therefore, the slag can be considered as a rare earth concentrate suitable for leaching operations using sufuric acid and for a subsequent recovery of REEs.

The formation of slag during iron manufacture is the result of a number of complex operations between silica, oxides, other oxidation by-products from melting and reactions with refractory linings, etc. It is therefore a complex liquid phase made of oxides of iron, manganese, magnesium, silicon, silicates and sulfides plus other complex compounds that may include alumina, calcium oxides and sulfides, and rare earth oxides. Depending on the elements present in bastnasite ore, the formed slag will probably contain MgO, SiO_2, Fe_2O_3, CaO, and MnO as well as rare earth compounds.

An advantage of reduction smelting of bastnasite ore with high iron oxides grades is that the mineral already contains calcium carbonate which is normally used as an additive in iron smelting. A popular additive is limestone with small quantities of calcium fluoride.

The main aim of the following experimental study was to compare the leaching efficiencies of rare earth elements from bastnasite ore by smelting and a subsequent leaching of the slag using sulfuric acid.

The proposed strategy for the treatment of bastnasite ore was shown in Figure 1. In this paper, we will be focused only on reductive smelting and acidic leaching.

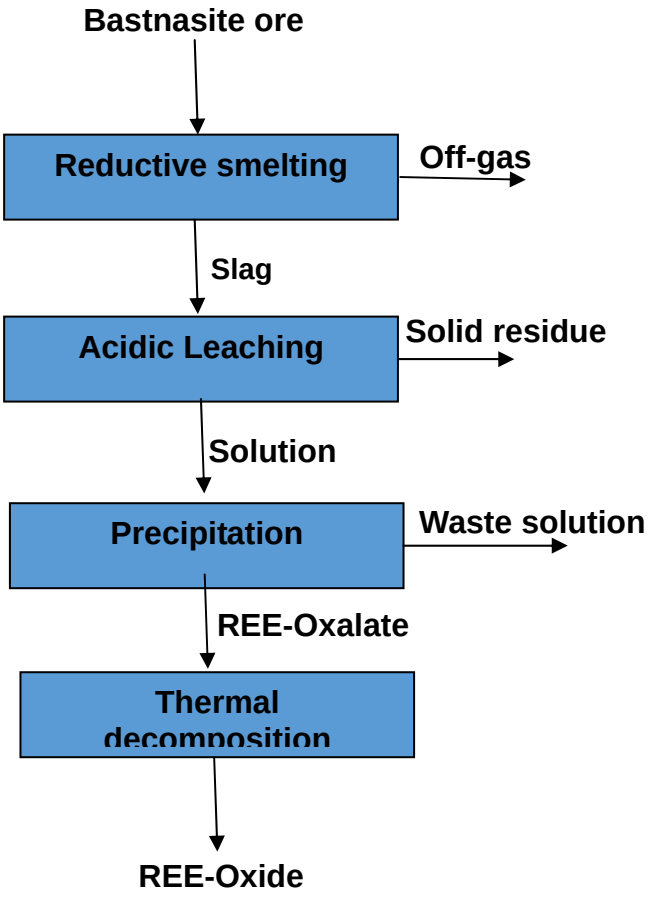

Figure 1 – Research strategy from bastnasite ore to rare earth oxide
Рис. 1 – Исследовательская стратегия от бастнезитовой руды до оксидов редкоземельных элементов
Слика 1 – Стратегија истраживања од бастнезитне руде до оксида ретке земље

The precipitation was performed using oxalic acid in order to produce rare earth oxalate. Finally, rare earth oxides were prepared after thermal decomposition of rare earth oxalate at 800°C in a muffle furnace.

Experimental work, material, parameters, and procedure

The chemical composition of bastnasite ore was shown in Table 1.

Table 1 – Chemical composition of the Rodberg bastnasite ore sample
Таблица 1 – Химический состав образца «Родбергский бастнезит – минерал, содержащий, фторкарбонат»
Табела 1 – Хемијски састав узорка„Родберг руде бастнезит која садржи флуорокарбонатни минерал”

Compound	Fe_3O_4	$CaCO_3$	$MgCO_3$	MnO	TREO	ThO_2	SiO_2
(%)	78.1	11.0	6.0	0.5	1.5	0.1	2.8

The reduction smelting of bastnasite ore was carried out in a small electric arc furnace and carbon was added as a reducing agent.

Figure 2 – Reduction smelting of the Rodberg ore in an electric arc furnace (left) and a ladle with the resultant slag (right)
Рис. 2 – Восстановительная плавка образца Родберга в электродуговой печи (слева) и ковш с полученным шлаком (справа)
Слика 2 – Редуктивно топљење узорка Родберг у електролучној пећи (лево) и кутлача с добијеном шљаком (десно)

The bastnasite sample was a high iron grade ore used for reductive smelting. The initial mass of bastnasite ore added to the furnace was 1480 g. The furnace was kept at 1600°C for 45 minutes. After this time, the slag formed at the top of the furnace was poured onto a ladle and left to cool. Both the slag and the reduced portion of iron were weighed after cooling. The mass of the produced metallic iron after reduction was of 816 g. The mass of the produced slag was of 58 g.

Table 2 – Chemical composition of the produced slag
Таблица 2 – Химический состав полученного шлака
Табела 2 – Хемијски састав добијене шљаке

Compound (%)	SiO_2	Fe_2O_3	CaO	MgO	La_2O_3	Nd_2O_3	CeO_2
Amount	11.4	15.4	30.2	0.78	1.43	2.62	2.59
Compund (%)	Y_2O_3	Sc_2O_3	ThO_2	Gd_2O3	Pr_2O_3	Sm_2O_3	Total
Amount	0.15	0.059	0.94	0.30	0.64	0.28	66.79

The slag was then crushed and ground to powder with a comparable particle size similar to direct leaching. The leaching agent used was sulfuric acid. The apparatus and the experimental procedure were the same as in the first set of experiments (Stopić & Friedrich, 2019, pp 241-254). Once the 1L acidic solution had been prepared and heated on an induction plate, the available mass of slag, 49g, was added into the beaker. The samples were collected every 1, 2 and 3h. The leaching parameters are very similar to the ones used in the first set of experiments.

Table 3 – Parameters for the leaching of slag with sulfuric acid
Таблица 3 – Параметры для выщелачивание шлаков с помощью серной кислоты
Табела 3 – Параметри за лужење шљаке помоћу сумпорне киселине

Parameter	set value
Concentration of sulfuric acid (mol/L)	1
Temperature (°C)	70
Solid -liquid ratio (g/L)	49
Time (h)	1, 2, 3
Stirring rate (rpm)	400

Results and discussion

The chemical analysis results show that the slag became a rare earth concentrate with 6.67% of REE in comparison to original bastnasite ore which contained 1.36% REE.

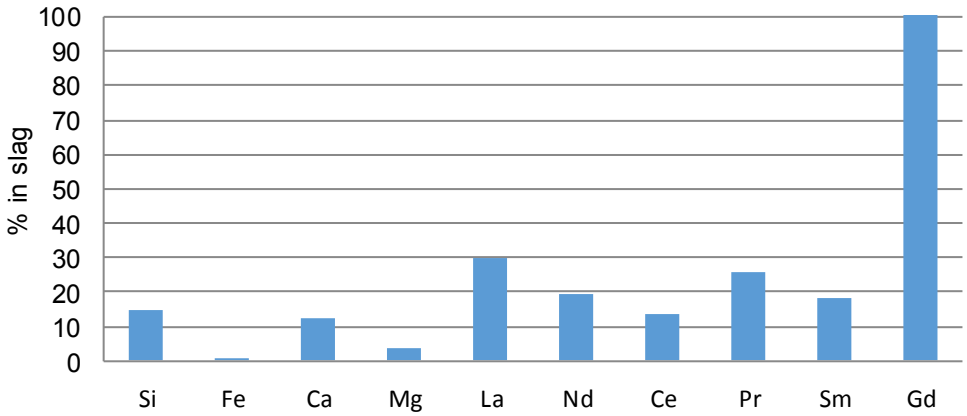

Figure 3 – Percentage of elements that have passed from bastnasite ore to slag
Рис. 3 – Доля элементов, перешедших из бастнезита в шлак
Слика 3 – Проценат елемената који су прешли из бастнезитне руде у шљаку

Figure 3 shows the percentage of REEs that the slag has acquired from the bastnasite ore. Only 0.58% of iron was passed onto the slag, together with 15.02% Si, 12.53% Ca and 3.69% Mg. The proportion of lanthanide elements that were passed onto the slag was greater: 29.87% La, 13.55% Ce, 25.79% Pr and 19.56% Nd, but still not very high. All of gadolinium, a representative of heavier rare earths, went into the slag. The average of rare earth incorporation into the slag is 34.54% (La+Ce+Nd+Pr+Sm+Gd). In general, it can be said that important amounts of REEs are not incorporated into the slag and will be lost for further processing. In order to establish the content of REE, the analysis of the formed iron metal was performed. The ground slag was dissolved in 1mol sulfuric acid at 70°C, as shown in Figure 3.

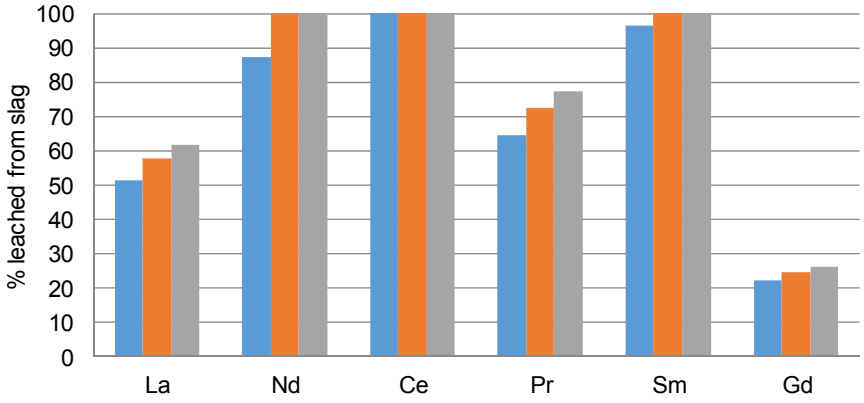

Figure 4 – Percentage of rare earth elements dissolved from slag in sulfuric acid after 1 hour (blue color), 2 hours (orange color) and 3 hours (gray color) using 1mol/L sulfuric acid
Рис. 4 – Доля элементов редкоземельных руд, выделенных из шлаков в растворе серной кислоты, по истечении одного часа (синий столбик), двух часов (оранжевый столбик) и трех часов (серый столбик), с использованием 1mol/L серной кислоты
Слика 4 – Проценат елемената ретких земаља растворен из шљаке у сумпорној киселини после једног сата (плава боја), два сата (наранџаста боја) и три сата (сива боја) уз коришћење 1mol/L сумпорне киселине

The pH-values of the solution during the leaching process between 1 and 3 hours amounted to between 0.44 and 0.53. As shown in Figure 3, the proportions of REEs leached from the slag using the sulfuric acid solution after 1h, 2h and 3h are sufficient. The maximum leaching efficiencies are 100% for cerium, neodymium and samarium. The minimum leaching efficiency is about 25 % for gadolinium. The differences in the leaching efficiency for single rare earth elements can be explained via the inhomogeneity of the produced slag.

In all cases, the leaching efficiency was increased with time from 1 hour to 3 hours, as it happened in direct leaching. For instance, the recovery of cerium and neodymium is around 18% higher after 3h than after 1h. The biggest proportion of rare earths is leached out after the first hour, then the rate of extraction decreases but does not reach a steady state rate within 3h of the experiment.

Gadolinium is the least dissolved element, followed by lanthanum and praseodymium. After 1h, the percentage of Gd extracted from the slag is 22.27%, followed by 51.22% La and 64% Pr. The rest of the elements, cerium, neodymium and samarium, exhibit large dissolution ratios. 87% Nd and 96% Sm dissolve within the first hour. Cerium is

completely dissolved according to these results. The average percentage of the REEs (La+Nd+Ce+Pr+Sm+Gd) dissolved after 1h and 3h is 73.76% and 88.68%, respectively.

Finally, if we compare the leaching efficiency of the two step strategy: the smelting and slag leaching process with the direct leaching of bastnasite ore from the first set of experiments, (see Figure 5), we find that the direct leaching process is not more efficient. Direct leaching of bastnasite ore with sulfuric acid at 70°C gives the leaching efficiency between 16 of 20 % for rare earth elements (La+Ce+Nd+Sm) between 1 and 3 hours in comparison to 30 % and 60 % in the two step strategy. The best leaching efficiencies are obtained for samarium during 1hour smelting and the 3-hour leaching process. The reason for this behavior is that rare oxides are in a form more suitable for leaching. On the other hand, iron was removed during the smelting process as metallic iron. Finally, the leaching of the formed concentrate is more favorable than the leaching of bastnasite ore.

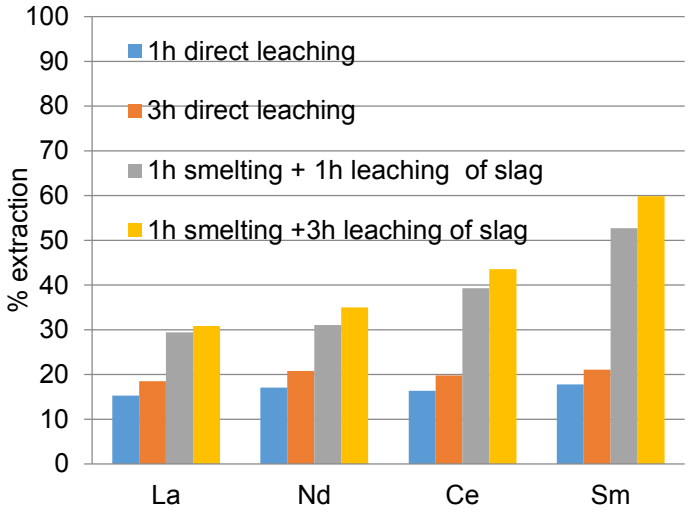

Figure 5 – Percentage of rare earth recovery by direct leaching in comparison to the two step strategy: smelting and leaching of slag
Рис. 5 – Доля восстановления редкоземельных руд, прямым выщелачиванием в сравнении с двухэтапным методом: плавление и выщелачивание из шлака
Слика 5 – Проценат опоравка ретких земаља директним луженьем у поређењу са стратегијом у два корака: топљење и луженье шљаке

The real advantage of the smelting method is the reduction of acid consumption. If we were to use the same amount of solid to liquid ratio, this means the smelting strategy would allow us to save 86% of the acid. Given the low prices of sulfuric acid, it is evident that the most favorable strategy for REE extraction is direct leaching for the bastnasite ore with a decreased content of iron. Rare earths are critical metals and, above all, a priority strategic resource, indispensable in economic well-being, industrial production and national security affairs.

Conclusions

The followings findings:

1. Two step strategy: carbothermic reduction of bastnasite ore with a high content of iron oxide and a subsequent leaching of the formed slag with sulfuric acid has shown some advantages (high leaching efficiencies of REE in sulfuric acid and the newly formed slag as a concentrate of REE with 8 % TREO) with some disadvantages (a high percentage of thorium is present in the slag).
2. The direct leaching process will be used for bastnasite ores with a decreased content of iron oxide.
3. Removal of thorium from the solution during precipitation after leaching will be considered using sodium pyrophosphate of different pH-values in the future work.
4. The future work will be continued in order to improve a transfer of rare earth elements from bastnasite ore to slag via changing the parameters for reductive smelting.

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ВЫЩЕЛАЧИВАНИЕ РЕДКОЗЕМЕЛЬНЫХ ЭЛЕМЕНТОВ ИЗ ПОРОД, СОДЕРЖАЩИХ ФТОРКАРБОНАТЫ – ТРЕТЬЯ ЧАСТЬ

Сречко Р. Стопич, *Бернд* Г. Фридрих
Технический университет города Ахен,
Институт металлургических процессов и рециклирования металлов,
Ахен, Федеративная Республика Германия

РУБРИКА ГРНТИ: 61.13.21 Химические процессы
ВИД СТАТЬИ: оригинальная научная статья
ЯЗЫК СТАТЬИ: английский

Резюме:

При исследовании процесса выщелачивания редкоземельных рудных пород, содержащих фторкарбонат, применялся метод восстановительного плавления в углеродной среде при температуре 1600° С, состоящий из двух этапов: 1) карботермическое восстановление и 2) растворение в серной кислоте при атмосферном давлении, с целью увеличения селективного извлечения редкоземельных элементов из шлака, содержащего редкоземельные элементы.

Ключевые слова: редкоземельные элементы, плавление, выщелачивание, серная кислота.

РАСТВАРАЊЕ ЕЛЕМЕНАТА РЕТКИХ ЗЕМАЉА ИЗ РУДА КОЈЕ САДРЖЕ ФЛУОРОКАРБОНАТНИ МИНЕРАЛ (ТРЕЋИ ДЕО)

Срећко Р. Стопић, *Бернд* Г. Фридрих
Технички универзитет у Ахену, Институт за процесну металургију и рециклирање метала, Ахен, Савезна Република Немачка

ОБЛАСТ: хемијске технологије
ВРСТАЧЛАНКА: оригинални научни рад
ЈЕЗИК ЧЛАНКА: енглески

Сажетак:

Растварање елемената ретких земаља из бастнезитне руде (руде која садржи флуорокарбонатни минерал) проучавано је после редуктивног топљења угљеником на 1600°C. Стратегија у два корака: 1. редукција угљеником, и 2. растварање помоћу сумпорне киселине примењено је на атмосферском притиску са циљем да се повећа екстракција елемената ретких земаља из шљаке која садржи елементе ретких земаља.

Кључне речи: елементи ретких земаља, топљење, лужење, киселина.

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MECHANICAL PROPERTIES AND METALLOGRAPHIC ANALYSIS OF PLASMA SPRAY APS - Ni5.5wt.%Al5wt.%Mo COATINGS

Mihailo R. Mrdak
Research and Development Center IMTEL Communications a.d.,
Belgrade, Republic of Serbia,
e-mail: miki@insimtel.com,
ORCID iD: http://orcid.org/0000-0003-3983-1605

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FIELD: Chemical technology
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Summary:

This paper presents the testing of the mechanical and microstructural characteristics of atmospheric plasma spray (APS) coatings of Ni5.5wt.%Al5wt.%Mo composite powder. The aim of this study was to optimize powder feed (g/min) in order to deposit NiAlMo coating layers with optimum mechanical and structural characteristics to worn aviation parts made of Ni alloy exposed to a combination of corrosion and wear. The microhardness of the deposited layers was tested using $HV_{0.3}$ and tensile bond strength was tested by tensile testing. The morphology of powder particles was examined on a SEM (scanning electron microscope). The NiAlMo coating microstructure was examined on an optical microscope (OM). Fracture morphology of the top layer was tested on an electronic scanning microscope (SEM). It was found that the control of powder feed can result in coatings with good bond strength.

Key words: atmospheric plasma spraying (APS), microstructure, Ni5.5wt.%Al5wt.%Mo, microhardness, bond strength.

Introduction

The development of surface engineering is mostly dynamic due to the fact that this discipline of science and technology is increasingly reliant on all key contemporary technological conditions such as: improving efficiency, saving materials, environmental protection, and so on.

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The surface engineering approach is even more useful since surfaces of metal components can be modified mechanically, chemically or physically. In the wide field of mechanical, chemical and metallurgical engineering, a series of problems is associated with wear and corrosion. Significant financial costs are caused by repair measures and downtime of plants. Many of these problems can be prevented by applying different coatings on highly loaded constructional parts. Technologies such as flame spraying and atmospheric plasma spraying (APS) are used where the application of coatings is economically justified to protect structural parts. Such produced coatings can provide new features to constructional parts (Mrdak, 2016). The plasma spraying method is one of the most flexible methods for thermal deposition of coatings and may be configured so that the jet of particles has a wide range of temperatures and speeds (Mrdak, 2018, pp.415-430). Fine powder particles are injected into plasma gas feed and they accelerate because of the transfer of velocity and temperature of ions onto powder particles. Under the substrate influence, particles deform plastically and bond to the substrate to form a coating. The process allows the deposition of a wide range of powders. Powder deposition speed is one of the most important parameters affecting the stress state of the coating which is directly related to the coating cohesion strength, microhardness and adhesion. Powder deposition speed can largely regulate a share of unmelted particles, pores and oxides in the coating. Powder deposition speed must be optimal in order to ensure complete melting of powder particles and reduce unmelted particles, pores and oxides in coating layers to the minimum. With powder deposition speed higher than the optimum speed, powder particles do not have enough time to melt completely, what leads to an increase in the share of unmelted particles and coarse pores in coating layers. Unmelted particles, together with pores, reduce cohesion and adhesion strength of the coating. A large proportion of unmelted particles and pores significantly reduces the protective effect of the coating in exploitation. Similar effects are caused by the feed of plasma gas, the intensity of electrical current and the distance of the substrate from the plasma gun (Mrdak, 2016). NiAlMo coating is one from a series of coatings based on Ni which, due to its characteristics, has found a wide application in the fields of mechanical, chemical and metallurgical engineering for protection and repair of functional parts. The coating is produced by applying powder Metco 447NS which can be deposited by all thermal spray processes. Metco 447NS (Ni5.5wt.%Al5wt.%Mo) is a composite of nickel-aluminum-molybdenum powder intended for depositing coatings applying thermal

spray processes. It is produced by mechanical deposition or by gas atomisation using an inert gas. A coated material consists of a core of nickel coated with aluminum and molybdenum. The morphology of produced particles is spherical with a nominal density of 3.5 g/cm^3. During thermal spraying, there is an exothermic reaction between nickel and aluminum (Al-Ni) and molybdenum and aluminum (Al-Mo), which increases the bond strength of the coating with the substrate and the cohesive strength between deposited particles. High values of mechanical properties of the NiAlMo coating were confirmed in the papers (Chen et al, 2015, pp.281). Plasma spraying of powders has produced perfect results of bonding between the substrate and the coating. Coatings are self-bonding with very good resistance to shock. The coating is applied at the operating temperature of ≤ 650 °C. The NiAlMo coating is a good choice for the area which requires high toughness, corrosion resistance with moderate resistance to friction, erosion and scratch. The coating is applied to the areas such as: machine elements and bearings, wear rings, exhaust fans and collectors, diesel engines, fuel pump, valve seats, etc. (Oerlikon Metco, 2017). The microstructure of the triple alloy Ni-Al-Mo rich in Ni consists of small, coherent precipitates of the γ'-Ni_3Al phases embedded in the base of the γ - phase rich in Ni. The high mechanical strength of the Ni-based super alloy at elevated temperatures is mainly due to the presence of two phases consisting of a fine distribution of hard, coherent γ'-Ni_3Al precipitates embedded in the base of the γ - phase rich in Ni. This heterogeneity of the composition and the presence of different crystallographic structures impede movements of dislocations, which leads to high strength and resistance to creep (Lin et al, 2018, pp.1550-1575). After the formation of the critical size of the nucleus, precipitates increase to reduce basis saturation, and in later stages, to reduce the total interface in the growth of large precipitates at the expense of smaller precipitates. The part of the Ni-Al-Mo system rich in Ni was intensively investigated. Parts of the three Ni-Al-Mo phase diagram have been published in the literature by (Miracle et al, 1984, pp.481-486). The isothermal cross-section of the three-phase diagram of Ni-Al-Mo at 1200 °C near the corner rich in Ni is presented in Figure 1. At this temperature, the two phase region of γ-Ni + γ'-Ni_3Al is separated from the region of the γ - phase, with the region of the γ'' - phase and the three-phase region which includes γ, γ' and δ - phases, where the last phase is δ-NiMo intermetallic compound. One of the main reasons for alloying the dual Ni-Al system with Mo arises from a possibility of changing the mismatch between the γ lattice and the γ' phase. Another important

parameter is a possibility of adjusting the content of Al in relation to Ni (Conley et al, 1989, pp.1251-1263). Ni-Al-Mo composite is produced by the method of unidirectional solidification of the alloy eutectic composition. Solidification of Ni-Al-Mo alloy produces the γ-Ni phase as the basis and coherent γ'-Ni_3Al precipitates embedded in the γ basis, as well as the phase of the α-Mo lamellar structure (Ishak & Takagi, 2012, pp.416-420), (Rico et al, 2010, pp.531-550).

The main objective of this study was to homogenise Ni 5.5wt.%Al5wt.%Mo coating layers and apply them on the worn aircraft parts of Ni alloys exposed to a combination of corrosion and wear. The two groups of samples were made with two powder feed values of 30 g/min and 60 g/min. We analyzed the mechanical properties and the microstructure of the coating layers on the basis of which the best-quality coating was chosen.

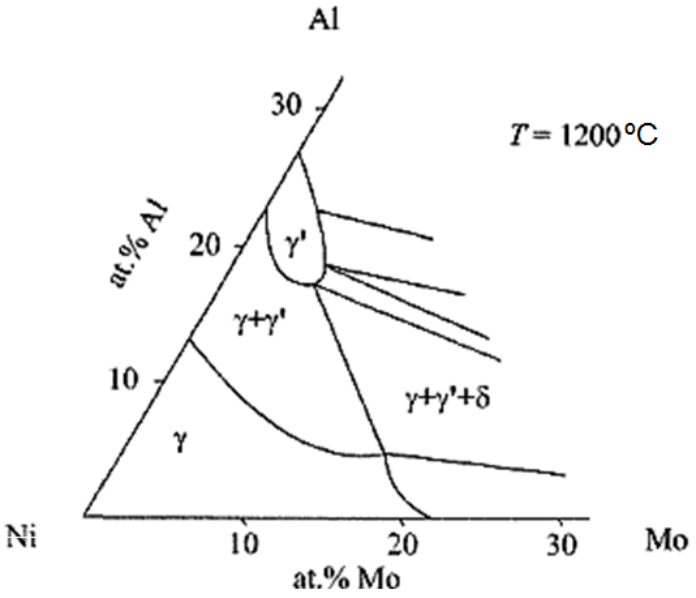

Figure 1 – Part of the Ni-rich Ni-Al-Mo phase diagram at 1200 ºC (Miracle et al, 1984, pp.481-486)
Рис. 1 – Часть фазовой диаграммы Ni-Al- Mo, обогащенного Ni при 1200 ºC (Miracle et al, 1984, pp.481-486)
Слика 1 – Део фазног дијаграма Ni-Al- Mo богатог Ni на 1200 ºC (Miracle et al, 1984, pp.481-486)

Materials and experimental details

Powder of the Oerlikon Metco company labelled Metco 447 NS was used for the experiment. Ni5.5wt.%Al5wt.%Mo composite powder is produced by mechanical deposition or by gas atomisation using an inert gas (Oerlikon Metco, 2017). Powder particles are spherical which enables smooth flow of powder in the plasma jet. The range of granulation of powder particles used in the experiment was from 45 to 90 μm. Figure 2 shows the SEM scanning electron photomicrographs of the morphology of Ni5.5wt.%Al5wt.%Mo powder particles.

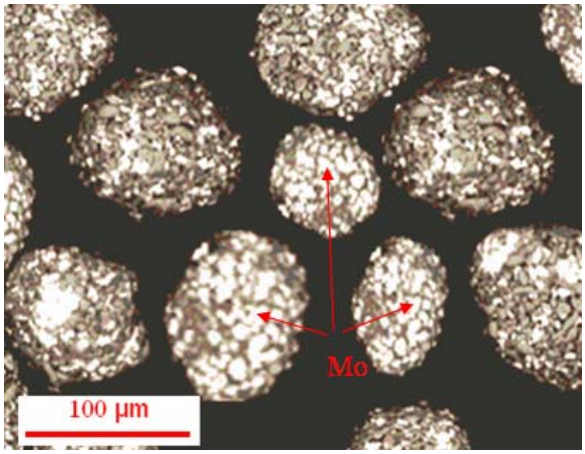

Figure 2 – (SEM) Scanning electron micrography of Ni5,5wt.%Al 5wt.% Mo powder particles
Рис. 2 – (СЭМ) Сканирующая электронная микроскопия частиц порошка Ni5,5вес.%Al 5вес.% Mo
Слика 2 – (СЕМ) Скенинг електронска микрографија честица праха Ni5,5теж.%Al 5теж.% Mo

For the deposition of Ni5.5wt.%Al5wt.%Mo composite powder, the atmospheric plasma spraying system (APS) of the Plasmadyne company was used as well as the SG-100 plasma gun consisting of the K 1083-129 cathode, the A 2084-145 anode and the GI 2083-113 gas injector. Ar was used as arc gas in a combination with He and the power supply was 40 kW. Powder feed (g/min) was the basic parameter for the preparation of coatings. The experiment involved two powder feed values, 30 g/min and 60 g/min. Powder feed is one of the important parameters affecting the quality of the coating, which is directly related to cohesion strength, microhardness and adhesion of the coating. With

large powder feed, particles do not have enough time to melt fully, which leads to an increased share of partially molten particles and pores in the coating layers. Partially molten powder particles, together with pores, reduce the cohesive and adhesion strength of the coating. With reduced powder feed, particles are completely melted and, under the substrate influence, deform plastically in a more appropriate way, bonding to the substrate with a smaller proportion of pores. The detailed values of the plasma spray parameters are shown in Table 1. Prior to powder deposition, the substrate surface is roughed with corundum Al_2O_3 with a particle size of 0.7 - 1.5 mm. The coatings were deposited with a thickness of up to 0.30 mm.

Table 1 – Plasma spray parameters
Таблица 1 – Параметры плазменного напыления
Табела 1 – Плазма спреј параметри

Deposition parameters	Values
Plasma current, I (A)	800
Plasma Voltage, U (V)	32
Primary plasma gas feedrate Ar, (l/min)	47
Secondary plasma gas feedrate He, (l/min)	32
Carrier gas feedrate Ar, (l/min)	7
Powder feed rate, (g/min)	30/60
Stand-off distance, (mm)	80

The testing of the structural and mechanical characteristics of the coatings was done in accordance with the Pratt & Whitney standard (Pratt & Whitney, 2002). The bases on which Ni5.5wt.%Al5wt.%Mo coatings were deposited for microhardness testing and evaluation of microstructure in the deposited state were made of thermally unprocessed Č.4171 (X15Cr13 EN10027) steel with the dimensions of 70x20x1.5mm (Pratt & Whitney, 2002). The bases for testing bond strength were also made of thermally unprocessed Č.4171 (X15Cr13EN10027) steel wih the dimensions of Ø25x50 mm (Pratt & Whitney, 2002). Microhardness testing of Ni5.5wt.%Al5wt.%Mo coating layers was done using the method $HV_{0.3}$ and bond strength was tested by tensile testing. The microhardness measurement was performed in the direction along the lamellae. Five readings were obtained, in the middle and at the ends of the samples, which were then averaged. Bond

strength testing was done at room temperature with a tensile speed of 1cm/60s. For each group of samples, three specimens were tested. The morphology of Ni5.5wt.%Al5wt.%Mo powder particles was examined by scanning electron microscopy (SEM). The microstructure of Ni5.5 wt.%Al5wt.% Mo coating layers in the deposited state was tested on an optical microscope (OM). The fracture morphology of the best Ni5.5 wt.%Al5wt.%Mo coating layers in the deposited state was examined on the SEM.

Results and discussion

The values of the microhardness and the bond strength of the deposited Ni5.5wt.%Al5wt.%Mo coating, depending on powder feed, are shown in Figures 3 and 4.

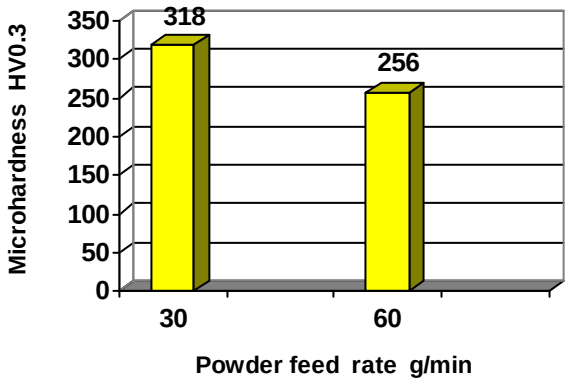

Figure 3 – Microhardness of Ni5,5wt.%Al5wt.%Mo layers
Рис. 3 – Микротвердость Ni5,5вес.%Al5вес.%Mo слоев
Слика 3 – Микротврдоћа Ni5,5теж.%Al5теж.%Mo слојева

The microhardness values of the layers directly depended on the powder feed. The bond microhardness and strength values of Ni5.5wt.%Al5wt.%Mo deposited layers were significantly affected by powder feed. The layers deposited with a lower powder feed of 30 g/min had a higher microhardness value of 318 $HV_{0.3}$. These layers showed the best microstructure with the densest packing of molten particles and with a lower proportion of pores, which was confirmed by metallographic examination. The layers with the largest share of pores which were deposited with the largest powder feed of 60 g/min have a microhardness

value lower than 256 $HV_{0.3}$. The microhardness values of these layers were significantly lower. Larger powder feed resulted in less pronounced melting of powder particles and less packaging on each other accompanied by a higher share of interlamellar pores.

Tensile bond strength was directly related to the feed of Ni5.5wt.%Al 5wt.%Mo powder. The highest value of the bond strength of 56MPa was found in the layers with a higher microhardness value and the smallest proportion of pores. These layers were deposited at a powder feed rate of 30 g/min. The lowest bond strength value of 32 MPa was found in the layers deposited with a powder feed rate of 60 g/min which had lower microhardness. The failure mechanism for both deposited coatings was adhesion at the interface between the substrate and the Ni5.5 wt.%Al5wt.%Mo coating.

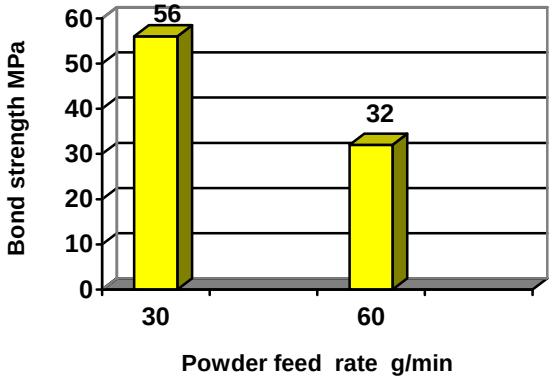

Figure 4 – Bond strength of Ni 5,5wt.%Al5 wt.%Mo layers
Рис. 4 – Прочность сцепления Ni5,5вес.%Al5вес.%Mo слоев
Слика 4 – Чврстоћа споја Ni5,5теж.%Al5теж.%Mo слојева

Figures 5 and 6 show the (OM) photomicrographs of the Ni5.5wt.%Al5wt.%Mo layers deposited with a powder feed rate of 30 g/min and 60 g/min. The microstructural analysis of the NiAlMo coatings showed that the layers were deposited on the substrate continuously without interruption and without the presence of micro-cracks and macro-cracks at the interface. At the interface between the coating and the substrate, contamination provoked by roughening was not observed (Fig. 6). The well-prepared substrate surface enabled obtaining good bond strength values. The micrographs clearly show different proportions of pores in the deposited layers. The smallest proportion of pores was

present in the layers of the NiAlMo coatings deposited with a powder feed of 30 g /min. In these layers, the total proportion of pores was 2%. In the coating layers deposited with a powder feed rate of 60 g/min, the proportion of pores was 5%. The proportion of pores in the NiAlMo coating layers correlated with the proportion of unmelted particles. The microstructure of the inner layers of the coating deposited at a powder feed rate of 30 g/min. is lamellar (Fig. 5).

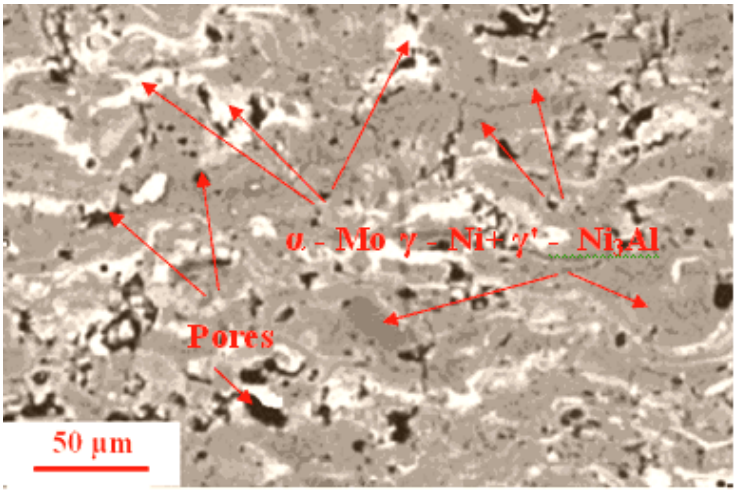

Figure 5 – (OM) Microstructure of the Ni5,5wt.%Al5 wt.%Mo coating deposited with a powder feed rate of 30 g/min

Рис. 5 – (ОМ) Микроструктура Ni5,5вес.%Al5вес.%Mo покрытия, нанесенного порошковым напылением 30 г/мин

Слика 5 – (ОМ) Микроструктура Ni5,5теж.%Al5теж.%Mo превлаке депоноване протоком праха 30 g/min

The coating base consists of a solid solution of γ–Ni rich in nickel in which the precipitates are γ'-Ni_3Al phases. In the microstructure of the coating, the lamellae of a lighter phase of molybdenum α–Mo are clearly observed (Ishak & Takagi, 2012, pp.416-420), (Rico et al, 2010, pp.531-550). In the lamellar base of the solid solution of γ - Ni and the intermetallic phases of γ'-Ni_3Al, there are clearly visible dark fields representing inter-lamellar pores which are much finer in relation to the micro pores present in the coating layers deposited with a feed rate of 60g/min. The coating layers do not contain unmelted powder particles and precipitates which may occur as a result of collision of molten drops with the substrate (Fig. 5).

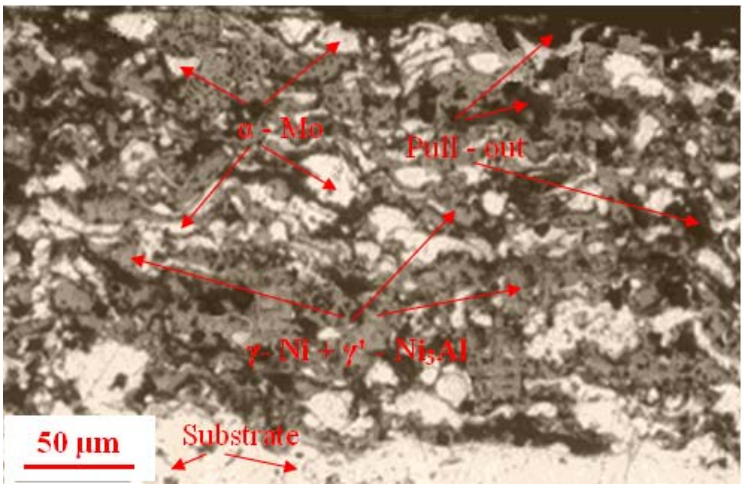

Figure 6 – (OM) Microstructure of the Ni5,5wt.%Al5 wt.%Mo coating deposited with a powder feed rate of 60 g/min
Рис. 6 – (ОМ) Микроструктура Ni5,5вес.%Al5вес.%Mo покрытия, нанесенного порошковым напылением 60 г/мин
Слика 6 – (ОМ) Микроструктура Ni5,5теж.%Al5теж.%Mo превлаке депоноване протоком праха 60 g/min

In the microstructure of the NiAlMo coatings deposited with a powder feed of 60 g/min (Fig. 6), it is possible to see a significant proportion of incompletely melted powder particles which are less plastically deformed in a collision with the substrate surface. The morphology of the deposited particles is more spherical; therefore, the structure is not fully lamellar. Between partially molten globules there are black pores which are quite rough and irregular. Due to a large amount of powder feed into the plasma jet and its low melting point, a properly layered lamellar structure of the deposit could not be formed. Black fields in the microstructure (pull-out) represent the locations of extracted particles nearly spherical in shape, which result from pulling out incompletely melted powder particles from the base during sample preparation. Solidification of Ni-Al-Mo composite powder particles resulted in the microstructure as in Fig. 5 consisting of γ-Ni phases rich in Ni as the basis and coherent γ'-Ni_3Al precipitates embedded in the γ basis. The α-Mo molybdenum phases of more globular than lamellar morphology are clearly ooserved in the microstructure (Ishak & Takagi, 2012, pp.416-420), (Rico et al, 2010, pp.531-550). Micro-cracks are not

observed through the deposited layers. The best microstructure is found in the layers deposited at a feed rate of 30 g/min.

Figure 7 shows the fracture photomicrographs of the NiAlMo coating layers deposited with a powder feed of 30 g/min. The fracture surfaces of the coatings were examined on the SEM in order to analyze their morphology. The fracture of the NiAlMo coating surface shows a continuous structure with layered deposited melted particles. The analysis of the sample showed that the coating was decomposed and highly fractured, as it can be seen in the figure, especially in the area above the fracture toughness zone. The fracture occurred between the lamellae of the deposited particles. During fracture, cracks commonly propagate along lamelar interfaces where the bond is weaker than through lamellae which requires much higher strain.

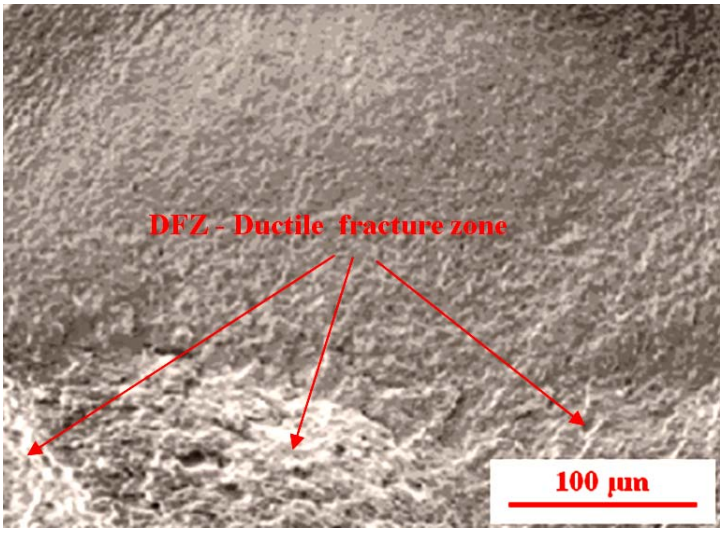

Figure 7 – (SEM) fracture morphologies of NiAlMo coatings deposited with a powder feed rate of 30 g/min
Рис. 7 – (СЭМ) Морфология трещин в NiAlMo покрытии, нанесенном порошковым напылением 30 г/мин
Слика 7 – (SEM) Морфологије лома NiAlMo превлаке депоноване протоком праха 30 g/min

Figure 7, therefore, presents the interlamellar fracture mode. The fracture toughness zone is clearly visible in the lower part of the sample.

Conclusion

In this paper, APS - atmospheric plasma spraying was used for depositing Ni-Al-Mo powder coatings with a feed rate of 30 and 60 g/min. The mechanical properties have been analyzed as well as the microstructures of the coatings in the deposited state, and the following conclusions were drawn.

The mechanical properties of microhardness and bond strength as well as the microstructure of Ni-Al-Mo coatings were directly dependent on powder feed. The layers deposited with a lower powder feed of 30g/min had a higher microhardness value, 318 $HV_{0.3}$. These layers were more homogeneous and denser with a share pore of 2%, which resulted in a higher value of bond strength.

The structure of the Ni-Al-Mo coating layers deposited with a lower powder feed of 30g/min is lamellar consisting of a solid solution of γ – Ni rich in nickel in which there are precipitates of the γ'-Ni_3Al phase and the molybdenum α–Mo phase lamellae.

The fracture of the Ni-Al-Mo coating surface deposited with a lower powder feed of 30g/min shows compact microstructure with layers of deposited melted particles. The crack propagates easier along border surfaces of deposited molten particles where the bond is weaker than through the γ-Ni + γ'-Ni_3Al grain boundaries in each molten particle. During fracture, the mode of fracture was favorable interlamellar with a present fracture toughness zone.

The obtained results showed that powder feed in the process of deposition affects the mechanical properties and the microstructure of the coating layers. The examination of the coatings have confirmed that the best layers are those deposited with a powder feed of 30g/min.

The application of Ni-Al-Mo coatings in repair of aircraft parts based on Ni-alloys exposed to a combination of corrosion and wear significantly improves the efficiency and reliability of parts in service and significantly reduces costs of repair.

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МЕХАНИЧЕСКИЕ СВОЙСТВА И МЕТАЛЛОГРАФИЧЕСКИЙ АНАЛИЗ Ni5.5вес.%Al5вес.%Mo ПОКРЫТИЯ, НАНЕСЕННОГО ВОЗДУШНО-ПЛАЗМЕННЫМ НАПЫЛЕНИЕМ

Михаило Р. Мрдак
Центр исследований и развития А.О. «ИМТЕЛ коммуникации»,
г. Белград, Республика Сербия

РУБРИКА ГРНТИ: 61.13.21 Химические процессы
ВИД СТАТЬИ: оригинальная научная статья
ЯЗЫК СТАТЬИ: английский

Резюме:

В данной статье представлены результаты испытаний механических и микроструктурных характеристик покрытия из композитного порошка Ni5,5вес.%Al5вес.%Mo, нанесенного воздушно-плазменным напылением (ВПН). Целью исследования являлась оптимизация потока порошковой струи (г/мин) при нанесении слоев NiAlMo покрытия, обладающего оптимальными

механическими и структурными характеристиками, на части самолетов, которые подвергаются сочетанию коррозии и износа. Данные части изготовлены из сплавов Ни. Микротвердость нанесенных слоев, испытывалась методом HV0.3, а прочность на разрыв сцепления – методом растяжения. Морфология поверхности частиц порошка исследовалась с помощью СЭМ – сканирующего электронного микроскопа. Микроструктура НиАлМ покрытия была исследована с помощью оптического микроскопа (ОМ). Морфология трещин, образовавшихся в лучших слоях, исследовалась с помощью сканирующего электронного микроскопа (СЭМ). Испытания показали, что при контролируемом потоке порошковой струи слои нанесенного покрытия обладают высокой прочностью сцепления.

Ключевые слова: воздушно-плазменное напыление (ВПН), микроструктура, Ni5,5вес.%Al5вес.%Mo, микротвердость, прочность сцепления.

МЕХАНИЧКА СВОЈСТВА И МЕТАЛОГРАФСКА АНАЛИЗА ПЛАЗМА СПРЕЈ АПС – Ni5.5теж.%Al5теж.%Mo ПРЕВЛАКЕ

Михаило Р. Мрдак
Истраживачки и развојни центар ИМТЕЛ -КОМУНИКАЦИЈЕ а.д., Београд, Република Србија

ОБЛАСТ: хемијске технологије
ВРСТА ЧЛАНКА: оригинал научни рад
ЈЕЗИК ЧЛАНКА: енглески

Сажетак:

У овом раду представљена су испитивања механичких и микроструктурних карактеристика атмосферски плазма спреј (АПС) превлака од композитног праха Ni5,5теж.% Al5теж.%Mo. Циљ истраживања био је да се оптимизира проток праха (г/мин) како би се депоновали слојеви NiAlMo превлаке оптималних механичких и структурних карактеристика који ће се применити на похабаним ваздухопловним деловима од легура Ни изложени комбинацији корозије и хабања. Микротврдоће депонованих слојева урађене су методом $HV_{0.3}$ и затезне чврстоће споја методом испитивања на затезање. Морфологија површине честица праха испитана је на СЕМ-у (скенинг-електронском микроскопу). Микроструктура НиАлМо превлака испитана је на оптичком микроскопу (ОМ), а морфологија лома најбољих слојева на СЕМ-у. Утврђено је да се контролом протока праха могу произвести слојеви превлаке са добром чврстоћом споја.

Кључне речи: атмосферски плазма спреј (АПС), микроструктура, Ni5,5теж.%Al5теж.%Mo, микротврдоћа, чврстоћа споја.

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RELIABILITY AND AVAILABILITY OF THE INTERNET OF THINGS

Slavko J. Pokorni
Information Technology School, Belgrade, Republic of Serbia,
e-mail: slavko.pokorni@its.edu.rs,
ORCID iD: http://orcid.org/0000-0002-3173-597X

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Abstract:

The problem of reliability and availability of the Internet of Things (IoT) from the point of view of the classical approach of reliability assessment using MIL-HDBK 217 is discussed in this paper. With the classical approach of reliability assessment using MIL-HDBK 217, only hardware reliability can be assessed, and the situation with the IoT is more complicated: billions of different things (devices), software programs, and human users are involved (networked). The reliability and availability of the IoT is not only a matter of a failure rate of elements (things), but also protocols, standardization, logistics support and other influences. The relation for the reliability calcuation of an IoT system is proposed.

Key words: reliability, availability, maintainability, Internet of Things.

Introduction

Reliability as theory and practice began to develop in the 50s of the last century. Very soon MIL-HDBK-217 appeared. Reliability prediction by MIL-HDBK-217 has been done for about 60 years. By the time it has been shown that this manual, which is essentially based on an exponential distribution of failure, has a number of limitations, and that other approaches are needed (Pokorni, 2016).

Besides this, new challenges in reliability appeared in recent years. They are Cloud Services and the Internet of Things, and since they are very complex and with many dependencies, this puts new requirements on research and education in reliability and reliability culture (Pokorni, 2016), (Pokorni, 2018).

The Internet of Things (IoT) consists of hardware and software which can communicate without human intervention (in that case we can consider it to be machine to machine (M2M) communication); sometimes the human factor is involved, so hardware reliability is connected not only

to software reliability, but also to human reliability, thus creating a need to discuss these relations.

The problem of reliability and availability of the Internet of Things from the point of view of the classical approach of reliability assessment using MIL-HDBK 217 is discussed in this paper. With the classical approach of reliability assessment using MIL-HDBK 217, only hardware reliability can be assessed, and the situation with the IoT is more complicated: billions of different things (devices), software programs, and human users are involved (networked). The reliability of the IoT is not only a matter of a failure rate of elements (things), but also of software, human factor, logistics support, standardization and other influences, such as, for example, energy efficiencies (green), security (hacking, etc.).

Definition of reliability and availability

Reliability is defined as a probability that a component or a system will meet certain performance standards in yielding correct output for a desired time duration in certain environmental conditions.

Availability is a metric used to assess the performance of repairable systems, incorporating both the reliability and maintainability properties of a component or a system. There are different definitions of availability and different ways to calculate it.

Instantaneous availability (usualy called availability) is defined as the probability that a system (or a component) will be operational at a specific point of time.

For an unrepaired component or system, reliability and availability means the same, but for a repaired component or system, availability is bigger than reliability (Pokorni, 2014).

Internet of Things

A growing number of physical objects are being connected to the Internet at an unprecedented rate realizing the idea of the IoT (Popa et al, 2017), (Prasad & Kumar, 2013), Figure 1. The IoT first started in 1990s with industrial automation systems (Prasad & Kumar, 2013).

The Internet of Things will soon, if not already, permeate to all industries and have influence in everyone's life (Rohde & Schwarz, nd).

The IoT is regarded as the next phase in the evolution of the Internet. Electronic miniaturization, cost of electronic components, and the trend towards wireless communications are the three main drivers for the IoT (Ryan & Watson, 2017).

The Internet of Things is going to change a wide variety of real-time monitoring applications, for example, E-healthcare, homes automation system, environmental monitoring and industrial automation (Popa at al, 2017).

It is stated in (Andersen, 2018) that a lot of attention in recent time seems to be on building highly reliable (up to carrier grade) clouds, but another area is the IoT.

According to ITU-T, the IoT is defined as (Popa at al, 2017) „In a broad perspective, the IoT can be perceived as a vision with technological and societal implications. From the perspective of technical standardization, IoT can be viewed as a global infrastructure for the information society, enabling advanced services by interconnecting (physical and virtual) things based on, existing and evolving, interoperable information and communication technologies. Through the exploitation of identification, data capture, processing and communication capabilities, the IoT makes full use of things to offer services to all kinds of applications, while maintaining the required privacy."

In recent years, with the improvement in Internet connectivity and advances in smart personal computing devices, the IoT, along with its applications and supporting hardware platforms, has become a hot topic in both academic and practitioner communities. IoT systems can be deployed in many scenarios, where the scale of IoT deployments can vary from personal wearables to city-wide infrastructures (Zhu et al, 2018).

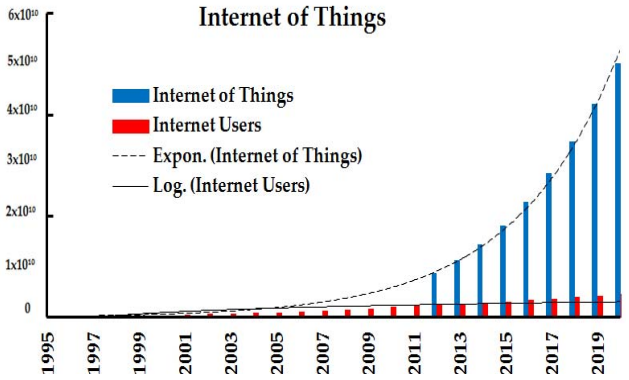

Figure 1 – Internet of Things growth (Ryan & Watson, 2017)
Рис. 1 – Рост интернета вещей (Ryan & Watson, 2017)
Слика 1 – Раст интернета ствари (Ryan & Watson, 2017)

The architecture of the Internet of Things consists of sensor nodes, the network domain, and application domains, Figure 2, (Popa et al, 2017), (Prasad & Kumar, 2013).

The Sensor Node domain is the same as the M2M node domain in M2M communication. After collecting the packets from the nodes, the gateway GW is able to intelligently manage the packets and provide efficient paths for forwarding these packets to the remote back-end server (BS) via wired/wireless networks. The network domain provides cost-effective and reliable channels for transmitting sensory data packets from the sensor domain to the application domain. The application domain is the last part with BS as the key component for the whole IoT communication.

Reliability of the IoT elements

Reliability is defined as the ability of an item to perform a required function under stated conditions for a stated time period (Bauer & Adams, 2012), (Pokorni, 2014). Quantitatively, it is expressed in probability.

Reliability is critical for efficient IoT communication, because unreliable sensing, processing, and transmission can cause false monitoring data reports, long delays, and even data loss, which would reduce people's interest in IoT communication. Therefore, the rapid growth of IoT communication demands high reliability (Prasad & Kumar, 2013).

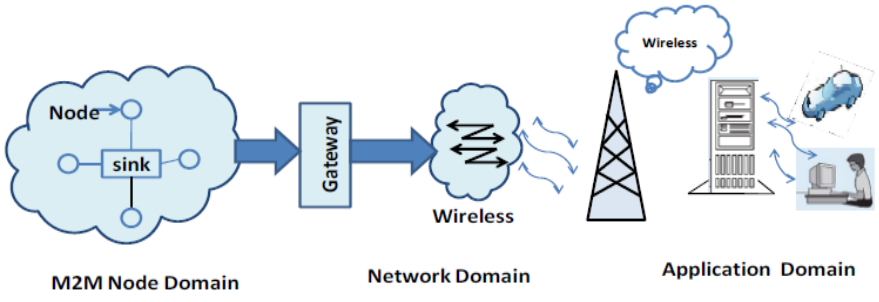

Figure 2 – Architecture of the IoT (Popa et al, 2017), (Prasad & Kumar, 2013)
Рис. 2 – Архитектура интернета вещей (Popa et al, 2017), (Prasad & Kumar, 2013)
Слика 2 – Архитектура интернета ствари (Popa et al, 2017), (Prasad & Kumar, 2013)

However, these deployments, as IoT implementations, depend heavily on the Internet connectivity, therefore on the network

infrastructure. In large-scale IoT deployments like those in smart cities and smart communities, failures in the network infrastructure can be fatal to the operation when large events or emergencies stress or strike the public network facilities. Enabling the reliability and resilience of large-scale IoT deployments is critical in these scenarios and promising for further research (Zhu et al, 2018).

There are several research challenges that must be resolved to support the operation of IoT systems for communities (Zhu et al, 2018). The first challenge is that of scale, i.e. the huge number of devices. In community-wide IoT systems, the number of participating devices can make a big difference in the design of system architecture and influence the network infrastructures. Bring-in mobility and crowd participation can make a bigger challenge. The second challenge is that of the dynamics. Both the physical and networking environment in communities can change. Mobility brings in more changes and adaptation to changes is important. The third challenge is that of the inter-operability. With the growing number and heterogeneity of IoT devices, the interoperation and coordination are keys to make all these devices, platforms, and their supporting software an integrated system instead of a pile of independent pieces (Zhu et al, 2018).

Obviously, the IoT is very complex. It comprises hardware, software, and sometimes a human is envolved in an IoT system. Since the IoT is regarded as the next phase in the evolution of the Internet, and the iInternet is a network of networks, and the functioning of networks is based on protocols, then, except hardware and software, protocols also must be considered in the reliability of the IoT. Although protocols are esentially realized in software, there is a need to consider them separately because there are reliable and unreliable protocols.

IoT hardware reliability

Up to now, hardware reliability has been calculated mostly using MIL-HDBK-217, military manual, for the calculation of the reliability of electronic devices. The first version was developed in 1961 (version A). But MIL-HDBK-217 has limitations, and has not been updated since 1995 (the last version F). In spite of its limitations, MIL-HDBK-217 is still used by more than 80% of engineers in calculating reliability. Of course, there are other industrial and commercial standards for calculating reliability. RIAC's 217Plus^{TM} methodology and a software tool is a replacement for MIL-HDBK-217, it is no longer free, it is more complex, and, at least, this methodology is the same as with former MIL-HDBK-217 (Pokorni, 2016).

Besides this, the calculation of hardware reliability is also faced with a number of problems. In (Elerath & Pecht, 2012), it is stated that there is no standard method for creating hardware reliability prediction, so predictions vary widely in terms of methodological rigor, data quality, extent of analysis, and uncertainty, and documentation of the prediction process employed is often not presented. Because of that, the IEEE has created a standard, IEEE Std.1413 (Standard Framework for the Reliability Prediction of Hardware) in 2009.

The IoT comprises different hardware concerning quality and reliability: very often this hardware is of a commercial type, without established reliability, and very often without any data about the failure rate or the mean time to failure (MTTF), or the mean time between failures (MTBF), so exact reliability calculation is very difficult.

IoT software reliability

Software reliability is an important attribute determining the quality of the software as a product. There are many models of software reliability assessment, but none of them is generally accepted (Pokorni, 2016, Kapur, 2014). Except that, the requirements for the reliability of software are often not adequately specified if specified at all, especially for the IoT.

The problem also lies in a different nature of software compared to hardware. Although defined as a probabilistic function, software reliability is not a direct function of time. Another problem is that techniques for software reliability prediction are rarely used as routine software engineering practices. It calls for collaboration between software and reliability subject matter experts to take appropriate steps to include software into the reliability case for the system (Pokorni, 2016), (Kapur, 2014).

The real issue with reliable software is that the critical function fails safe. Failing safe is often misunderstood and is often misinterpreted as never failing. Software safety and software reliability are allies in the realization of their mutual goal of developing safe and reliable software. Again, there is a need for a cooperation between software and reliability engineers. However, few educational institutions or industry professionals teach the basics of software reliability and its dependence upon software safety to be effective (Pokorni, 2014).

Enhancing reliability by redundant of software is a special problem, because it is different from hardware, and every copy of software has the error at the same place (Pokorni, 2014).

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IoT human reliability

As we stated in the introduction, a human factor can be involved in the IoT system. So, a human action can influence the reliability of the IoT.

Human reliability can mean preventing accidents and minimizing the consequences of accidents that do occur. The effects of decisions made by people to act or not to act have consequences for the technological systems they operate. Disasters and major system failures are frequently a sequence of events where one or more people have made a decision or taken some action while operating, maintaining or repairing some technological system. When these potential consequences are significant, such as catastrophic loss of equipment, long term damage to the environment, or loss of life, then reliability engineers working collaboratively with others (such as risk management, human factors and safety engineers) can have an important impact (Pokorni, 2016).

There are different approaches and models to human reliability (Pokorni, 2016).

Procedures, rules, codes, standards and laws cannot completely prevent system failures, but, in this author's experience, they can reduce system failures.

This author has considered human reliability important from the beginning of his work in reliability, so human reliability is included in his textbooks (Pokorni, 2014).

About reliable and unreliable protocols

In computer networking, a reliable protocol is the name for a protocol which notifies the sender whether or not the delivery of data to intended recipients was successful.

For example, the TCP (Transmission Control Protocol), the main protocol used on the Internet, is a reliable protocol, and the UDP (User Datagram Protocol) is unreliable (because there is no guarantee of delivery of data, as in the TCP). Therefore, the UDP can be used in situations where some data loss may be tolerated.

There are also the Hot Standby Router Protocol (HSRP), the Virtual Router Redundancy Protocol (VRRP), and the Gateway Load Balancing Protocol (GLPB) used to enchance availability of computer networks providing redundancy. The HSRP provides routing redundancy for routing IP traffic without being dependent on the availability of any single router. The GLBP provides routing redundancy similar to that of the

HSRP and also provides load balancing over multiple routers by using a single virtual IP address and multiple virtual MAC addresses.

Maintainability and availability

Reliability is connected with maintainability. In order to achieve optimal cost in the life cycle of the IoT, maintainability must be considered in the design phase of the IoT. Maintainability refers to the ability for an intelligent system to be seamlessly and easily uncoupled, fixed and modified without causing an obstruction in the system processes or functionality. To evaluate the maintainability property of the IoT system, in case of a problem, the system should allow easy replacement of faulty components without loss of service. Therefore, to characterize IoT systems as highly maintainable, they have to enable maintenance tasks to be completed effectively, efficiently and with satisfaction (Thomas & Rad, 2017).

If we include maintainability, we speak about availability instead only of reliability. Availability is defined as the probability that the system or element is in a functional state at the moment the user needs it. If the system is unrepaired, then reliability and availability are the same. If the system is repaired, then availability is not the same as reliability. Availability (inherent availability) can be calculated using the next relation (Pokorni, 2014)

$$A = \frac{MTBF}{MTBF + MTTR} \tag{1}$$

where

- $MTBF$ is mean time to failure, and
- $MTTR$ is mean time to repair.

Obviously, for example, replacing an exhausted battery in an IoT device can reduce availability if the IoT system is not in the working state during the replacement.

Other influences on the IoT reliability

The reliability of IoT is not only a matter of a failure rate of hardware and software, but also of protocols, energy efficiencies (green), standardization and other influences, such as, for example, security, etc.

The energy efficiency, reliability and security issues in the IoT (M2M communications) have not been well explored. The energy efficiency (green) becomes a challenging issue especially in the IoT sensor domain. IoT communications dominates energy consumption. There are

measures with which energy efficiency can be increased (Al-Fuqaha et al, 2015).

In (Higginbotham, 2018), it is stated that the IoT makes systems vulnerable to new security treats: consequences of failure are more dire (when car or infusion pumps are hacked people can die); today adversaries to the IoT security are not only hackers, but nation states; software and hardware vendors nowadays do not provide support as before; many IoT devices are built with software, hardware and firmware created by different companies and the problem can appear if some of these companies does not update its software; and many IoT devices live in environments unlike any IT systems.

Reliability and availability policies

Different users can expect different levels of reliability and availablity. So, aproaches to design an IoT system can be different depending of types of users. For example, the target level of availability for a given Google service usually depends on the function it provides and how the service is positioned in the marketplace. The following list includes issues to consider (Alvidrez, 2017):

What level of service will users expect?

Is this service directly connected to the revenue (either our revenue, or our customers' revenue)?

Is this a paid service, or is it free?

If there are competitors in the marketplace, what level of service do these competitors provide?

Is this service targeted at consumers or at enterprises?

Reliabilityof the IoT system

Because of a complexity of the IoT and because the IoT includes hardware and software and sometimes humans, we suggest assessing the reliability of hardware, the reliability of software and the reliability of the human factor, and then the reliability of the IoT system is calculated by the formula

$$R_S(t) = R_{HW}(t)R_{SF}(t)R_H(t) \tag{2}$$

where R_{HW}, R_{SF} and R_H are hardware reliability, software reliability and human reliability, respectively.

The above formula is valid if failures of hardware, software and human are mutually exclusive.

The IoT is obviously very complex, so it is difficult, almost impossible, to determine the analytical solution for the reliability and availability of such a complex system.

Because of the complexity of the IoT, we suggest using simulation to asses the reliability of the IoT. We used simulation for some examples of complex systems and showed that simulations can give useful results (Pokorni & Janković, 2011), (Pokorni et al, 2011), (Ostojić et al, 2012).

Conclusion

The problem of the reliability of the Internet of Things from the point of view of the classical approach of reliability assessment using MIL-HDBK 217 is discussed in this paper. Because of the complexity of the IoT (the IoT includes hardware, software and sometimes human users), and because data in MIL-HDBK 217 are obsolete, the classical approach of reliability assessment of hardware using MIL-HDBK 217 is not appropriate, so we need other approaches for assessing reliability of hardware (for example RIAC's methodology, based on PRISM and new MIL-HDBK-217Plus), and of course adequate approaches for the assessment of reliability of software and the human factor. There are also other influences such as protocols, energy efficiencies, standardization security, etc.

Reliability assessment and the analysis of the IoT require knowledge from many different technical and other areas and team work.

Reliability of the IoT is not always of the primary concern in the IoT, but understanding reliability can help in case of failure, i.e. where to look for a failure.

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НАДЕЖНОСТЬ И ДОСТУПНОСТЬ ИНТЕРНЕТА ВЕЩЕЙ

Славко Й. Покорни
Колледж информационных технологий, г. Белград, Республика Сербия

РУБРИКА ГРНТИ: 47.00.00 ЭЛЕКТРОНИКА. РАДИОТЕХНИКА,
20.00.00 ИНФОРМАТИКА
ВИД СТАТЬИ: оригинальная научная статья
ЯЗЫК СТАТЬИ: английский

Резюме:

В данной статье обсуждается проблема надежности и доступности Интернета вещей (IoT) с точки зрения классического метода оценки надежности с помощью MIL-HDBK 217. Однако при применении классического метода оценки надежности с помощью MIL-HDBK 217 можно оценить только надежность аппаратного обеспечения, в то время как ситуация с IoT намного сложнее, так как задействованы (объединены в сеть) миллиарды различных факторов: вещей (устройств), программных обеспечений, включая и людей. Надежность и доступность интернета вещей зависит не только от частоты отказов элементов (вещей), но также и от протоколов, стандартизации, логистической поддержки и других факторов. Предложено соотношение для расчета надежности системы IoT.

Ключевые слова: надежность, доступность, ремонтопригодность, интернет вещей.

ПОУЗДАНОСТ И РАСПОЛОЖИВОСТ ИНТЕРНЕТА СТВАРИ

Славко J. Покорни
Висока школа струковних студија за информационе технологије,
Београд, Република Србија

ОБЛАСТ: електроника, информатика
ВРСТА ЧЛАНКА: оригинални научни рад
ЈЕЗИК ЧЛАНКА: енглески

Сажетак:

У раду се разматра проблем поузданости и расположивости доступности интернета ствари (ИоТ) са становишта класичног приступа процене поузданости помоћу МИЛ-ХДБК 217. Коришћењем класичног приступа процене поузданости помоћу МИЛ-ХДБК 217 може се проценити само поузданост хардвера, а ситуација са ИоТ-ом је сложенија: милијарде различитих ствари (уређаја), софтвера, укључујући људе, укључено је (умрежено). Поузданост и доступност интернета ствари није само питање степена отказа елемената (ствари) већ и протокола, стандардизације, логистичке подршке и других утицаја. Предложена је релација за израчунавање поузданости ИоТ система.

Кључне речи: поузданост, расположивост, погодност одржавања, интернет ствари.

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SUBMICROSECOND ATMOSPHERIC ELECTRIC DISCHARGE FROM THE NON-UNIFORM ELECTRODE (TIP) TOWARDS THE PLANE ELECTRODE

Vasily Y. Kozhevnikov[a], *Andrey* V. Kozyrev[b], *Aleksandr* O. Kokovin[c], *Vladislav* S. Igumnov[d]

[a] Institute of High Current Electronics, Department of Theoretical Physics, Tomsk, Russian Federation,
e-mail: Vasily.Y.Kozhevnikov@ieee.org,
ORCID iD: http://orcid.org/0000-0001-7499-0578

[b] Institute of High Current Electronics, Department of Theoretical Physics, Tomsk, Russian Federation,
e-mail: kozyrev@to.hcei.tsc.ru,
ORCID iD: https://orcid.org/0000-0002-7078-7991

[c] Institute of High Current Electronics, Department of Theoretical Physics, Tomsk, Russian Federation,
e-mail: alexander.kokovin.desch@gmail.com,
ORCID iD: http://orcid.org/0000-0003-2068-7674

[d] National Research Tomsk Polytechnic University, Laboratory N 46, Tomsk, Russian Federation,
e-mail: vladislavigumnov@yahoo.com,
ORCID iD: http://orcid.org/0000-0002-3847-5322

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Abstract:

This paper deals with the results of a numerical simulation of the fast atmospheric pressure discharge in a strongly non-uniform configuration of a tip-to-plane diode filled with a nitrogen and oxygen mixture. The simulation is based on the advanced hydrodynamic plasma discharge accounting also gas photoionization. It was shown that, in the absence of photoionization, discharge develops similarly to the case with photoionization, except the case of reversed voltage polarity. The theoretical results correspond to the existing experimental data for the spatial discharge structure and the current/voltage discharge characteristics.

Key words: plasma, numerical simulation, atmospheric discharges.

Introduction

Various gas-filled diodes are widely used in modern electro-technical devices. The tip-to-plane electrodes system represents probably the most common design of a gas diode unit with a strongly non-uniform configuration of an electric field. Namely, they are used as spark-gap high-voltage switches (Shaefer et al, 1990) as well as the main component of technological devices for the discharge plasma surface treatment (Akishev et al, 2001). Therefore, major theoretical problems of discharge development in such a system are intensively investigated by using various theoretical simulation approaches (Eichwald et al, 2011).

The discharges in gas-filled diodes are attractive due to the non-trivial switching characteristics and the low-temperature plasma parameters. Among the switching parameters, the breakdown formation time and the corresponding voltage amplitude are the most important. The plasma parameters, e.g. its spatial structure or its plasma-chemical composition are also of great importance, especially w.r.t. time-dependent studies. While the switching characteristics can be easily measured experimentally, the measurement of plasma parameters is much more complicated. That is the main reason to perform a theoretical simulation of gas discharge.

At present, we have a rather extensive base of experimental studies of this type of discharge, including those performed with picosecond and subnanosecond time resolutions, as well as with time synchronization of measured signals. As part of the series of experimental studies done by groups of Russian and Chinese researchers (Shao et al, 2013), a comparison can be made with the results of actual theoretical studies.

In this paper, we use a two-moment “liquid” discharge plasma model (Gogolides & Sawin, 1992) implemented in the Plasma module of COMSOL Multiphysics 5.2 software. It allows modeling the time-dependent discharge propagation from the metal non-uniform electrode (tip) towards the second electrode (plane) accounting for all necessary plasma-chemical reactions. The main aim here is to simulate nanosecond gas discharge and accurately obtain the spatial discharge structure evolution.The introduction is an introductory part of the article.

Experimental setup

The experimental setup is represented in Figure 1. The triggering pulse from 1 provides a signal that the voltage pulse generator 2 transforms into a negative polarity voltage pulse with the amplitude values in the range of $U_0 \approx$ 27-30 kV with the rise time $t_f \approx$ 200 ns. The

cathode here is a thin needle with a diameter of 0.4 mm having the tip curvature radius of 0.1 mm (medical syringe needle), while the anode is a simple plane electrode made of aluminum foil. The distance between the electrodes is equal to d = 9 mm. The nitrogen at 1 atm pressure with small (~2 %) oxygen admixture is used as the operating gas.

An ICCD camera was used to obtain a sequence of instant images of the discharge dynamics (depicted in Figure 2). The images from an ICCD camera are an integral picture of the glow of non-stationary discharge, which, to a certain extent, can be compared with the distribution of the discharge plasma at a given point in time. Based on this comparison of experimental and theoretical data can be done in the present work.

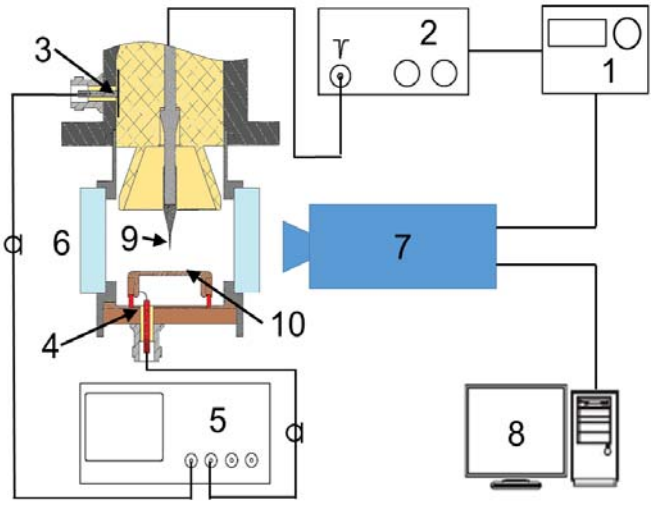
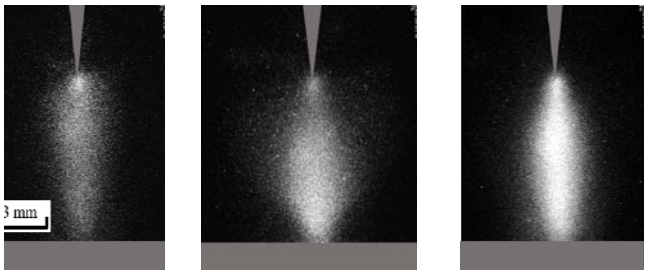


Figure 1 – The experimental setup: 1 – triggering pulse generator, 2 – pulsed voltage source, 3 – capacitive voltage divider, 4 – current shunt resistor, 5 – storage oscilloscope, 6 – output window, 7 – ICCD camera, 8 – personal computer, 9 – metal tip cathode, 10 - plane anode electrode

Рис. 1 – Схема эксперимента: 1 – запускающий генератор, 2 – импульсный источник напряжения, 3 – емкостный делитель напряжения, 4 – токовый шунт, 5 – цифровой запоминающий осциллограф, 6 – выходное окно, 7 – скоростная камера, 8 – компьютер, 9 – острийный катод, 10 – плоский анод

Слика 1 – Поставка експеримента: 1 – генератор окидног импулса, 2 – пулсни извор напона, 3 – капацитивни разделник напона, 4 – шант отпорник, 5 – меморијски осцилоскоп, 6 – заштитни прозор, 7 – камера ИЦЦД, 8 – лични рачунар, 9 – катода – метални врх, 10 – анода – обична плочаста електрод



a) 71-74 ns *b) 74-77ns* *c) 77-80 ns*

Figure 2 – Instant photographs from the ICCD-camera (grey areas depict the electrodes)
Рис. 2 – Мгновенные фотографии свечения, полученные скоростной камерой (области, отмеченные серым цветом обозначают электроды)
Слика 2 – Инстант фотографије добијене камером ИЦЦД (сиве зоне представљају електроде)

Theoretical model

For the simplicity reasons, a real three-dimensional diode in the model is substituted by a two-dimensional axisymmetric structure (Figure **3**).

The gas discharge model is based on the two-moment “liquid” model where the movement of charged particles is covered by the drift-diffusion approximation (Gogolides & Sawin, 1992). Since the discharge characteristic time is short, the model implements only three important plasma-chemical reactions: electron impact ionization $e + N_2 \rightarrow 2e + N_2^+$, molecular nitrogen dissociation $e + N_2 \rightarrow e + 2N$ and photoionization $h\nu + N_2 \rightarrow e + N_2^+$.

The photoionization model we implement is based on the assumption (Kulikovsky, 1995) that the major contribution to the photoionization rate is produced by the radiation in the spectral range 980-1025 Å, where the radiation absorption by nitrogen N_2 can be omitted. The wavelength of 1025 Å is the natural threshold for the molecular oxygen photoionization reaction. Below 980 Å, the radiation is strongly absorbed by nitrogen providing insignificant contribution to the production of photoelectrons. Taking into account the fine structure of the oxygen absorption spectrum, in the integral over the wavelength range 980-1025 Å in the general expression for the rate of photoionization was calculated and adopted for further computations.

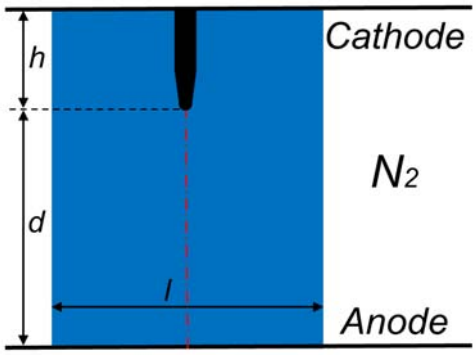


Figure 3 – The computational domain configuration (h = 1.6 mm, l = 4 mm, d = 9 mm)
Рис. 3 – Счётная область пространства (h = 1.6 мм, l = 4 мм, d = 9 мм)
Слика 3 – Конфигурација области израчунавања (h = 1,6 mm, l = 4 mm, d = 9 mm)

We also draw the attention to the importance of taking into account the molecular nitrogen dissociation reaction as the main factor leading to electron energy losses (Cosby, 1993). Other plasma-chemical reactions typical to nitrogen, e.g. involving ions of atomic nitrogen, are omitted due to their smaller contribution to the fast discharge development. For the same reasons, we also exclude different kinds of neutral excited species. The electron component is described by the following equations system:

$$\begin{cases} \dfrac{\partial n_e}{\partial t} + \nabla \cdot \boldsymbol{\Gamma}_e = R_e \\ \dfrac{\partial n_\varepsilon}{\partial t} + \nabla \cdot \boldsymbol{\Gamma}_\varepsilon + \boldsymbol{E} \cdot \boldsymbol{\Gamma}_e = R_\varepsilon \end{cases} \quad (1)$$

where n_e is the electron number density, n_ε is the electron energy density, t is the time variable, and $\boldsymbol{E}$ is the electric field strength. The source coefficients R_e and R_ε are defined by

$$\begin{aligned} R_e &= k_{ion}\left(\overline{\varepsilon}\right) n_n n_e + S_{ph}, \\ R_\varepsilon &= k_{ion}\left(\overline{\varepsilon}\right) n_n n_e + k_{diss}\left(\overline{\varepsilon}\right) n_n n_e, \end{aligned} \quad (2)$$

where $k_{ion}(\overline{\varepsilon})$ is the ionization rate as a function on the mean electron energy, $\overline{\varepsilon} = n_\varepsilon / n_e$, n_n is the total neutral number density, $k_{diss}(\overline{\varepsilon})$ is the dissociation rate coefficient, and S_{ph} is the photoionization rate.

The ion component is described by

$$\frac{\partial n_i}{\partial t} + \nabla \cdot \boldsymbol{\Gamma}_i = R_e \tag{3}$$

where n_i is the N_2^+ number density.

The electron, the electron energy and the ion density fluxes $\boldsymbol{\Gamma}_e$, $\boldsymbol{\Gamma}_\varepsilon$ and $\boldsymbol{\Gamma}_i$ respectively, are given by the expressions

$$\begin{aligned} \boldsymbol{\Gamma}_e &= -n_e \mu_e \boldsymbol{E} - D_e \nabla n_e \\ \boldsymbol{\Gamma}_\varepsilon &= -\frac{5}{3} n_\varepsilon \mu_e \boldsymbol{E} - \frac{5}{3} D_e \nabla n_\varepsilon \\ \boldsymbol{\Gamma}_i &= -n_i \mu_i \boldsymbol{E} - D_i \nabla n_i \end{aligned} \tag{4}$$

where μ_e and μ_i are the electron and ion mobilities, and D_e and D_i are the electron and ion diffusivities.

The electric field is accounted self-consistently in the model by implementing the Poisson's equation:

$$\varepsilon_0 \nabla \cdot \boldsymbol{E} = -q\left(n_i - n_e\right) \tag{5}$$

where, q is the elementary charge, and ε_0 is the electrical constant.

The photoionization rate S_{ph} is implemented in the "differential" formulation i.e. based on the numerical solution of the Helmholtz equations set (Bourdon et al, 2007).

$$\nabla^2 S_{ph} - \Lambda_{ph}^{-2} S_{ph} = -G_{ph} R_e \tag{6}$$

Here, Λ_{ph} is the effective photon path length, G_{ph} is the coefficient of the conversion of the ionization rate R_e into photon radiation. The percent of oxygen admixture was set to 2 % (15 Torrs in the equivalent partial pressure units).

We use uniform plasma number density not exceeding 10^3 cm^{-3} and the zero electric field and the photoionization rate S_{ph} as the initial conditions. The boundary conditions are given in terms of generalized expressions for the particle and the electron energy density fluxes on the solid electrode walls (Kozhevnikov et al, 2015)

$$\mathbf{\Gamma}_e \cdot \boldsymbol{n} = \frac{1}{4} n_e \overline{v}_e - \gamma \left(\mathbf{\Gamma}_i \cdot \boldsymbol{n} \right) + \mu_e n_e \left(\boldsymbol{E} \cdot \boldsymbol{n} \right),$$
$$\mathbf{\Gamma}_i \cdot \boldsymbol{n} = \frac{1}{4} n_i \overline{v}_i + \mu_i n_i \left(\boldsymbol{E} \cdot \boldsymbol{n} \right), \quad (7)$$
$$\mathbf{\Gamma}_\varepsilon \cdot \boldsymbol{n} = \frac{1}{2} n_\varepsilon \overline{v}_e - \overline{\varepsilon} \cdot \gamma \left(\mathbf{\Gamma}_i \cdot \boldsymbol{n} \right),$$

where $\boldsymbol{n}$ is the normal vector to the wall surface, $\overline{v}_e$ and $\overline{v}_i$ are the electron and ion thermal velocities, respectively, and $\gamma = 0.1$ is the secondary electron emission coefficient of the ion-wall interaction in nitrogen.

The simulation also accounts the contribution of the field emission (autoelectronic emission) from the cathode surface due to the increase of an electrostatic field near the emission centers formed by the metallic surface roughness. This electron flux is given in terms of a convenient Fowler-Nordheim expression (Kozyrev et al, 1987).

The complete discharge plasma system of equations (1)−(4) is solved in the COMSOL Multiphysics software with Plasma Module implementing the above two-moment model DC-discharge physics. Prior to this, the ionization rates and the electron mobility were calculated using the BOLSIG+ solver (Hagelaar & Pitchford, 2005) except the dissociation rate coefficient that was taken from another source (Cosby, 1993).

We compare the simulation results according to two discharge models. In the first one (I), photoionization was not included, while the second model (II) implements all enlisted elementary processes. The following simulation results of the calculations are the refinement of the preliminary computations of a similar discharge type presented in the conference paper (Kozhevnikov et al, 2018). The effects of oxygen molar fraction increasing in nitrogen (more than 2%) and gas diode parameters variations on the gas discharge dynamics have not been studied focusing on the configurations close to the experimental one.

Results of the simulation

The comparison of the voltage - time profiles is shown in Figure 4 (switching characteristics) for both discharge models. We assume the breakdown formation to be a time point having the maximum voltage at the discharge gap.The breakdown occurs at $t_{breakdown} \approx 92$ ns ($U_{breakdown} \approx 12$ kV) for both simulation regimes (with photoionization and

without it). The presence of photoionization just slightly reduces the breakdown voltage value by no more than 50 V. Such difference is negligibly small, so we can assume that the switching characteristics of two modes are practically identical.

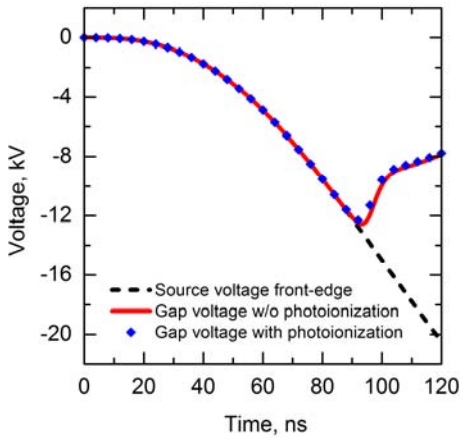


Figure 4 – Discharge voltage- time profiles
Рис. 4 – Коммутационные характеристики разряда
Слика 4 – Профили пражњења напон–време

The discharge evolution is demonstrated in the sequence of the static images in Figure 5. In both cases, the discharge initiation occurs approximately at the time point of t = 50 ns. The movement of the plasma channel begins with the expansion of the initial cathode formation in both spatial directions. After that, approximately from the time point of t = 80 ns, the formation of a plasma tip on the spherical plasma cloud surface occurs. This tip is the main channel of the discharge which slightly expands in the radial direction during the motion. The formation of the initial spherical distribution is associated with the intense losses of the electron energy in the electron impact N_2 dissociation reaction. After the electric field exceeds the Lozansky-Firsov criterion threshold value, the rapid ionization wave development starts from the 0.5-1.0 mm spherical layer surface. The process ends with the discharge gap switching stage at the time point of the gap intersection with the ionization wave channel (t = 90 ns). The gap voltage drop and the corresponding significant increase of the total discharge current accompanies this.

The comparison of calculations with photoionization and without it shows that the effect of the latter on the development of gas discharge is insignificant if the electron impact dissociation reaction of molecular

nitrogen is included in the model. Also, the quantitative characteristics of the plasma do not change. The significant increase of the oxygen partial pressure in the photoionization model, and hence the fraction of oxygen in gas mixture will probably lead to a visible change in the spatial discharge structure, but also the simulation will require a more accurate plasma-chemical reaction set. Nevertheless, one of this paper's aims is to investigate the influence of a minor electro-negative mixture to the discharge formation and evolution.

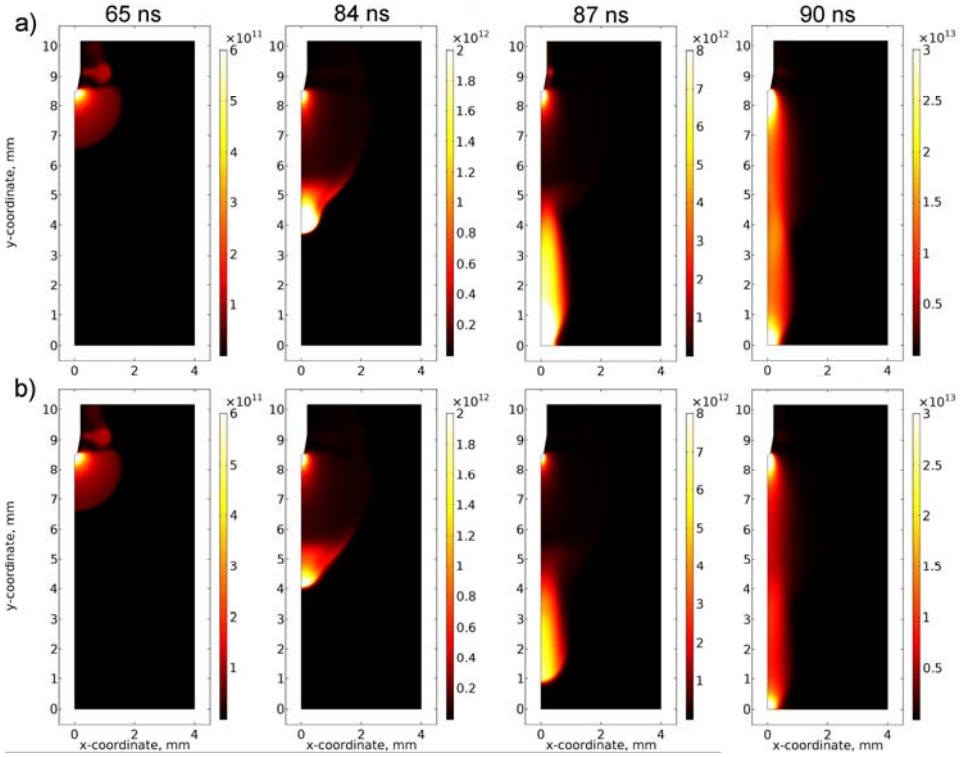


Figure 5 – Spatial distribution of the electron number density (scale in cm^{-3}) for gas discharge a) without and b) with the photo-ionization process for the same time points
Рис. 5 – Пространственные распределения концентрации электронов (в единицах в куб.см.) в газовом разряде а) без и b) с учётом процесса фотоионизации в одинаковые моменты времени
Слика 5 – Просторна дистрибуција густине броја електрона (скала у cm^{-3}) за пражњење гаса: а) без процеса фотојонизацијеза исте временске тачке и б) са процесом фотојонизације за исте временске тачке

Additionally, the parameters of runaway electrons have been calculated in order to discover their influence on the discharge dynamics. The calculations were based on the "hybrid" theoretical approach, involving the principles of physical kinetics described earlier (Kozyrev et al, 2016). The results show that the runaway electron current passing through the anode is too small compared to the full discharge current, so the influence of the runaway electrons on the discharge is negligible. Such conclusions are connected with the long rise time (more than 100 ns) of the operating voltage pulse.

Conclusion

The simulation of the gas-filled diode breakdown in the tip-to-plane electrodes configuration shows good agreement with the existing experimental data. The current theoretical study shows that gas photoionization insignificantly affects the discharge spatial structure for the positive polarity of the anode voltage. It was also shown that, in gas mixtures containing a valuable amount of nitrogen, the electron impact dissociation plays an important role in the formation of the spatially-inhomogeneous discharge structure.

Our theoretical study of gas discharges of submicrosecond duration substantially complements the existing experimental base. The obtained information about the time-spatial discharge structure allows studying the generation of runaway electrons and X-rays under the atmospheric pressure. This opens up broad prospects for the creation of high voltage power supplies for UV and VUV excilamps as well as for the application in the fields of industrial X-ray radiography.

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СУБМИКРОСЕКУНДНЫЙ РАЗРЯД АТМОСФЕРНОГО ДАВЛЕНИЯ С НЕОДНОРОДНОГО ЭЛЕКТРОДА (ОСТРИЯ) В НАПРАВЛЕНИИ ПЛОСКОГО ЭЛЕКТРОДА

Василий Ю. Кожевников[а], *Андрей В.* Козырев[а],
Александр О. Коковин[а], *Владислав С.* Игумнов[б]

[а] Институт сильноточной электроники, Лаборатория теоретической физики, г. Томск, Российская Федерация
[б] Томский политехнический университет, Лаборатория номер 46, г. Томск, Российская Федерация

РУБРИКА ГРНТИ: 29.27.00 Физика плазмы
ВИД СТАТЬИ: оригинальная научная статья
ЯЗЫК СТАТЬИ: английский

Резюме:

В данной работе рассматриваются результаты численного моделирования быстрого разряда при атмосферном давлении в сильно неоднородной конфигурации диода «острие-плоскость», заполненного смесью азота и кислорода. Моделирование основано на современной гидродинамической модели разрядной плазмы, учитывающей также фотоионизацию газа. Было показано, что при отсутствии фотоионизации разряд развивается аналогично случаю с фотоионизацией (за исключением случая обратной полярности приложенного напряжения). Теоретические результаты соответствуют существующим экспериментальным данным для структуры пространственного разряда и для временных характеристик тока / напряжения разряда.

Ключевые слова: плазма, численное моделирование, атмосферные разряды.

ПРАЖЊЕЊЕ У НАНОСЕКУНДАМА ПРИ АТМОСФЕРСКОМ ПРИТИСКУ ОД НЕУНИФОРМНЕ ЕЛЕКТРОДЕ (ВРХ) ПРЕМА РАВНОЈ ЕЛЕКТРОДИ

Василиј Ј. Кожевников[а], *Андреј* В. Козирев[а],
Александар О. Коковин[а], *Владислав* С. Игумнов[б]

[а] Институт високе струје, Лабораторија за теоријску физику, Томск, Руска Федерација
[б] Политехнички универзитет у Томску, Лабораторија бр. 46, Томск, Руска Федерација

ОБЛАСТ: физика плазме
ВРСТА ЧЛАНКА: оригинални научни рад
ЈЕЗИК ЧЛАНКА: енглески

Сажетак:

У раду се разматрају резултати нумеричке симулације брзог пражњења при атмосферском притиску у високо нехомогеној конфигурацији диоде типа врх–раван напуњене смешом азота и кисеоника. Симулација се заснива на савременом хидродинамичком моделу пражњења плазме, који такође узима у обзир фотојонизацију гаса. Показано је да се, у одсуству фотојонизујућег пражњења, он развија слично као и код фотојонизације, са изузетком напона инверзне поларизације. Теоријски резултати су конзистентни са постојећим експерименталним подацима за просторну структуру пражњења и за карактеристике пражњења напона/струје.

Кључне речи: плазма, нумеричка симулација, атмосферска пражњења.

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ПРЕГЛЕДНИ РАДОВИ
ОБЗОРНЫЕ СТАТЬИ
REVIEW PAPERS

RISK ASSESSMENT FRAMEWORK: APPLICATION OF BAYESIAN BELIEF NETWORKS IN AN AMMUNITION DELABORATION PROJECT

Slobodan B. Malbašić[a], *Stefan* V. Đurić[b]
[a] Ministry of Defence of the Republic of Serbia, Sector for Material Resources, Belgrade, Republic of Serbia,
e-mail: slobodan.malbasic@mod.gov.rs,
ORCID iD: http://orcid.org/0000-0001-5053-4033
[b] University of Kragujevac, Faculty of Engineering, Kragujevac, Republic of Serbia,
e-mail: sdjuric@kg.ac.rs,
ORCID iD: http://orcid.org/0000-0003-0660-7551

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Summary:

Models that represent real problems have been relying so far on historical data to draw upon conclusions. One negative aspect of these models was that they could not predict future states based on real data instantly collected or new sources of risk that suddenly appeared. To overcome this problem, this work presents the process of building a realistic predictive model using Bayesian Belief Networks (BBNs) and the AgenaRisk software. BBNs are a direct representation of real problems where their graphical structure represents real causal connections and not just a flow of information. Software tools providing algorithms for dealing with conditional probabilities have been developed. The Bayesian Theorem, a theoretical background for conditional probability, was also explained in the paper. Another benefit of using BBNs is that the reasoning process can operate by propagating information in any direction (top-down or bottom-up) which makes it a powerful tool in risk assessment and a decision-making process. The paper also provides the core principles and the power of BBNs and their application in the project planning phase for ammunition delaboration (resolving problems of surplus and obsolete ammunition in stockpiles), where risk assessment is one of the required processes which helps in making a final decision for project approval or

not. The sensitivity and SWOT analyses are also performed as valuable and helpful tools for validation and making conclusions.

Key words: conditional probability, Bayesian Belief Networks, risk assessment, sensitivity analysis, SWOT analysis.

Introduction

The project risk management process is seen as a process that accompanies the project through its life cycle. The Project Management Book of Knowledge recognizes risk management as one of knowledge areas (together with its inside processes) that need to be addressed during project planning and can have a significant impact on the project success.

A number of variations for the risk management process have been proposed, (Marcelino-Sádaba et al, 2014), (Petrović et al, 2010), (Andrejić et al, 2011), (Malbašić et al, 2016). According to (Fang & Marle, 2012), there is a general agreement on what is included in the process but differences exist in "the level of details and assignment of activities to steps and phases". Based on the previous resources, the main processes for risk management are: risk planning, risk assessment, risk mitigation, risk monitoring, and documentation.

Stakeholders are the ones among many who constantly insist on risk management/assessment processes because they want to be protected against different consequences (financial or legal) if some unwanted risk occurs (internal and external source of risk), or at least to be warned against potential problems. Their ultimate goal is to have a project successfully finished. Besides the aforementioned, project managers have to consider a number of other parameters such as safety, security, social and environmental issues, which are interrelated and hence increase the complexity of problems. This complexity leads to the existence of a network of interdependent risks (Fang & Marle, 2012).

The risk management/assessment process requires tools for its implementation, and many tolls have been developed so far. Adoption of certain tools depends on several reasons (investment for the implementation is a significant one) but one of the most important is what benefits a tool can provide to a system, (Raz & Michael, 2001). The same authors argue that many of the developed tools are based on the concept of probability and impact, assessed through qualitative and quantitative approaches.

In most cases, these approaches focus their calculations on several independent risks, emphasizing those of a high value, and then take

mitigation measures. Often, they are able to take into account complex interrelations between them, influences, causes and consequences, but in the end, they still concentrate on a single risk and cannot calculate influences that exist between them. We can also argue which approaches are better and why.

In order to overcome and resolve the mentioned issues, this paper presents a process of risk assessment using Bayesian belief networks and their application in the project planning phase for ammunition delaboration as part of the Trust Fund project, where it is necessary to make a decision for the project approval or against it. In the ammunition delaboration project, insufficient attention has been paid to risk assessment in the planning phase. This process has been mainly done by forming a list of the most frequent risks that have appeared in similar past or current projects. It is obvious that this approach needs to be changed and adapted to new circumstances using BBNs.

Bayesian belief networks also use qualitative and quantitative approaches. In this case, the qualitative approach is the process of graphical representation of the relations among variables (structural learning) while the quantitative approach relies on conditional probability among variables (parameter learning), (Lee at al, 2009).

Introduction to Bayesian Belief Networks (BBNs) - theoretical and graphical background

It can be said that any event (A) is a statement about conditional probability, because we have made this statement with background knowledge or context (K), so it would be accurate to write conditional probability as P(A|K), (Fenton & Neil, 2011).

From the scientific point of view, we explain the previous by introducing a hypothesis - H, beliefs, evidence (E) and conditional probabilities P(H|E) and this process is called probabilistic reasoning. So, for calculating P(H|E), we use Bayes Theorem,

$$P(H/E) = \frac{P(E/H)P(H)}{P(E)} \tag{1}$$

where:

P(H) – the prior probability of the hypothesis H,

P(E) – the prior probability of the evidence E,

P(H/E) is the probability of H, conditional on a new piece of evidence E or a posterior belief about H,

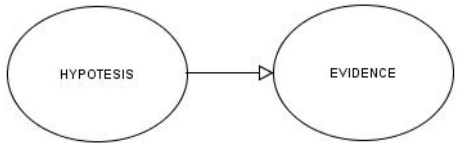
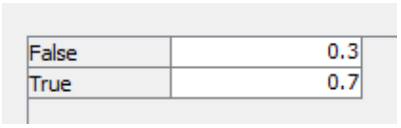
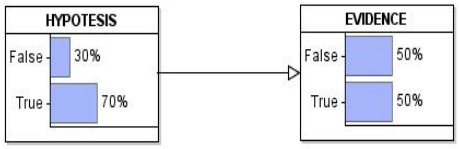
P(E/H) is the probability of E given the H.

Bayes Theorem tells us how to calculate conditional probabilities. In our case, it tells us how to calculate the conditional probabilities of the H given the new evidence (E). It also tells us that this probability depends on three things: the prior probabilities of H and E, and the conditional probabilities of E given the H.

Now, from this very simple but basic explanation, we are transferring from conditional probability into the visualization of the above mentioned situation and a BBN. As we said earlier, it makes no sense to assign a direct probability (the node E or the child node) without considering the events it is conditional on (the node H or the parent nodes).

For the purpose of further explanation, let us assume that both variables are discrete and have just two possible states: true and false, with prior probabilities as shown in the Figure.

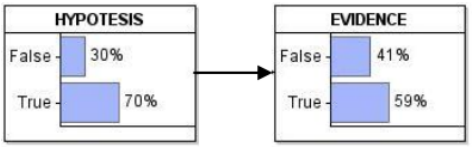
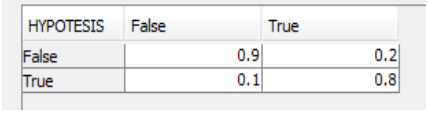
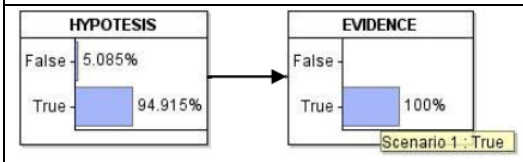
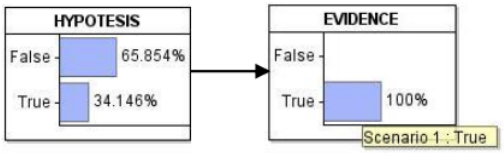
Table 1 – Basic two-node Bayesian Network
Таблица 1 – Базовая концепция байесовской сети с двумя элементами
Табела 1 – Основни концепт Бајесове мреже са два елемента

	
	With initial probabilities for the hypothesis, we do not know anything about the evidence, meaning that the probability of E is 50%.

It is important to note that the Bayesian calculation should never be done manually. Different tools are created to help the modeling process and to run a simulation with the Bayesian algorithm in the background - AgenRisk software is one of them.

In light of new evidence, we enter the Conditional Probability table (CPT) for the evidence E. This means that, for each state of H (2 states), we define probability for the states of E (2 states) and get a matrix for the CPT as explained in Table 2.

Table 2 – Propagation through the Bayesian network
Таблица 2 – Процесс расчета в байесовской сети
Табела 2 – Процес израчунавања у Бајесовој мрежи

	 Initial probability for evidence has slightly changed.
	Now we ran a simulation entering that the evidence has a true value and observe how our hypothesis changes. We have 94.9 % that the initial hypothesis is true.
	Vice versa, in the situation when the evidence has a false value, the initial hypothesis will be 65.8% false.

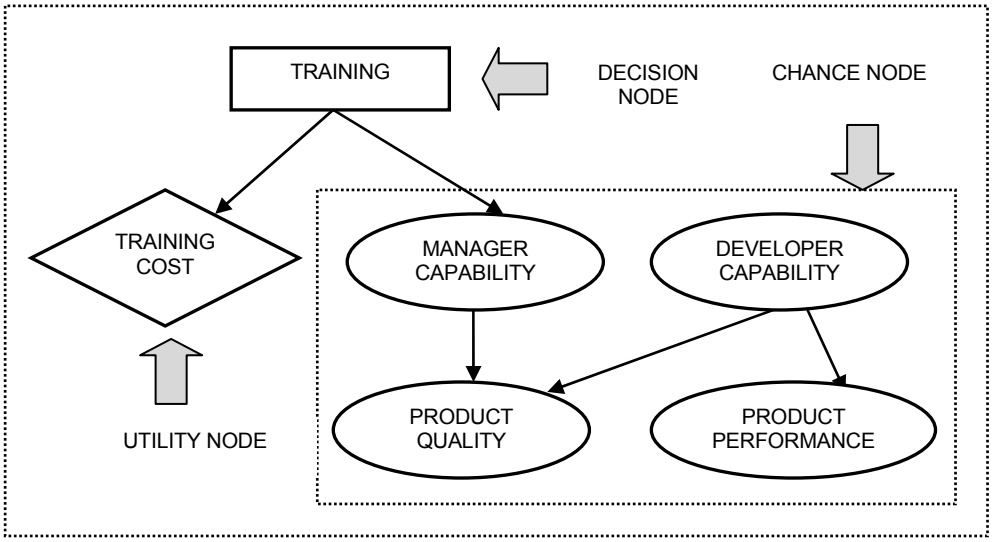
The conclusion form Table 2 is as follows: at first glance, do not rely on the initial probability (or make a decision) until you see new evidence. New evidence might cause some changes in the initial states and help to make a better decision, based on real data.

With more variables, states and dependencies between variables, the risk asssessment problem becomes more complex, hence a Bayesian Belief Nework (BBN). Figure 1 shows a complex BBN with the explanation of the nodes utilities. The BBN structure consists of the qualitative structure (graph structure) and the quantitative components (probability tables). It is a Directed Acyclic Graph (DAG) with an associated set of Conditional Probability Tables (CPT), as shown in Figure 1 (Fan & Yu, 2004).

A node represents event occurrence (a variable of interest in the problem), the arrows (directed edges) between the nodes mean the relationships of events i.e. a dependency structure within the problem, while other nodes serve as:

- Utility node – representing the quantity of interest, generating a numerical value, and helping to rank the alternatives in order to obtain the best option,

- Decision node – representing the alternatives for the decision maker,
- Chance node – probabilistic quantities.



Manager capability	High		Low	
Developer capability	High	Low	High	Low
Pr ("product quality="High")	0.9	0.85	0.35	0.15
Pr ("product quality="Low")	0.1	0.15	0.65	0.85

Figure 1 – Example of a Bayesian Decision Network – BDN
Рис. 1 – Пример динамической байесовской сети
Слика 1 – Пример динамичке Бајесове мреже

According to (Marcot & Penman, 2019), BBN models with inclusion of decision and utility nodes create Bayesian decision networks (BDNs). They can be also highly useful in the risk assessment process. The nodes that have no parents are called “root nodes”and the nodes without children are called “leaf nodes”.

Application of BBNs

The use of BNs is spreading to almost all areas: safety and reliability modeling, operational risk in finance, information retrieval, environment, medicine or, according to (Fenton & Neil, 2013) and (Weber et al, 2012), to modeling operational risk, system reliability modeling,

dependability, risk analysis and maintenance as well as to architecture design developing models to capture change impact analysis (Tang et al, 2007), data mining, determining and explicitly displaying the relationship among variables, representing expert knowledge and combining expert knowledge and empirical data, and identifying key uncertainties (Marcot & Penman, 2019).

In addition to the previously mentioned, Bayesian Belief networks also have a variety of applications in the following fields:

- In a risk assessment approach, to improve the resilience of a seaport system (giving a flexible tool to the safety analysts to increase resilience strategy), (John et al, 2016),
- In a project management assessment modeling framework that calculates costs, benefits and returns on investments (use hybrid and dynamic BBNs, case study for agricultural development projects), (Yet et al, 2016),
- In modeling large and complex infrastructure systems (addressing one of the major obstacles i.e. the exponentially increasing amount of information that needs to be stored as the number of components in the system increases), (Tien & Der Kiureghian, 2016),
- In medical decision support systems (overcoming problems of complex, unstructured and incomplete patient questionnaires and interviews that inevitably contain examples of repetitive, redundant and contradictory responses and to ensure the BN model can be used for the interventional analysis), (Constantinou et al, 2016),
- Modeling research on ecosystem service (ESS), (Landuyt et al, 2013) or,
- In land forces, to aid reasoning and decision making under uncertainty (Starr & Shi, 2004).

Having in mind the previous explanations, the benefits of using BBNs are:

- Explicitly modelling causal factors.
- Reasoning from the effect to the cause and vice versa.
- Overturning previous beliefs in the light of new evidence.
- Making predictions with incomplete data.
- Combining diverse types of evidence including both subjective beliefs and objective data.
- Arriving at decisions based on visible auditable reasoning.

As it is stated in (Marcot & Penman, 2019), BBNs are probabilistic models (filled with real data) which help us to “investigate the consequences of conditions or deducing conditions resulting in an outcome”.

AgenaRisk Software

The AgenaRisk software tool (Fenton & Neil, 2013) has been used by some of the world's leading organizations to model risk and improve decision making across a range of industry sectors and to implement solutions to a range of critical business and safety problems.

AgenaRisk is a powerful tool which overcomes problems that existed with the previous versions of BBN tools, making BBN building much easier (each node type is associated with an extensive set of probability distributions which can be chosen from a predefined list), making calculations or a decision process more accurate and giving a variety of solutions for a wide range of end users.

AgenaRisk Lite version 7.0 that has been used for modeling in this paper consists of: risk map, risk table, risk explorer views and risk graphs and has some powerful and advanced features for creating the Node Probability Table (NPT): rank node, simulation node, partitioned expression, and continuous graphs. For the created model, the software provides a various set of tools for analysis and optimization such as: sensitivity analysis, multivariate analysis, compound sum analysis, and it creates a node probability table based on spreadsheet data.

As a free download version, it has some constraints regarding the saving mode for ranked, simulation nodes and multiple Bayesian network objects. Also, there is no maintenance and upgrade support. Recently, this AgenaRisk Lite version has been withdrawn from the site and has been replaced with the 14 day free trial of a new AgenaRisk 10 version. Anyway, all developed models can run under this new version. The reason for this is a custodian effort to further promote the commercial/academic subscription license version only.

Trust Funds project policy

The policy of the Trust Fund projects is to assist countries (financially and managerially) with the safe destruction of stockpiles of surplus and obsolete landmines, weapons and ammunition. There are various reasons for this approach. The destruction of surplus stockpiles of arms and ammunition reduces the threat to individual partner countries, the wider region and ensures that such materials are not subject to any proliferations. When it is possible, the project can use country facilities and resources for project completion and can hire local population.

Modeling of Trust Funds Project

After a request is initiated from individual partner countries, based on the voluntary basis and an extensive negotiation process, the "Lead nation" is chosen and it is responsible for gathering political and financial support for the project as well as for selecting the executing agent for the project.

Different agencies have been often appointed to act as the executing agent for demilitarization projects by the lead nation, contributing to the project through: development of a feasibility study, technical advice, management activities, overseeing the project development, and ensuring a competitive bidding process. It is very important for legal agreements to be in place between the parties involved in the process.

For the final approval of the project proposal from a higher authority, several elements or preconditions need to be in place: a feasibility study developed by the executing agency, the donation countries, the threshold level of donations, and a clear financial picture (donated money – enough to start the project, costs for running the project – donated money decreased for management and administrative costs).

The whole process of negotiations, gathering political and financial support, and the development of the feasibility study takes some time and is full of uncertainty since it depends a lot on the preconditions and is subjected to everyday risk, known and unknown.

The existing process and the structure for Trust Funds projects involves a number of participants from different jurisdictions, for example, for the feasibility study or for collecting donations and normative legal regulations. The project manager has the main responsibility for the feasibility study. The existing structure within the Trust Fund policy for the project approval does not provide the visibility of the whole process, the progress of one component is not reflected in the other dependent component, coordination is necessary and sometimes difficult, and the project manager sublimates all the information even though he has no jurisdiction over the whole process. All the mentioned things and their interconnections pose a great risk to project execution.

In order to overcome these problems and risks, it is necessary to model the process and causal connections and to reflect the daily changes of individual components on other components (positive or negative) as well as on the final decision.

Risk assessment framework for the Trust Fund project

The modeling process with the help of BBNs overcomes most of the problems and risks listed before. For better understanding the whole process, it is necessary to turn them into a causal model with a Bayesian network, Diagram 1. Most of the previously mentioned is presented in the risk framework model, except legal agreement.

The whole process of building the risk framework and running the simulation is explained in the continuation of this text. The **Risk identification process** has been performed using the interactions and the elements that characterize the Trust Fund policy. Determining the risk interactions is actually the process of building a risk map and the map was modeled using the network structure.

The question that needs to be asked is: “How to build a risk map”? According to (Fenton & Neil, 2013), the following steps are useful in building a risk map:

- Consider the set of risk events from a given perspective.
- Identify the risk triggers for the identified risk events.
- Identify the consequences and mitigations for the identified risk events.
- Define probabilities for the risk events.
- Generate risk predictions for the issues such as simulation, backward reasoning, and a what-if scenario.

By chaining together different risks, we can model multiple risks, risks from different perspectives, and common causes, consequences and mitigate all within the same model.

Another question related to building risk maps is risk perspective. It is obvious that there are different views or perspectives of risk: stakeholder perspective (owners, shareholders, employees, suppliers), customer/user or manager perspective, and local community perspectives. Generally, different experts consider risk at very different levels of granularity and perspective (Wright, 2011). While risk for someone (stakeholder, risk responsibility authority, etc.) can be an opportunity, for others it can be a cause, a consequence or a mitigation and this is something that can be a limitation in constructing a risk map since it has an impact on how a risk map will be constructed. What is good in this approach is that once risk events are identified from a particular perspective, there will be very little or no ambiguity at all about the causal structure.

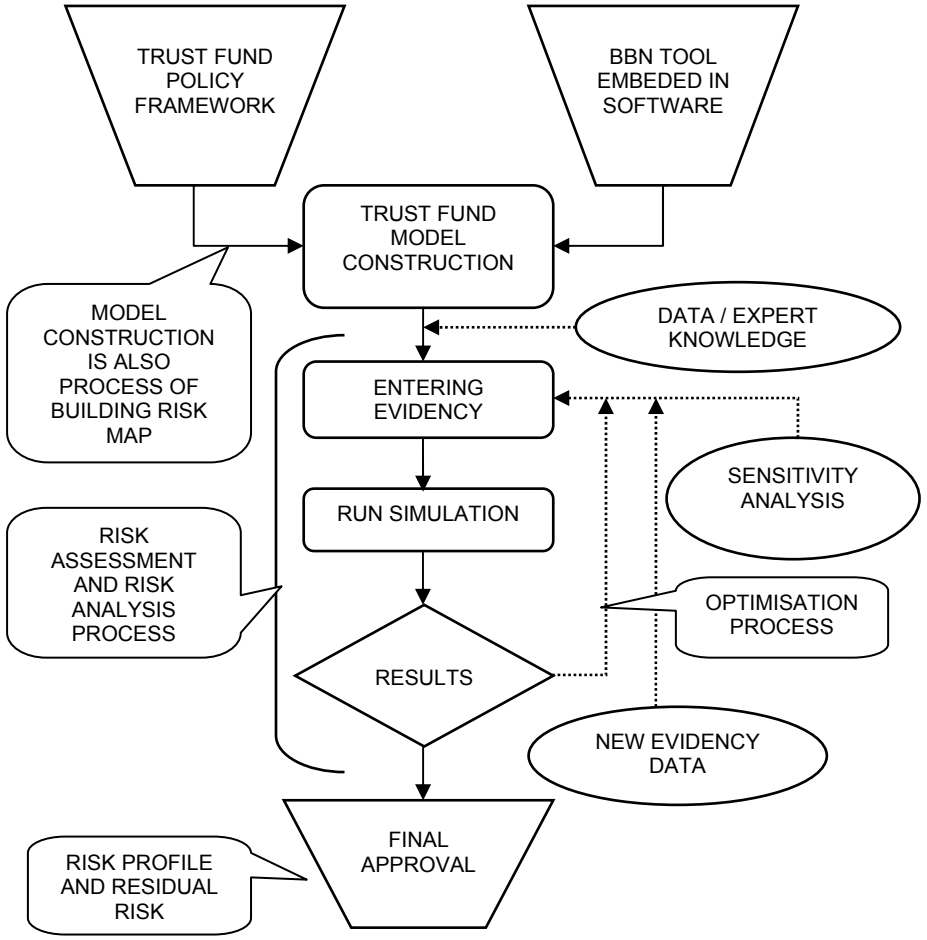


Diagram 1 – Framework for the risk assessment process using a BBN and the AgenaRisk software

Диаграмма 1 – Рамки для анализа рисков при использовании программного обеспечения AgenaRisk, с внедренным модулем для условной вероятности

Дијаграм 1 – Оквир за процену ризика коришћењем софтвера AgenaRisk са уграђеним модулом за условну вероватноћу

Risk assessment and risk analysis: A tool for modeling and entering evidence is the AgenaRisk software that uses the BBN tool for modeling and conditional probability. Performing the evaluation process is as follows: running a simulation is a process of measuring the

interactions between risks and comparing the results with the predefined boundaries for an identified risk. The sensitivity analysis is also performed to enhance the reliability of the network analysis phase and to define which and how the identified risks influence the main variable or the decision variable – project approval. When new evidence appears from the environment, from expert knowledge or as an input from the sensitivity analysis, the optimization or re-evaluation process of the model starts.

This optimization/or response phase is performed until all balance between elements is found (i.e. effectiveness of the **mitigation measures** are in place) and all identified risks are within the defined boundaries. The simulation is helpful for estimating the effects of the mitigation measures.

The end of the process is a risk profile. This profile consists of the list of identified and measured risks, meaning that some risks still exist in the system (i.e. residual risk) but they are under **control and constantly monitored.**

Construction of the framwork for risk assessment using the AgenaRisk software

Further steps in this paper comprise the following: model developing using the AgenaRisk software, specifying the variables, entering the probabilities, a case study (back and forth propagation), the validation of the model (sensitivity analysis) and the conclusions.

Based on the policy of Trust Funds (activities and conditional dependence) and the basic principles for constructing a model within the AgenaRisk software together with user perspectives, a model was created as shown in Figure 2. The established model provides a visual image of the process where each node represents the potential risks identified in the process.

The model represents a chain of events with uncertainties that will be assigned later and gives clear visibility of the risk map. The ability to decompose a risk problem into chains of interrelated events and variables should make the risk analysis more meaningful, practical and coherent.

The model also represents the integration of different levels of decision makers involved in this process: international organization, different countries, the government level, and the factory/customer level.

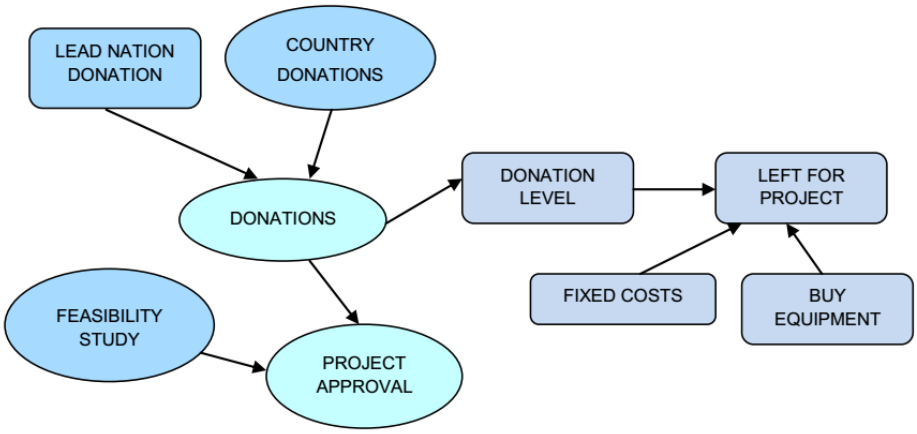


Figure 2 – Basic Trust Fund model in the AgenaRisk environment
Рис. 2 – Базовая модель проекта, представленная в программном обеспечении
Слика 2 – Основни модел пројекта приказан у софтверу

Based on the explanation presented earlier for the creation of a Bayesian Belief Decision Network, the utility nodes in the proposed model are: donation level, left for project, fixed costs and buy equipment (Figure 2). The chance nodes are: lead nation donation, country donation, donations and flexibility study, while the node "project approval" is the decision node.

Data acquisition problem and the process of entering the probabilities

Assigning the probability tables in a risk map is not always an easy task. The process requires expert knowledge or relevant statistical data, well suited for decision making. Expert knowledge is especially needed in a case where the existing data cannot be extended except for the incorporation of expert knowledge.

Depending on a problem in question, one example of acquiring data is given in (John et al, 2016) where they explain that audit reports from maintenance departments framed in the probabilistic way can be a valuable source.

When there are not enough data, purely subjective values can be supplied and it is essential to make the most of what is given.

(Constantinou et al, 2016) focus their work on complex data problems that come from poorly structured questionnaires and interviews (with inevitable examples of repetitive, redundant and contradictory

responses, different classes of data) and on how to transform them to be useful for inclusion in BNs.

AgenaRisk provides a wealth of tools to make the task of entering probability as easy as possible. It can be done manually through filling the Node/Conditional Probability Table (NPTs/CPTs), using expressions or through a process called “learn tables from spreadsheet”.

Since this is not the first time to run such a project in this particular facility, but the first time to model it, the expert knowledge from people who once were involved in the first project was now available (through the interview process and data collection). This helped us to distinguish between important and less important elements in the modeling process.

Also, to overcome the problem of information shortage, the model was developed as a post-appraisal process of the project planning phase, when we had enough information or feedback from the reality to build it up.

After entering the NTP for the nodes, the initial probabilities are as in Figure 3.

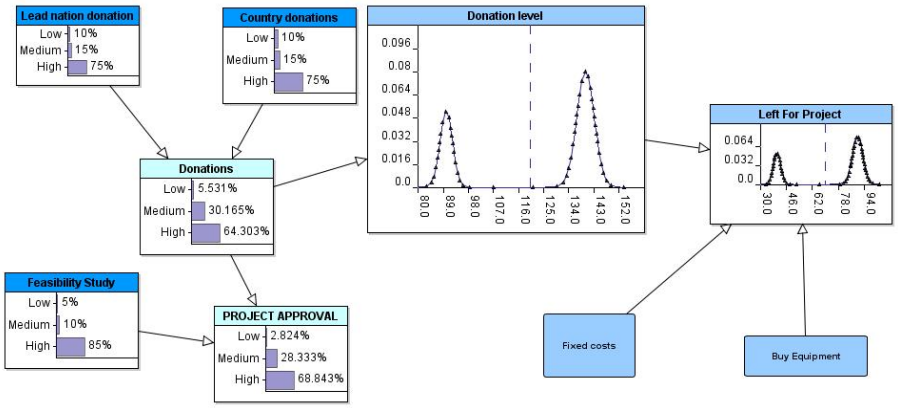


Figure 3 – Risk Map model with the initial probabilities for the NTF Policy
Рис. 3 – Карта рисков с инициальной вероятностью
Слика 3 – Мапа ризика са иницијалним вероватноћама

For the use in the AgenaRisk software, the following variables are created (with their abbreviations):

- Ranked nodes are: Lead nation donation (LND), Country donation (CD), Donations (D), Feasibility Study (FS), and Project approval (PA). This is important because, to be of any use to define the Node Probability Table (NPT), the node type has to be Ranked.

- Simulation node: Donation level, Left for Project, Fixed costs, and Buy equipment, were the last two are constant (pre-defined costs).

The NPT for the parent nodes can be generated manually (when filling in the table, three states can be chosen: low, medium, high; the software provides up to 5 states). For quantifying the strength of the relationships among variables and for forming the CPT (for the child node), a software option is used for entering the weight and partitioned expressions for the parent nodes..

The use of the weight expression in the model is as follows:

- For the variable Donations where the variable LN has weighted influence by 2:1 against the CD, and
- For the variable Project Approval where the variable FS has weighted influence by 2:1 against the DL.

The use of the Partitioned expression for creating the NPT for the variable Donation level is useful to create the NPT using different expressions for each combination of the parent states. In our model, low, medium and high statuses for the variable D were created using the TNormal expression type with the mean, the variable and the bounds that actually represent low, medium and high levels of donations.

Utilization of the utility nodes: Using the Arithmetic Expressions, the variable LFP was created. The arithmetic value for this is: donation level minus two constants. The constant is also a simulation node. The constant can be used in a combination with the Arithmetic Expressions for calculating another simulation node values.

The constant variable “Bye Equipment” refers to Capability improvements costs (in logistic support, new process machines, etc.). The constant variable “Fixed Costs” refers to Management and contingency costs.

What is left, or the variable “Left for Project”, refers to Operational costs for running projects, in this case for the delaboration activity.

Running the model (case study)

One of the most powerful features of AgenaRisk is the ability to compare different scenarios side by side. Models are used to generate predictions about the variables LFP and PA in the case of different donations from the variables CD and LN (these scenarios simulate financial risk). The Feasibility study (FS) variable has a high value in both scenarios:

- Scenario 1: CD and LN have donated a small amount of money. This means that donators are not interested enough to support the project.
- Scenario 2: CD and LN have donated a big amount of money. This means that the project should have enough support for start and further running.

The question is how these states influence the variables Project approval, Donation level and Left for project (Table 3):

- Scenario 1: It is obvious that a smaller donation has a smaller influence on decision makers whether to accept a project, especially in the situation when project fixed costs reduce the donation sum necessary for project approval (Project approval (only 30% of high probability thanks to the variable FS with weighted influence by 2.5:1.5 against the DL), Donation level (55.9), and Left for project (5.9).
- Scenario 2: The situation is different in the case of a bigger donation: Project approval (86% of high probability thanks to the variable FS with weighted influence by 2.5:1.5 against the DL), Donation level (135.5), and Left for project (84.5).

Table 3 – Data comparison after running both scenarios
Таблица 3 – Сопоставление данных после изучения случая
Табела 3 – Поређење података након студије случаја

	Scenario 1 Small	Scenario 2 Big
Donation Level	55.961	135.54
Left for project	5.931	84.528
Donations	66.8%	89%
Project approval	30%	86%

A visualization of these scenarios is presented in Figures 4 and 5. In Figure 6, the comparison of two scenarios is shown.

Malbašić, S. et al, Risk assessment framework: application of Bayesian Belief Networks in an ammunition delaboration project , pp.614-641

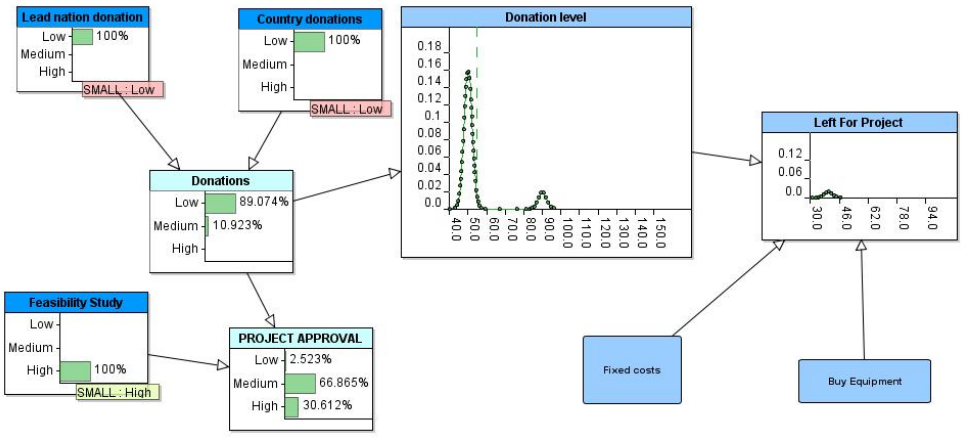


Figure 4 – Risk Map model with the initial probabilities for scenario 1
Рис. 4 – Карта рисков с инициальной вероятностью по сценарию 1
Слика 4 – Мапа ризика са иницијалним вероватноћама за сценарио 1

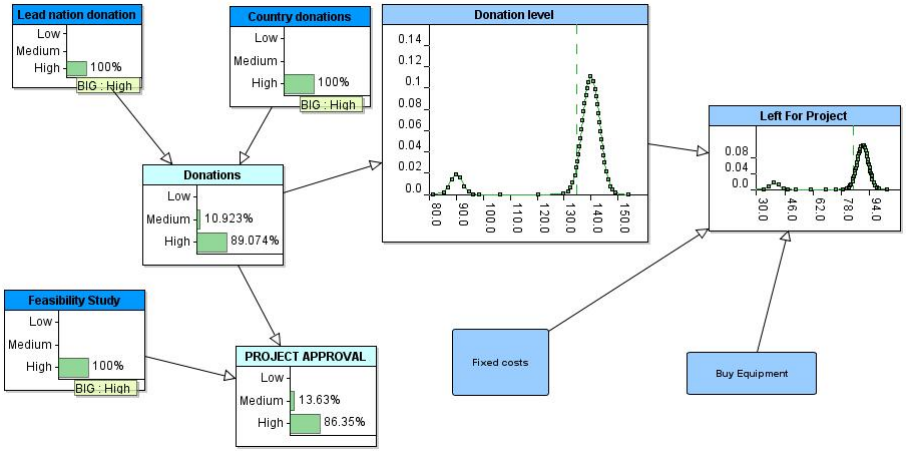


Figure 5 – Risk Map model with the initial probabilities for scenario 2
Рис. 5 – Карта рисков с инициальной вероятностью по сценарию 2
Слика 5 – Мапа ризика са иницијалним вероватноћама за сценарио 2

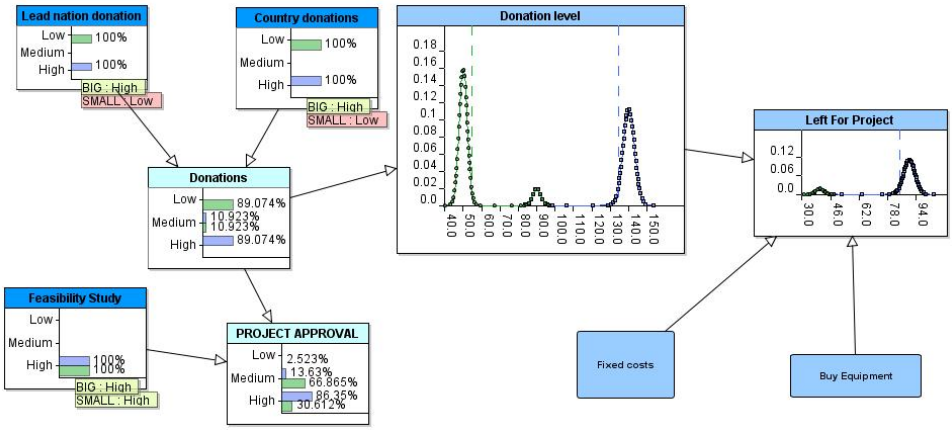


Figure 6 – Comparing two data scenarios
Рис. 6 – Сравнение двух сценариев
Слика 6 – Поређење два сценарија

Back propagation capabilities

Another very useful tool in using the AgenaRisk software is the "back propagation" option, meaning that a value for the last variable in the chain (or the child node) can be defined and after running the model, the values for other variables in the chain (or for the parent nodes) are obtained.

Now, let the probability of project approval be high (scenario 3), so let us see which probabilities other variables need to have. The scenario gives the threshold level, i.e. if we want to have 100% of project approval, what would be the minimum level of donations and the donations level?

Scenario 3 gives the important information of the threshold level for donations in order to have the probability of project approval of 100%. In real situations, this percentage and the donation level can be lower (other variables have also their influences) and in that case the project can be run in phases, meaning that the next phase can start when there is enough money on the account. The threshold level is one of the boundaries in the risk assessment process (the obtained values are compared with this one), meaning that, in case there are lower values, the new threshold value optimization process should be run again.

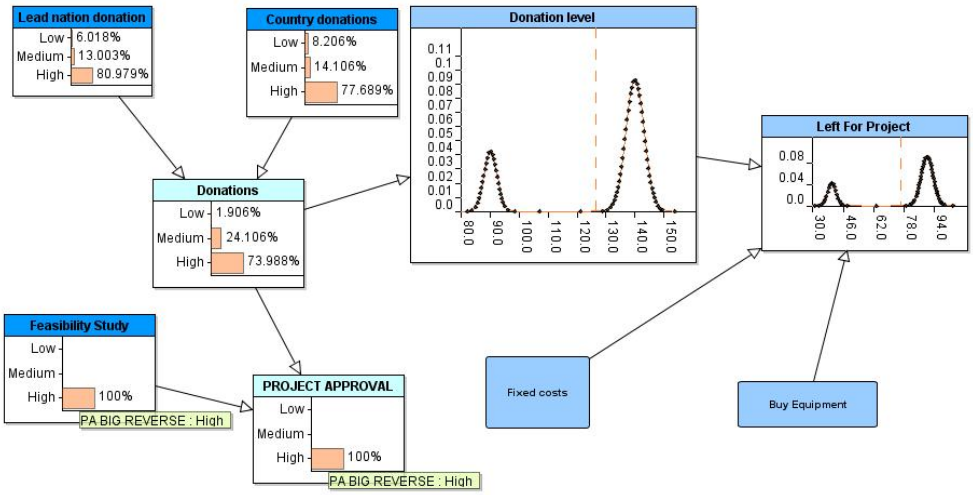


Figure 7 – Risk Map model for "back-propagation" scenario 3
Рис. 7 – Карта рисков по сценарию 3 (снизу вверх)
Слика 7 – Мапа ризика за сценарио 3 (одздо на горе)

Table 4 – Data after running scenario 3
Таблица 4 – Полученные данные по сценарию 3
Табела 4 – Добијени подаци за сценарио 3

	Scenario 3 PA Big
Donation Level	126
Left for project	76
Donations	74%
Project approval	100%

As it is presented in Figure 7, the node FS has a significant influence (with 100%) on our targeted node (Project approval). One reason is that in this model, this node has twice as big impact as the other nodes, due to a pure practical reason. In order to run a project of interest (in our case it is a delaboration project), we need to have a facility/factory and there is no better way to represent that idea in the model than through the variable FS. In our case, the feasibility study shows that the project can be run in the designated facility with all preconditions fulfilled: line for demilitarization, quality system, environmental protection engaged, operational health at high level, skilled workforce, adequate machines, etc.

Sensitivity analysis

A very useful tool to check the built model is to perform the sensitivity analysis. Although there are different interpretations of the meaning of this analysis ("What is important for model or system development?", "What is important for calculated measures of uncertainty?"), in this case, we tried to find out which nodes have the greatest impact on the “targeted” node PA (Project approval). This is important for a risk assessment process and also to see which node/nodes to pay attention to.

The sensitivity analysis is presented through a tornado graph were the bar length corresponds to the sensitivity which a paticular variable has regarding the targeted variable. The largest bar appears at the top of the graph (depicting the highest sensitivity).

The sensitivity analysis was done for the case scenario where all variables already have their prior probabilities. A further interpretation means that with “high probability” for the variable PA, the influence from the variable FS ranges from 0.019 (when the FS has low probability) up to 0.776 (when the PA has high probability). The same explantion is valid for other variables. By comparing the influences of other variables, we can conclude that almost every variable (in the state of its high value), except constant variables, has a big infulence (ranging form 0.229 up to 0.799) on the FS to reach its high value (0.7) as well, meaning that, in the risk assessment proces, each of them requires special attention, Figure 8.

For the purpose of this work and a further explanation of the power of the sensitivity analysis, we have run the sensitivity analysis for case scenario 2 (variables have “high” values) in order to define which variable would have a big influence on the variable PA.

Figure 9 depicts quite well a real situation where the variable PA depends on the amount of money collected – Donation level and Left for project (amount of money needed to run it) - knowing that other variables (CD and LN) already have “high”values. A high probability of influence for the constant variable means that, as a representer of fixed cost, this variable should be lower meaning that the variable LFP would be higher enough for running the project (comparing to the treshold level).

Knowing the sensitivity of some nodes to the targeted node, we should try to estimate the states of these nodes with as much accuracy as possible.

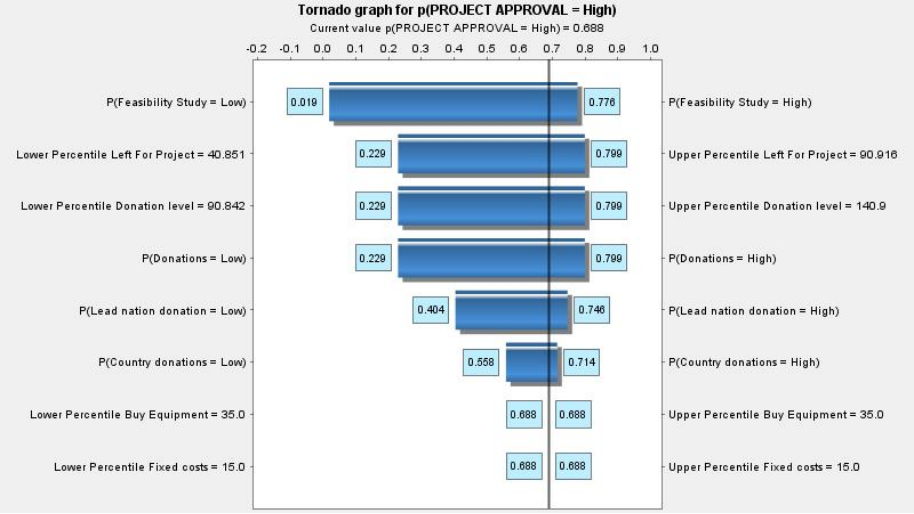


Figure 8 – Sensistivity data when the variable FS has the highest value (other variables have prior probabilities)
Рис. 8 – Диаграмма анализа чувствительности для тех случаев, когда значение переменной FS является наибольшим (остальные переменные соотносятся с предыдущими вероятностями)
Слика 8 – Дијаграм анализе осетљивости у случају када варијабла FS има највећу вредност (остале варијабле имају претходне вероватноће)

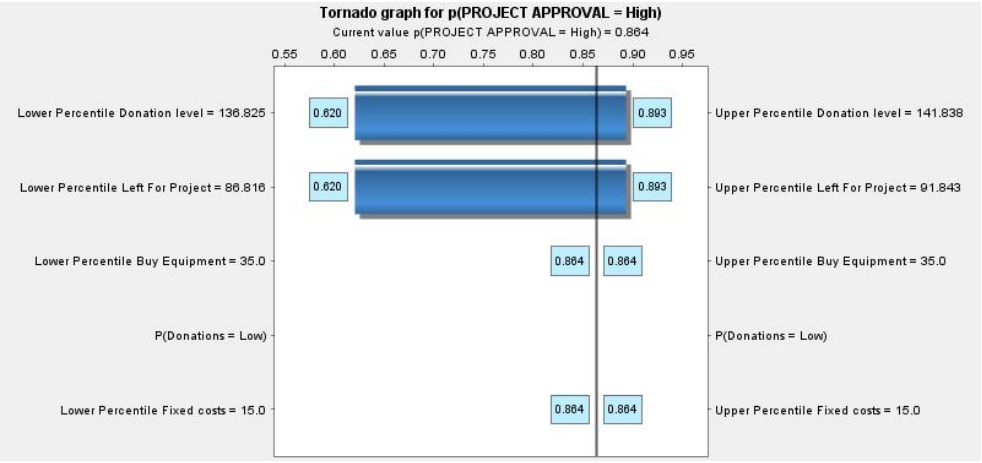


Figure 9 – Sensitivity anlaysis for case scenario 2
Рис. 9 – Анализ чувствительности по сценарию 2
Слика 9 – Анализа осетљивости за сценарио 2

Conclusions

One of the main ideas of this paper was not to rely only on mathematical and statistical elements during risk assessment, but also to incude modeling and reasoning procedures. This work gives its contribution in several ways:

- Provides a risk assessment framework applicable during the project planning phase in the ammunition delaboration process that has not been used so far in similar projects.
- Presents how a simplified framework can provide valuable results related to potential risk contributors.
- Introduces probabilities into the risk assessment process as an advanced approach comparing to statistical data, through the use of BBNs.

The proposed model has brought some innovative elements. The Trust Fund Policy was studied from the risk management perspective. The model itself presents a clear and visual risk map explaining how risk emerges or how it is connected, thus providing a good base for a risk identification process, including an optimization process through which new data are incorporated in light of new evidence. Finally, the approved project with its residual risk is a real picture of the risk profile. This risk profile should be documented and carefully monitored.

Several scenarios were evaluated, some of them were not covered, but those which were covered had a significant influence on the decision making process and provided enough elements to make a right decision. The evaluated scenarios are also risk indicators a lot of attention should be paid to.

For performing all the aforementioned, we used most of the advantages that the AgenaRisk software provides (Gadeberg & Luedeling, nd):

- Models built using BBNs provide a real tool to update belief in some uncertainty event when we observe new evidence about the event (in our case, about new donations, feasibility study beliefs, etc).
- One helpful feature of BBNs is the option to integrate expert knowledge with data, which could prove to be a cost-effective way to assess development projects.
- BBNs are well suited to address uncertainties about benefits and costs due to their ability to work without precise numbers and to incorporate expert knowledge.

- Decision makers can use the BN framework by entering values related to the project budget, impact and risks into the model.

The sensitivity analysis is another powerful tool of the applied software which helps highlight the significancy of some variables. In this paper, the sensitivity analysis was run to define which variables have the greatest impact on the targeted variables, i.e which variable is of the biggest interest for/in the presented problem (to make a decision about the project approval). Decision makers can devise necessary schemes to optimize the process or some operations within the process based on the impact factors.

What can be a limitation in constructing a risk map, or, generally, in risk definition, is that different experts consider risk at very different levels of granularity and perspective. While risk can be an opportunity for someone (stakeholders, risk responsibility authorities, etc), for others, risk can be a cause, a consequence or a mitigation. This can have an impact on how a risk map is to be constructed.

Another problem might be a case when someone is uncomfortable with the reliance on expert assessments and the inclusion of cause-effect relationships that have not been confirmed in controlled experiments. For that reason, the presented model was made as a post-project appraisal when we have enough data to incorporate in it.

As stated in (Fenton & Neil, 2013), special attention needs to be paid in the process of decomposing a problem into classes of events and relationships (with enough granularity to be meaningful and accurate enough for the purpose required), states of variables and probabilities that reflect our best knowledge (we have supposed that probabilities for some variables are T-normal although real-life situations are different in most cases).

For the purpose of defining positive and negative aspects of the proposed model, we have also done a SWOT analysis where we highlighted the following aspects of using BBNs and the AgenaRisk software:

- **Strength**: visibility of the process through a graphical interpretation, risk measurement using probability, defining causal relationships, use of expert knowledge upon empirical data in case of lack of data, defining uncertainty through the probabilistic set of rules, possibility of using validation tools, reasoning process in light of new evidence, possibility to develop a model for a type of problems related to project planning.

- **Weaknesses**: oversimplification of the model due to the limitation of using the AgenaRisk Lite version, lack of historical data, using knowledge of only one or two experts which can lead to subjectivity, modeling this type of the problem for the first time, and lack of experience with BBNs which can lead to misunderstandings.
- **Opportunities**: growing interest in using BBNs can lead to improved models, use of the full version of AgenRisk will provide numerous options for modeling, use of recent advances in BBNs (object oriented BNs, dynamic BNs, hybrid BNs, integrated BNs, hybrid BNs, neural networks, (Marcot & Penman, 2019)), and possibilities for expanding the model including other variables.
- **Threats**: low acceptance of this model in a wider community (academic, public, political, etc.), and availability of only a full AgenRisk version for purchasing.

For further work, a new model needs to be complex, to cover different fields, and to be developed, if possible, in a new version AgenaRisk 10.0. It is also necessary to depict the interactions between organizational, human and technical factors/risks.

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МЕТОДОЛОГИЯ АНАЛИЗА РИСКОВ: ПРИМЕНЕНИЕ БАЙЕСОВСКИХ СЕТЕЙ ВЕРОЯТНОСТИ В ПРОЕКТЕ УТИЛИЗАЦИИ БОЕПРИПАСОВ

Слободан Б. Малбашич[а], *Стефан* В. Джурич[б]

[а] Министерство обороны Республики Сербия, Департамент материальных ресурсов, г. Белград, Республика Сербия,

[б] Университет в г. Крагуевац, Факультет инженерных наук, г. Крагуевац, Республика Сербия

РУБРИКА ГРНТИ: 78.00.00 ВОЕННОЕ ДЕЛО;
78.01.81 Измерения, контроль и управление качеством. Испытание образцов вооружения и военной техники

ВИД СТАТЬИ: обзорная статья

ЯЗЫК СТАТЬИ: английский

Резюме:

Модели, представляющие реальные проблемы при принятии решений, зачастую руководствуются историческими данными. Негативный аспект данных моделей заключается в том, что они не могут предусмотреть обстоятельства в будущем, которые основаны на реальных событиях и новых источниках риска. Для преодоления этой проблемы в данной статье представлен процесс разработки реальной предиктивной модели с применением байесовской сети вероятности и программного обеспечения AgenaRisk. Байесовские сети вероятности напрямую отражают реальные проблемы посредством графических структур, которые представляют не только поток информации, но и условные связи. В качестве теоретического обоснования в данной работе приведена и объяснена теорема Байеса. Преимущество использования байесовых сетей вероятности в процессе принятия решений, заключается в том, что этот процесс производится в „двух

направлениях“ (снизу вверх и наоборот), что делает его мощнейшим инструментом для оценки рисков в процессе принятия решений. В статье также представлены базовые принципы и значение байесовых сетей и их применение в процессе разработки проекта по утилизации боеприпасов (утилизация запасов устаревших и непригодных боеприпасов), в котором оценка рисков является одной из сложнейших задач, непосредственно влияющей на принятие окончательного решения о запуске проекта. Наряду с вышеперечисленными методами для обоснования принятия окончательных решений проведены: анализ чувствительности и SWOT анализ.

Ключевые слова: условная вероятность, байесовская сеть вероятности, оценка рисков, анализ чувствительности, SWOT анализ.

МЕТОДОЛОГИЈА ЗА ПРОЦЕНУ РИЗИКА: ПРИМЕНА БАЈЕСОВИХ МРЕЖА ВЕРОВАТНОЋЕ У ПРОЈЕКТУ ДЕЛАБОРАЦИЈЕ МУНИЦИЈЕ

Слободан Б. Малбашић[а], *Стефан* В. Ђурић[б]
[а] Министарство одбране Републике Србије, Сектор за материјалне ресурсе, Београд, Република Србија,
[б] Универзитет у Крагујевцу, Факултет инжењерских наука, Крагујевац, Република Србија

ОБЛАСТ: менаџмент пројектима
ВРСТА ЧЛАНКА: прегледни рад
ЈЕЗИК ЧЛАНКА: енглески

Сажетак:

Модели који репрезентују реалне проблеме приликом доношења закључака већином се ослањају на историјске податке. Негативан аспект ових модела јесте да они не могу да предвиде будућа стања заснована на тренутно прикупљеним подацима као и новим изворима ризика. Да би се превазишао овај проблем, у раду је приказан процес изградње реалног предиктивног модела коришћењем Бајесових мрежа вероватноће и софтвера AgenaRisk. Бајесове мреже вероватноће најдиректније репрезентују реалне проблеме преко графичке структуре која представља условне везе, а не само токове информација. Развијени су и софтвери који имају алгоритме за рачунање условних вероватноћа. Као теоретска основа користи се Бајесова теорема која је такође објашњена у овом раду. Друга предност коришћења Бајесових мрежа вероватноће јесте процес закључивања који се може вршити у „оба правца” (одозго надоле и обратно), што га чини веома моћним алатом у процени ризика и процесу закључивања.

Такође, у раду су приказани основни принципи и предности примене Бајесових мрежа у процесу припреме пројекта делаборације муниције (решавање вишкова и неперспективне муниције у складиштима). У њему је процена ризика један од захтеваних активности који помаже у процесу доношења коначне одлуке за покретање или непокретање пројекта. Анализа осетљивости и SWOT анализа примењени су као корисни алати за валидацију и доношење коначних закључака.

Кључне речи: условна вероватноћа, Бајесове мреже вероватноће, процена ризика, анализа осетљивости, SWOT анализа.

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СТРУЧНИ РАДОВИ
ПРОФЕССИОНАЛЬНЫЕ СТАТЬИ
PROFESSIONAL PAPERS

MODERN ASSETS IN SECURITY SCREENING AND COUNTER TERRORISM

Predrag M. Kojadinović

Serbian Armed Forces, Military Police Department, Military Police Training Center, Department of Forensic - Technical Affairs, Belgrade, Republic of Serbia,
e-mail: kojabk@hotmail.com,
ORCID iD: http://orcid.org/0000-0001-9166-6008

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Summary:

The article first briefly discusses hazardous materials, namely their concept and classification. One part of the article is focused on the detection of hazardous materials and the detection of fuzes and initial components of explosive devices. In addition, it presents some of modern counter-terrorist and security screening devices used in Serbia as well as in foreign countries, based on the data collected during a visit to the counter terrorist units of the Serbian Army and the Ministry of Interior of the Republic of Serbia. The aim of the paper is to contribute to gaining an insight into the acquired knowledge of security and protection equipment, detection devices and hazardous materials in particular. The knowledge gained by analyzing and comparing available literature and previous research is expected to lead to raising awareness of the importance of usage of modern equipment which must keep pace with means used by terrorists and commandos in their attacks.

Keywords: counter- diversion protection, hazardous materials, detection of hazardous materials, detection of fuzes - inital components of explosive devices, detection devices.

Introduction

Global changes in the late 20th and early 21st century contributed to an increasing threat of terrorism, organized crime and other security challenges, risks and threats, not only at national but also at international and even global security levels. Perhaps the greatest danger in this

respect is terrorism which requires security operators that confront it with all available forces and means.

An important element to combat both terrorism and commando operations is certainly counter-diversion protection. Counter-diversion protection is a technical discipline that basically involves finding, neutralization, transportation, deactivation and destruction of all types of explosive devices. Making all this possible to perform requires some technical assets for detection of the aforementioned devices with dangerous substances in their structure.

The use of hazardous materials in sabotage and terrorist activities

If we look back, we can see that the choice of the means to attack the target was following the development of science and technology and it developed in several historical phases: knife-poison, gun, dynamite, and, finally, bomb or explosive device. Nowadays terrorists primarily use technological achievements in the manufacture of improvised explosive devices in order to achieve their goals. By using hazardous materials, terrorists can disable or kill a large number of people either in the civilian or military sector, and cause panic and fear thus undermining the security of the state.

It is obvious that hazardous materials are closely related to sabotage - terrorist activities. There is almost no sabotage or terrorist action without some of hazardous materials. But what are hazardous materials?

According to the Law on Safety and Health at Work, hazardous materials are explosive, flammable, oxidizing, poisonous, repulsive, contagious, corrosive, carcinogenic and radioactive substances, established by standards and other law regulations, produced, used or stored in the work process, and also materials that have such characteristic, when attached to a certain substance are dangerous to life and health of employees (Službeni glasnik RS, 101/2005), (Službeni glasnik RS, 91/2015).

According to another definition, hazardous materials include chemical compounds, mixtures of chemical compounds or chemical elements which have a dangerous (harmful) characteristic such as explosion, flammability, radioactivity, or other toxicity (Poštić et al, 1998). Hazardous materials can be classified on the basis of different criteria, but based on the hazardous effects manifested, they are divided into the following four groups:

- explosive,

- flammable substances,
- radioactive substances, and
- toxic materials.

By studying the characteristics of hazardous materials, it is easy to conclude that they are all very suitable for use in sabotage - terrorist purposes for which we have a lot of evidence in current events in the world. There is a real risk that protagonists of international terrorism in the future will use nuclear, biological, chemical agents more and more, and those most widely used will be dangerous substances of high toxicity, high volatility, simple to use, and difficult to detect (industrial substances, toxic chemical substances, etc.). Hazardous materials are easily available on the market and they can be easily synthesized using information from the Internet, which makes terrorists' job much easier.

It is clear that their use is detrimental to people and material and technical resources, so the knowledge about them and modern equipment for their timely detection are the basic preconditions for the prevention of such scenarios and fight against them in case they occur.

Devices for the detection of hazardous materials and fuzes - initial components of devices

When analyzing sabotage and terrorist activities today, it can be concluded that special attention must be paid to preventive measures. Consequently, anti-terrorist measures and actions are imposed as necessary preventive actions, or actions that prevent the execution of terrorist attacks using hazardous materials and their harmful consequences for the safety of people and property. Also, modern methods are applied as well as technical developments which detect terrorists with their materials and resources used to achieve their goals. From this stems the importance and role of modern assets of detection in counterdiverson protection.

Detection is closely related to security screening. Various detection devices are used for that purpose. These devices can be divided into:

- devices for the detection of hazardous materials, and
- devices for detection of fuzes - initial components of devices.

Devices for the detection of hazardous materials can be classified as follows:

- devices for explosives detection,
- devices for the detection of flammable substances,

- devices for the detection of radioactive substances, and
- devices for the detection of toxic substances.

The following devices are used for detecting fuzes - initial components:
- metal detectors,
- X-ray apparatus, and
- stethoscopes.

Each of these devices uses certain methods of work, which will not be discussed in detail on this occasion. We will try to show here some of the advanced representatives of each of the mentioned groups of devices.

Explosives detection devices

When it comes to devices for explosives detection, contemporary devices are able to simultaneously detect explosives and narcotics. All these devices are reliable, fast, flexible, and safe to handle. Some of the leading companies in this field are American FLIR Systems (Forward Looking Infrared), Syagen Technology Inc, SEDET (Sociedad Europea de Deteccion S.L.) in Europe LDS (Laser-Detect system) in Israel, etc.

One of the representatives is a handheld explosives detector E3500 Chemilux. This is a handheld device which works on the principle of chemiluminescence and its purpose is detection of explosives. It is one of the first such devices in the world (Figure 1). It detects military, industrial, and even hand-made explosives, liquid, powder, plastic, nitrate, black powder, and more. It has a dual mode of particles and vapor, and is characterized by a very fast detection (up to 16 seconds) and accurate detection results. The device detects particles and vapors of explosives in a non-invasive way in luggage, letters, vehicles, clothing, electronic devices, documents, etc. It is resistant to various weather and soil conditions, simple to use (one button), with an LCD display with status messages, red and green LED lights, and optional headphones for the audio signal. Data from the device can be forwarded via Wi-Fi. It is powered by a 12V battery whose life is about 6 hours. It weighs about 2.7 kg. No isotopes, radioactive sources, and no license are required. It is suitable for police and military units, customs, ports, airports, bus and railway stations, nuclear facilities, embassies, etc. (Autoclear, 2013)

Figure 1 – E3500 Chemilux
Рис. 1 – E3500 Chemilux
Слика 1 – E3500 Chemilux

The Fido NXT is a hand-held wand which uses the method of molecular spectroscopy, and the principle on which it works is amplifying fluorescent polymers (AFP - amplifying fluorescent polymers). The sensor is made of a capillary glass tube whose interior is covered with a polymer film. It is a product of the famous company FLIR Systems, Inc (Figure 2). Its dimensions are 368.3 x 114.3 x 69.9 mm, and it weighs only 1.4 kg. A lithium battery used to provide power ensures the autonomy of 8 hours. It has a USB port and the MS Office operating system for storing data. It can operate at temperatures ranging from -10 ° to + 55 ° C.

It detects TNT (trinitrotoluene), DNT (dinitrotoulen), Semtex, C4, RDX (Research Department explosive or Royal Demolition explosive or simply hexogen), PETN (pentaerythritol tetranitrate), powder explosive, some industrial explosives, improvised materials, but not peroxides. The start-up time is about 5 minutes and the detection time about 10 seconds. (Laurus systems, 2019)

Figure 2 – Fido® NXT
Рис. 2 – Fido® NXT
Слика 2 – Fido® NXT

Devices for the detection of flammable substances

When it comes to flammable materials, it should be noted that combustible gases and vapors are particularly dangerous. Any type of gas or vapor reacts explosively under certain temperature and pressure determined by the lower explosive limit (LEL) and the upper explosive limit (UEL). Risks are reduced by a permanent control of these limits. There are two types of devices for the detection of flammable vapors, gases and particles, those that detect a specific gas and those that detect several gases. Explosive/flammable ones are hydrogen (H2), a natural gas/methane (CH4 propane - butane, isopropyl alcohol, hexane (C6H14), octane fuel, acetylene (C2H2), ethylene (C2H4), ammonia (NH3), butanone, ethanol (C2H5OH), methanol (CH3OH), toluene, pentane (C6H12), ethylene - oxide (C2H40), (Spectra, 2019). One of the newest representatives of devices for the detection of these substances is a PS200 Series from the Gas Measurement Instruments Ltd company. This sturdy and accurate portable gas detector provides unparalelled protection in the closed space with the audio and visual alarm in case of exposure to gases or combustible substances. It detects up to 4 types of gases simultaneously. It can be configured to detect methane, oxygen, carbon monoxide, hydrogen sulfide, and other flammable gases (Figure 3).

Figure 3 – Combustible gas detector PS200 Series
Рис. 3 – Газоанализатор горючих газов PS200 серия
Слика 3 – Детектор запаљивих гасова PS200 Series

Optionally, it can use an internal pump. Its dimensions are 121 mm x 59 mm x 32 mm and it weighs 230 grams with a pump or 215 without it. A lithium battery allows an autonomy of about 8 hours with the

pump. Charging takes about 4 hours. The operating temperature range is -20 °C to + 50 °C and it withstands falls from a height of 3 meters. Its measurement range is:

LEL	0 – 100%
O_2	0 – 25%
CO	0 – 1000ppm
H_2S	0 – 100ppm

In the case of the aforementioned gases, there is a sound, light and vibration alarm (GMI, 2019).

Apparatus for the detection of radiation

The operation of the majority of radiation detectors is based on a ionization chamber. The radiological detector RadSeeker is a handheld, portable, rugged and highly accurate detector and an identifier of radioisotopes detected by gamma and neutron radiation. Easy to use, it provides fast, simple, and specific information for risk assessment. It is suitable for customs control, border protection, emergency response, and radiological control of objects and persons (Figure 4).

The detector can be used for searching or "screening" to detect radioactive sources, and then to clearly identify whether the detected radioactive material is harmless natural radiation or a more dangerous source, such as special nuclear materials or those contained in 'dirty bombs'. For each source identified, the detector provides risk assessment and describes the source as harmless or as a threat, so that there is no need for the operator to guess.

Figure 4 – Radiological detector RadSeeker
Рис. 4 – Радиологической детектор RadSeeker
Слика 4 – Радиолошки детектор RadSeeker

The built-in wireless capabilities, including Wi-Fi and satellite telephone interface, give those in the remote command center an easy access to information such as identified threats and the location of the device/operator.

In situations when it is considered unsafe to send an operator to the location, the detector can be set mechanically, and monitoring and device control can be performed from a safe distance. It is equipped with three types of alarms (visual, light and vibration) as well as with a GPS (Smiths detection, 2019a). The technical characteristics of the device are given in Table 1.

Table 1 – Technical features of the RadSeeker
Таблица 1 – Технические характеристики RadSeeker
Табела 1 – Техничке карактеристике уређаја RadSeeker

Measuring range counter	25 keV – 3 MeV (Gamma)
Weight	2.4 kg
Power source	Li battery that provides 8h of work
Library	Easily expandable library with 41 radionuclides
Temperature range	from - 32 ^{o}C to +50 ^{o}C
Dimensions	17.8 x 30.5 x 11.4cm

Devices for the detection of toxic substances

The monitor of chemical agents - CAM (Chemical Agent Monitor) is a manual transmission asset, designed for the detection of nerve toxic substances and blister agents in the air (point monitor), for rapid determination of the boundaries of the contaminated area, for detecting contamination of people, ships, planes, motor vehicles, buildings and facilities, for checking the performance of decontamination works, and for monitoring the situation in the objects of collective protection (Figure 5).

The CAM detects nerve and blister agents in the form of vapor in the lowest concentrations that may affect people in a short period. The lowest concentration for nerve agents is G>0.03 mg/m^3 per minute and for V>0.01 mg/m^3 per minute. For blister agents, the lowest concentration is H>0.01 mg/m^3 per minute. It can also detect chlorine, phosgene and hydrogen cyanide (HCN) in the PLUS configuration mode. It contains a beta radiation source of Ni-63 (10 mCi). It works with one battery whose durability depends on temperature (normally 12 hours at a temperature of about 20ºC). The basic features of the monitor are:

- Weight: 1.7 kg,
- Dimensions: length 390 mm, width 80 mm, height 145 mm,
- Power source: LiSO2 battery voltage 6 V,
- Battery life: 45 °C - 18 hours, 20 °C - 14 h, -25 °C - 4.5 h,
- Operating temperature: -25 to 45°C, storage temperature: -55 - to 70°C,
- Suction power of 400 ml/min of air;

It is used in military units, medical units and units of civil protection against terrorist chemical weapons. The manufacturer of the monitor is the Smiths Detection CAMTM from Great Britain. About 30 armies in the world are supplied with CAMs (57000 units), whith about 13 NATO countries which have this monitor as a primary asset. The first CAM was manufactured in the mid 80s. An improved version was produced in 1990 - ICAM (CAM2), and includes the software CAM Plus. The monitor is the primary asset of detection in the “Organization for the Prohibition of Chemical Weapons OPCW". (Privremeno uputstvo za upotrebu CAM, 2014)

Figure 5 – Monitor of chemical agents CAM
Рис. 5 – Газосигнализатор CAM
Слика 5 – Монитор хемијских агенса CAM

Metal detectors

These assets are divided into: devices to screen people, devices for inspection of postal items, and devices for field search. We will show some of the latest representatives of each group.

The Garrett Super Wand is a handheld metal detector of optimal sensitivity. It detects ferrous and nonferrous metals and weapons of non-ferrous metals, and other metal objects (Figure 6). Calibration: digital microprocessor technology eliminates the need for periodic calibration. It

has precise and easy scanning from head to foot. It is easy and convenient to use with one-touch keys and three-color LED lights. The green LED indicates ON (included); the amber LED indicates low battery, and the red LED indicates alarm. The ergonomically designed grip fits comfortably in hand of any size (Garret metal detectors, 2019).

Figure 6 – Handheld metal detector Garrett SuperWand
Рис. 6 – Ручной металлодетектор Garrett SuperWand
Слика 6 – Ручни метал-детектор Garrett SuperWand

The Fisher CW20 is another hand-held metal detector with high performance, able to locate all kinds of metal, and offers the user a choice of three frequencies to eliminate the possibility of any interference. It has the possibility of eliminating interference from steel or reinforced concrete floors (low momentary switch). It is powered by a 9-volt battery and can be set to vibrate or sound when it finds metal. It operates at a frequency of 7.1 kHz (Fisherlab, 2019). (Figure 7)

Figure 7 – Handheld metal detector Fisher CW20
Рис. 7 – Ручной металлодетектор Fisher CW20
Слика 7 – Ручни метал-детектор Fisher CW20

The portable walk-through metal detector Fisher M-SCOPE (Figure 8) provides maximum protection of objects and events in places where there are no static detectors installed. The entire unit weighs only about 38 kg and it can be assembled or disassembled by one person in about 5 minutes. The M-SCOPE has three detection zones with LED indicators which extend from the bottom to the top of the device as well as the signal strength indicator which allows easy assessment of the situation, and a greater flow of persons. By using a simple control interface to the display, the operator can select one of 100 different levels of sensitivity. Rechargeable batteries provide approximately 40 hours of continuous operation. Ruggedized electronics and shock-resistant materials used in the casing guarantee long life even in the most severe working conditions (Fisherlab, 2016).

Figure 8 – Walk-through metal detector Fisher M-SCOPE
Рис. 8 – Рамка-металлодетектор Fisher M-SCOPE
Слика 8 – Металдетекторска врата Fisher M-SCOPE

The security cylindrical metal detector door has shock and bullet-resistant glass and the sides. There is a weight control - a system that allows the passage of only one person. Metal detector sensitivity is set high in the structure. There are possible connections to external peripherals: tags, biometric systems, etc., on request. Entering at an angle of 90 ° is on request. A security door inside the cage can be formed by the door, the floor, the ceiling and side walls, depending on the sensor mass (measuring cell). These special solutions allow the entry of only one person. It automatically checks the inside of the security doors to determine whether, after the metal detector alarm, metal objects have been deliberately left there (Tesla sistemi, 2019). (Figure 9).

Figure 9 – Security metal detector gates with automatic opening
Рис. 9 – Досмотровый металлодетектор, с автоматическим открытием
Слика 9 – Сигурносна металдетекторска врата са аутоматским отварањем

When we talk about inspecting postal items, one of the representatives is the MB1710A device (Letter bomb detector). It is a highly sensitive desktop unit for detecting metal objects in letters or small packages. It weighs 4.5 kg, and power supply and batteries are located in the desktop. There is an alarm for metal detection, both a LED and an audio signal (Vallon, 2012). (Figure 10).

Figure 10 – MB1710A device
Рис. 10 – Устройство MB1710A
Слика 10 – Уређај MB1710A

One of the devices to check the terrain is the VXT1 (All-digital magnetometer for the location of large UXOs at very large depths). It allows the detection on the ground and in water. It has a detachable sensor for underwater detection. It weighs about 13 kg, is powered by a rechargeable battery, and possesses a visual (LED) or an audio signal. It has a long sensor base (about 1.7 m). It is not necessary to adjust the sensor. It has outputs for sending data via RS232 or a USB cable or Bluetooth (Vallon, 2016), Figure 11.

Figure 11 – Metal detector VXT1
Рис. 11 – Металлоискатель VXT1
Слика 11 – Детектор метала VXT1

X-ray devices

Other types of devices which need to be mentioned are x-ray devices, which can be portable and stationary.

The portable X-ray device XRS-4 Golden engineering is a small, lightweight X-ray device that runs on its own batteries. This pulsatile X - beam device produces an X-ray pulse of a very short duration (50 ms). The energy produced is up to 370 KV, which allows penetration through 3.81 cm of steel. Standard equipment consists of two buttons, two battery packs of 18 V, and a battery charger. A remote cable, a carrying case and film processing equipment are also common accessories. The unit weight is about 10 kg (Figure 12). (Golden Engineering, 2018).

Figure 12 – Handheld X-ray device XRS-4
Рис. 12 – Переносной рентгеновский аппарат XRS-4
Слика 12 – Ручни рендген уређај XRS-4

The HI-SCAN 10080 XCT device is a stationary flow device, an EDS (Explosive Detecion system) of the latest generation for high-speed recording of packages and luggage, certified by the US TSA (United States Transportation Security Administration), Figure 13. The device uses X-ray technology and computerized tomography (CT), which represents an ideal solution for processing obtained images. 2D X-ray images (X-ray obtained by the multi-energy ventilation (Figure 14) are completed with 3D CT images, which enables an unprecedented improvement in the detection and identification of forbidden TSA objects (Figure 15). The conveyor belt speed of 0.5 m / s with a scanner tunnel of 1070 mm x 810 mm allow automatic checking of up to 1,800 bags per hour. This represents the fastest ever control system for cargo and luggage (Smiths detection, 2019b).

Figure 13 – Stationary device HI-SCAN 10080 XCT
Рис. 13 – Стационарное устройство HI-SCAN 10080 XCT
Слика 13 – Стационарни уређај HI-SCAN 10080 XCT

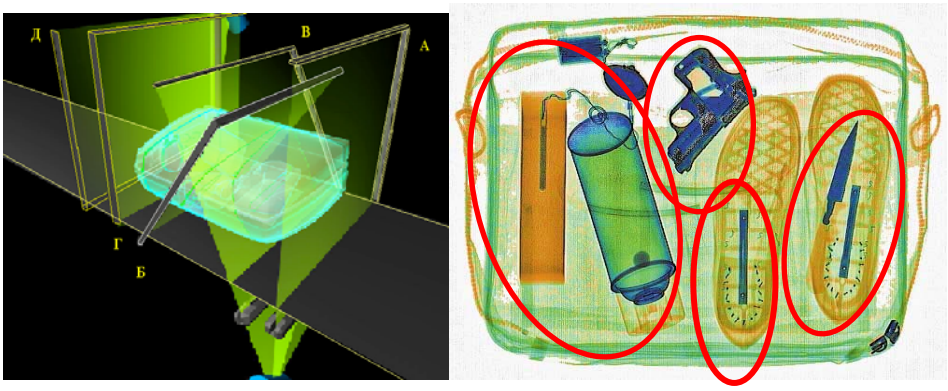

Figure 14 – X-ray multi-energy ventilation through five angles and the images of the detected prohibited items (marked: an improvised explosive device, a gun, a detonator, and a two-part knife)
Рис. 14 – Высокоэнергетическое рентгеновское сканирование под пятью углами и изображение обнаруженных запрещенных предметов (отмечены: самодельное взрывное устройство, пистолет, детонатор и складной нож)
Слика 14 – Рендгентско мултиенергетско прозрачивање кроз пет углова и слика откривених забрањених предмета (обележени: импровозована експлозивна направа, пиштољ, детонатор и дводелни нож)

Figure 15 – 3D CT image and the possibility of its rotation in order to find objects that are not visible from the original angle (labeled: ceramic knife and explosive)
Рис. 15 – 3Д КТ изображение и возможность его поворота с целью нахождения объектов, которые не видны под исходным углом (отмечены: керамический нож и взрывчатка)
Слика 15 – 3D CT слика и могућност њеног ротирања како би се пронашли предмети који нису видљиви из првобитног угла (обележени керамички нож и експлозив)

Stethoscopes

If we talk about modern stethoscopes, it is characteristic that they often have the ability to operate both as contact and contactless devices.

The electronic stethoscope of the Med - Eng Holdings company enables the operator to detect whether the device is armed or located in the liquid condition. It is a sensitive system for monitoring and detecting timing, electronic and mechanical systems which are located within the improvised explosive devices and some unexploded bombs. It contains two types of sensors – a contactless microwave sensor, and a contact handheld audio sensor. The system is extremely easy to use. The equipment includes audio headphones, a small electronic control unit / amplifier (to be worn on the shoulder or a belt), a battery and a charger. Everything is provided in a rugged case, Figure 16 (EOD Technology, 2017).

Figure 16 – Electronic stethoscope Med – Eng
Рис. 16 – Электронный стетоскоп Med – Eng
Слика 16 – Електронски стетоскоп Med – Eng

The electronic stethoscope LIEDS 2220 (Electronic Stethoscope plus Non-Linear Junction Detector) is a very sensitive tool that can detect a very faint sound of mechanical and electronic watches in improvised mines. The crystal detection part is used for the detection of electronic circuits that are typically found in improvised explosive devices, radio transmitters and wireless devices such as mobile phones, various electronic and digital devices (Figure 17). All this can be detected through solid materials such as walls, bricks, glass, plastic, wood, etc.

The control unit is made of aluminum, it weighs around 700 g and has the dimensions of 90 x 42 x 150 mm. The operating temperature range is from -5 to + 70 ° C. The operating frequency range is 10 - 25.000 Hz. It has a very sensitive handset. The device can be connected to a computer (Worldwide technologies, 2007).

Figure 17 – Electronic stethoscope LIEDS 2220
Рис. 17 – Электронный стетоскоп LIEDS 2220
Слика 17 – Електронски стетоскоп LIEDS 2220

The electronic stethoscope BDS-VX (Beijing Defense Stethoscope) has the ability to be used in complex electromagnetic conditions and the conditions of use of interference systems at the same time, and can also detect electronic and mechanic explosive devices under all kinds of covering. Explosive devices include electronic watches, beepers, intercoms, mobile phones and all kinds of telecontroled explosive devices. It can also be used as an antispyware device which can detect covert listening devices and hidden video devices. This device meets the requirements of security of military facilities, airports, stations and ports, as well as the requirements for securing important buildings and police evidence of an explosion.

The device weighs about 900g and its dimensions are 13 × 14.5 × 21cm. The operating temperature range is from -15 to + 45 ° C (Figure 18). It detects mobile phones at a distance of 3 meters or mechanical clocks at 2 meters, and electronic clocks at 0.5 meters (Made-in-China.com, 2019).

Figure 18 – Electronic stethoscope BDS-VX
Рис. 18 – Электронный стетоскоп BDS-VX
Слика 18 – Електронски стетоскоп BDS-VX

Conclusion

Terrorism is the biggest threat to the security of the international community. The methods and means used for such purposes are on higher and higher technical, technological and efficiency levels, and their impact is steadily increasing. Victims are not only individuals, but a much wider circle of people and even states themselves.

In an attempt to locate, neutralize, transport, deactivate and destruct all types of devices used by terrorists and saboteurs, security forces use modern assets. Due to the complexity and sophistication of modern assets used in counter-diverson protection, the key necessity is their understanding and knowledge of their use. We must also take into account technical - technological advances in science and in means used by terrorists and saboteurs to achieve their goals.

In addition to the knowledge and use, it is necessary to constantly monitor the development and procurement of new devices and equipment for detection, identification and neutralization of dangerous devices used by terrorist and saboteurs, in order to effectively counteract modern security challenges, risks and threats.

To be able to successfully oppose to terrorism and other forms of security threats, members of security services need to learn and improve on a daily basis. In that sense, perhaps the best teacher is practice. In their work, members of counter diversion units use experiences from their own practice as well as those from related services in the world, thus improving their performance and efficiency as well as counter-terrorist measures in general.

In a conversation with the members of military police and the Police Brigade counter diversion units, it is possible to hear a number of cases which show the effectiveness of modern assets for detection as well as the skills of their use, but due to the sensitivity of the subject matter, it will not be elaborated further on here.

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САВРЕМЕННЫЕ СРЕДСТВА ПРОТИВОДИВЕРСИОННОЙ ЗАЩИТЫ

Предраг М. Коядинович

Вооружённые Силы Республики Сербия, Управление военной полиции, Учебный центр военной полициии, Оперативно-техническое отделение, г. Белград, Республика Сербия

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Резюме:

Во введении данной статьи представлены краткие определения опасных материалов, а также приведена их классификация. Следующая часть статьи посвящена методам обнаружения опасных материалов, взрывчатых веществ и исходных компонентов взрывных устройств. В статье также представлен ряд современных средств противодиверсионной защиты, применяемых как в нашей стране, так и за рубежом. Данные для написания статьи были собраны в ходе обмена информацией во время визитов Контртеррористическим подразделениям Вооруженных сил Республики Сербия и МВД Республики Сербия. Работа написана с целью повышения осведомленности общественности о существующих средствах противодиверсионной защиты, в частности ознакомление с металлодетекторами, а также с иными устройствами и приборами, участвующими в поиске и обнаружении опасных материалов. Надеемся, что знания, полученные в результате анализа и сравнения доступной литературы и предыдущих исследований приведут к повышению осознания и понимания того насколько важно иметь в распоряжении и пользоваться современным оборудованием, которое не должно уступать средствам, которые используют террористы и диверсанты в всвоих атаках.

Ключевые слова: противодиверсионная защита, опасные материалы, обнаружение опасных материалов, взрывчатых веществ и исходных компонентов взрывных устройств, детекторы.

САВРЕМЕНА СРЕДСТВА У ПРОТИВДИВЕРЗИОНОЈ ЗАШТИТИ

Предраг М. Којадиновић

Војска Србије, Управа Војне полиције, Центар за обуку кадрова Војне полиције, Одсек за криминалистичко-техничке и оперативне послове, Београд, Република Србија

ОБЛАСТ: наоружање и војна опрема
ВРСТА ЧЛАНКА: стручни рад
ЈЕЗИК ЧЛАНКА: енглески

Сажетак:

У раду се укратко описују опасне материје, наводи се њихов појам и класификација и говори о детекцији опасних материја и детекцији упаљачко-иницијалног дела направа. Представљена су и нека од савремених средства која се користе у противдиверзионој заштити код нас, али и у свету, а на основу података који су сакупљени у оквиру посета противдиверзионим јединицама Војске Србије и МУП-а Републике Србије. Циљ овог рада јесте да допринесе стицању увида у досадашња сазнања о средствима противдиверзионе заштите, са тежиштем на средствима за детекцију, али и опасним материјама, чије је откривање задатак средстава за детекцију. Сазнања стечена анализом доступне литературе и досадашњих истраживања, као и њиховим међусобним поређењем, иницираће потребу за познавањем и коришћењем савремене опреме, која мора ићи у корак са средствима која терористи и диверзанти користе у свом деловању, а ради остваривања зацртаних циљева.

Кључне речи: противдиверзиона заштита, опасне материје, детекција опасних материја, детекција упаљачко-иницијалног дела направа, уређаји за детекцију.

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MODERN SNIPER RIFLES IN THE ARMAMENT OF THE SERBIAN ARMED FORCES

Darko D. Janković[a], *Darko* M. Vasiljević[b],
Ljubiša D.Tomić[c], *Srđan* J. Duvnjak[d]

[a] University of Defense in Belgrade, Military Academy, Dean Office, Belgrade, Republic of Serbia,
e-mail: jankoodarko@gmail.com,
ORCID iD: http://orcid.org/0000-0003-3553-2747

[b] University of Belgrade, Institute of physics, Belgrade, Republic of Serbia,
e-mail:darko@ipb.ac.rs,
ORCID iD: https://orcid.org/0000-0001-6737-6000

[c] Military Tehnical Institute, Belgrade, Republic of Serbia,
e-mail: ljubiisa.tomic960@gmail.com,
ORCID iD: http://orcid.org/0000-0003-4572-3096

[d] University of Defense in Belgrade, Military Academy, Dean office, Belgrade, Republic of Serbia,
e-mail: srdjanduvnjak@hotmail.com,
ORCID iD: http://orcid.org/0000-0002-9269-6310

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Summary:

The paper describes sniper rifles and optical sights in use in the Serbian Armed Forces. For the purpose of possible design of an optical sight that would meet modern technical and technological standards and needs of the Serbian Armed Forces, the paper analyzes the optical and mechanical characteristics of the aforementioned.

Key words: small arms, sniper rifle, caliber, optical sight, optics, magnification, reticle, rectification adjustment, surface protection, mounting on weapons.

Introduction

The subject of this paper is a presentation of modern sniper rifles with appropriate optical sighting devices used in the infantry units of the

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Serbian Armed Forces and special units for anti-terrorist activities of the units of the Ministry of Internal Affairs. The paper presents these optical sights and the parameters that characterize their construction and use. Optical sights will be analyzed from several aspects such as: possibilities of use, marksman's needs, construction, trend of use and price. The paper compares the sniper rifles and the optical sights used in the units of the Serbian Armed Forces.

In the armament of the Serbian Armed Forces, optical sights inherited from the period of the former Yugoslav People's Army (in Serbian: JNA) are still present, while only certain specialized units of the Army and the Police are equipped with more modern infantry weapons and, consequently, adequate optical sights.

Description of the weapons of the Serbian armed forces using optical sights

For the purpose of a successful comparative analysis of optical sights, this paper deals with the sights that were in use, the ones currently in use, as well as the ones that are in use in the countries in the region and the countries that rank among most technologically developed; it also gives the tactical - technical characteristics of infantry small arms onto which they are mounted. The optical sights used in the Serbian Armed Forces (and JNA) have been so far: the M76 optical sight for the 7.9 mm semi-automatic sniper rifle M76, and the optical sight M94 for the Black Arrow.

For the purpose of an adequate analysis, certain data for these infantry weapons will be given in the paper, while the tabulation of publicly available data will be presented at the very end. Based on the aforementioned, some proposals will be made for the selection of a sniper rifle and an optical sight that will ensure better execution of marksman's tasks.

The Zastava 7.9 mm semi-automatic sniper rifle M76 (Wikipedia Contributors, 2018) is a 7.92 x 57 mm Mauzer rifle of domestic production. The rifle is designed as a platoon sniper, or, in the western military nomenclature, as a designated marksman rifle. The concept of this sniper rifle comes from the Soviet military doctrine in which this type of weapon is different from real sniper rifles of high precision. It was officially introduced into the armament of the JNA in 1976, but the massive equipping of units began in the early eighties. This recoil-operated rifle was designed and produced by the company Zavod

Crvena Zastava, today Zastava Oružje from Kragujevac. The M76 sniper rifle was created on the basis of the Zastava M70 rifle, but longer and heavier, around the bullet 7.92 x 57 mm, with the optical sight M76 Zrak 4 x 5 ° 10 '(4 x 24) - a direct copy of the Soviet PSO-1 from the SVD rifle and an altered fire separator that allows only single firing. The longer barrel and the heavier round provide a significantly higher effective range compared to the M70, while the 7.92 mm round possesses considerably more favorable ballistic properties on the trajectory and, due to greater mass and higher velocity, has a much stronger effect on the target.

The basic tactical and technical characteristics of the 7.9 mm semi-automatic sniper rifle M76:

- Caliber: 7.92x57 mm
- Mass of the rifle without the optical sight: 4.6 kg
- Mass of the optical sight with the carrier: 0.65 kg
- Rifle length: 1135 mm
- Barrel length: 550 mm
- Number of grooves: 4
- Muzzle velocity: 730 m / s
- Magazine capacity: 10 rounds
- Maximum barrel gas pressure: 3200 bar

Figure 1 – Semi-automatic sniper rifle 7.9 mm Zastava M76 (Wikipedia Contributors, 2018)
Рис. 1 – Полуавтоматическая снайперская винтовка 7.9 мм Zastava M76 (Wikipedia Contributors, 2018)
Слика 1 – Полуаутоматска снајперска пушка 7,9 мм Застава М76 (Wikipedia Contributors, 2018)

It can effectively operate up to a distance of 1000 m, and optimally the best results are achieved within the range up to 800 m. For aiming, the ON M76 optical sight is used with a magnification of 4x and reticle

illumination, while a mechanical sight is also retained. At the beginning of the nineties, the M94 optical sight with a magnification of 6x was additionally developed, and the passive 5x80 sight can also be mounted on the rifle.

The Zastava M76 was manufactured in Iraq under Zastava licence on machines shipped from Yugoslavia in the 1980s in the 7.62 x 39 caliber under the name of the Tabuk sniper rifle. This rifle resembles the M76 a lot and features a black plastic ergonomic grip with a thumb pad of the Zastava design.

Black Arrow (Crna Strela) (Zastava arms, 2019) was produced in Serbia, at the Zavodi Crvena Zastava factory. The accuracy of the weapon changes with the number of rounds fired, and the test results have indicated so far that precision is reduced, but not necessarily, after 10,000 rounds fired. After ten to twenty thousand rounds fired, precision is reduced by approximately 10%.

Figure 2 – Sniper rifle Zastava M93 Black Arrow equipped with the M94 optical sight (Zastava arms, 2019)
Рис. 2 – Снайперская винтовка Застава М93 „Черная стрела” с оптическим прицелом М94 (Zastava arms, 2019)
Слика 2 – Снајперска пушка Застава М93 „Црна стрела” опремљена оптичким нишаном М94 (Zastava arms, 2019)

The M93 Black Arrow is intended for engaging targets in the open and in non-armoured vehicles at distances up to 1500m as well as for targets in light armoured vehicles and in concealment at distances up to 800m. In addition to destroying live force, the Black Arrow can also be used for targets such as non-armoured and light-armoured vehicles, grounded aircraft, radars and other electronic equipment, communication centers and command posts. It is also effective against enemy snipers. The Black Arrow has bolt action based on the Mauser system. The rifle was developed in two calibers - the Serbian Army uses the 12.7 x 108 mm caliber (Russian cartridge for heavy machine guns DŠK and NSV, while the exported version is customized with the 12.7 x 99 mm

American cartridge (Browning M2HB machine gun cartridge). The heavy barrel is made of chromium-nickel-vandium steel used for the production of cannon barrels. The feed system is the 5-round magazine.The recoil energy is reduced by placing a two-chamber gas brake on the muzzle and by installing two shock absorbers into the butt. The rifle is provided with the Zrak 8x56 M94 optical sight, and there are no mechanical sights. A bipod is mounted as well as a folding handle for easier carrying.

The basic characteristics of the Black Arrow:

- 12.7 x 108 mm round (developed in the former Soviet Union for SMK and NSV machine guns)
- feed – 5-round magazine,
- muzzle velocity - 888 m / s,
- mass - 16 kg,
- length - 1,670 mm,
- effective range - 1600m.

In relation to the previously described sniper rifle, certain structural improvements have been made to this one:

- it is much better balanced,
- butt with two shock absorbers,
- muzzle gas brake which makes firing easier (it reduces recoil to 62%),
- butt and cover are made of glass fiber reinforced polymer,
- folding bipod is adjustable depending on the size of the marksman's shelter,
- the Mauser system locking,
- the bolt has guides throughout its path in the carrier, and
- a heavy barrel provides a precise and accurate trajectory for a high-energy projectile.

In order to perform a comparative analysis of sniper rifles, this article will also mention sniper rifles currently in use in specialized units of the Serbian Armed Forces and Police.

Barrett M95 (Military-Today, 2018) is a sniper rifle designed by Barrett Firearms Manufacturing Company. It is an improved version of the Barrett M90. The most important difference is that the trigger grip has been moved slightly forward in order to make it easier to use. This weapon is lighter, more compact and easier to use than its older versions. The Barrett Company has announced that this sniper rifle is used in 15 countries, e.g. in Argentina, Austria, Denmark, Finland,

Greece, Georgia, Italy, Jordan, Malaysia, Philippines, Spain, Thailand, Turkey and some other countries. However, the sniper rifle Barrett M95 could never reach the popularity of the original Barrett M82, which is in standard use in nearly 60 countries.

The basic tactical and technical characteristics:

- caliber - 12.7 x 99 mm,
- weight - 10.7 kg,
- length – 1,143 mm,
- barrel length - 736 mm,
- muzzle velocity - 854 m / s,
- effective range - 1,000 m,
- maximum effective range of action – 1,800 m,
- accuracy - 1.5 - 2 MOA.

Figure 3 – Barrett M95 (Military-Today, 2018)
Рис. 3 – Barrett M95 (Military-Today, 2018)
Слика 3 – Barrett M95 (Military-Today, 2018)

Sako TRG (SAKO, 2018) represents a family of Finnish sniper rifles. It is intended for equipping military and special police units, and due to its exceptional precision, it is very suitable for anti-terrorist activities. Sako TRG rifles are considered to be among the best in the world in their class. In military and police units, they are generally available in 7.62x51mm caliber, as well as in .338 "Lapua Magnum." During exploitation, it proved to be an extremely high quality and reliable weapon in all conditions. The length is from 510 to 690 mm and it has 4 right twist grooves. The rifle has a high quality two-stage trigger mechanism and the trigger force can be adjusted in the range of 1 to 2.5 kg. The command lever of the brake is located inside the trigger guard. The stock is also fully adjustable and designed so that the rifle can also

be used by left-handed shooters. At the muzzle, there is an asymmetric gas brake which also serves as a flash suppressor. A silencer can be quickly and easily mounted on the gas brake. The rifle is fed by a 10-round box magazine and has a folding and removable bipod. It is delivered without a sight, and various optical, opto-electronic and backup mechanical sights can be mounted. In anti-terrorist units, Schmidt & Bender optics, 3-12x50, is most commonly used. In addition to the 7.62x51mm version, the rifle is produced in the calibers "300 Winchester Magnum" and "338 Lapua Magnum", under the TRG-41 label. Since 1999, TRG-22 (successor of the TRG-21) and TRG-42 (replacement for the TRG-22) have been manufactured with a different stock and some small improvements.

Several versions of this rifle have been created:

- **TRG-21** (1989) - original light version, 7.62x51mm,
- **TRG-22** (1999) - improved light version available in military 7.62x51mm and in civilian .260 Remington,
- **TRG-22A1** (2018) - advanced TRG-22, with a brand new redesigned stock. Available in military 7.62x51mm and in civil 6.5mm Creedmoor,
- **TRG-41** (1989) - original heavy version, in .338 Lapua Magnum and .300 Winchester Magnum,
- **TRG-42** (1999) - improved heavy version, available in .338 Lapua Magnum and .300 Winchester Magnum,
- **TRG-42A1** (2018) - advanced TRG-42, with a brand new redesigned stock,
- **Beretta TRG-42** (2008) - a civilian version for the US market, presented in 2008. It contains a folding stock and a short barrel, and is distributed by the Beretta USA company.

Figure 4 – Sako TRG 42 (SAKO, 2018)
Рис. 4 – Sako TRG 42 (SAKO, 2018)
Слика 4 – Sako TRG 42 (SAKO, 2018)

Tactical-technical characteristics:

Weight TRG-22: 4.7-4.9 kg	TRG-42: 5.1-5.3 kg
TRG-22 folding stock: 5.2 kg	TRG-42 folding stock: 5.8 kg
Length TRG-22 1,150 mm	TRG-42: 1,200mm
TRG-22 folding stock: 1.100 mm	TRG-42 folding stock: 1.020 mm
Barrel length TRG-22: 660 mm	TRG-42: 690 mm
TRG-22 folding stock: 510mm	TRG-42 folding stock: 510 mm
Caliber TRG-41 and TRG-42: .338 Lapua Magnum	TRG-21 and TRG-22: 7.62x51 mm
Type of operation Repetition	Action Bolt action
	Round velocity 900 m / s
Max. effective. range 400 m	Removable box magazine with 5, 7 and 10 rounds
Sight Optical	

Description of the optical sights used in the Serbian Armed Forces

Equipping the Serbian Armed Forces is well under way in accordance with the stated needs. Priority in the procurement of new equipment and weapons has been given to the specialized units of the Army. For example, the Special Brigade of the Serbian Armed Forces is equipped with some of the most modern optical sights such as Schmidt & Bender 3-12 x 50 and 4-16 x 50, Leupold and Swarovski 10 x 42, as well as with adequate sniper rifles.

ON-M76B optical sight

The ON-M76B optical sight (P.A. Distributing, 2018) is used for aiming at stationary, mobile, uncovered and camouflaged targets when firing form the sniper rifle 7.9 mm M76, 7.62 x 54, 7.62 x 51 (N), both in day and night time conditions, which ensures high accuracy when hitting small and distant targets during reduced visibility (twilight and dawn). The basic optical, mechanical and electrical characteristics are shown in the table.

Figure 5 – Optical sight M76B (P.A. Distributing, 2018)
Рис. 5 – Оптический прицел М76Б (P.A. Distributing, 2018)
Слика 5 – Оптички нишан М76Б (P.A. Distributing, 2018)

Table 1 – Technical-technological characteristics of the Zrak Sarajevo ON-M76B optical sight (Zrak d.d, 2016)
Таблица 1 – Технико-технологические характеристики оптического прицела „Зрак Сараево" ОН-М76Б (Zrak d.d, 2016)
Табела 1 – Техничко-технолошке карактеристике оптичког нишана „Зрак Сарајево" ОН-М76Б (Zrak d.d, 2016)

Zrak Sarajevo ON-M76B	
Dimensions	
Length	270 mm
Weight (mass)	0.450 kg
Optical data	
Magnification	4 x
Field of view	5º
Lens diameter	24 mm
Exit pupil diameter	6 mm
Exit pupil distance	77 mm
Resolution	10"
Diopter adjustment	od -0.7 do -0.5 dptr
Measuring scale for determining the distance to the standing human figure	od 200 do 800 m
Distance measuring	from 0 to 900 m, by turning the distance turret
Distance measuring	from 1000 m to 1100 m, by choosing the appropriate scale value on the reticle
Electrical data	
Reticle illumination	tritium-based

ON 6 x 32 optical sight

The ON 6 x 32 optical sight is used for aiming at stationary, moving, visible, and camouflaged targets when firing from the sniper rifle 7.62 x 51N, which ensures high accuracy when hitting small and distant targets. The basic optical, mechanical and electrical characteristics are shown in Table 2.

Table 2 – Technical-technological characteristics of the Zrak Sarajevo ON 6 x32 optical sight (Zrak d.d, 2016)
Таблица 2 – Технико-технологические характеристики оптического прицела „Зрак Сараево" ОН 6 x32 (Zrak d.d, 2016)
Табела 2 – Техничко-технолошке карактеристике оптичког нишана „Зрак Сарајево" ОН 6×32 (Zrak d.d, 2016)

Zrak Sarajevo ON 6 X 32	
Dimensions	
Length	270 mm
Weight (mass)	0.450 kg
Optical data	
Magnification	6 x
Field of view	4°
Lens diameter	32 mm
Exit pupil diameter	5.8 mm
Resolution	≤9"
Diopter adjustment	from -0.7 to -0.5 dptr
Distance measurement	from 0 to 900 m by turning the distance turret
	from 1000 m to 1100 m by taking the appropriate scale value on the reticle
Compensation	by turning the azimuth turret to the left and right 1-10 (10 milliradians)
	scale on the reticle to the left and right 1-10 (10 milliradians)
Electrical data	
Reticle illumination	tritium-based

ON 8 x 42 optical sight

The ON 8 x 42 optical sight (Zrak d.d, 2016) serves for aiming at stationary, moving, uncovered, and camouflaged targets with the 7.9 mm sniper rifle, thus achieving high accuracy when firing at small and distant

targets. The basic optical, mechanical and electrical characteristics are shown in Table 3.

Table 3 – Technical-technological characteristics of the Zrak Sarajevo ON 8 x42 optical sight (Zrak d.d, 2016)
Таблица 3 – Технико-технологические характеристики оптического прицела „Зрак Сараево" ОН 8 x42 (Zrak d.d, 2016)
Табела 3 – Техничко-технолошке карактеристике оптичког нишана „Зрак Сарајево" ОН 8×42 (Zrak d.d, 2016)

Zrak Sarajevo ON 8 X 42	
Dimensions	
Length	320 mm
Weight (mass)	0.480 kg
Optical data	
Magnification	8.2 x
Field of view	2.8º
Lens diameter	42 mm
Exit pupil diameter	5.13 mm
Resolution	≤7"
Dioptric adjustment	from -0.7 to -0.5 dptr
Distance measurement	from 0 to 900 m by turning the distance turret
	from 1000 m to 1200 m by taking the appropriate scale value on the reticle
Compensation	by turning the azimuth turret to the left and right 1-10 (10 milliradians)
	scale on the reticle to the left and right 1-10 (10 milliradians)
Electrical data	
Reticle illumination	tritium-based

ON-10 x 42 optical sight

The 10 x 42 optical sight (Teleoptik-Gyros, 2018a) is designed to aim at stationary, moving and detectable targets in daylight, reduced visibility and at night. This optical sight is useful for long range sniper rifles. It meets all the requirements for high accuracy at long distances, as well as for practical use in extreme climatic and terrain conditions. The range of movement changes is 60 MOA. The basic optical, mechanical and electrical characteristics are shown in Table 4.

Table 4 – Technical-technological characteristics of the Teleoptik ON-10 x 42 optical sight (Teleoptik-Gyros, 2018a)
Таблица 4 – Технико-технологические характеристики оптического прицела „Телеоптик" ОН- 10 x42 (Teleoptik-Gyros, 2018a)
Табела 4 – Техничко-технолошке карактеристике оптичког нишана „Телеоптик" ОН-10×42 (Teleoptik-Gyros, 2018a)

Teleoptik ON 10 X 42	
Dimensions	
Length	340 mm
Climate conditions	
Temperature range of operation	- 30ºC – + 55ºC
Optical data	
Magnification	10 x
Field of view	2º
Lens diameter	42 mm
Exit pupil diameter	4.2 mm
Exit pupil distance	85 mm
Resolution	7"
Diopter adjustment	± 2.5 diopters
Reticle	MilDot
Parallax	≤ 0.2 diopters
Electrical data	
Reticle illumination	tritium-based

Teleoptik ON 8 x 56

This optical sight is intended for long range 12.7mm sniper rifles. The ballistics of the distance detection and the reticle is at the request of the customer. The 8 x 56 optical sight (Teleoptik-Gyros, 2018b) is very reliable and guarantees long-term use in all climate conditions. Due to its advanced design and superb optics, the view is clear and well illuminated, which allows optimum viewing in conditions of insufficient visibility.

The reticle can be adjusted to the direction and elevation, ensuring the stability of the position chosen during rectification. The basic optical, mechanical and electrical characteristics are shown in Table 5.

Figure 6 – ON 8 x 56m optical sight (Teleoptik-Gyros, 2018b)
Рис. 6 – Оптический прицел ОН 8 x 56м (Teleoptik-Gyros, 2018b)
Слика 6 – Оптички нишан ОН 8×56м (Teleoptik-Gyros, 2018b)

Table 5 – Technical-technological characteristics of the Teleoptik ON 8 x 56 optical sight (Teleoptik-Gyros, 2018b)
Таблица 5 – Технико-технологические характеристики оптического прицела „Телеоптик" ОН- 8 x56 (Teleoptik-Gyros, 2018b)
Табела 5 – Техничко-технолошке карактеристике оптичког нишана „Телеоптик" ОН 8×56 (Teleoptik-Gyros, 2018b)

Teleoptik ON 8 X 56	
Dimensions	
Length	400 mm
Height, width	63.5 mm
Weight (mass)	0.850 kg
Climate conditions	
Temperature range of operation	- 30ºC – + 55ºC
Optical data	
Magnification	8 x
Field of view	3º
Lens diameter	56 mm
Exit pupil diameter	7 mm
Exit pupil distance	75 mm
Diopter adjustment	± 2.5 diopters
Electrical data	
Reticle illumination	tritium-based

Schmidt&Bender 3-12x50 and 4-16x50 sights

The Schmidt & Bender 3-12x50 and 4-16x50 sights (Schmidt&Bender, 2016) are intended for shooting at individual stationary and moving targets, uncovered or camouflaged, in daytime and under poor visibility conditions. The optical sight enables high accuracy when aiming at small and distant targets in unfavorable visibility conditions. Thanks to reticle illumination, it is possible to shoot at twilight and in a clear night with a full moon.

The reticle of the optical sight enables:

– aiming,
– distance detection,
– elevation adjustment from 0 to 13 milliradians (mil), and
– left-right compensation in the range of 0 to 10 milliradians on the turret and from 0 to 5 mils on the reticle scale on each side.

The optical sight consists of:

– mechanical circuits and
– optical circuits.

The mechanical circuits are:

– mechanism of elevation,
– mechanism of direction,
– mechanism of parallax, and
– reticle illumination system.

The optical circuits are:

– objective lens,
– rotating lens system,
– eyepiece, and
– reticle.

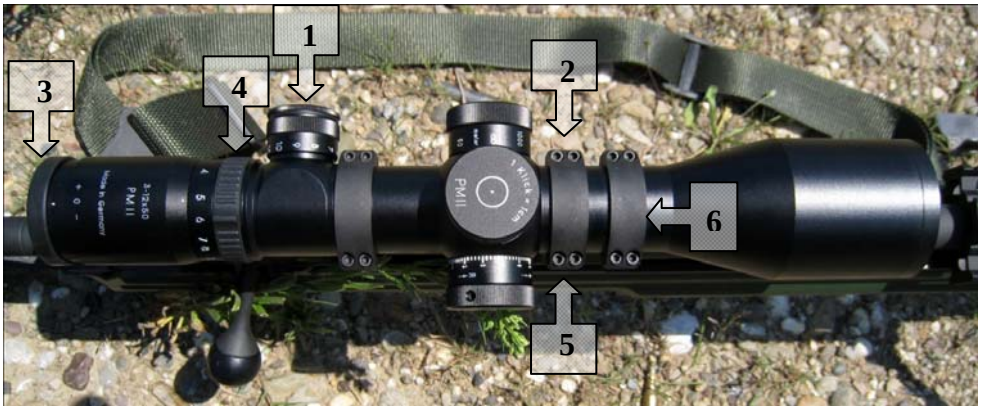

Figure 7 – Optical sight: 1. system for reticle illumination, 2. parallax mechanism, 3. diopter adjustment ring, 4. magnification adjustment ring, 5. elevation mechanism, and 6. direction mehanism (Schmidt&Bender, 2016)
Рис. 7 – Оптический прицел: 1) система подсветки сетки, 2) механизм учета поправки на параллакс, 3) кольцо регулировки диоптрий, 4) кольцо регулировки кратности, 5) механизм вертикальной корректуры и 6) механизм выверки прицела по направлению (Schmidt&Bender, 2016)
Слика 7 – Оптички нишан: 1. систем за осветљење кончанице, 2. механизам паралакса, 3. прстен за диоптријско изоштравање, 4. прстен за подешавање увећања, 5. механизам елевације, 6. механизам правца (Schmidt&Bender, 2016)

The basic optical, mechanical and electrical characteristics are shown in the table.

Table 6 – Technical-technological characteristics of the Schmidt & Bender 3-12x50 PM II P optical sight (Schmidt&Bender, 2016), (Serbian Armed Forces, 2016)
Таблица 6 – Технико-технологические характеристики оптического прицела Schmidt & Bender 3-12x50 PM II P (Schmidt&Bender, 2016), (Serbian Armed Forces, 2016)
Табела 6 – Техничко-технолошке карактеристике оптичког нишана Schmidt & Bender 3-12×50 PM II P (Schmidt&Bender, 2016), (Serbian Armed Forces, 2016)

Schmidt&Bender 3-12x50 PM II P	
Mechanical characteristics	
Casing material	It is made of one piece of aluminum alloy
Surface protection	Anodised casing in matte finish, scratch-proof
Lens protectors	The eyepiece lens is protected by a rubber cover from scratches
Rectification adjustment	One click value is 0.1 mil (1cm per 100m)
Mounting	Mechanical compatibility according to MIL-STD-1913 standard (picatinny or weaver rails)

Schmidt&Bender 3-12x50 PM II P	
Dimensions	
Length	343 mm
Weight (mass)	0.866 kg
Climate conditions	
Temperature range of operation	- 40ºC – + 65ºC
Resistance to immersion	Waterproof
Sealing	300mbar internal pressure
Optical data	
System	Magnification adjustment with the rotation ring, the reticle center elevation is ¼ MOA
Magnification	3-12x (variable magnification)
Field of view	11.1 m - 3.4 m at 100 m and 6.3 ° to 2.5 °
Lens diameter	50 mm
Exit pupil diameter	14.3 mm - 4.3 mm
Exit pupil distance	90 mm
Diopter adjustment	od +2 do -3 dptr
Elevation adjustment - cm / 100m (turret + recitle)	200
Direction adjustment - cm / 100m (turret + reticle)	+/-100
Parallax adjustment	50m bis ∞
Illumination intensity	0-11
Illumination timer	6 h
Reticle	Illuminated Mil-Dot reticle, P3L type
Optical layers	Anti-reflective layers for visible light on all optical surfaces
Electrical data	
Battery type	Battery (CR 2032/3V)
Average battery life	100 hours

Table 7 – Technical-technological characteristics of the Schmidt & Bender 4-16x50 PM II LP optical sight (Schmidt&Bender, 2016), (Serbian Armed Forces, 2016)
Таблица 7 – Технико-технологические характеристики оптического прицела Schmidt & Bender 3-12x50 PM II P (Schmidt&Bender, 2016), (Serbian Armed Forces, 2016)
Табела 7 – Техничко-технолошке карактеристике оптичког нишана Schmidt&Bender 3-12×50 PM II P (Schmidt&Bender, 2016), (Serbian Armed Forces, 2016)

Schmidt&Bender 4-16x50 PM II P	
Mechanical characteristics	
Casing material	It is made of one piece of aluminum alloy

Schmidt&Bender 4-16x50 PM II P	
Surface protection	Anodised casing in matte finish, scratch-proof
Lens protectors	The eyepiece lens is protected by a rubber cover from scratches
Rectification adjustment	One click value is 0.1 mil (1cm per 100m)
Mounting	Mechanical compatibility according to MIL-STD-1913 standard (picatinny or weaver rails)
Dimensions	
Length	393 mm
Weight (mass)	0.933 kg
Climate conditions	
Temperature range of operation	- 40ºC – + 65ºC
Resistance to immersion	Waterproof
Sealing	300mbar internal pressure
Optical data	
System	Magnification adjustment with the rotation ring, the reticle center elevation is ¼ MOA
Magnification	4-16 x (variable magnification)
Field of view	7.5 m - 2.4 m at 100 m and 4.3 ° to 1.4 °
Lens diameter	50 mm
Exit pupil diameter	12.5 mm to 3.1 mm
Exit pupil distance	90 mm
Diopter adjustment	od +2 to -3 dptr
Elevation adjustment - cm / 100m (turret + recitle)	200
Direction adjustment - cm / 100m (turret + recitle)	+/-75
Parallax adjustment	50m bis ∞
Illumination intensity	0-11
Illumination timer	6 h
Reticle	Illuminated Mil-Dot finish, P3L type
Optical layers	Anti-reflective layers for visible light on all optical surfaces
Electrical data	
Battery type	Battery (CR 2032/3V)
Average battery life	100 hours

Leupold sight

The Leupold 4.5-14 x 50 Mark 4 ER / T M1 Side Focus Riflescope (Leupold, 2018) is designed for long distance aiming. This optical sight has a large 50 mm diameter lens that captures more light in very low light conditions and provides clear and crisp view. The DiamondCoat 2 protective coatings on the external surfaces of optical elements protects against scratches and other mechanical damage. The optical sight offers adjustment for windage and ballistic drop of rounds within the range of 100 MOA and elevation adjustment with a correction of 1/4 MOA mil-dots.

The reticle provides a total range of 60 MOA for the round. The casing is made of 6061-T6 aluminum alloy which is durable and waterproof. In order to eliminate the effects of thermal shock and reduce blurring while in the environment with temperature changes, the casing is filled with a mixture of krypton and argon gases. The basic optical, mechanical and electrical characteristics are shown in the table.

Figure 8 – Leupold Mark4 4.5-14x50 Side Focus CDS optical sight
Рис. 8 – Оптический прицел Leupold Mark4 4.5-14x50 Side Focus CDS
Слика 8 – Оптички нишан Leupold Mark4 4.5-14×50 Side Focus CDS

Table 8 – Technical and technological characteristics of the Leupold Mark4 4.5-14x50 Side Focus optical sight (Leupold, 2018)
Таблица 8 – Технико-технологические характеристики оптического прицела Leupold Mark4 4.5-14x50 Side Focus (Leupold, 2018)
Табела 8 – Техничко-технолошке карактеристике оптичког нишана Leupold Mark4 4.5-14×50 Side Focus (Leupold, 2018)

Leupold Mark4 4.5-14x50 Side Focus CDS	
Mechanical characteristics	
Casing material	It is made of 6061-T6 aluminum alloy
Surface protection	Anodization in matte black
Lens protectors	The eyepiece lens is protected by a rubber cover from scratches

Leupold Mark4 4.5-14x50 Side Focus CDS	
Rectification adjustment	One click is 1/4 MOA (1cm per 100m), for elevation 110 MOA and for windage 15 MOA
Mounting	Mechanical compatibility according to MIL-STD-1913 standard (picatinny or weaver rails)
Dimensions	
Length	312 mm
Weight (mass)	0.482 kg
Climate conditions	
Temperature range of operation	- 40ºC – + 65ºC
Resistance to immersion	Waterproof
Optical data	
Magnification	4.5-14x
Field of view	6.82 m to 2.53 m at 100 m or 3.9 ° to 1.45 °
Lens diameter	50 mm
Exit pupil diameter	from 11.1 mm to 3.6 mm
Exit pupil distance	98 mm
Reticle	Duplex
Optical layers	Anti-reflective layers for visible light on all optical surfaces
Electrical data	
Battery type	Battery (CR 2032/3V)

Swarovski sight

The Swarovski 1.7- 10x42 L sight (Swarovski Optik, 2018) shows its good performance on the battlefield. It provides quick action to shooters. This sight is modest in size and weight, made of aluminum alloy. Its large field of view shows its quality. The basic optical, mechanical and electrical characteristics are shown in the table.

Figure 9 – Swarovski 1.7- 10x42 L optical sight (Swarovski Optik, 2018)
Рис. 9 – Оптический прицел Swarovski 1.7- 10x42 L (Swarovski Optik, 2018)
Слика 9 – Оптички нишан Swarovski 1.7- 10x42 L (Swarovski Optik, 2018)

Table 9 – Technical-technological characteristics of the Swarovski 1.7- 10x42 L optical sight (Swarovski Optik, 2018)
Таблица 9 – Технико-технологические характеристики оптического прицела Swarovski 1.7- 10x42 L (Swarovski Optik, 2018)
Табела 9 – Техничко-технолошке карактеристике оптичког нишана Swarovski 1.7- 10×42 L (Swarovski Optik, 2018)

Swarovski 1.7- 10x42 L	
Mechanical characteristics	
Casing material	It is made of one piece of aluminum alloy
Surface protection	Anodised casing in matte finish, scratch-proof
Lens protectors	The eyepiece lens is protected by rubber
Rectification adjustment	One click is 1/4 MOA (1cm per 100m)
Mounting	Mechanical compatibility according to MIL-STD-1913 standard (picatinny or weaver rails)
Dimensions	
Length	324 mm
Weight (mass)	0.490 kg
Climate conditions	
Temperature range of operation	- 20ºC – + 50ºC
Resistance to immersion	Waterproof
Optical data	
Magnification	1.7-10x
Field of view	14.3° do 2.4°
Lens diameter	42 mm
Exit pupil diameter	9.6 mm to 4.2 mm
Exit pupil distance	95 mm
Diopter adjustment	od +2 do -3 dptr
Reticle	Mil-Dot reticle, 4A-I type
Optical layers	Anti-reflective layers for visible light on all optical surfaces
Electrical data	
Battery type	Battery (CR 2032/3V)

POSP 8 x 42 sight

The POSP 8 x 42 sight (Binoculars from Russia, 2018) is an upgraded version of the POSP -1 optical sight. The main difference between these two scopes is magnification increase, from 4 to 8 x. The POSP 8 x 42 is particularly effective when shooting at small and well-

camouflaged targets. It enables distance measurement to the destination, as well as the introduction of lateral corrections and operation under reduced visibility conditions. The POSP 8 x 42 optical sight is hermetically sealed and filled with nitrogen so that it does not get blurred when used during frequent temperature changes.

Figure 10 – POSP 8 x 42 optical sight (Binoculars from Russia, 2018)
Рис. 10 – Оптический прицел POSP 8 x 42 (Binoculars from Russia, 2018)
Слика 10 – Оптички нишан POSP 8×42 (Binoculars from Russia, 2018)

Table 10 – Technical-technological characteristics of the POSP 8 x 42 optical sight (Binoculars from Russia, 2018)
Таблица 10 – Технико-технологические характеристики оптического прицела POSP 8 x 42 (Binoculars from Russia, 2018)
Табела 10 – Техничко-технолошке карактеристике оптичког нишана POSP 8×42 (Binoculars from Russia, 2018)

POSP 8 x 42	
Dimensions	
Length	380 mm
Weight (mass)	0.700 kg
Climate conditions	
Temperature range of operation	- 50ºC – + 50ºC
Resistance to immersion	Waterproof
Optical data	
Magnification	8 x
Field of view	13°
Lens diameter	40 mm

POSP 8 x 42	
Exit pupil diameter	5 mm
Exit pupil distance	75 mm
Optical layers	Anti-reflective layers for visible light on all optical surfaces

Comparative analysis of the long range sniper rifles used in the Serbian Armed Forces

For the purpose of a qualitative and quantitative analysis of the sniper rifles used in the Serbian Armed Forces, the table (Table 11) will show the data of the rifles of similar tactical-technical characteristics. The 7.9 mm semi-automatic sniper rifle M76 will not be taken into consideration, as it is considered outdated.

Table 11 – Technical-technological characteristics of the sniper rifles in use in the Serbian Armed Forces
Таблица 11 – Технико-технологические характеристики снайперских винтовок, используемых Вооруженными силами Республики Сербия
Табела 11 – Техничко-технолошке карактеристике снајперских пушака које се налазе у опреми Војске Србије

	Mass	Length	Barrel length	Caliber	Round velocity	Range	Maximum effective range of action	Sight
Black arrow	16 kg	1670 mm	1007 mm	12.7x108 mm	888 m/s	1600 m	1800 m	Optical M94
Barrett 95	10.7 kg	1143 mm	736 mm	12.7x99 mm	854 m/s	1000 m	1800 m	More types
Sako TRG 22-42	4.7-5.8 kg	1150-1200 mm	660-690 mm	7.62x51 mm	900 m/s	400 m	1000m	More types

Comparative analysis of the optical sights used in the Serbian Armed Forces

For the purpose of a qualitative and quantitative analysis of the optical sights in use in the Serbian Armed Forces, the tabular data of these optical sights with their tactical and technical characteristics will be presented. The Zrak Sarajevo ON M-76B and ON 6 x 32 optical sights will not be taken into consideration because they are outdated and already replaced with more technologically advanced optical sights.

Only technical and technological parameters relevant for quality use and maintenance of optical sights will be taken into consideration. The analysis of the optical sights is shown in two tables. In Table 12, the optical and mechanical characteristics of the optical sights with fixed magnification are shown, while the optical and mechanical characteristics of the optical sights with variable magnification are presented in Table 13.

Table 12 – Optical and mechanical characteristics of the optical sights with fixed magnification
Таблица 12 – Оптические и механические характеристики прицела с фиксированной кратностью
Табела 12 – Оптичке и механичке карактеристике оптичких нишана са фиксним увећањем

	Teleoptik ON 8 x 56	Zrak Sarajevo ON 8 x 42	Teleoptik ON 10 x 42	POSP 8 x 42
Magnification	8 x	8,2 x	10 x	8 x
Field of view	3º	2.8º	2 º	13º
Lens diameter	56 mm	42 mm	42 mm	40 mm
Exit pupil diameter	7 mm	5.13 mm	4.2 mm	5 mm
Exit pupil distance	-	-	85 mm	75 mm
Diopter adjustment	± 2.5	-0.7 -0.5	±2.5	-
Length	400 mm	320 mm	340 mm	380 mm
Weight (mass)	0.850 kg	0.480 kg	-	0.700 kg

Note:
- No data was found for the indicated optical sight.

Table 13 – Optical and mechanical characteristics of the optical sights with variable magnification
Таблица 13 – Оптические и механические характеристики прицела с переменной кратностью
Табела 13 – Оптичке и механичке карактеристике оптичких нишана са променљивим увећањем

	Swarovski 1.7- 10x42 L	Leupold Mark4 4.5-14x50 Side Focus CDS	Schmidt&Bender 4-16x50 PM II P	Schmidt&Bender 3-12x50 PM II P
Magnification	1.7-10 x	4.5-14 x	4-16 x	3-12 x
Field of view	14.3-2.4º	3.9-1.45º	4.3-1.4º	6.3-2.5º
Lens diameter	42 mm	50 mm	50 mm	50 mm
Exit pupil diameter	9.6-4.2 mm	11.1-3.6 mm	12.5-3.1 mm	14.3-4.3 mm

	Swarovski 1.7- 10x42 L	Leupold Mark4 4.5-14x50 Side Focus CDS	Schmidt&Bender 4-16x50 PM II P	Schmidt&Bender 3-12x50 PM II P
Exit pupil distance	95 mm	98 mm	90 mm	90 mm
Diopter adjustment	+2 - -3	-	+2 - -3	+2 - -3
Length	324 mm	312 mm	393 mm	343 mm
Weight (mass)	0.490 kg	0.482 kg	0.933 kg	0.866 kg

Note:
- No data was found for the indicated optical sight.

Conclusion

The paper presents an overview of the tactical-technical-technological characteristics of the sniper rifles in use in the Serbian Armed Forces. The Black Arrow sniper rifle (produced in the Crvena Zastava factory in Kragujevac) is described as well as sniper rifles of foreign production, such as Barrett 95 (American manufacturer Barrett Firearms Manufacturing Company) and Sako TRG 22-42 (Finnish manufacturer Sako Limited). In addition to the sniper rifles, the paper provides a detailed overview of the optical and mechanical characteristics of the optical sights mounted on the mentioned sniper rifles. A comparative analysis was made based on the manufacturers' data available to the general public.

Based on the comparative analysis, it was concluded that the Black Arrow sniper rifle does not lag behind the tactical-technical characteristics of foreign rifles shown in this paper; therefore, it can be modernized and its weight possibly reduced.

Regarding the comparative analysis of the optical sights, it can be concluded that the Serbian Armed Forces should initiate the procedure of designing a modern optical sight with variable magnification thus increasing a potential use of the Serbian Armed Forces in multinational operations.

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СОВРЕМЕННЫЕ СНАЙПЕРСКИЕ ВИНТОВКИ, ИСПОЛЬЗУЕМЫЕ ВООРУЖЕННЫМИ СИЛАМИ РЕСПУБЛИКИ СЕРБИЯ

Дарко Д. Янкович[а], *Дарко* М. Васильевич[б],
Любиша Д. Томич[в], *Срджан* Й. Дувняк[а]

[а] Университет обороны в г. Белград, Военная академия, Деканат, г. Белград, Республика Сербия
[б] Белградский университет, Институт физики, г. Белград, Республика Сербия
[в] Военно-технический институт, г. Белград, Республика Сербия

РУБРИКА ГРНТИ: 78.00.00 ВОЕННОЕ ДЕЛО;
78.25.00 Вооружение и военная техника
ВИД СТАТЬИ: профессиональная статья
ЯЗЫК СТАТЬИ: английский

Резюме:

В данной статье описаны снайперские винтовки и оптические прицелы, используемые Вооруженными силами Республики Сербия. В статье также приведен сравнительный анализ оптических и механических характеристик различных прицелов, с целью возможного проектирования оптического прицела,

соответствующего технико-технологическим стандартам и нуждам Вооруженных сил Республики Сербия.

Ключевые слова: стрелковое вооружение, снайперская винтовка, калибр, оптический прицел, оптика, кратность, сетка, центрирование, защитное покрытие, установка на оружие

САВРЕМЕНЕ СНАЈПЕРСКЕ ПУШКЕ У ОПРЕМИ ВОЈСКЕ СРБИЈЕ

Дарко Д. Јанковић[а], *Дарко* М. Васиљевић[б],
Љубиша Д.Томић[в], *Срђан* Ј. Дувњак[а]

[а] Универзитет одбране у Београду, Војна академија, Деканат, Београд, Република Србија
[б] Универзитет у Београду, Институт за физику, Београд, Република Србија
[в] Војнотехнички институт, Београд, Република Србија

ОБЛАСТ: наоружање
ВРСТА ЧЛАНКА: стручни рад
ЈЕЗИК ЧЛАНКА: енглески

Сажетак:

У раду су представљене снајперске пушке и оптички нишани који се налазе у опреми Војске Србије. Ради евентуалног пројектовања оптичког нишана, који би задовољио савремене техничко-технолошке стандарде и потребе Војске Србије, анализиране су оптичке и механичке карактеристике оптичких нишана.

Кључне речи: стрељачко наоружање, снајперска пушка, калибар, оптички нишан, оптика, увећање, кончаница, подешавање ректификације, површинска заштита, монтажа на оружје.

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Незаустављива хиперсонична ракета *Tsirkon*[1]

Подаци о развоју хиперсоничне ракете 3М22 *Tsirkon* први пут су се појавили у јавности 2011, а период тестирања започет је 2015. године. Ракета има ефективан радијус до 1000 км и компатибилна је са бродовима, подморницама, као и са одређеним врстама авиона бомбардера.

Tsirkon (Zirkon)

Ракета ће бити лансирана из специјалних контејнера. Очекује се да ће бити смештена на нуклеарне крстарице руске морнарице, али и на фрегате и корвете. Претпоставља се, такође, да ће чинити нову компоненту наоружања и на руским нападним подморницама. Мањи хиперсонични пројектили ће променити морнаричку тактику. Крстарице, фрегате, корвете и подморнице биће у прилици да нападају непријатељске бродове из заседа и моћи ће забранити приступ руској обали нападним групама.

[1] The National Interest 23 December 2018

Vučković, D., SAVREMENO NAORUŽANJE I VOJNA OPREMA / MODERN WEAPONS AND MILITARY EQUIPMENT, pp.689-704

Очекује се да ће две до три руске крстарице на нуклеарни погон, некадашње совјетске класе *Kirov Petr Veliky, Admiral Nakhimov* и можда и *Admiral Lazarev,* добити по десет контејнера – лансера типа 3S-14 или ZS-14 од којих сваки може примити до осам хиперсоничних ракета типа *Tsirkon*, што значи до осамдесет ракета по крстарици.

Уколико се буде користио универзални лансер – контејнер типа *Universal Vertical Launching System (UKSK),* значи да ће ракете *Tsirkon* бити инсталиране и на фрегате класе *Project 22350,* као и на корвете класе *Project 20380*. Поред тога, ракете ће бити инсталиране и на нападној нуклеарној подморници типа *Yasen,* а помиње се и опремање нове класе подморница *Lider* за коју се очекује да ће се појавити у наоружању средином ове деценије.

Хиперсонична ракета *Tsirkon* имаће брзину од 8 маха и домет до 1000 км, а биће оспособљена да гађа поморске или копнене мете.

До сада су извршена тестирања са обалских платформи, док ће тестирања са поморских платформи, са бродова и подморница, почети током 2019. године.

Противбродске ракете биће лансиране појединачно или групно у координираном нападу.

Интересантно је да ракета лети у омотачу од плазме који је управљив по висини и по правцу (у војним изворима се помиње управљање крилним површинама које мењају облике плазменог омотача ракете). Плазмени омотач ракете има и особину да упија радарске таласе, па је ракета у суштини „невидљива", а с обзиром на велику брзину и путању лета тренутно не постоји ниједан одбрамбени систем који би могао да је пресретне и уништи.

Руска војска је на путу да добије офанзивни ракетни систем који је немогуће пресрести (постојећим средствима) и довољно је малих димензија да може бити смештен на јефтине бродове врло малих габарита, као нпр. корвете, који би били у стању да униште много веће и неупоредиво скупље циљеве као што су носачи авиона.

С обзиром на домет ракете и могућност лансирања на копнене циљеве са познатим координатама знатно би порасла вредност малих површинских бродова које су јефтинији и бржи за изградњу.

Драган М. Вучковић (*Dragan* M. Vučković),
e-mail: draganvuckovic64@gmail.com,
ORCID iD: http://orcid.org/0000-0003-1620-5601

Тихи минобацач[2]

Руске специјалне јединице добијају ново тихо, али смртоносно оружје. Ради се о новом „пригушеном" минобацачу типа 2B25 82 mm који је пројектовала компанија *Burevestnik Institute*.

2B25 82mm

Према војним изворима, звук испаљивања мине из овог минобацача не прелази звук испаљења јуришне аутоматске пушке „калашњиков" опремљене пригушавачем PBS-1, док се на самом минобацачу не може видети ни блесак ни дим. Тежак око петнаест килограма функционише на исти начин као и други минобацачи. Војник убацује мину у цев и повлачи полугу обарача. Нишанџија налази циљ преко оптичког нишана и подешава угао цеви.

Оно што минобацач 2B25 издваја од других минобацача јесте муниција. Обична минобацачка мина калибра 82 мм има погонско експлозивно пуњење постављено око репа мине, а посада додаје или одузима пуњења у зависности од даљине гађања.

Мина овог минобацача потпуно задржава детонацију експлозивног пуњења у свом дугом телу. Нагли, екстремни трзај физички гура клип против основе цеви из које се лансира мина.

Минобацачка мина 3VO35 садржи високоексплозивно пуњење са неколико десетина малих челичних куглица које су идеалне за

[2] The National Interest 08 September 2018

дејство против пешадије, лаких возила и складишта муниције и горива на отвореном.

Недостатак овог минобацача је знатно мањи радијус дејства. Компанија *Burevestnik* тврди да је максимални домет минобацача 2B25 мало мањи од хиљаду метара, што значи упола мањи од било ког модерног лаког минобацача од 60 мм.

Овакав минобацач је добар у прикривеним ноћним дејствима приликом дејства типа „нападни и бежи". Минобацач и муниција су довољно лаки да их војници могу носити на патролама, као и за време ваздушнодесантних операција.

Типична каденца ватре је 15 мина у минути, али посада може испалити и до 30 мина сваких шездесет секунди уколико је то неопходно. То је јако ватрено дејство на непријатеља који није у стању да одреди одакле долазе мине.

Иако минобацач 2B25 има озбиљне недостатке у погледу домета, ипак се ради о врло интересантној могућности изненадног, јаког напада где се нападачи могу повући на сигурно и пре него што непријатељ открије ко га и одакле напада.

Драган М. Вучковић (*Dragan* M. Vučković),
e-mail: draganvuckovic64@gmail.com,
ORCID iD: http://orcid.org/0000-0003-1620-5601

„Непобедиви" – подморница за сингапурску морнарицу[3]

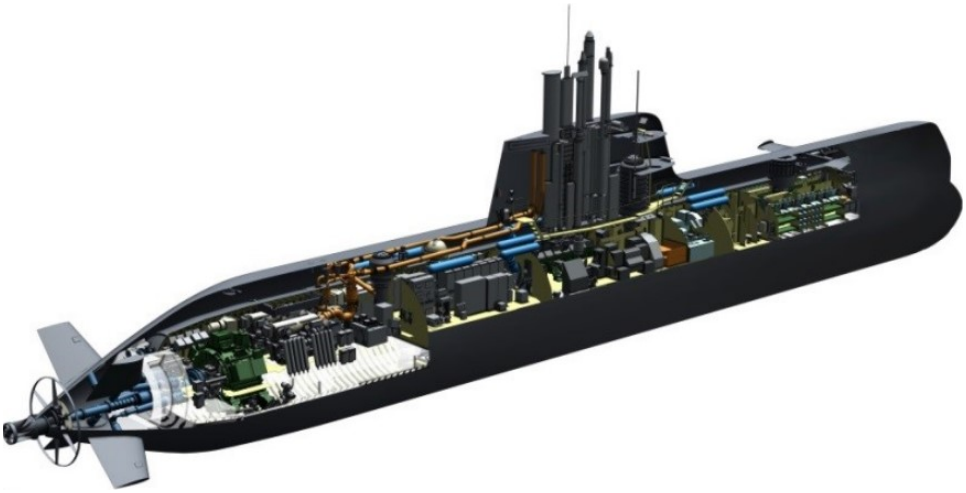
Подморница *Invincible* (Непобедиви) ускоро ће запловити топлим пацифичким водама у служби морнарице Републике Сингапур. Она ће, као и следеће три подморнице, представљати нови фактор утицаја у Јужном кинеском мору.

Осамнаестог фебруара извршено је поринуће најновије подморнице у бродоградилишту *Kiel*, у Немачкој. Ипак, она, слична класи *Type 212,* неће пратити руске подморнице у хладним водама Балтичког мора. Уместо тога, пловиће по топлим пацифичким водама око мореуза Малака у служби сингапурске морнарице.

Сингапур је острвска град-држава која се налази у близини мореуза Малака преко којег се одвија директан трговачки саобраћај између источне Азије и Индијског океана, што представља једну четвртину светске трговине.

[3] The National Interest 2 March 2019

Vučković, D., SAVREMENO NAORUŽANJE I VOJNA OPREMA / MODERN WEAPONS AND MILITARY EQUIPMENT, pp.689-704



Type 218SG

Ова богата, али мала држава инвестирала је у врло јаку и изразито скупу војну машинерију . Током 2017. године имала је пети војни буџет на свету. Поред осталог, купљени су главни западни оружни системи, укључујући 100 ловаца F-16 и F-15SG, тенкове *Leopard 2* и, недавно, четири до дванаест ловаца F-35.

Сингапур своју државу сматра неутралном у односу на државе у окружењу, као што су Малезија, Индонезија и Кина, али се супротставила кинеским аспирацијама ка већем делу Јужног кинеског мора.

Кина не гледа благонаклоно на ову државицу и труди се да је изолује од САД, па није случајно што је размишљала о заобилажењу Сингапура преко изградње канала Кра преко Тајланда.

Подморница *Invincible* припада класи 218SG и све већем броју подморница са погоном независним од ваздуха – air-independent propulsion (AIP). Овакав погон са горивним ћелијама омогућава релативно јефтиној дизел-електричној подморници да крстари испод воде и до 6 недеља брзинама до 10 чворова уместо изласка на површину и употребе дизел мотора помоћу шноркела сваких пар дана.

Подморница *Type 218* употребљава горивне ћелије на водоник уместо нешто напредније и мање бучне конфигурације система *Stirling* која је инсталирана на сингапурским подморницама класе *Archer* које су израђене у Шведској, а које су ушле у оперативну употребу током 2011. и 2013. године. Сматра се да подморница

Invincible има и до 50 процената већу аутономију у односу на шведске подморнице, односно четири до шест недеља. Са друге стране, ова врста горивних ћелија је скупља, али и опаснија.

Подморнице са погоном независним од ваздуха ипак не могу одржавати брзине од 30 чворова и не могу остати неограничено време испод воде. Подморница класе *Type 218* има максималну подводну брзину до 15 чворова, односно 10 чворова на површини. Сматра се да је њен радијус дејства око 13 000 км при брзинама до 5 чворова. Овакве подморнице су ипак знатно јефтиније од нуклеарних, до четвртине цене нуклеарне подморнице, а нису ни предвиђене за патроле на светским океанима.

Подморница *Type 218* опремљена је софистицираним новим борбеним системом који су заједнички развиле Немачка и Сингапур. Овај систем карактерише висок ниво аутоматизације и омогућава подморничку посаду од само 28 чланова који се ротирају током смена од по 8 сати, уместо уобичајених смена од 12 сати.

Подморница *Invincible* има у свом наоружању осам лансирних цеви за лансирање тешких торпеда од 533 мм, уместо типичних шест цеви у другим подморницама. Поред торпеда, ова подморница може бити опремљена поморским минама или противбродским ракетама, односно ракетама за дејство по копненим циљевима. Поред овог стандардног наоружања, за своју одбрану може бити наоружана немачким вођеним пројектилом *IDAS*, са вођењем путем оптичког влакна за напад на копнене циљеве и спорије летеће циљеве као што су хеликоптери.

Пројектили *IDAS* имају масу до 120 кг, дужину до 2,5 м и ширину до 180 мм, налазе се се у лансирном контејнеру у којем се налази до четири пројектила спремних за употребу. Ракете имају систем за вођење са инфрацрвеним трагачима за процесуирање слике високе прецизности. Ракета се наводи на циљ путем дата-линка којим се врши размена података фибер-оптичким каблом који контролише борбени систем подморнице. Оператор може контролисати пројектил током целог лета, што значи да га може наводити на циљ или прекинути мисију. Бојева глава има 20 кг експлозива и омогућава одбрану од ваздушних, поморских или копнених циљева.

Подморница има кормило у облику слова X, што јој омогућава већу маневарабилност што је императив у плитком и стеновитом мореузу који је широк само 2 км у свом најужем делу. Мореуз је пун малих увала и острва где је могуће спустити подморницу на дно и чекати у заседи.

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Подморница *Invincible* може изводити и дуже патроле у Индијском океану или у близини Тајвана са којим је Сингапур потписао одбрамбени савез.

Напредни сензори омогућиће Сингапуру добављање обавештајних података, нарочито у виду пресретања сигнала, употребе обавештајаца, праћења кретања кинеских дизел-електричних подморница у околини мореуза и стварања базе „непријатељских шумова". Очекује се да ће Сингапур делити овакве информације са САД и са својим регионалним партнерима као и до сада.

Засада, подморница *Invincible* тек почиње са поморским тестовима са посадом која се обучава у Немачкој, а очекује се да ће ући у оперативну употребу 2021. године. Остале подморнице ове класе – *Impeccable, Illustrious* и *Indomitable* биће поринуте током 2022, 2024. и касније и замениће шведске подморнице класе *Archer.*

Драган М. Вучковић (*Dragan* M. Vučković),
e-mail: draganvuckovic64@gmail.com,
ORCID iD: http://orcid.org/0000-0003-1620-5601

Русија наоружава своје тенкове контроверзним новим „метком"[4]

Зрна од осиромашеног уранијума израђена су од изразито тешког и густог метала и имају велику пробојност. Међутим, многи верују да зраче радијацијом као мале неутронске бомбе. Сједињене Америчке Државе употребиле су ову врсту муниције у Ираку, Авганистану и Сирији.

Билтен руског Министарства одбране навео је да ће руски тенкови *T-80BV,* који се доводе на ниво *T-80BVM,* ускоро бити наоружани овом моћном муницијом. Наведено је, такође, да ће поменути тенкови ускоро бити опремљени напредним стабилизатором за топ и механизмом за пуњење зрна под ознаком 3ВМ59 *Svinets*-1 и 3ВМ60 *Svinets-2*.

Svinets-1 има језгро од волфрама, док је језгро пројектила *Svinets-2* израђено од осиромашеног уранијума. Године 2016. први пут су се појавиле информације да Русија већ неколико година уназад производи ова специјална зрна за тенковску муницију.

[4] The National Interest 24 December 2018

T-80BVM

Тенковске гранате „употребљавају алуминијумски носач са три тачке контакта – што је јединствено, јер већина носача пенетратора зрна типа APFSDS има само две тачке контакта". Није јасно на који начин овакво решење може утицати на тачност и на хабање цеви топа.

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Svinets-2 није прво руско зрно које користи пенетратор од осиромашеног уранијума. Граната ознаке *3BM-32 Vant* калибра 125 мм такође има пенетратор од поменутог материјала, али је ново зрно много дуже.

У односу на гранату *3BM-32, Vant* APFSDS која има пенетратор дужине 380 мм, два нова типа граната имају пенетраторе дуже за 79 до 84 процената, што би могло довести до знатног повећања пробојне моћи, али и прецизности.

Развој нових граната са пенетратором од осиромашеног уранијума почео је због тога што тенкови руске производње нису могли пробити оклоп америчких и израелских тенкова типа *M-1 Abrams* и *Merkava,* што је ирачка војска болно искусила. Тенковска граната *3BM-42 Mango* ослања се на застарели дизајн пенетратора који се састоји од два релативно кратка пенетратора у челичном телу, а познато је да челик тешко пробија оклоп од легуре тешких метала.

Независни извори на интернету наводе да зрно *Svinets-1* са пенетратором од волфрама може пробити 700–740 мм челика на раздаљини до 2 км, док зрно *Svinets-2* са осиромашеним уранијумом пробија 800 до 830 мм челика на истој раздаљини. Таква пробојност, уколико буде остварена, могла би бити већа од пробојности америчке гранате типа M829A1 која пробија 650 до 700 мм челика на раздаљини до 2 км.

Амерички војни стручњаци сматрају да је муниција од осиромашеног уранијума углавном безбедна, осим у случајевима када циљ који је погођен таквом муницијом експодира и изгори, јер тада долази до формирања ситних честица радиоактивне прашине које су врло опасне по људски организам. На Косову је одређен број италијанских војника страдао од канцерогених болести након што су били близу циљева погођених поменутом муницијом, односно када су се сликали поред ретких олупина борбених возила југословенске војске. Тренутно су у току судске парнице којима се доводи у везу дејство осиромашеног уранијума са канцерогеним болестима.

Драган М. Вучковић (*Dragan* M. Vučković),
e-mail: draganvuckovic64@gmail.com,
ORCID iD: http://orcid.org/0000-0003-1620-5601

Тајванска хиперсонична ракета Sky Sword II[5]

Тајванско ратно ваздухопловство у свом саставу има највећи број ловаца F-5E Tiger II на свету. Ради се о трећој генерацији лаких ловаца чији је дизајн претходио америчком ловцубомбардеру F-16 Fighting Falcon. Овај лаки ловац се под лиценцом у великом броју

[5] Military Watch Magazinet 07 April 2018

производио у Тајвану. С обзиром на бројку од произведених 308 ловаца и његову употребу у борбеним мисијама над Јеменом, тајвански инжењери имали су лакши задатак у вези са унапређењем ове платформе у домаћим условима. То је важно, јер је улазак америчког ловцабомбардера F-16 у масовну производњу довео до смањеног интересовања за модернизацију ловца F-5E. Тајван је развио четврту генерацију ловаца типа F-CK Ching Kuo током осамдесетих година на основу пројекта F-5 што је довело до развоја великог броја нових високотехнолошких решења као што је радарски систем који је компатибилан са ловцем Tiger II.

Тајвански ловци F-5E

Упркос својим годинама, F-5E се доказао као врло способна платформа након модернизације, па га земље као што су Сингапур, Тајван, Јужна Кореја и Швајцарска и даље поседују у својим оперативним флотама. Авион је врло цењен због своје високе поузданости, малих оперативних трошкова и опцијама за унапређење. Ловци F-5E у тајванском ратном ваздухопловству унапређени су на знатно виши стандард у односу на авионе треће генерације. Опремљени су четвртом генерацијом радара и системима за електронско ратовање, као и дата-линком MIL-STD-1553B. Ипак, најинтересантније је да су наоружани и врло модерном ракетом ваздух-ваздух Sky Sword II која је ушла у оперативну употребу током 2018. године.

Варијанта ракете *Sky Sword II* – TC-2C има могућност напада на циљеве који се налазе на великим даљинама и до 100 км и то хиперсоничном брзином, што умногоме надилази могућности сличних платформи које производе САД, Русија и Кина, као што су ракете ваздух-ваздух типа AIM-120C и PL-12. Ова ракета припада врло малом броју ракета у оперативној употреби и својом брзином од 6 маха знатно је бржа од америчке ракете AIM-120, руске R-77PD и кинеске PL-12, које се крећу брзинама око 4 маха. Ракету је пројектовао национални тајвански институт за науку и технологију *Chung-Shan*. Ова ракета и по домету надмашује свог америчког ривала AIM-120C, а по том критеријуму једино јој парира кинеска ракета PL-15 са дометом до 150 км.

Радарски вођена тајванска ракета је технички хиперсонична с обзиром на брзину од преко 5 маха и по брзини јој једино парира руска ракета R-37 „Убица Авакса". Руска ракета је намењена нападима на веће и мање покретљиве циљеве, као што су летећи радари, што доводи до закључка да је тајванска ракета *Sky Sword II* и најбржа ракета своје врсте на свету.

Ловац четврте генерације Ching Kuo

Систем електронских противмера ракете *Sky Sword II* сматра се најбољим у својој класи. Користи инерцијално-навигациони систем са дата-линком за вођење у средњој фази, као и активно радарско навођење у финалној фази захвата ракете. Ракета је наводно знатно јефтинија од америчких варијанти ракете AIM-120 и има једну

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од главних улога у одбрани Тајвана од потенцијалног напада знатно моћнијег суседа.

Ракете *Sky Sword II* употребљавају ловци треће и четврте генерације, као што су F-5E и *Ching Kuo,* а тренутно се разматра могућност наоружавања и француских ловаца *Mirage* 2000 у тајванском ратном ваздухопловству с обзиром на постојеће проблеме француских ракета као што су MICA.

Ловци треће генерације успешно парирају много скупљим и борбено ефикаснијим ловцима, као и летећим радарима.

Драган М. Вучковић (*Dragan* M. Vučković),
e-mail: draganvuckovic64@gmail.com,
ORCID iD: http://orcid.org/0000-0003-1620-5601

3Д штампа за војне потребе[6]

Америчка војска прилагођава легуре војног квалитета у сврхе 3Д штампе ултрајаких резервних делова.

Нови материјали су демонстрирали и до 50% већу снагу од доступних комерцијалних материјала. Истраживачи из лабораторије *U.S. Army Combat Capabilities Development Command's Army Research Laboratory* успели су да прилагоде специјализовану металну легуру у форми праха за фузијско 3Д штампање. Захваљујући новом материјалу, у складу са специфичним производним параметрима, могуће је произвести делове који су око 50% јачи од расположивих комерцијалних делова.

У војном смислу оваква врста производње може радикално изменити војну логистику тако што нуди начин за добијање резервних делова и производа у ходу. Иако је технологија већ доступна, употреба је још ограничена. Након овог технолошког помака, могућност производње ултрајаких металних компоненти од челика војног квалитета могла би у потпуности променити начин рада војне логистике. Уместо конвоја пуних резервних делова може се направити све што је потребно уколико се поседује сировински материјал.

Метална легура AF96 првобитно је развијена за тело бомби за пробијање бункера. Истраживачи су успели да је претворе у прашкасту форму која се може употребити уз фузијску технологију 3Д штампача. Током истраживања већ су одштампане сложене

[6] www.armyrecognition.com 05 March 2019

компоненте уз употребу металног прашка, које не би могле бити произведене уз помоћ традиционалног процеса штампања.

Метална легура AF96 коју је америчка војска развила за бомбе намењене пробијању бункера

Овај прашкасти материјал може послужити за штампање резервних делова, на пример за копнена борбена возила, који су и до 50% јачи од постојећих резервних делова. Дакле, нови прашкасти материјал штампањем прави боље резервне делове од оригиналних.

Ради испитивања извршено је 3Д штампање малих импелер-вентилатора за турбину тенка *M1 Abrams* који су уграђени у турбину и раде без икаквих проблема. Ипак, не постоји званична гаранција као у случају резервног дела званичног произвођача где гаранција наводи колико дуго се може користити резервни део. С друге стране, сигурно је да тако штампан део може покренути борбено возило неколико сати или неколико дана, макар до тренутка када стигну наручени резервни делови. Али, још увек није могуће дати одговор на питање да ли је овакав производ исти или бољи од оригинала.

Тренутно се у лабораторији ради на производњи нових легура и њихових тестирања. Циљ је да се произведе што бољи материјал – легура која би послужила својој сврси на терену.

Драган М. Вучковић (*Dragan* M. Vučković),
e-mail: draganvuckovic64@gmail.com,
ORCID iD: http://orcid.org/0000-0003-1620-5601

Нови кинески носач авиона Type 002[7]

Аналитичари су дуго шпекулисали о трећем кинеском носачу авиона, једној од четири поморске платформе која би требало да буде у оперативној употреби до средине 20-их година. Остале три платформе су три тешка носача хеликоптера класе *Type 075,* за које се претпоставља да ће носити специјализоване авионе са вертикалним полетањем. Носач класе *Type 002* следиће носач класе *Type 001 Liaoning* који је ушао у оперативну употребу 2012. године, док је носач авиона класе *Type 001A* још увек на тестирању. За разлику од своја два претходника који су настали од совјетских носача авиона класе *Kuznetsov* и имају ски-рампу за лансирање авиона, нови носач имаће равну палубу са лансирним системом типа катапулта. Народна армија Кине објавила је да је успешно развила електромагнетни лансирни систем који се тестира већ неколико година. Овај систем тренутно користе ловци *J-15 Flying Shark* који су посебно модификовани за ову употребу.

Амерички аналитичари су скептични, јер сматрају да Кина није у стању да развије тако софистициран систем. Данашњи носачи авиона углавном немају катапулте за лансирање авиона, осим три америчке класе носача авиона од којих ће само класа *Gerald Ford* имати електромагнетне катапулте, док друге две класе користе класичне јефтиније парне катапулте.

Електромагнетни катапулти заузимају мање простора и омогућавају лансирање авиона са већим убојним товаром и више горива, што је велика предност у односу на авионе лансиране са носача авиона са ски-рампом.

Сателитски снимци носача авиона класе *Type 002* указују на то да се ради о класичном носачу са равном палубом и системом катапулта, првом носачу такве врсте ван Западног блока. Брод се налази у бродоградилишту Jiangnan у Шангају, где се граде и остали највећи бродови као што су разарачи класе *Type 052D* и *055*.

Нови кинески носач авиона имаће и знатно већу носивост у односу на постојеће кинеске носаче типа *Type 001 Liaoning* и *Type 001A,* носивости до 55 000 тона, па чак и до 85 000 тона. Западни аналитичари процењују да је нови кинески носач авиона у ствари заснован на пројекту бившег совјетског носача авиона класе *Ulyanovsk*, првог правог совјетског носача авиона са интегрисаним системом катапулта и носивости између 80 000 и 85 000 тона.

[7] militarywatchmagazine.com 13 May 2019

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Кинески носач авиона класе Type 001A

Поред најављене интеграције електромагнетних катапулта, нови носач имаћи и већи број укрцаних летелица, јаче сензоре и усавршенију електронику. Спекулише се да ће се развити и нова класа ловаца која би била укрцана са постојећим ловцима типа *J-15 Flying Shark*. У оквиру таквих разматрања помиње се и варијанта ловца *Shenyang J-31*. Нова верзија овог ловца биће у стандарду генерације 4++. Поред модификација неопходних за лансирање путем катапулта, нови ловци имаће и радар типа AESA и тродимензионално векторисане моторе, модификовано тело авиона са већим процентом употребљених композитних материјала и компатибилности са новим ракетама типа *PL-15* и *YJ-12* у мисијама ваздух-ваздух и ваздух-море. Очекује се да ће бити модернизована и адаптирана верзија ловца *J-15D* за противелектронска дејства, што би кинеским ударним групама омогућило електронску заштиту на нивоу америчког авиона за противелектронска дејства типа *E/A-18G Growler*. Носач би у својој ваздушној групи требало да има и авион за рано упозоравање и контролу *KJ-600* који би био аналоган америчком авиону *Grumman E-2 Hawkeye*.

Очекује се да ће носач авиона класе *Type 002* бити само први од многих суперносача авиона кинеске народне армије који ће имати носивост преко 100 000 тона и нуклеарни погон. Носаче ће у

борбеним групама пратити нова генерација кинеских разарача, као што су *Type 052D* и *Type 055* који ће бити задужени за обезбеђивање вишеслојне ваздушне одбране и борбе против непријатељских бродова на врло великим даљинама.

Драган М. Вучковић (*Dragan* M. Vučković),
e-mail: draganvuckovic64@gmail.com,
ORCID iD: http://orcid.org/0000-0003-1620-5601

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, DOI: 10.5937/VojnotehnickiGlasnik; https://doi.org/10.5937/VojnotehnickiGlasnik), 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 *Војнотехничком гласнику* класификују се на научне и стручне чланке.

Научни чланак је:

– оригиналан научни рад (рад у којем се износе претходно необјављени резултати сопствених истраживања научним методом);

– прегледни рад (рад који садржи оригиналан, детаљан и критички приказ истраживачког проблема или подручја у којем је аутор остварио одређени допринос, видљив на основу аутоцитата);

– кратко или претходно саопштење (оригинални научни рад пуног формата, али мањег обима или прелиминарног карактера);

– 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 чланак је:

– стручни рад (прилог у којем се нуде искуства корисна за унапређење професионалне праксе, али која нису нужно заснована на научном методу);

– информативни прилог (уводник, коментар и сл.);

– 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, DOI: 10.5937/VojnotehnickiGlasnik; https://doi.org/10.5937/VojnotehnickiGlasnik, 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:

– оригинальная научная статья (работа, в которой приводятся ранее неопубликованные результаты собственных исследований, полученных научным методом);

– обзорная статья (работа, содержащая оригинальный, детальный и критический обзор исследуемой проблемы или области, в который автор внёс определённый вклад, видимый на основе автоцитат);

– краткое сообщение (оригинальная научная работа полного формата, но меньшего объёма или имеющая предварительный характер);

– 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:

– профессиональная работа (приложения, в которых предлагаются опыты, полезные для совершенствования профессиональной практики, но которые не должны в обязательном порядке быть обоснованы на научном методе);

– информативное приложение (передовая статья, комментарий и т.п.);

– 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

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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.

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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,
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– on the list of periodicals for mechanical engineering,
category: scientific periodical of national interest **(M52)**,
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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

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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.

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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.

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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.

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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.

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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.

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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.

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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

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: miletic.dobrila@gmail.com

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: draganvuckovic64@gmail.com, http://orcid.org/0000-0003-1620-5601

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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: miletic.dobrila@gmail.com

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: draganvuckovic64@gmail.com, http://orcid.org/0000-0003-1620-5601

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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: miletic.dobrila@gmail.com

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: draganvuckovic64@gmail.com, http://orcid.org/0000-0003-1620-5601

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