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O. V.BOROVYK,
Doctor of Engineering, Professor, Chief of General Scientific and Engineering Disciplines Department of the National Academy of the State Border Guard Service of Ukraine named after Bohdan Khmelnytskyi (city of Khmelnytskyi)
L. M. TRASKOVETSKA,
Candidate of Physical and Mathematical Sciences, Associate Professor, Professor of General Scientific and Engineering Disciplines Department of the National Academy of the State Border Guard Service of Ukraine named after Bohdan Khmelnytskyi (city of Khmelnytskyi)
G. Ya. STOPEN,
Candidate of Physical and Mathematical Sciences, Lecturer of Higher Mathematics and Computer Application Department of Khmelnytskyi National University (city of Khmelnytskyi)

STATIC THERMOELASTIC FIELDS IN SOLID MULTICOMPONENT CYLINDRICAL AND ANISOTROPIC PLATE

Formulation of the problem in general. Development and improvement of production at the present stage is associated with the extensive usage of composite materials in various technical processes, construction, radio electronics, nuclear-power engineering, and space technology. While doing stress calculations of the structural elements of vehicles and machinery, heating devices, and for other many technical problems solving there is a need to explore the temperature fields and caused by them elastic stresses in piecewise and homogeneous bodies consisting of several materials and characterized with various physical and mechanical properties.

The topicality of investigating the boundary value problems for the heat-transfer equations of parabolic type is stipulated by their usage in modelling such physical processes as heat diffusion in nonhomogeneous media, combustion in solid fuel rocket engines, while exploring the problems of nuclear energy and nuclear reactors safety.

Analysis of the recent researches and publications with initial solution of this problem the authors base themselves upon. One of the effective methods, which is successfully used nowadays along with numerical methods for the mathematical modelling of the boundary value problems for the heat-transfer equations of parabolic type is the method of integral transformations [1,2]. In the research [1] the hybrid finite integral transformation of Euler-Fourier

(Kontorovych-Lebedev) in the segment $[R_0, R_3]$ has been made that is why the follow-up is the usage of integral transformations to determine the structure of fixed and static temperature fields.

The aim of the article is to generate a solution of the problem on the structure of the stationary temperature field and structure of descendant static thermoelastic field modelled for the solid (n+1)-components cylindrical anisotropic plate whereupon the solution has been received in the closed form which is the most convenient for the usage.

Statement of the main material of the research.

1. Stationary temperature fields. Setting of the problem.

Let us consider the problem of the structure of the stationary temperature field in the solid multicomponent cylinder-anisotropic plate. Let us construct the limited to the set

$$I_n = \left\{ r : r \in (0, R_1) \cup (R_1, R_2) \cup ... \cup (R_n, R_{n+1}) \equiv \bigcup_{j=1}^{n+1} \left(R_{j-1}, R_j \right); R_0 = 0, R_{n+1} = R < \infty \right\}$$

solution of the separator system of the stationary equations of thermal conduction in polar coordinate system

$$\left(\frac{d^2}{dr^2} + \frac{1}{r}\frac{d}{dr} - \chi_j^2 \right) T_j(r) = -f_j(r),\ j = \overline{1, n+1} \tag{1}$$

under conditions of non-ideal thermal contact [3]

$$\left[\left(b_j \frac{d}{dr} + 1 \right) T_j - T_{j+1}(r) \right] \Big|_{r=R_j} = 0,\ j = \overline{1, n},$$

$$\left(\frac{dT_j}{dr} - \nu_j \frac{dT_{j+1}}{dr} \right) \Big|_{r=R_j} = 0, \nu_j = \overline{\lambda}_{j+1} / \lambda_j \tag{2}$$

and boundary conditions

$$\frac{dT_1}{dr} \Big|_{r=0} = 0, \left(\alpha_{22}^{n+1} \frac{d}{dr} + \beta_{22}^{n+1} \right) T_{n+1} \Big|_{r=R_{n+1} \equiv R} = g_r. \tag{3}$$

Let us solve the boundary value problem (1)-(3) using the method of the Hankel finite integral transformation of the 1st order on the segment $[O, R] \equiv [O, R_{n+1}]$ [2].

Let us define the variables and functions:

$$C_{1j}=1, C_{2j}=\nu_j>0, \sigma_k=(a_k^2\bar{\lambda}_{n+1})^{-1}\bar{\lambda}_k; q_{ks}=a_k^{-1}(\gamma_k^2+\lambda_s^2)^{1/2};$$

$$U_{11}^{k1}(q_{js}R_k)\equiv(b_k\frac{d}{dr}+1)I_0(q_{js}r)\Big|_{r=R_k}=I_0(q_{js}R_k)-b_k q_{js}I_1(q_{js}R_k);$$

$$U_{11}^{k2}(q_{js}R_k)\equiv(b_k\frac{d}{dr}+1)N_0(q_{js}r)\Big|_{r=R_k}=N_0(q_{js}R_k)-b_k q_{js}N_1(q_{js}R_k);$$

$$U_{21}^{k1}(q_{js}R_k)\equiv\frac{dI_0(q_{js}r)}{dr}\Big|_{r=R_k}=-q_{js}I_1(q_{js}R_k);$$

$$U_{21}^{k2}(q_{js}R_k)=\frac{dN_0(q_{js}(r))}{dr}\Big|_{r=R_k}=-q_{js}N_1(q_{js}R_k);$$

$$U_{12}^{k1}(q_{js}R_k)=I_0(q_{js}R_k); U_{12}^{k2}(q_{js}R_k)=N_0(q_{js}R_k);$$

$$U_{22}^{k1}(q_{js}R_k)=-\nu_k q_{js}I_1(q_{js}R_k);$$

$$U_{22}^{k2}(q_{js}R_k)=-\nu_k q_{js}N_1(q_{js}R_k);$$

$$\psi_{jm}^{k}(q_{ks}R_k, q_{k+1,s}R_k)=U_{11}^{kj}(q_{ks}R_k)U_{22}^{km}(q_{k+1,s}R_k)-U_{21}^{kj}(q_{ks}R_k)U_{12}^{km}(q_{k+1,s}R_k)$$

Here λ_s are the roots of the transcendental equation

$$\Delta_k(\lambda)\equiv U_{22}^{n+1,1}(q_{n+1}R)\omega_2^{(n)}(q_1R_1, q_2R_1; q_2R_2, q_3R_2; ...; q_nR_n, q_{n+1}R_n)-$$
$$-U_{22}^{n+1,2}(q_{n+1}R)\omega_1^{(n)}(q_1R_1, q_2R_1; q_2R_2, q_3R_2; ...; q_nR_n, q_{n+1}R_n)=0;$$
$$\omega_j^{(1)}(\lambda)\equiv\psi_{1j}^{1}(q_1R_1, q_2R_1);$$
$$\omega_j^{(k)}(\lambda)\equiv\omega_j^{(k)}(q_1R_1, q_2R_1, q_2R_2, q_3R_2; ...; q_kR_k, q_{k+1}, R_k)= \quad (4)$$
$$=\omega_2^{(k-1)}(q_1R_1, q_2R_1, q_2R_2, q_3R_2; ...; q_{k-1}R_{k-1}, q_kR_{k-1})\times$$
$$\times\psi_{1j}^{(k)}(q_kR_k, q_{k+1}R_k)-\psi_{2j}^{(k)}(q_kR_k, q_{k+1}R_k)\times$$
$$\times\omega_1^{(k-1)}(q_1R_1, q_2R_1, q_2R_2, q_3R_2; ...; q_{k-1}R_{k-1}, q_kR_{k-1}), k=\overline{2,n}; (k)=\overline{1,k}; j=1,2.$$

If we assume that

$$V_1(r,\lambda_s)=\left(\prod_{m=1}^{n}\frac{2\bar{\lambda}_{m+1}}{\pi R_m}\right)I_0(q_{1s}r),$$

$$\text{.....} \quad (5)$$

$$V_k(r,\lambda_s)=\left(\prod_{m=1}^{n}\frac{2\bar{\lambda}_{m+1}}{\pi R_m}\right)\left[\omega_2^{(k-1)}(\lambda_s)I_0(q_{ks}r)-\omega_1^{(k-1)}(\lambda_s)N_0(q_{ks}r)\right],$$

$$V_{n+1}(r,\lambda_s)=\omega_2^{(n)}(\lambda_s)I_0(q_{n+1,s}r)-\omega_1^{(n)}(\lambda_s)N_0(q_{n+1,s}r),$$

then the spectral function is

$$V(r,\lambda_s)=\sum_{k=1}^{n+1}V_\kappa(r,\lambda_s)\theta(r-R_{\kappa-1})\theta(R_\kappa-r), \tag{6}$$

and its squared norm is

$$\|V(r,\lambda_S\|^2=\sum_{\kappa=1}^{n+1}\int_{R_{\kappa-1}}^{R_\kappa}[V_k(r,\lambda_s)]^2\sigma_\kappa r dr,\ R_0=0,\ R_{n+1}=R \tag{7}$$

Let us define direct $H_{Sn;I}$ and inverse $H_{Sn;I}^{-1}$ Hankel finite integral transformation of the 1st order on the segment *[0, R]* with *n* points of conjugation by convention:

$$H_{Sn;I}[f(r)]=\int_0^R f(r)V(r,\lambda_S)\sigma_1 r dr\equiv\tilde{f}_S; \tag{8}$$

$$H_{Sn;I}^{-1}[f_S]=\sum_{S=1}^{\infty}f_s\frac{V(r,\lambda_S)}{\left\|V(r,\lambda_S)\right|^2}=f(r); \tag{9}$$

$$H_{Sn;I}\left[\chi(r)B_0[f(r)]\right]\equiv\sum_{\kappa=1}^{n+1}a_\kappa^2\int_{R_{\kappa-1}}^{R_\kappa}\left(\frac{d^2}{dr^2}+\frac{1}{r}\frac{d}{dr}\right)\left[f(r)\right]\times$$

$$\times V_\kappa(r,\lambda_S)\sigma_\kappa r dr=-\lambda_S^2 f_S+\sigma_{n+1}\frac{a_{n+1}^2}{\alpha_{22}^{n+1}}R_{n+1}V_{n+1}(R_{n+1},\lambda_S)g_R- \tag{10}$$

$$-\sum_{\kappa=1}^{n+1}\gamma_\kappa^2\int_{R_{k-1}}^{R_\kappa}f(r)V_\kappa(r,\lambda_S)\sigma_\kappa r dr.$$

Let us write system (1) in the matrix form:

$$\begin{bmatrix}\left(\frac{d^2}{dr^2}+\frac{1}{r}\frac{d}{dr}-\chi_1^2\right)T_1(r)\\ \left(\frac{d^2}{dr^2}+\frac{1}{r}\frac{d}{dr}-\chi_2^2\right)T_2(r)\\ \ldots\ldots\ldots\ldots\\ \left(\frac{d^2}{dr^2}+\frac{1}{r}\frac{d}{dr}-\chi_{n+1}^2\right)T_{n+1}(r)\end{bmatrix}=\begin{bmatrix}f_1(r)\\ f_2(r)\\ \ldots\ldots\\ f_{n+1}(r)\end{bmatrix}. \tag{11}$$

Let us represent the operator $H_{Sn,I}$, acting by convention (8), as the operator matrix-row

$$H_{Sn,I}[...]=[\int_0^{R_1}...V_1(r,\lambda_S)\sigma_1 rdr\int_{R_1}^{R_2}...V_2(r,\lambda_S)\sigma_1 rdr...$$
$$...\int_{R_{n+1}}^{R_n}...V_n(r,\lambda_S)\sigma_n rdr\int_{R_n}^{R}...V_{n+1}(r,\lambda_S)\sigma_{n+1}rdr]. \quad (12)$$

Let us apply the operator matrix-row (12) by convention of the matrix multiplication to the system (11). Using the identity (10), we obtain the equation where $\alpha_1=\alpha_2=...=\alpha_{n+1}=1$

$$\sum_{j=1}^{n+1}(\lambda_S^2+\gamma_j^2+\chi_j^2)T_{jS}=\sum_{j=1}^{n+1}f_{jS}+\frac{Rq_R}{\alpha_{22}^{n+1}}V_{n+1}(R,\lambda_S) \quad (13)$$

Let us assume that

$$\max\{\chi_1^2,\chi_2^2,...,\chi_{n+1}^2\}=\chi_{n+1}^2$$

Since $\chi_{n+1}^2-\chi_j^2\le 0$ for $j=\overline{1,n}$, then assigning $\gamma_{n+1}^2=0$, $\gamma_j^2=\chi_{n+1}^2-\chi_j^2$ for $j=\overline{1,n}$, let us write equation (13) in the following way:

$$(\lambda_S^2+\chi_{n+1}^2)T_S=f_S+RV_{n+1}(R,\lambda_S)(\alpha_{22}^{n+1})^{-1}g_r. \quad (14)$$

The following designations are adopted in the equations (13), (14):

$$T_S=\sum_{j=1}^{n+1}T_{jS}=\sum_{j=1}^{n+1}\int_{R_{j-1}}^{R_j}T_j(r)V_j(r,\lambda_S)\sigma_j rdr,$$
$$f_S=\sum_{j=1}^{n+1}f_{jS}\equiv\sum_{j=1}^{n+1}\int_{R_{j-1}}^{R_j}f_j(r)V_j(r,\lambda_S)\sigma_j rdr$$

Let us find the function from the equation (14)

$$T_S=\frac{f_S}{\lambda_S^2+\chi_{n+1}^2}+\frac{RV_{n+1}(R,\lambda_S)}{\alpha_{22}^{n+1}(\lambda_S^2+\chi_{n+1}^2)}g_R \quad (15)$$

Since the superposition of the operators $H_{Sn;I}$ and $H_{Sn;I}^{-1}$ are the unity operator then let us depict the operator $H_{Sn;I}^{-1}$ as operator column matrix:

$$H^{-1}_{Sn;I}[...]=\begin{bmatrix} \sum_{S=1}^{\infty}...V_1(r,\lambda_S)\left\|V(r,\lambda_S)\right\|^{-2} \\ \sum_{S=1}^{\infty}...V_2(r,\lambda_S)\left\|V(r,\lambda_S)\right\|^{-2} \\ ..... \\ \sum_{S=1}^{\infty}...V_{n+1}(r,\lambda_S)\left\|V(r,\lambda_S)\right\|^{-2} \end{bmatrix} \tag{16}$$

Let us apply to the matrix of the element $[T_S]$ where the function T_S is calculated according to the rule (15), the operator matrix-column (16) by convention of the matrix multiplication. As a consequence of elementary transformations we obtain the solution of the boundary value problem (1)-(3):

$$T_j(r)=W_{nj}(r)g_R+\sum_{\kappa=1}^{n+1}\int_{R_{\kappa-1}}^{R_\kappa} H_{j\kappa}(r,\rho)\,f_\kappa(\rho)\sigma_\kappa\rho d\rho,\ j=\overline{1,n+1}, \tag{17}$$

In equations (17) Green functions are defined

$$W_{nj}(r)=\sum_{S=1}^{\infty}\frac{R\sigma_{n+1}V_{n+1}(R,\lambda_s)V_j(r,\lambda_S)}{\alpha_{22}^{n+1}(\lambda_S^2+\chi_{n+1}^2)\left\|V(\tau,\lambda_S)\right\|^2},\ j=\overline{1,n+1}, \tag{18}$$

generated by the given thermal conditions on the surface of the plate $r=R$, and dominant functions

$$H_{j\kappa}(r,\rho)=\sum_{S=1}^{\infty}\frac{V_j(r,\lambda_S)V_\kappa(\rho,\lambda_S)}{(\lambda_S^2+\chi_{n+1}^2)\left\|V(r,\lambda_S)\right\|^2},\ j,\kappa=\overline{1,n+1}, \tag{19}$$

generated by the influence of the cnontinuously distributed heat sources.

Let us mention that the parameters α_{22}^{n+1}, β_{22}^{n+1} and b_κ permit to straightly separate out from the common structures almost any important situation (within the limits of the proposed model).

2. Static thermoelastic fields.

In the loaded (n+1) component of the plate having cylindrical anisotropy as respects the elastic constants (the material characteristics), the static stress field generated by the stationary temperature field, assuming that the problem of elasticity is axisymmetric, will describe the functions [3].

$$\sigma_{rr,j}(r) = E_{*j}\left[\left(\frac{d}{dr} + \frac{\nu_{\varphi\varphi,j}}{r}\right)u_j - \alpha_{tj}^{*}T_j(r)\right],$$
$$\sigma_{\varphi\varphi,j}(r) = E_{*j}\left[\left(\nu_{r\varphi,j}\frac{d}{dr} + \frac{\kappa_j^2}{r}\right)u_j - \alpha_{*j}^{t}\kappa_j^2 T_j(r)\right],\ j=\overline{1,n+1} \quad (20)$$

The functions $u_j(r)$ are the solution of the separate equations system of equilibrium in displacements [3]

$$B_{\kappa j}[u_j] \equiv \left(\frac{d^2}{dr^2} + \frac{1}{r}\frac{d}{dr} - \frac{\kappa_j^2}{r^2}\right)u_j = F_j(r),\ j=\overline{1,n+1} \quad (21)$$

under conditions of ideal mechanical contact

$$\begin{cases} [u_j(r) - u_{j+1}(r)]\big|_{r=R_j} = 0, \\ \left[\left(\frac{d}{dr} + \frac{\nu_{r\varphi,j}}{r}\right)u_j - \mu_j\left(\frac{d}{dr} + \frac{\nu_{r\varphi,j+1}}{r}\right)u_{j+1}\right]\Big|_{r=R_j} = g_j \end{cases} \quad (22)$$

and boundary conditions

$$\left.\frac{dU_1}{dr}\right|_{r=0} = 0, \left(\bar{\alpha}_{22}^{n+1}\frac{\alpha}{dr} + \bar{\beta}_{22}^{n+1}\right)U_{n+1}\Big|_{r=R} = \bar{g}_R. \quad (23)$$

In the equation (20)-(23) the following designations are adopted:

$$F_j(r) = \alpha_{t_j}^{*}\frac{dTj}{dr} - \alpha_{t_j}^{0}\frac{T_j(r)}{r},\ \alpha_{t_j}^{0} = \alpha_{t_j}^{*} - \kappa_j^0\alpha_{*j}^{t},\ \kappa_j^2 = {E_{\varphi_j}}\Big/{E_{\tau_j}};$$
$$\mu_j = \frac{E_{*,j+1}}{E_{*,j}},\ E_{*j} = \frac{E_{rj}}{1-\nu_{r\varphi,j}\nu_{\varphi r,j}},\ j=\overline{1,n+1};$$
$$g_j = \alpha_{tj}^{*}T_j(R_j) - \mu_j\alpha_{t,j+1}^{*}T_{j+1}(R_j) \equiv \alpha_{tj}^{*}T_{jj} - \mu_j\alpha_{t_{j+1}}^{*}T_{j,j+1},$$
$$\alpha_{t_j}^{*} = \alpha_{r_j}^{t} + \nu_{r\varphi,j}\alpha_{\varphi_j}^{t},\ \alpha_{*j}^{t} = \alpha_{\varphi_j}^{t} + \nu_{\varphi r,j}\alpha_{rj}^{t},$$

$E_{rj}, E_{\varphi j}$ - Young's modulus for tension (compression) along the radial and tangential directions: $\alpha_{r_j}^{t}, \alpha_{\varphi_j}^{t}$ - temperature coefficients of linear expansion in these

directions: $v_{\varphi r,j}, v_{r\varphi,j}$ Poisson's coefficient; $T_j(r)$ is calculated using the formulas (17).

If a plate (one of the components of the plate) is isotropic, then

$$v_{r\varphi,j} = v_{\varphi r,j} \equiv v_j, \alpha^t_{rj} = \alpha^t_{\varphi j} = \alpha_{tj}, \alpha^*_{tj} = \alpha^t_{*j} = \alpha_{tj}(1+v_j),$$
$$\alpha^0_{tj} = 0, E_{rj} = E_{\varphi j} = E_j; \kappa_j = 1, E_{*j} = E_j(1-v_j^2)^{-1}.$$

Let us construct the solution of the boundary value problem (21)-(23) using the method of Hankel finite integral transformation of the 1st order on the segment *[0, R]* with *n* points of conjugation.

Let us define the variables and functions:

$$C_{1j} = 1, C_{2j} = \mu j; \vec{\sigma}_j = \left(C_j^2 \prod_{m=j}^{n} \mu_m \right)^{-1}; q_{jS} = C_j^{-1}\beta_S, j = \overline{1,n+1}, S = 1,2,3,...$$

$$U^{j1}_{\kappa_j;11}(q_{jS}R_j) = I_{kj}(q_{jS}R_j); \quad U^{j2}_{\kappa j,11}(q_{jS}R_j) = N_{kj}(q_{jS}R_j),$$

$$U^{j1}_{\kappa_j;21}(q_{jS}R_j) = R_j^{-1}(\kappa_j + v_{r\varphi,j})I_{\kappa j}(q_{jS}R_j) - q_{jS}I_{\kappa_j+1}(q_{jS}R_j),$$

$$U^{j2}_{\kappa_j;21}(q_{jS}R_j) = R_j^{-1}(\kappa_j + v_{r\varphi,j})N_{\kappa j}(q_{jS}R_j) - q_{jS}N_{\kappa_j+1}(q_{jS}R_j),$$

$$U^{j1}_{\kappa_j+1;12}(q_{j+1,S}R_j) = I_{k_j+1}(q_{j+1,S}R_j), U^{j2}_{\kappa_j+1,12}(q_{j+1,S}R_j) = N_{k_j+1}(q_{j+1,S}R_j);$$

$$U^{j1}_{\kappa_j+1;22}(q_{j+1,S}R_j) = \mu_j\left[(\kappa_{j+1} + v_{r\varphi,j+1})R_j^{-1}I_{k_j+1}(q_{j+1,S}R_j) - q_{j-1,S}N_{\kappa_j+1}(q_{j+1,S}R_j)\right];$$

$$\psi^j_{\kappa_j,\kappa_j+1;im}(q_{jS}R_j q_{j+1,S}R_j) = U^{ji}_{\kappa_j;11}(q_{jS}R_j)U^{jm}_{\kappa_j+1;22}(q_{j+1,S}R_j) -$$
$$-U^{ji}_{\kappa_j,21}(q_{jS}R_j)U^{jm}_{\kappa_j+1;12}(q_{j+1,S}R_j), \; j = \overline{1,n},$$
$$(\kappa) \equiv (\kappa)_{n+1} = \{\kappa_1, \kappa_2, ..., \kappa_n, \kappa_{n+1}\}, \{\kappa_1, \kappa_2, ..., \kappa_j\} \equiv (\kappa)_j; \; (m) = 123...m,$$
$$\omega^{(1)}_{(\kappa)_2,j}(q_{13}R_1 q_{2S}R_1) \equiv \psi^1_{\kappa,\kappa_2;tj}(q_{1S}R_1 q_{2S}R_1) \equiv \omega^{(1)}_{(\kappa)_2;j}(\beta_S), \; j = 1,2,$$
$$\omega^{(m)}_{(\kappa)_{m+1},j}(\beta_S) \equiv \omega^{(m)}_{(\kappa)_{m+1},j}(q_{1S}R_1, q_{2S}R_1, q_{2S}R_2, q_{3S}R_2, ..., q_{mS}R_m, q_{m+1,S}R_m) =$$
$$= \omega^{(\kappa-1)}_{(\kappa)_m,2}(q_{1S}R_1, q_{2S}R_1, ..., q_{m-1,S}R_{m-1}, q_{mS}R_{m-1})\psi^m_{\kappa_m;\kappa_{m+1};1j}(q_{mS}R_m, q_{m+1,S}R_m) -$$
$$-\omega^{(\kappa-1)}_{(\kappa)_m,1}(q_{1S}R_1, q_{2S}R_1, ..., q_{m-1,S}R_{m-1}, q_{mS}R_{m-1})\psi^m_{\kappa_m,\kappa_{m+1},2j}(q_{mS}R_m, q_{m+1,S}R_m).$$

Here β_S are the roots of the transcendental equation creating point spectrum

$$\Delta_{(\kappa);n}(\beta) \equiv U^{n+1,n}_{\kappa_{n+1},22}(q_{n+1}R_{n+1})\omega^{(n)}_{(\kappa);2}(q_1R_1, q_2R_1, q_2R_2, ..., q_nR_n, q_{n+1}R_n) -$$
$$-U^{n+1,2}_{\kappa_{n+1},22}(q_{n+1}R_{n+1})\omega^{(n)}_{(\kappa);1}(q_1R_1, q_2R_1, q_2R_2, ..., q_nR_n, q_{n+1}R_n) = 0. \qquad (24)$$

The presence of the spectral function $W_{(\kappa)}(r,\beta_S)$, the square of its norm $\left\|W_{(\kappa)}(r,\beta_S)\right\|^2$ allows to bring into action a finite direct $H^{(\kappa)}_{Sn;I}$ and inverse $H^{-(\kappa)}_{Sn,I}$ Hankel finite integral transformation of the 1st order on the segment *[0, R]* with *n* points of conjugation by convention [2]:

$$H^{(\kappa)}_{Sn;I}[f(r)]=\int_0^R f(r)W_{(\kappa)}(r,\beta_S)\overline{\sigma}(r)dr\equiv f_S; \tag{25}$$

$$H^{-(\kappa)}_{Sn;I}\left[f_S\right]=\sum_{S=1}^{\infty} f_S\frac{W_{(\kappa)}(r,\beta_S)}{\left\|W_{(\kappa)}(r,\beta_S)\right\|^2}\equiv f(r); \tag{26}$$

$$\begin{aligned}&H^{(\kappa)}_{Sn;I}\left[\chi(r)B_{(\kappa)}[f(r)]\right]\equiv\sum_{j=1}^{n+1}C_j^2\int_{R_{j-1}}^{R_j}B_{\kappa_j}[f(r)]W_{(\kappa);j}(r,\beta_S)\times\overline{\sigma}_j r dr=\\&=-\beta_S^2 f_S+C^2_{n+1}\overline{\sigma}_{n+1}R(\overline{\alpha}^{n+1}_{22})^{-1}W_{(\kappa);n+1}(R,\beta_S)\times\\&\times\left(\overline{\alpha}^{n+1}_{22}\frac{df}{dr}+\overline{\beta}^{n+1}_{22}f\right)\Bigg|_{r=R}+\sum_{j=1}^{n}C_j^2\overline{\sigma}_j R_j W_{(\kappa);j}(R_j,\beta_S)g_{j.}\end{aligned} \tag{27}$$

If $\overline{\alpha}^{n+1}_{22}=0,\ \overline{\beta}^{n+1}_{22}=1,$ then we obtain the problem in transfers i.e. the first boundary value problem; and if $\overline{\alpha}^{n+1}_{22}=1,\ \overline{\beta}^{n+1}_{22}=R^{-1}V_{r\varphi,n+1}$ then we obtain the second boundary value problem – the problem in tensions (the boundary $r=R_{n+1}\equiv R$ of the plate is loaded).

Let us write system (21) in matrix form:

$$\begin{bmatrix}\left(\frac{d^2}{dr^2}+\frac{1}{r}\frac{d}{dr}-\frac{\kappa_1^2}{r^2}\right)U_1(r)\\\left(\frac{d^2}{dr^2}+\frac{1}{r}\frac{d}{dr}-\frac{\kappa_2^2}{r^2}\right)U_2(r)\\\ldots\ldots\ldots\ldots\\\left(\frac{d^2}{dr^2}+\frac{1}{r}\frac{d}{dr}-\frac{\kappa_{n+1}^2}{r^2}\right)U_{n+1}(r)\end{bmatrix}=\begin{bmatrix}F_1(r)\\F_2(r)\\\ldots\ldots\\F_{n+1}(r)\end{bmatrix} \tag{28}$$

Let us represent the operator $H_{Sn;I}^{(\kappa)}$, acting by convention (25), as operator matrix-row:

$$H_{Sn;I}^{(\kappa)}[...]=\left[\int_0^{R_1}...W_{(\kappa);1}(r,\beta_S)\overline{\sigma}_1 rdr\int_{R_1}^{R_2}...W_{(\kappa);2}(r,\beta_S)\overline{\sigma}_2\, rdr...\right.$$
$$\left....\int_{R_{n-1}}^{R_n}...W_{(\kappa);n}(r,\beta_S)\overline{\sigma}_n rdr\int_{R_n}^{R}...W_{(\kappa);n+1}(r,\beta_S)\overline{\sigma}_{n+1}rdr\right]. \quad (29)$$

Let us apply by convention of matrix multiplication the operator matrix-row (29) to the system (28). As a consequence of elementary transformations and congruence (27) where $C_1^2=C_2^2=...=C_{n+1}^2=1$ we will obtain the algebraic equation:

$$-\beta_S^2\sum_{j=1}^{n+1}U_{jS}+\sum_{j=1}^{n}\overline{\sigma}_j R_j W_{(\kappa);j}(R_j,\beta_S)g_i=$$
$$=\sum_{j=1}^{n+1}F_{jS}-\overline{\sigma}_{n+1}R(\overline{\alpha}_{22}^{n+1})^{-1}W_{(\kappa);n+1}(R,\beta_S)g_{1R.} \quad (30)$$

The adopted designations in the algebraic equation (30) are:

$$U_{jS}=\int_{R_{j-1}}^{R_j}U_j(r)W_{(\kappa);j}(r,\beta_S)\overline{\sigma}_j rdr;F_{jS}=\int_{R_{j-1}}^{R_j}F_j(r)W_{(\kappa);j}(r,\beta_S)\times$$
$$\times\overline{\sigma}_j rdr=\alpha_{t_j}^{*}\overline{\sigma}_j\left[R_jT_j(R_j)W_{(\kappa);j}(R_j,\beta_S)-R_{j-1}T_j(R_{j-1})\times\right.$$
$$\times W_{(\kappa);j}(R_{j-1},\beta_S)-\int_{R_{j-1}}^{R_j}T_j(r)\left[\alpha_{t_j}^{*}\left(\frac{dW_{(\kappa);j}}{dr}+\frac{1}{r}W_{(\kappa);j}\right)+\frac{\alpha_{tj}^{0}}{r}\times\right.$$
$$\left.\left.\times W_{(\kappa);j}(r,\beta_S)\right]\overline{\sigma}_j rdr.\right. \quad (31)$$

If we denote

$$\alpha_{t_j}^{*}\frac{dW_{(\kappa);j}(r,\beta_S)}{dr}+(\alpha_{tj}^{*}+\alpha_{tj}^{0})\frac{1}{r}W_{(\kappa);j}(r,\beta_S)=\varepsilon_{(\kappa);j}(r,\beta_S);$$
$$\sum_{j=1}^{n+1}U_{jS}=U_S;\sum_{j=1}^{n+1}\int_{R_{j-1}}^{R_j}T_j(\rho)\varepsilon_{(\kappa);j}(\rho,\beta_S)\overline{\sigma}_j\rho d\rho=\Phi_{(\kappa);S}$$

and assume that

$$g_{1R} = \overline{\alpha}_{22}^{n+1} \alpha^*_{t_{n+1}} T_{n+1}(R), \tag{32}$$

then the equation (33) will have the form

$$\beta_S^2 U_S = \Phi_{(\kappa);S.} \tag{33}$$

If we refuse the equation (32), then the right hand side of the equation (33) will get the item

$$\overline{\sigma}_{n+1} R(\overline{\alpha}_{22}^{n+1})^{-1} W_{(\kappa);n+1}(R, \beta_S)\left(g_{1R} - \overline{\alpha}_{22}^{n+1} \alpha^*_{t_{n+1}} T_{n+1}(R)\right). \tag{34}$$

From the equation (33) we find that

$$U_S = \beta_S^{-2} \Phi_{(\kappa);S.} \tag{35}$$

Since the superposition of the operators $H^{(\kappa)}_{Sn;I}$ and $H^{-(\kappa)}_{Sn;I}$ is the unity operator, then

$$H^{-(\kappa)}_{Sn;I}[...] = \begin{bmatrix} \sum\limits_{S=1}^{\infty} ... W_{(\kappa);1}(r, \beta_S) \left\| W_{(\kappa)}(r, \beta_S) \right\|^{-2} \\ \sum\limits_{S=1}^{\infty} ... W_{(\kappa);2}(r, \beta_S) \left\| W_{(\kappa)}(r, \beta_S) \right\|^{-2} \\ ..... \\ \sum\limits_{S=1}^{\infty} ... W_{(\kappa);n+1}(r, \beta_S) \left\| W_{(\kappa)}(r, \beta_S) \right\|^{-2} \end{bmatrix} \tag{36}$$

Let us apply the operator matrix-column (36) by multiplication convention of the matrixes by the matrix element $[U_S]$, where U_S is defined by the formula (35). As a consequence of elementary transformations we obtain the solution of the boundary value problem (21)-(23):

$$U_m(r) = \sum_{j=1}^{n+1} \int_{R_{j-1}}^{Rj} T_j(\rho) H_{(\kappa);mj}(r, \rho) \overline{\sigma}_j \rho d\rho; \; m = \overline{1, n+1}. \tag{37}$$

Here the basic functions of the system are involved (21)

$$H_{(\kappa);mj}(r,\rho)=\sum_{S=1}^{\infty}\frac{W_{(\kappa);m}(r,\beta_S)\varepsilon_{(\kappa);j}(\rho,\beta_S)}{\beta_S^2\left\|W_{(\kappa)}(r,\beta_S)\right\|^2};\ m,\ j=\overline{1,n+1}. \tag{38}$$

If the right hand side of the equation (35) is represented by the item (34), then

$$\begin{aligned}U_m(r)&=\sum_{j=1}^{n+1}\int_{R_{j-1}}^{R_j}T_j(\rho)H_{(\kappa);mj}(r,\rho)\overline{\sigma}_j\rho d\rho+\\&+\overline{\sigma}_{n+1}R\left(g_{1R}-\overline{\alpha}_{22}^{n+1}\alpha^*_{t_{n+1}}T_{n+1}(R)\right)\sum_{S=1}^{\infty}\frac{W_{(\kappa);n+1}(R,\beta_S)W_{(\kappa);m}(r,\beta_S)}{\beta_S^2\left\|W_{(\kappa)}(r,\beta_S)\right\|^2}.\end{aligned} \tag{39}$$

Let us mention that there is the congruence (32) in the case of the second boundary value problem - the problem in tensions.

Conclusion. According to the results of the conducted research in the article the solution of the problem on the structure of the stationary temperature field and structure of descendant static thermoelastic field modelled for the solid (n+1)-components cylindrical anisotropic plate has been made in the closed form.

The lines of further researches are considered in the investigation of the most utilized practically applied cases of two- and three-component plates having cylindrical anisotropy.

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V.A. HOLOVKO,
graduate student of Kyiv Aviation University, city of Kyiv

SOLVING OF DIRECT TOMOGRAPHIC PROBLEM BY MEANS OF BILINEAR SPLINE

Problem statement in general. Today tomographic problem (TP) is well known, including Radon transformation, which is used in X-ray radiography (tomography). Approximation of solution by means of inverse TP by spline is one way of regularization relating to projection methods. However, there are tomography problems, the solution of which is complicated (seismic and acoustic tomography). The monograph [2] gives examples of spline for solving seismic imaging.

The purpose of the article – to provide direct solution of tomographic problem using bilinear spline.

Presentation of the main material of the research. The paper proposes to solve the direct tomographic problem assuming that the probing area is bilinear spline on a rectangular grid. Using bilinear spline provides a rather simple analytical expression for direct tomographic problem solving.

In order to solve tomographic problems it is important to assess the capabilities of the method, as these problems are related to incorrect ones by Hadamard. Let us obtain the solution for direct tomographic problems, that will subsequently enable us to assess accuracy of the solution of the inverse problem for obtaining accurate data.

Let the rectangular probing area $x \in [0,4), y \in [0,4)$ is described by the test function:

$$w(x,y) = \cos\left(x \cdot m + \frac{\pi}{2}\right)^2 \cdot \sin(y \cdot n + \pi)^2 + k, \qquad (1)$$

where m = 0.7, n = 2, k = 0.

with receivers and emitters. Probing scheme consists of one transmitter (T1) and 8 receivers (R1-R8) (Fig. 1). Emitter is at point (0,0) and receiver is set by the matrix

$$CR = \begin{bmatrix} 0.5 & 4 \\ 1.5 & 4 \\ 2.5 & 4 \\ 3.5 & 4 \\ 4 & 3.5 \\ 4 & 2.5 \\ 4 & 1.5 \\ 4 & 0.5 \end{bmatrix} \qquad (2)$$

With such allocation scheme of emitter and receivers we get 8 probing beams.

The probing area is divided into rectangular probing areas, on which two-dimensional spline is set

$$S(x,y) = S_x(x) \otimes S_y(y)\,. \tag{3}$$

Bilinear spline is a tensor product of two linear splines

$$S_x(x) = A_{xi}\left(\frac{x_{i+1}-x}{x_{i+1}-x_i}\right) + A_{xi+1}\left(\frac{x-x_i}{x_{i+1}-x_i}\right), \tag{4}$$

$$S_y(y) = A_{yj}\left(\frac{y_{j+1}-y}{y_{j+1}-y_j}\right) + A_{yj+1}\left(\frac{y-y_j}{y_{j+1}-y_j}\right), \tag{5}$$

where $i \in [0, I),\ j \in [0; J).$

$A_{xi}, A_{xi+1}, A_{yj}, A_{yj+1}$ is the coefficient of linear splines.

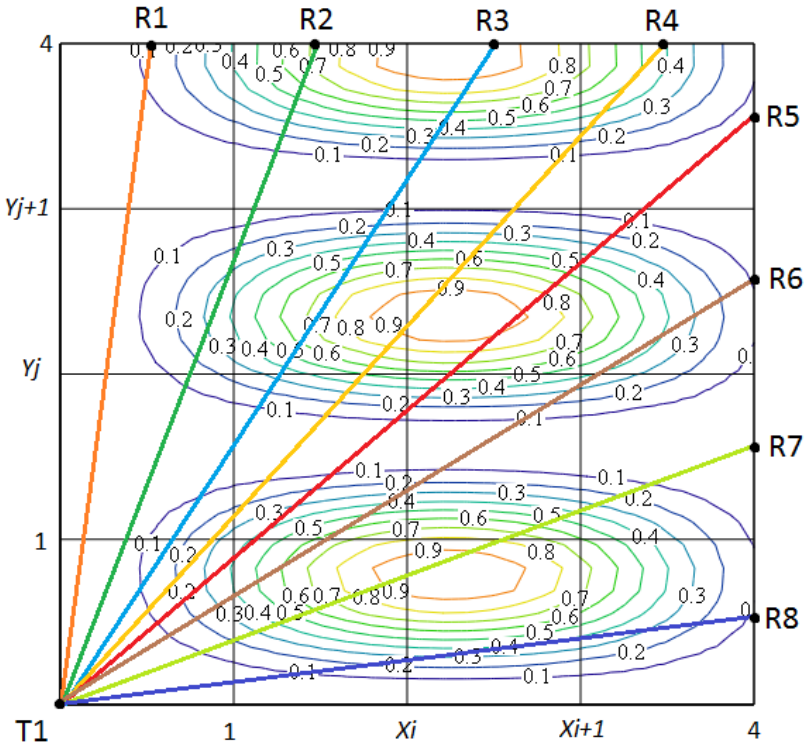

Figure 1. Probing diagram

If we consider the bilinear spline calculation values at a separate fragment (Fig. 3), it will be expressed as follows:

$$S(x,y) = \sum_{i=1}^{I}\sum_{j=1}^{J} a_{ij} \cdot B(x,y)\,, \tag{6}$$

Where a_{ij} - values at specific grid nodes,

$B(x, y)$ - special basis functions of bilinear spline for a given fragment.

Let us represent (6) in the expanded form

$$S(x,y) = a_{ij} \cdot B_1(x,y) + a_{ij+1} \cdot B_2(x,y) + a_{i+1j} \cdot B_3(x,y) + a_{i+1j+1} \cdot B_4(x,y), \quad (7)$$

where $x \in [xu_i, xu_{i+1}), y \in [yu_j, yu_{j+1}).$

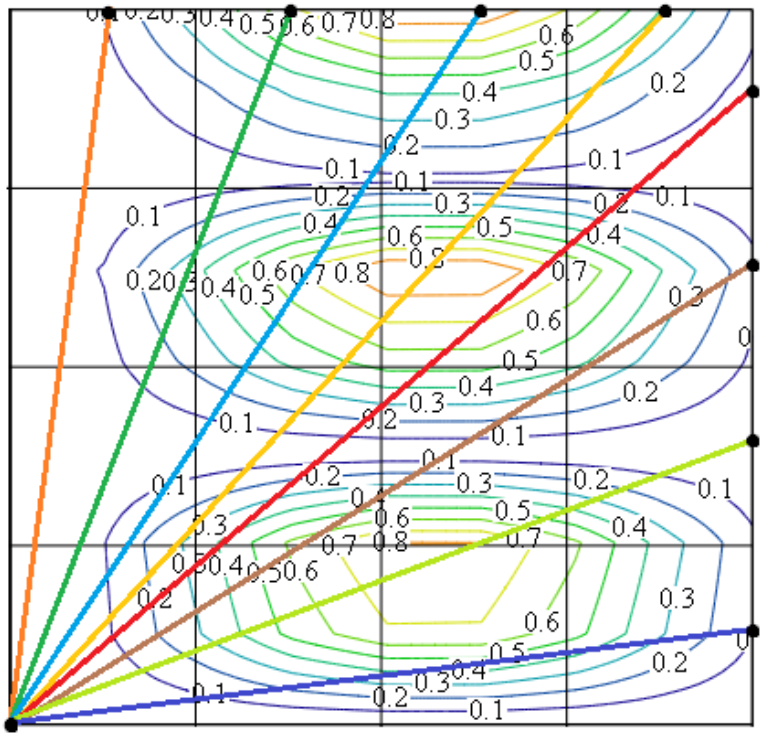

Figure. 2 Approximation of $W(x, y)$ function by $S(x, y)$ spline.

Let us consider how the receiver's signal is formed at a separate fragment.

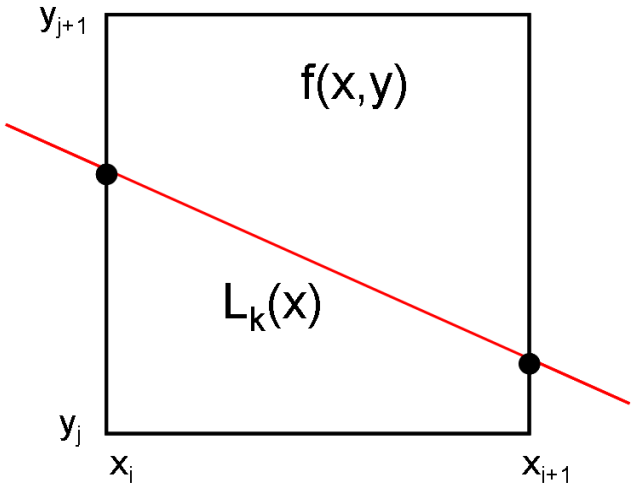

Figure. 3 Direct probing at a local fragment (segment).

Figure 3 shows the probing line passing through a local fragment of a given area. Let us assume that the beam passes along the $L_k(x)$ - line. Then, the signal generated at this period will be equal to the integral of the $f(x, y)$ - function along the line. To avoid two-dimensionality of integration let us substitute $L_k(x)$ -line

equation instead of the "y" value. We will obtain $f(x, L_k(x))$. Thus, we can move from integration over two variables to a single variable. If we consider the solution of this problem in many areas, they are composed of the sum of the individual fragments (Fig. 4).

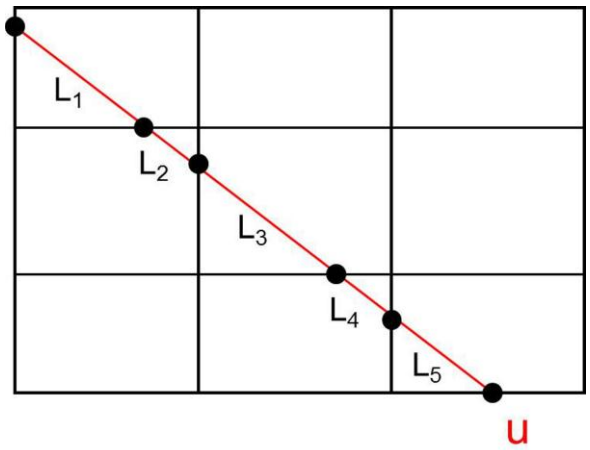

Figure. 4. Direct probing throughout the area

Taking into account that the probing area is a spline, the received signal finally will depend on the probing scheme and on parameters of a_{ij}, which are the values at the nodes of this grid. In general view the value of a separate receiver along all the line shall be calculated according to the expression:

$$u = \sum_{k=1}^{K} \int_{x_k}^{x_{k+1}} S(x, L_k(x), A)dx \tag{8}$$

Substituting (8) with the values of basis functions, we obtain

$$u = \sum_{k=1}^{K}\sum_{i=1}^{I}\sum_{j=1}^{J} a_{ij} \cdot \hat{B}_{kij} = \sum_{k=1}^{K} \int_{x_k}^{x_{k+1}} \left[\sum_{i=1}^{I}\sum_{j=1}^{J} a_{ij} \cdot B(x, L_k(x)) \right] dx = \\ = \sum_{k=1}^{K}\sum_{i=1}^{I}\sum_{j=1}^{J} a_{ij} \cdot \int_{x_k}^{x_{k+1}} B(x, L_k(x))dx \tag{9}$$

Let us find the calculated expressions. From (7) we know that the spline area is set as follows:

$$S = a_{11} \cdot \left[\frac{x_2 - x}{x_2 - x_1} \cdot \frac{y_2 - y}{y_2 - y_1} \right] + a_{12} \cdot \left[\frac{x_2 - x}{x_2 - x_1} \cdot \frac{y - y_1}{y_2 - y_1} \right] + \\ + a_{21} \cdot \left[\frac{x - x_1}{x_2 - x_1} \cdot \frac{y_2 - y}{y_2 - y_1} \right] + a_{22} \cdot \left[\frac{x - x_1}{x_2 - x_1} \cdot \frac{y - y_1}{y_2 - y_1} \right] \tag{10}$$

The line equation is:

$$l = y_p \cdot \left[\frac{x_k - x}{x_k - x_p} \right] + y_k \cdot \left[\frac{x - x_p}{x_k - x_p} \right], \quad (11)$$

where x_p, y_p are the coordinates of the beginning of the probing line,

x_k, y_k are the coordinates of the end of the probing line.

Substituting expression (11) to (10) instead of the "y" variable we obtain the following:

$$S = \frac{a_{11} \cdot (x - x_2) \cdot (x \cdot y_k - x \cdot y_p - x_k \cdot y_2 + x_p \cdot y_2 + x_k \cdot y_p - x_p \cdot y_k)}{(x_1 - x_2) \cdot (x_k - x_p) \cdot (y_1 - y_2)} -$$
$$- \frac{a_{12} \cdot (x - x_2) \cdot (x \cdot y_k - x \cdot y_p - x_k \cdot y_1 + x_p \cdot y_1 + x_k \cdot y_p - x_p \cdot y_k)}{(x_1 - x_2) \cdot (x_k - x_p) \cdot (y_1 - y_2)} -$$
$$- \frac{a_{21} \cdot (x - x_1) \cdot (x \cdot y_k - x \cdot y_p - x_k \cdot y_2 + x_p \cdot y_2 + x_k \cdot y_p - x_p \cdot y_k)}{(x_1 - x_2) \cdot (x_k - x_p) \cdot (y_1 - y_2)} + \quad (12)$$
$$+ \frac{a_{22} \cdot (x - x_1) \cdot (x \cdot y_k - x \cdot y_p - x_k \cdot y_1 + x_p \cdot y_1 + x_k \cdot y_p - x_p \cdot y_k)}{(x_1 - x_2) \cdot (x_k - x_p) \cdot (y_1 - y_2)}$$

We obtain a function that depends only on one "x" variable.

Having integrated (12) we obtain

$$I_S = \int_{xd}^{xu} \frac{a_{11} \cdot (x - x_2) \cdot (x \cdot y_k - x \cdot y_p - x_k \cdot y_2 + x_p \cdot y_2 + x_k \cdot y_p - x_p \cdot y_k)}{(x_1 - x_2) \cdot (x_k - x_p) \cdot (y_1 - y_2)} -$$
$$- \frac{a_{12} \cdot (x - x_2) \cdot (x \cdot y_k - x \cdot y_p - x_k \cdot y_1 + x_p \cdot y_1 + x_k \cdot y_p - x_p \cdot y_k)}{(x_1 - x_2) \cdot (x_k - x_p) \cdot (y_1 - y_2)} -$$
$$- \frac{a_{21} \cdot (x - x_1) \cdot (x \cdot y_k - x \cdot y_p - x_k \cdot y_2 + x_p \cdot y_2 + x_k \cdot y_p - x_p \cdot y_k)}{(x_1 - x_2) \cdot (x_k - x_p) \cdot (y_1 - y_2)} + \quad (13)$$
$$+ \frac{a_{22} \cdot (x - x_1) \cdot (x \cdot y_k - x \cdot y_p - x_k \cdot y_1 + x_p \cdot y_1 + x_k \cdot y_p - x_p \cdot y_k)}{(x_1 - x_2) \cdot (x_k - x_p) \cdot (y_1 - y_2)} dx$$

Let us find the integral from (13). After reduction of similars and elimination of coefficients we obtain:

$$I_S = a_{11} \cdot A_{11} + a_{12} \cdot A_{12} + a_{21} \cdot A_{21} + a_{22} \cdot A_{22}, \quad (14)$$

where $A_{11}, A_{12}, A_{21}, A_{22}$ are bilinear spline coefficients for local fragment,

$a_{11}, a_{12}, a_{21}, a_{22}$ are function values at the vertices of a local fragment.

Below are obtained coefficients A_{11},A_{12},A_{21},A_{22} in the expanded form

$$A_{11} = -\frac{1}{2}C\cdot\left(x_u^2 - x_d^2\right)\cdot\left(x_2\cdot y_k + x_k\cdot y_2 - x_2\cdot y_p - x_p\cdot y_2 - x_k\cdot y_p + x_p\cdot y_k\right) -$$
$$-C\cdot x_2\cdot\left(x_d - x_u\right)\cdot\left(x_k\cdot y_2 - x_p\cdot y_2 - x_k\cdot y_p + x_p\cdot y_k\right) - \quad (15)$$
$$-\frac{1}{3}C\cdot\left(x_d^3 - x_u^3\right)\cdot\left(y_k - y_p\right)$$

where $C = \dfrac{1}{\left(x_1 - x_2\right)\cdot\left(x_k - x_p\right)\cdot\left(y_1 - y_2\right)}$

x_p, y_p - Coordinates of the beginning of the probing line,

x_k, y_k - The coordinates of the end of the probing line,

x_d - Coordinate of the beginning of probing line for the local fragment

x_u - Coordinates of the end of probing line for this local fragment.

Using (15) - (18) we can find the coefficients of spline area (field). Having grouped obtained coefficients we can form the planning matrix. Thus, equation (9) can be represented in the matrix form

$$U = PA, \quad (19)$$

where A - the value in the nodes of the grid,

P - planning matrix.

The P - matrix has specifically attenuated form. Dimensions of the matrix are 8×25.

Number of rows of the planning matrix always equals the number of probing beams. Having written this matrix, we have the algorithm for the numerical solution of the direct tomographic problem for bilinear splines.

The algorithm for solving of direct tomographic problem is the following:

1. Set the grid area:

$x_1, x_2 \ldots x_i \ldots x_I$;

$y_1, y_2 \ldots y_j \ldots y_J$.

2. Set the value at the nodes of the area:

$A = a_{11}, a_{12}, \ldots a_{IJ}$.

3. Set the coordinates of the emitters and receivers.

4. Determine the probing beams.

5. Calculate the spline parameters for local rectangular areas passed through by the beam. Repeat the action for all probing beams.

6. Reduce similar coefficients and create a planning matrix.

7. Calculate the values at the nodes of the area.

This algorithm is implemented in MatLab programming environment.

To verify the obtained calculation expressions the numerical solution of the direct tomographic problem in MathCad has been done.

The exact values of the received signal along the beam were calculated as the numerical solution of the integral

$$u = \int w(x, L(x))dx \tag{20}$$

The value of the integral for each beam equals

(21)

$$I = \begin{bmatrix} 0.011 \\ 0.234 \\ 0.707 \\ 1.046 \\ 1.11 \\ 1.062 \\ 1.611 \\ 0.66 \end{bmatrix}$$

Using formulas (10) - (18) we can calculate the value of the signal at each of the receivers. In this case the value of the signal along the beam is the sum of local integrals for each of the local areas. We obtain the following values:

$$\tilde{I} = \begin{bmatrix} 0.026 \\ 0.244 \\ 0.652 \\ 0.983 \\ 1.105 \\ 1.394 \\ 1.347 \\ 0.496 \end{bmatrix} \tag{22}$$

Let us estimate the measure of inaccuracy and show the result as a percentage rating

$$\delta = \frac{I}{\Delta I} \cdot 100\% \approx \begin{bmatrix} 142\% \\ 4.4\% \\ 7.7\% \\ 6\% \\ 0.5\% \\ 31\% \\ 16\% \\ 24.8\% \end{bmatrix}, \qquad (23)$$

where $\Delta I = I - \tilde{I}$.

As can be seen from (23), some values have significant inaccuracy (error). To reduce the inaccuracy we have to increase the number of fragments.

Numerical solution in MathCad along the probing line with approximated spline by the formula (8) demonstrated the values at the receivers that are consistent with $\tilde{I}$ (22) calculated according to the obtained expressions (10) - (18).

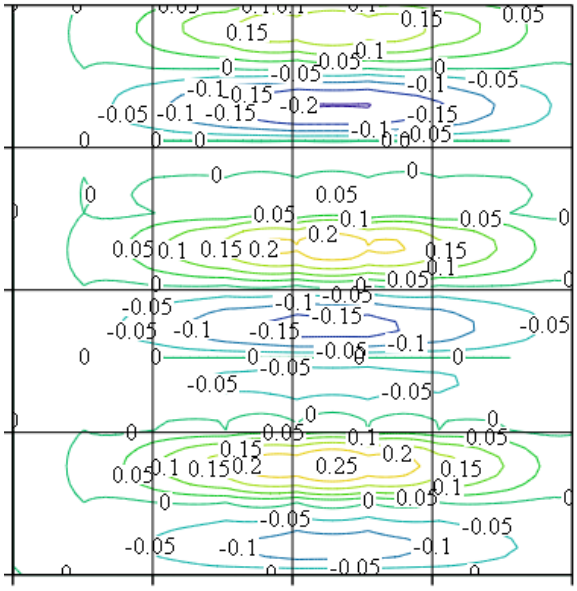

Figure. 5. Spline approximation inaccuracy

Conclusions. 1. Estimated expressions for a given tomographic probing scheme with approximation of the field by bilinear spline have been obtained.

2. Fidelity of calculated expressions for the received signals has been verified by comparing the analytical and numerical calculations, which coincided with high accuracy.

3. The basic inaccuracy (error) when solving direct tomographic probing has been caused by the approximation inaccuracy of the real field by bilinear spline. Inaccuracy reduction is achieved by increasing the number of spline fragments.

4. The obtained expressions for solving of direct tomographic problem are the basis for further solving of inverse tomographic problem.

Prospects for research in this area is the development of computational

expressions for further solution of inverse tomographic problem.

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O.M. PECHORIN,
Junior scientific assistant of theAirborne Forces and Special Operations Forces Department
The National University of Defence of Ukraine named after Ivan Chernyakhovskyj, Kyiv

THE VIEWS OF THE MILITARY EXPERTS OF LEADING WORLD COUNTRIES ON THE EMPLOYMENT OF AIRBORNE (AIRMOBILE) FORCES IN PRESENT CIRCUMSTANCES

Formulation of the problem in general. The events of recent decades in the military-political situation, the emergence of new weapon, special and military equipment make it necessary to clarify officially accepted views on the character and methods for conducting of modern operations and respectively the formation of new approaches to the use of airborne (airmobile) troops which remain to be a major mean in the implementation of the concept of deep coverage of the enemy during carring out of the operations.

Analysis of foreign publishing house devoted to consideration of the issues of reform and development of airborne (airmobile) forces [1,2,3] indicates that at this time the Armed Forces of leading countries of the world have well-equipped airborne (airmobile) forces and their military experts predicting the character of warfare in operations involving of their wide employment.

Illustrative example of this is the war in the Persian Gulf in 1991. In conformity with to the level of armament and military equipment during the period of the war were demonstrated the efficiency and perspectiveof employmentof vertical coverage of enemy and establishment of active, an assertivestanding behind the enemy front, which allow to use the results of fire impacts and facilitate to advancing troops in defeat of enemywhich defend.

The purpose of the article is the fact that by analyzing of open sources to research the views of military experts of the world leading contries on the employment of airborne (airmobile) forces, based on the order of itsemploymentin war (armed conflict) of last decades.

The main material research paper. Under the statute FM 90-26 Airborne Operations [4] (Action of airborne troops) airborne operationsare an integral part of operations of ground forces, which are conductedwith the aim to transfer by air to the area of landing troops and means of logistics provision in order to ensure carring out of tactical and operational - strategic tasks.

According to the views of command of block NATO employment of aircraft landings allows the joint operational formationstoaccomplish significant influence on the course of actions and on carring out the tasks.

Airborne compounds are designated for close combat with the enemy. The purpose of their actions is to destroy the enemy, withdrawal of the ranks of basic elementsof infrastructure and the implementation of moral and psychological impact on the enemy.

Airborne formations are planned to implement strategic, operational and tactical tasks in any point of the world by landing (airborne landing). Support of their actions are carried be the Air Force (AF) and includes: air transportation (transference); combat with the enemy aircraft (including the Army Air Corps); close air support; conducting of tactical air reconnaissance; isolation of the battle area from the air; carring out of special air operations; radio electronic warfare and air raid precautions defense of the enemy.

The main advantages of airborne operations, military experts of the world leading countries include: a variety of responses to given tasks; independence of geographical conditions; suddenness of action; ability to conduct long-term airborne units fighting.

The task which are carried out by airborne troops can be divided into: tactical, operational and strategic.

Tactical tasks are usually conduct by the assault operations, the implementation of the vertical coverage in order to isolate the battle area. Airborne units attackthe determined objects and put forward to meet with their advancing troops. Usually only assault echelon carries out landing parachute method on an object of admiration.

Operational missions can be solved on any theater of operations, which has operational significance. For example, entrancement of airfields, bridges, passes of other objects in depth of the enemy's defense. Such actions are usually short-term and require interaction with other forces and means. The example of carring out of operational tasks is Arnemsk airborne operation, conducted by the allies in the autumn of 1944 in the Netherlands against German troops.

The decisionof strategic tasks are carried out by demonstration of force that belongs more to the military policy. Airborne forces have the opportunity to make a short term redeployment from remote locations deployment to attack important facilities in the heart of enemy-occupied territory. Examples of strategic objective operation may be operation "Just Cause», held in Panama, 20-23 December 1989.

Considering the practice of aircraft landings in the Persian Gulf and in local wars and also armed conflicts of an earlier period (Arab -Israeli War (1956-2006); Great Britain against Argentina in the Falkland Islands (1982.) USA against Grenada (1983.), Nicaragua (1985.), Panama (1998.), invasion on the Comoros and Seychelles), it should be noted that in most cases the troops were reinforced by battalion of airborne to (landing and assault) brigade. Means of strengthening and support for them were determined according to the character of the fighting.

The following basic principles of aircraft landing according to the views of leading military experts of the worldare :

- air landings can be made in areas that are poorly preparedby enemy in engineering relation;
- in case of necessity to capture objects on the ground, prepared to defend by the enemy in landing area it is necessary to conduct pre-fire training;
- air landings have not tobe used for performing the tasks that can be performed by other troops or weapons;

- one of the most important conditions of the airborne operations are complete domination in the air;

- preparation of airborne operations must be carried out covertly and acomplished suddenly, as quickly as possible.

Another area of application of airborne (airmobile) troopsis conducting of airborne operations.

According to the statute FM 71-100-3 Air Assault Operations (air assault formations action) [5] airborne operation includes transfer of assault troops by air landing (combat and logistics) and their joint activities with staff units and divisions of the army aviation.

Airborne operations can be carried out both in attack and in defense and in the conduct of special operations. They are designed for operational-tactical and tactical assignments in the interests of arms formations and units. These operations are carried out by the decision of the corps commanders, divisions and brigades, which have in their command the Airborne units and elements, necessary staff and addedelements of the Army Aviation.

Airborne troops are able to perform successfully tasks in areas where enemy action are suppressed by the influence of high-precision weapons, acting on a broad front or in hard accessible areas and have a weak faction. As in the attack and in defense they are able to solve various problems. Their actions should contribute the main forces to defeat or completing the defeat of the enemy and capturing of important areas in operational and tactically relation. They are also involved in reconnaissance, solving the conservation and cover their troops, and the width of defense of airborne division can be up to 100 km. Units and elements of the Airborne Forces may destroy the enemy tank groups, such as units of combat helicopters of the 101st air assault division and the 82th Airborne Division of United States Army have shown its effectiveness in destroying of manpower and armoured objects of appropriate reserves of the Iraqi troops (one combat helicopter destroyed 2-3 tanks during flight). Airborne forces can be used for false and demonstration actions in the conduct of hostilities in order to save other capabilities.

Units and elements which are determined for airborne operations are combined into temporary tactical airborne group (TTAg). These groups have no permanent staff, they depend on the particular case of a combat mission, enemy forces and the character of the terrain in the area of operations. TTAg may be brigade, battalion, companyin some cases even platoon. The basis of the land component are typically airborne (light infantry, mechanized infantry, paratroopers) brigades, battalions, companies. In the composition of groups can be incorporated units and elements reinforce and support (fire support, intelligence, engineering, communications, military police and rear). As the air component for the transfer of company released TTAg mouth battalion - a battalion, brigade - a group of army aviation. According to the views of the world leading countriesmilitary experts in the present conditions should be expected the use as company and battalion and brigade TTAg. It is possible to carry Airborne

operations by forces of airborne divisionin general, reinforced by army aviation and other capabilities and means of support and maintenance.

Airborne operations are conducted under a single management, with the first command authority that defines the general question of airmobile operations, combat missions, and necessary means and forces deadlines of performance are operational command headquarters or Army Corps.

Army Corps (which operates on the main line) can be dowry to air assault division or separate airborne brigade, as the air component to form TTAg - Army Aviation Brigade. Based on the available capabilities Army Corps can form a brigade TTAg corps subordinate battalion and one or two or three companyTTAg in mechanized (armored) divisions of the first echelon. If part of the body includes air assault division or separate airborne brigade, the number of TTAg will increase. TTAg which are involved in the operation of the Army Corps can be used consistently to perform multiple tasks, interact with each other on the objectives, time and place of the transaction.

Conclusions: Thus, military and political leadership of the leading countries of the world as to the plan of practical implementation of the concept of netcentral war from a position of strength pay special attention to the improvement of airborne (airmobile) forces as an important element of the destruction of the enemy in his rear, especially its second echelon (reserve) .

The works are conducted for implementationof this conceptin the following areas:

1. Alignment of organizational military unit airborne (airmobile) troops to the optimum, uniform default organization (eg in the USA).

2.It is planned to put into service new models of weaponry of modulartypeand unmanned aircrafts of different assignment including reconnaissance and attack aircrafts, as well as new models of field artillery, self-propelled mortars and helicopters.

3.New parachute systems, providing reliable and accurate landing of weapons and military equipment to the prepared area of limited size with an extremely low altitude - 100 meters are conducted.

4. Works on improving of the flexibility of logistics system are copnducted, by containeringof assault cargo, reducing of their weight characteristics, unification of ammunition, fuel-lubricant materialsand other means of support.

5. Improving of directions of operational training battalions, brigades, divisions and levels of combat training and units with the aim to achieve readiness to accomplish tasks in any form of physical and geographical conditions in various theater. The search of the best ways of combat battalion and brigade TTAg use in landing areas by increasing of their autonomy, protection from air strikes measures of precision weapons.

Further development of airborne (airmobile) troops are planned towards enhancing of their strategic and operational mobility, autonomy of action, increase of the capacity to combat with armoured objects and air targets during fulfillment of combat missions.

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Androshchuk A. S., Ivashkov U. B, Andrushko V. Z. **Neuro-fuzzy model for forecasting the intensity of checkpoints activity**

Organization of State border guard service of Ukraine operational activity involves forecasting the development of the situation on the border.

The main disadvantage of using classical approaches is one-dimensional initial data, which significantly reduces the accuracy of the forecast. Respective shortcomings can be addressed through the implementation of a multi-dimensional forecasting.

Structure of the model of artificial neuro-fuzzy network is given. This model comprises three layers of neurons. Number of inputs equal to the dimension of the state vector of the object. Elements of the first layer realize the functions of linguistic variables (eg – Gaussian function with parameters of the center and width of the Gaussian curve). The number of elements of the second layer corresponds to the number of fuzzy rules of the knowledge base; elements of the layer implement output function. The third layer implements the function of defuzzification. A «clear» initial value of the output variable is formed by at the output of the third layer.

The task network training is in such correction of fuzzy control module that the measure of the error given by the known expression was minimal.

According to the results of operational and service activity the rules and the intensity of passenger cars flows are set. Days of the week (weekends) must be encoded.

Work proposed model examined with a demo.

Technology ANFIS are used for training fuzzy inference system. Generation rules of forecasting fuzzy inference system Sugeno was conducted on the base of multilayer artificial neuro-fuzzy network using backpropagation algorithm (signal).

The presented structure of module fuzzy rule has a property that is not in the usual "fuzzy" systems − the ability to learn using artificial neural-fuzzy network and database precedents as training sample. At the same time, the network is not a «black box», its weight and parameters retain their physical interpretation that allows us to analyze new knowledge gained during training.

The results of comparative evaluation of the application of the statistical method (average smoothing), artificial multilayer feedforward neural network signal and the proposed network, which showed the last application preferences, have been presented.

Studies also show that it is necessary to conduct further analysis of all the possibilities of fuzzy models used to solve specific problems in a given subject area.

Keywords: *forecast, model, neuron network, coding.*

Androshchuk O. S., Onyshchuk S. V. **On the question predicting illegal activities in the areas of responsibility of guarding the state border crossing points outside**

Prediction of illegal activity is a key element of assessment of the situation and guarantees the adoption of appropriate and informed decisions during the

organization of operational activity of the State Border Guard Service of Ukraine. A good forecast is the key to solving such problems in the management of state border protection, as risk assessment, planning and so on.

Prediction of illegal activity outside crossing points is quite a challenge as statistical data on such violations much less than at the checkpoints, especially in areas that is not “active”. The complexity of this prediction is also driven by a large number of factors that affect the implementation of illegal activity. These factors include: the socio-economic situation in the border areas of Ukraine and neighbouring countries, the existence and extent of the difference in the prices of certain goods in Ukraine and neighbouring countries, employment borderland, a population density of border areas, the condition of access routes, cross-section depending on the season and weather conditions, presence and severity of liability (criminal, administrative, financial) for certain types of offenses, the state border surveillance and technical equipment condition area, both from Ukraine and from neighbouring states and others. Most of these factors are quite difficult to assess and describe. In addition, these factors may change, requiring a prediction of change. Prediction result of illegal activities and seized should answer the question: where, when , by whom, using what means may be an offense, the nature of the wrongful action, factors that have a significant impact on the illegal actions.

The work carried out an analysis of existing methods prediction of illegal activity on the state border crossing points outside. Based on the above analysis shows that currently available methods of prediction do not provide a comprehensive answer to the question: where, when, by whom, using what means may be an offense, the nature of the wrongful action, factors that have a significant impact on the illegal actions and therefore cannot be used for qualitative prediction illegal activities crossing points outside, which makes further research to improve the efficiency of decision-making on the protection of the state border on the basis of the application of the estimation method of illegal activity in the area of responsibility of the State Border Protection crossing points outside.

Keywords: *prediction of, illegal activities, state border.*

Demidchyk F. A., Sytnik O. V. **Troops and military equipment camouflage improvement**

The experience of local wars and armed conflicts confirms the important role of intelligence for troops activities, herewith its importance in task performance tends to grow. This is associated by a complex reconnaissance in several physical fields at the same time as well as by integration of various information sources on data medium and control chains. In addition, reconnaissance sources may include unmanned plains, strategic reconnaissance aircraft and air-space systems. In this case, tactical camouflage, which is a type of combat support, becomes more significant.

A number of works are dedicated to camouflage of troops and military equipment; they are also mentioned in the existing guidelines and textbooks. The analysis of these works, for all their value, show that the aforementioned issues

with the continuous development of reconnaissance means, are not adequately considered and require further studies.

Visibility of troops and military equipment is a set of differences that reflect and radiate its properties and background, which enables it to detect the troops and military equipment and aim its weapons. Accordingly, reduced visibility of troops and military equipment is a set of measures to change its radar and optical properties to reduce differences between properties of the troops and military equipment and the background.

Key measures to reduce visibility of ground troops and military equipment to protect from the aircraft should be carried out in the following wavelengths : optical- visual (visible) - 0.3 ... 0.8 microns infrared - 3 ... 5 ... 8 and 14 microns, the laser - 1.06 and 10.6 microns radar - 0.8...4.5 cm

To reduce visibility of objects in the optical-visual range, major efforts must be aimed at reducing the contrast between the object and the background.

Highly effective, visibility reducing method of optical-visual range should include various types of artificial elements that deform object contours: the bulwarks, anti- shadow screens, camouflage net masks (usually radio-absorbing). It is also effective to use improvised camouflage, such as brushwood, tree branches, shrubs, grass, cane, moss, hay, straw, turf, foliage, turf and etc.

Another common way to hide troops and military equipment in the area include the use of camouflage nets, which are used in the armies of many countries , the use of existing radio-absorbing camouflage coatings such as “Ternovyk”, MKP -L, MRPK , MKO combined with mats that absorb or disperse the heat, allows to camouflage troops and military equipment on set level from optical and infrared reconnaissance means and has protective radar quality in the wavelength range of 0.8 ... 17 cm; use of different foaming chemicals to hide troops and military equipment on the ground.

Currently, the infrared wavelength range main efforts are focused on reducing the temperature contrast of the object surface and their alignment with the background temperature. For this purpose , the following visibility reducing means of ground troops and military equipment such as “double roof ” over the engine compartment of armored vehicles, bulwarks of the rubber-cord elements over the chassis of the heated cupboards with various additives (including radar), which are quickly applied and easily washed , and insulating coating that is quickly removed.

With the radar wavelengths, the main effort is primarily aimed at reducing or changing the effective surface scattering from troops and military equipment. The main way to reduce visibility of ground troops and military equipment is to apply radio-absorbing coatings and materials, polymeric foams with quick- radar additives.

Important role in the protection of troops and military equipment is paid to smoke means that were lately developed by leading armies of the world. Thus, for setting smoke screens on tanks, infantry fighting vehicles and armored personnel carriers, the so-called smoke grenade are used that are mounted on the sides of the front part of the turret. Efficiency of the smokescreen is achieved by the successive rupture of grenades in the air at a distance of 25 m from the tank. As a result, high

temperature zones (thermal noise) are created that reduce the enemy infrared equipment effect.

When camouflaging troops and military equipment, it is recommended to use light masking tools - black-out device for headlights, tail and signal lights and sound masking tools - devices to hide tell-tale sound characteristics (engine, traffic, etc.).

The complex measures, when concealing troops and military equipment, should deceive the enemy by full use of simulating traps, high-accuracy models which have their own thermal and electromagnetic fields.

Keywords: *engineer reconnaissance , camouflage, imitation.*

Zhuk S. M. **Methods of determining the rational composition of personnel and means of the border division type "B" to perform operation and service tasks in forested mountainous terrain**

The need for efficient methods of determining the rational composition of personnel and means of the border division type "B" to perform operation and service tasks in forested mountainous terrain is connected with conditions of forested mountainous terrain (abrupt weather change during the day, presence of water obstacles, adverse areas, the possibility of rock falls, slope avalanches, landslides, sparcely populated area, poorly developed road network, carrying out seasonal work in the border zone and controlled border areas, etc.) that can both facilitate and hinder the actions of both the offenders and personnel of the border divisions in performing tasks of border protection. The rational composition of personnel and means of the border division type "B" performs operation and service tasks in forested mountainous terrain based on objective conditions for an adequate decision-making regarding the organization of service.

The question of rational structure determination of personnel and means of border division type "B" for accomplishing tasks of operation and service activities in forested mountainous terrain was not been considered in detail, and the existing methods developed for the conditions of security and protection of the USSR state border under the present conditions are ineffective. In connection to the mentioned, the aim of the article is to present the methodology and algorithm for determining the rational structure of personnel and means of the border division type "B" for the operation and service tasks accomplishment in forested mountainous terrain.

The algorithm and the method of determining the rational structure of personnel and means of the Border Service Division type "B" for performing of operational-service tasks in forested mountainous terrain, provide an opportunity to organize timely and adequate prevention of unlawful activity on the state border in the forested mountainous terrain with the least adequate personnel and means of the border divisions for carrying out actions under conditions of forested mountainous terrain, therefore the proposed methods allow to determine the optimal composition of the border division (in terms of strength and technical means of border protection) to carry out functions and tasks of the border division.

Keywords: *the border division type "B", personnel and means, forested mountainous terrain, border detail.*

Zhuravel V. G. **The methodical bases of estimation of efficiency of modeling of operationally-official activity of the state border protection units**

System and complex character of modeling, its wide usage in the practical and scientific spheres of society"s activities testifies about practicability of learning of frames of the modeling usage method and those possibilities which modeling gives for increasing of efficiency of researches including the frontier sphere of activity. The permanent changes of internal and external factors of influence on the state border situation require permanent revision of existent models of operationally-official activity, its specification, development of new and more effective for management providing tasks.

It is necessary to have perfect knowledge of laws and regularities for the estimation of influence on selected model on the object management condition, that are shown up in the border sphere activity, sufficient volume of reliable information about situation, and also determination of dependence between factor and effective features.

Scientific developments of previous years testify on possibility of the use of simple mathematical models for the learning of the different phenomena. Some tasks can be made with the help of different models means, and then appears a problem of choice of the model, that provides more exact result, and is more comfortable in the use, needs less of calculations, or there is a necessity for development of model, that did not yet have analogues.

Researches with the use of already known models or with development of new can take different time and require the different expenses of labour and money. That is why there is a task in each of the marked cases on the estimation of expediency of model development, choice of alternative model among present, realization of analysis of efficiency undertaken investigation.

There are known scientific works, that is dedicated to investigation of examined problem is considered as basis for development of methodologies of estimation of efficiency of activity. However the estimation of efficiency in the marked works has complex approach and can be adopted for development of methodologies of estimation of efficiency of modeling of operationally-official activity for practical activity of border units.

The article puts methodical bases of estimation of efficiency of modeling of operationally-official activity of border protection units with taking into account the conditions of modeling, that have complex character and can be a base during development of new models of operationally-official activity.

Keywords: *border unit, modeling, operationally-official activity, modeling conditions.*

Kirilenko V. A. **Methods of information-analytical solutions provide a special comprehensive assessment tasks of combat and mobilization readiness of subordinate units**

Presented methodology to assess the combat and mobilization readiness of subordinate units based on an integrated use of information and analytical tools to bring it (ready) to the appropriate setting state.

Methodology is based on tools, that allow to estimate quality of information that enters control system at strategic level of management. For a decision marked in целее tasks, the indexes of degree of co-ordination of present and necessary information (are used size of cosine of corner between the vectors of present and necessary information, index of initial authenticity of information, in the moment of her receipt from a source and calculation chart of estimation of authenticity taking into account time passing from the moment of receipt of information.

Battle and mobilizational readiness of inferior subdivisions must conform to the directive requirements and provide possibility of implementation of tasks on the guard of border on the areas of responsibility of subdivisions in accordance with the expected volumes of tasks of operatively-official activity and other parameters of situation. Informatively is the analytical providing of decision of the special complex task of estimation of the state battle and mobilizational.

Keywords: *information and analytical support, the methodology of combat readiness.*

Kyrylenko V. A., Petrov V. M. **Integrated border management as a mechanism for effective border control in automobile checkpoints across the state border**

One of the tasks entrusted to the State Border Guard Service of Ukraine, is the task of border control and border crossing of persons, vehicles and goods. To perform a specified task at checkpoints across the state border is set strict time standards for review of documents and on public inspection of vehicles and cargo.

The concept of integrated border management involves coordination of the competent state authorities to ensure the security and transparency of the state border; protection of the state border crossing in the prescribed manner on the state border of persons, vehicles and goods, implementation of information and investigative operations, analysis of risks and the implementation of preventive measures; Proceedings subjects integrated border management activities to prevent, detect of cross-border crime; the creation of a control system for a four-entry and stay of foreigners and stateless persons in Ukraine; to ensure international, cross-border and inter-agency cooperation.

The main problems to be solved which aim concept of integrated border management are poor coordination activities of the integrated border management and the need for the development of standards and new approaches to integrated border management.

The deployment of new systems of border control of persons and vehicles, including biometric access control systems, system of joint control of neighboring countries, streamlining border traffic, increase operational component in the overall system of border and the creation of automated information systems and border surveillance systems require theoretical validity and development of practical, research-based projects and proposals.

The specificity of the tasks assigned to road checkpoints is that these units perform tasks for the protection of certain areas of the state border and carry out border control and border crossing of persons, vehicles, cargoes and other property across the border.

The tasks in a complex, dynamic, tense require timely, objective and reliable information and objective indicators for assessing the risks and threats to the security of the state border in the area of responsibility of the unit at the border area of responsibility which is road crossing.

Ukraine is actively taking measures to resettlement and rehabilitation of the state border, creating an integrated system of his Protection and border crossing of persons, vehicles and goods.

The subjects of the integrated border management is the Administration of the State Border Guard Service of Ukraine, Ministry of Income and Revenues, Ministry of Interior Affairs, Ministry of Foreign Affairs and other government bodies under the jurisdiction.

The Concept is the definition of the basic principles and directions of state policy in the field of integrated border management.

The State Border Guard Service of Ukraine as a subject of national security of Ukraine organizes its activities in accordance with the main directions of the state policy of Ukraine's national security.

Information component of integrated border management is one of the main components. This component can be implemented through the organization and implementation of the information system of integrated border management, the quality of which depends on the effectiveness of implementation of the tasks of border control, which must meet the prescriptive requirements and provide the ability to perform the tasks of state border protection in areas of responsibility units based on expected volumes problems. Information support to solve the problem of border control subordinate units aims to estimate the parameters and performance of current and future state of border control subordinate units provide estimates appropriate values of these parameters with the needs of the assigned tasks and possibilities for their support.

Keywords: *State Border Guard Service of Ukraine, information support system of integrated border management, highway checkpoints.*

Kuchinskiy S. A. **Analysis of modern destruction methods and techniques of emergency buildings**

This article is an attempt to analyze methods, techniques and task performance succession to destroy buildings (constructions) that are not suitable for further use.

It becomes actual today, when we often hear about emergency situations, caused by natural disasters, floods, earthquakes, landslides, soil failures in Zakarpattya, Donetsk, Dnepropetrovsk and other regions, to search and bring to perfection elimination methods and techniques of natural disasters, namely destruction of unsuitable for further use buildings (constructions).

It’s worth underlining that an obstruction appears if the building is considered to be of high or complete destruction degree. Heavy destruction implies half obstruction of the build. By external appearance, obstructions can be single-sided, double-sided, V-sided or flat.

Depending on the obstruction appearance and form and material the building was built, there are several techniques to break down build ings and constructions. The choice depends on construction complexity, its sizes and other factors.

It’s worth mentioning that breakdown techniques include manual, aided, mechanical, explosive, electro-hydraulic, thermal and combined.

We’d like to emphasize that explosive type means compressed breakdown terms, complete destruction of buildings, simultaneous move of a large mass of building materials, brief explosive impact on the structure. The explosive destruction technique of dangerous structures is applied mainly to breakdown high buildings such as towers and pipes, concrete and reinforced concrete constructions, monolithic constructions, small but massive structures.

It is necessary to mark that explosive technique enables to achieve complete or partial breakdown of buildings.

Based on analysis of destruction methods and techniques of buildings (constructions) that are not suitable for further use, it’s worth to summarize that breakdown planning inventory includes the construction height, structural features, material, presence of utility lines and etc.; destruction of buildings by an explosion remains productive, rapid and inexpensive method. It should be noted that breakdown of buildings, constructions and their parts can be executed only by experienced specialists.

Keywords: *destruction, liquidation, destruction methods.*

Mentus I. E. **Definition of main specifications for non-contact explosives**

Based on non-contact charges, efficiency analysis of calculation, correlations are resulted which allow to calculate the explosive charge weight more accurately to destroy a construction support.

While liquidating consequences of building destruction the situations occur when there is no time to prepare the object for blast or it is impossible to apply non-contact or contact charges due to a risk of sudden breakage; that is why it is required to apply non-contact charges. As for calculation of non-contact charges, all building materials should be divided into three groups: fragile, ductile and composite materials.

Fragile materials are timber, concrete, stone, stone and other materials with the diagram of “effort - deformation” practically remain linear up to destruction. Recommendations are given as to main specifications of non-contact explosive charges to destroy wooden bridge supports.

Such materials as steel, aluminium and magnesium alloys, copper, brass and other materials are used in large amount in modern constructions which have a non-linear “effort-deformation” diagram and it can have a fluidity limit – physical or conditional. They are ductile materials.

There is no need to split constructions or their elements of such materials by means of non-contact charges, as charges are large and inconvenient for practical application. In some cases, constructions of ductile materials can be blasted and without split of elements, it is enough to deform support elements by blast so that they loose firmness or are removed from supports. Reinforced concrete is the most widespread composite material. In such materials an armature is protected from explosion, tense is passed through a massive layer of fragile concrete, capacity of which is increased by an armature that is why constructions elements can not be split even by explosion. Non-contact explosion of reinforce-concrete element supposes knockout of concrete and uncovering of steel. No split is supposed for compressing or bending elements to be blasted. To destroy damaged reinforce-concrete bridges, such form of destruction of support elements are even prevalent, as after their bringing down in a bridge wasp there remain non-split elements and uncomfortable to move away elements, thus bound, strongly deformed steel blocks of ruined constructions which are impossible to move away and split into pieces. Thus, destruction of a bridge applying this technique we create more complicated conditions to renew it by the enemy. Recommendations are given as for determination of basic descriptions of non-contact explosives to destroy bridge supports.

Keywords: *explosives, non-contact charge, bridge support.*

Mentus I. E., Krechko N. V. **Prospective directions of mining mean development of the leading armies of the world**

Intensive works are constantly conducted in the armies of the leading world states to design new and to modernize present mining means including remote mining systems with modern mines. Application of explosive obstacles in combat remains one of the main engineer support tasks that can paralyze (limit) maneuvering of troops, hamper their movement, and inflict losses to manpower and military equipment. Increase of explosive weapons role becomes possible due to perfection of both mines and tools and their installation technique.

The article regards views of combat engineering experts of the leading countries of the world on mining and mine obstacles development.

Resulting from the experience of the armed conflicts, requirements are raised as to modern mines. One of them assumes installation of mines without a combat engineer that means self-arming; rapid delivery of mines to the area prior the enemy can get their; a mine must be installed only there and when it is needed and engagement of an expert is not required; a mine must be self-destructive if gets useless; the main task of a mine is to stop or detain the enemy.

When analyzing experience of different intensity armed conflicts and modern mining development of leading states armies of the world, prospective directions of their development are defined that follow: perfection and further development of remote mining equipment as an effective weapon to fight against enemy manpower and military equipment; enhancement of arms and branches as to remote mining equipment when applying cassette mines to the wing-rockets, cassette type guided drop bombs; further development of high effective anti-tank

mines that can destroy the side armour of heavy tracked and wheeled machines at a distance of 100-150 m; efficiency increase of new mines due to application of directional charges and use of electronic (contact and non-contact) detonators with anti-lifting elements and application time; development and applications of robots to conduct search, identification and elimination of an object; a necessity to mines load in units that stipulates the increase of troops resources to organize obstacles and high effectiveness of new mining means.

Analysis of promising directions of mining means development of the armies of the leading countries gives the opportunity to improve the organization of the effective engineering support to overcome mine obstacles in modern combat operations of divisions.

Keywords: *explosive obstacles, mining equipment, remote mining systems.*

Mihaylenko A. V. **Methodology of criminal analysis illegal activity implementation on the area of responsibility of state border guard unit**

The methodology of logic fuzzy inference regarding the usage of criminal analysis of state border sector for illegal activity has been developed and experimentally checked. Formulation of the mathematical problem of criminal analysis was carried out in a non-linear estimation of object with multiple input variables and one output variable. The output variable is an indicator of the degree of possibility of use of sector for the offense in the security of the state border.

Considering the decision on the basis of criminal analysis occurs in circumstances where: events do not occur with sufficient frequency, most features are qualitative and serves natural language descriptions, and their assessment is based on vague opinions and estimates of experts, information on the basic parameters is incomplete and fuzzy, etc., − the use of probabilistic methods is impossible.

One of the promising areas of modern high technology is a fuzzy modeling, due to the trend of increasing complexity and formal mathematical models of physical systems and processes related to the desire to improve their adequacy and consider a set of different factors that influence the decision-making processes.

Stages of decision support methodology on the tasks of criminal analysis based on fuzzy logic.

1. Determination of linguistic variables. A set of individual indicators of generalized groups are formed. Factors in each group, which are essential for criminal analysis in specific areas of the State Border Guard Service of Ukraine are identified.

2. Characterization of (value) parameters. Parameter estimation provides direct expert or an automated system for statistics. In the second case, the variable is on the frequency of its occurrence in the previous cases.

3. Building a framework of rules (knowledge base). When filling the knowledge base in the process of building, different sources of knowledge are used: professional experts, database, commands (instructions), data on the decisions recorded in official databases and unstructured documents.

4. Configuring model fuzzy inference. Parameters of functions of terms and weights of fuzzy rules are adjusted the in fuzzy models. Active learning model to existing statistical material and the quality of inference significantly increased.

Applying this technique unlike existing allows: usage of quality indicators, taking into account inaccurate, approximate information about the importance of attributes, using the knowledge of experts − experts who served in the form of fuzzy inference rules, more qualitative assessment of the object under study in criminal analysis.

Keywords: *model, fuzzy inference, crime analysis, crime on the border.*

Pechorin O. M. **The views of the military experts of leading world countries on the use of airborne forces in modern conditions**

Based on the analysis of local wars and armed conflicts of recent decades the views of the military experts of leading world countries concerning the use of airborne forces during current operation have been revealed; also main issues of further reformations and approaches to their application have been described.

It has been established that the military and political authorities of leading world countries within the frames of the practical realization plan of concept of network-centric war from the position of strength pay considerable attention to improvement of airborne forces as an integral element of destruction of enemy in the rear and, primarily, its reserves. In order to realize this concept a range of works are conducted according to the following directions: arrangement of organizational and staff structure of military units of airborne forces to optimal, unified typical organization (for example, the USA); elaboration of new parachute systems maintaining reliable and accurate landing of armament and military equipment on specially prepared sites of limited size from boundary low height – up to 100 meters; works on improvement of flexibility of system of combat service support due to containerization of landing parties loads, decreasing its weight characteristics, unification of armament, combustible and lubrication materials and other support means; increasing of directions of operation training of headquarters of battalions, brigades, divisions and level of combat training of units and subunits with the purpose of achievement of readiness to accomplishment of tasks in any physical and geographical conditions using different turboprop engines.

Keywords: *air assault, airborne operation, vertical coverage*.

Rozum I. Yo. **Ways and directions of development of communication and automation control in the interests of military control**

As the experience of local wars and armed conflicts to achieve the goal of fighting combined arms units is directly dependent on effective management. Modern military operations are characterized qualitatively new parameters, which in turn places new demands of the military administration and the process of its implementation. Recently, the typical trend observed increase in the role of military communications as technical foundations of military administration, the implementation of the combat capabilities of military units during combat missions. Above, hence the need to elucidate the functioning of communication

systems at the tactical level in accordance with the reform and development units of the Armed Forces of Ukraine for the coming years. Therefore, the order of the Minister of Defense and Chief of the General Staff of the Armed Forces of Ukraine paid special attention to the need to find ways to improve management units (units) during the conduct of hostilities and the elucidation of improving communications, military, especially the tactical level of management.

The main routes and areas of communications and automation control tactical level in the interests of military control arms parts considered: ensuring their readiness to perform tasks, stability, mobility, capacity and protection-exploration; compatible with the telecommunications networks state telecommunications networks of other power structures of ministries and agencies, military units of NATO during common tasks; integration of all types of communications and automation of basic processes of information exchange and management; integration of several functions in one unit maintenance ; unification and standardization of means and systems of communication; introduction of advanced cryptographic protection of information; development of new frequency bands.

In further research is necessary on the basis of theoretical analysis to justify the application of innovative approaches to elements of information and telecommunication nodes in terms of their role and place in the overall process of information exchange in the coming years.

Keywords: *system of military command and control system of military communications, military communications network, the latest information technology.*

Servatyuk V.M., Naumov, V.I., Shvets, O.M. **Particular directions of reforming of highly mobile airborne troops of the Armed Forces of Ukraine**

Particular directions of reforming of highly mobile airborne troops of the Armed Forces of Ukraine have been described on the basis of analysis of development of airborne (helicopter-mobile units and units of special designation) forces of the armies of leading world countries.

The results of analysis of development of airborne (helicopter-mobile units and units of special designation) forces of the armies of leading world countries allow us to affirm that in modern conditions main efforts for their further development must be directed towards solving of complex of tasks concerning optimization of organizational and staff structure, development of forms and means of implementation, forms and methods of training and technical re-equipment.

Considering leading experience of development of airborne (helicopter-mobile units and units of special designation) forces of the armies of leading world countries regarding their organizational structure, forms and means of implementation, directions of technical re-equipment, enhancing of combat (operation) capabilities, its analysis and creative application allow to accomplish gradual transition to modern highly mobile airborne forces and the Armed Forces of Ukraine as well. Besides, it will allow to enhance considerable the level of operation (combat) capabilities and prevent form significant losses of financial and

material resources. From authors' point of view, the essence and content of determined directions of development of highly mobile airborne forces are topical, urgent and the most important problems for the Armed Forces of Ukraine at the stage of their reformation.

Keywords: *highly mobile airborne troops, airborne troops, special operations forces, landing operation, parachute systems.*

Sytnik O. V., Gerasimenko A. G. **Technical evaluation of engineer protection effectiveness of the bridge crossing and high-precision equipment (HPE) countermeasures**

The concept of air-ground operations and wide application of HPE by the enemy has a meaningful impact on organization and survivability of bridge crossings. Surveillance-assault and fire-reconnaissance systems counteraction (SAS, FRS), active or passive, is an important bridge crossing functioning measure. As a rule, active counteractions include: air defense cover of crossings, radio-electronic suppression of SAS and FRS by electronic warfare forces. Passive countermeasures include camouflage of crossings, bridge cross-section dispersal, thermal difference reduction of the crossing equipment, installation of thermal and radar targets, organization of flat-bed camouflage and imitation crossing sites. These engineering activities and means are of particular importance during the reconnaissance and homing of weapons.

Several research works are dedicated to engineering camouflage and included into guidelines and textbooks. Analysis of these works shows that the existing methods were intended to evaluate the effectiveness of engineer support tasks. Evaluating the effectiveness of engineer camouflaging tasks was performed by evaluation through the group object method with the operational and tactical coefficient of bridge crossing. Object protection issues were estimated as a passive protection method. There wasn't any assessment of engineer concealment and imitation measures and technical equipment for bridge crossings and countermeasures of current surveillance and destruction.

The attained experience in armed conflicts of various levels shows that protection of bridge crossings requires water and spray, foam and sprays screens, laser illumination of a false bridge. Integrated use of these means can contribute to 15 % bridge crossing defense.

Use of engineering ammunition, such as MON-90 and anti-helicopter mines (AHM), may be the main comprehensive approach to counter act the technical intelligence and destruction of HPE systems. Application of engineering ammunition to defend and counteract is estimated by the following rates: the probable HPE systems deviation from the bridge crossing in the final flight trajectory is assessed by laser reflectors , and for countermeasure – probable destruction of HPE systems on the final trajectory by the engineering ammunition.

Effectiveness countermeasure assessment is based on the integrated use of modern research methods, including mathematical modeling and others. Performance indicators, which are determined by enemy HPE systems use

patterns; the quantitatively defines the extent compliance with the operation tasks results.

Calculation of engineering and tactical ammunition use by complex fire to destroy HPE systems, which is the main means to fight them, involves air defense, electronic warfare and engineering ammunition. According to guidelines and implementation of engineering and tactical units by formulas (11–18), contribution of engineer ammunition to fire destruction of sub-munitions is 7...9 % [8]. In the future, to reduce destructions by missiles, bombs and sub-munitions, special engineer mines may be used which are based on new physical principles and can increase the contribution of engineer troops in defense of the bridge crossings.

Keywords: *engineer reconnaissance, camouflage, imitation, fighting of HPE systems, bridge crossing.*

Bashynskyi A. K., Ostashevskyi S. A. **Analysis of mechanism of state regulation of road safety**

The article touches upon the analysis of efficiency of the mechanism of state regulation of safe conditions for all traffic participants with regards to technical control of transport means and ensuring of their safety for traffic participants. In the process of analysis of a wide range of legislation acts concerning the problem being studied the main attention is drawn towards to principles of automobile transport organization and activity, requirements to construction and technical state of vehicles, procedure of their technical control, testing and certification. Also the article deals with general orientation of state regulation and control within the sphere of automobile transport towards ensuring of qualitative and safe vehicle functioning, development of constant improvement of existing normative basis of transport activity. One of the ways of the present state regulation system is standardization and certification of vehicles.

It has been admitted that in the process of examination of vehicles technical state the main attention is drawn towards estimation of state of passive safety elements of vehicles, and little attention is paid to checking of active safety elements and only some of them are controlled. Checking of steadfastness as a component active safety element of vehicle is not done, at the same time reliability of estimation of this vehicle parameter by a driver does not directly influence safety of maneuvering on the driveway.

As a proof of necessity of this parameter checking the article reveals the comparative statistics of ratio of general quantity of road accidents to quantity of road accidents happened as a result of maneuvering rules violation; correlation of these two indices makes up 44%.

The analysis of existing in Ukraine methods of studying of vehicle principal parameters showed that the present technique disregards requirements of current society. Today it is not considered that modern vehicles have significant power reserve to realize high vehicle speed while maneuvering. According to statistics it often becomes the most frequent reason of side roll-over that is known to be major road accident with damaging consequences. In this case there is a necessity of consideration of coordinates change in time at transverse inclines as single vehicle

as their groups at transverse inclines and on turn. This problem becomes especially topical in the process of estimation of steadfastness of road-trains designed for transporting of heavy and properly sized loads, poured and fluid cargo. Particularly, during movement of vehicle through ragged territory we do not consider displacement of poured and fluid cargo towards transverse force effect, change of placement of spring and non-spring weights that causes, in turn, decrease of transverse angle of transport means roll-over regarding appropriate indices indicated in the vehicle technical characteristic. That's exactly why all existing methods and dependencies of estimation of vehicle steadfastness demand further research of influence of masses center coordinates change upon vehicle steadfastness on side inclines; and we emphasize that it is one of the main tasks of automobile transport standardization. Also we determine the prospects for improvement of methods of estimation and control of

indices of static transverse steadfastness of vehicle with changing masses center.

Keywords: *automobile transport, road safety, steadfastness of vehicles, state regulation, standardization, certification.*

O. V. Borovik, L. V. Borovik **Applied Mathematical models of some problems of the operational activities of the border and the software implementation of the method of study**

The importance of search postulated that its solution worked out mathematical support tactical calculations. In the framework of theoretical foundations of the search parameters for its effectiveness, as well as methods of calculating the number of personnel it is needed to conduct the search and analysis of the degree of influence of environment factors on search performance. The above allows us to solve a large number of tasks for evaluating the effectiveness of search, namely likelihood detection of offenders, identifying areas of search area, the definition of the search area of the district in which the predetermined probability of detection, definition search, which provides the desired probability of detection, identification number of personnel necessary to conduct the search in a given area or provide a given probability of detecting offenders, determine the velocity of the search group for identifying offenders with a given probability.

However, despite the available mathematical software problem on purpose as part of special events has not been fully processed. According to this, the authors believe that important formalization process of appointment of personnel of border guard units during the formation of block search area based on time parameters and study the corresponding mathematical models from the standpoint of automation of the analysis and obtain operational decisions.

The relevance of the specified problems led to relevant research within this paper. Based on the results justified the mathematical model of decision support system for optimizing the building block area search offenders state border and reasonable conclusion about expediency added into the database management system model of an automated system to support making decisions of the State

Border Guard Service of Ukraine these models elaborated by the authors and software application solutions binds transportation problems.

Keywords: *search, mathematical model, assignment problem, transport problem, a software application.*

O. V. Borovik, M. M. Darmoroz **Current approaches to ensure adequate effectiveness of the operation of means of border protection as a complex engineering systems**

Theoretical and experimental studies of technical security of the border and on improving their operating systems through the use of new principles and technical solutions are important as this component is important enough in the system to ensure the effectiveness of state border protection in general. Therefore, considerable attention was given to a similar issue in a numbers of scientific papers. However, despite this, the formulated problems are not yet fully solved. And the authors believe this is due to the fact that structural and functional components of the operation were considered in isolation from each other.

It should be noted that the idea of the study of the operation of technical systems based on an integrated consideration of structural and functional components is not new. In particular, the system of operation of radar equipment of Border Troops of Ukraine studied as two-ply structure whose elements are the object of exploitation and modes of operation. On the basis of set theory process of operation of radar equipment was formalized. Done formal description revealed the essence of the interaction of elements of two-ply structure and systematize the process of functioning radar. However, questions remain unnoticed Consideration of formalizing the process of operation of other types of means of border protection (eg, systems for modern base) and how to ensure sufficient efficiency of their operation.

That is why the authors of the work paid attention to the study of approaches to ensure adequate effectiveness of the operation of means of border protection as complex technical systems.

The paper analyzes existing approaches to evaluate the effectiveness of the operation of complex technical systems identified key positions that are fundamental to account for the objective evaluation of the effectiveness of the systems , by posing the problem of structural and functional parameters optimization of operation, the algorithm provide sufficient efficiency systems.

Keywords: *complex technical system, operating system, efficiency, structural optimization, functional optimization*.

Borovyk O. V., Traskovetska L. M., Stopen G. J. **Static thermoelastic fields in solid multicomponent cylindrical and anisotropic plate**

Nowadays the development and improvement of the production closely deals with the wide usage of the composite materials in various types of technological processes, construction, radio electronics, atomic power engineering, space engineering. During the strength calculations of the parts of machines and mechanisms, heating devices and in many technical problems it is necessary to

determine the temperature fields and evoked by them elastic tensions in piecewise-uniform bodies which are composed of several materials and have different physical and mechanical characteristics.

The actuality of the researching of the boundary problems for the equations of the thermal conductivity of the parabolic type is explained by its physical appliance in the modeling of such processes as heat conduction in non-uniform environments, burning process in rocket engines with solid fuel, during the researching of the problems of atomic power engineering and safety of nuclear reactors. This problem is so important due to the wide usage of composite materials which are the non-uniform (piecewise-uniform) thin shell elements of the parts. The problems of heat conduction (stationary and non-stationary) were researched for the isotropic and for the piecewise-uniform isotropic thin shell elements of the parts. In most cases it was assumed the presence of one surface of conjugation with ideal thermal contact and absence of the heat sources.

The solution and researching of the quasi-static and dynamic thermoelastic problems was provided both in classical and generalized thermomechanics only for the uniform objects.

Problems about the structure of stationary temperature field and structure of descendant static thermoelastic field at the most common assumptions according to the classical thermodynamics for the solid cylindrical anisotropic plate with *(n+1)* components are solved in the article. The solving of the problems is given in the closed form which is the most convenient for the usage in engineering calculations. The essential role belongs to the method of the Hankel finite integral transformation of the 1st order which was applied twice on the segment *[0,R]* with *n* points of conjugation.

The importance of the received results is that the analytical formulae which describe the solution of the problems can be algorithmized and can be used in engineering calculations within the suggested model.

Key words: *Hankel integral transformation of the 1st order; cylindrical and anisotropic plate, equation of heat conduction, boundary conditions, conditions of imperfect thermal contact, points of conjugation.*

Gerasymyuk O. V., Podolian O. Y., Kosminin I. V. **The analysis of connection of the quality of motor vehicle and its operation**

There are several definitions of quality. The ambiguity of interpretations related to the fact that quality – a complex concept that describes all aspects of the life cycle of the facility: design, production, maintenance, disposal, etc. Great attention is paid to the production stage , so the concept of quality is often associated with the concept of "quality products".

"Quality of product – a set of features and measure the usefulness of products that meet certain social and personal needs in accordance with its purpose."

The problem of assessing the quality of motor vehicle emerged since the creation of the first automobile. The assessment of individual properties of motor vehicle considered, starting from now .

Automotive vehicle can be characterized by an infinite multitude of properties, but practical interest is limited to their list, which includes ten to fifteen items. The main features include load or capacity, dynamics, efficiency, performance, reliability, sustainability, manageability , stability, flexibility, permeability, comfort.

Some properties are complex, ie contain a group of simpler properties. For example, dynamic includes: traction, speed and braking. In turn, the reliability combines reliability, durability, maintainability and survival.

Each property is characterized by one or more parameters that can take on different numerical values .

The technical condition of the car – a set of properties that change with its operation and maintenance, which is characterized by a certain time values of parameters and (or) quality characteristics established in the maintenance and repair documentation for the specific vehicle. Comparing the categories of quality and technical condition, it should be noted, first, their similarities, and second, narrower meaning, which invested in the concept of "technical condition".

Indicators of most of the properties are changed in the process (aging) of motor vehicle. Changing the parameters derived from the initial or nominal values to the maximum allowable limit or.

Rationing (Planning) resource consumption at the level of motor vehicle (fuel, tires, lubricants, etc.) produced by elaboration (run). At the same time, enterprise-level planning of material and labor resources, the need for technological equipment and production areas is carried out on time.

In addition, as noted above, the level of implementation of potential properties of motor vehicle depends on the operating conditions , which, in turn, change over time.

The existing system maintenance, planning methods need labor and material resources, methods of setting the cost of material resources into account these points enough.

Keywords: *quality, properties, motor vehicle.*

Holovko V. O. **Solving of direct tomographic problem by means of bilinear spline**

The article concerns solutions direct tomographic problem using bilinear spline. The methods, tools, algorithms for solving problems concerning acoustic tomographic imaging and the use of tomographic problems splines are described. The paper solved directly tomographic problem under the assumption that sensing area is bilinear spline on a rectangular grid. Using bilinear spline enables to obtain rather simple analytical expressions for the solution of direct tomographic problem. Order to solve tomographic important tasks was to assess the capabilities of the method, since the problems related to incorrect by Hadamard. The resulting solution of the direct problem of tomographic were later to assess accuracy of the solution of the inverse problem for accurate data. The algorithm, software and the results on numerical models were tested. An estimated expression for a given tomographic sensing scheme with bilinear spline approximation of the field is

explained. Fidelity calculated expressions for the received signals is tested by comparing the analytical and numerical calculations, which coincided with high accuracy, the basic error of solving the direct problem of tomographic error due to the approximation of the real field bilinear spline. Error reduction is achieved by increasing the number of fragments spline. The expressions for the solution of the direct problem of tomography is the basis for the further solution of the inverse tomographic problem. The practical significance of the results presented is to improve the accuracy of acoustic tomography problem solution under high noise level by two-dimensional spline approximation solution. Getting a cheap simple non-destructive investigation of heterogeneous bodies (eg, foundations, biological objects) in technical and medical diagnosis is analyzed.

Keywords: *direct tomographic problem, bilinear spline, analytical and numerous calculation.*

Golovnya S.B. **Development of recommendations on improvement of the process of estimation of mechanical availability level of border detachment vehicles**

Various vehicles are widely used in the border guard units to ensure timeliness and mobility of border details activities. Vehicles ability to carry out tasks concerning state border security is determined by the level of their mechanical availability. The process of management of vehicles mechanical availability level depends on adequacy of mechanical availability estimation with regards to ensurance of operation and service activities of border units. Currently, existing system of estimation of level of mechanical availability of vehicle of border detachment has a wide range of disadvantages and this fact does not allow us to talk about appropriateness of obtained results to real processes.

Disagreement between a need, being adequate to real conditions, for estimation of mechanical availability level of border detachment vehicles and incompleteness of existing instruments; also it defines topicality of conducted research.

The article concerns the analysis of existing approach to mechanical availability estimation of border detachment vehicles. The defects affecting estimation adequacy have been described. According to results of author’s analysis the recommendations on improvement of the estimation process on account of introduction of complex reliability index (technical application coefficient) and its further improvement with the purpose of considering exploitation specificity of border detachment vehicles. To ensure reverse connection between mechanical availability and expenses of vehicles maintenance a list of value indices was suggested that directly connected with components of technical application coefficient. Besides, in the research on the basis of analyzed indices the criterion of appropri ateness estimation of technical availability level of vehicles designated for carrying out of tasks of particular border detachment. Presented criterion will allow us to make correct management decisions that are effective for particular border detachment. Also it concerns ensurance of necessary level of mechanical availability in correspondence with border situation and financing conditions.

Obtained results may be used by specialists of the Scientific and Research Institute of the State Border Guard Service of Ukraine and the Automotive Equipment Supply Unit of the Department of Material and Technical Basis of the Administration of the State Border Guard Service of Ukraine in order to improve existing techniques of estimation of mechanical availability level of border detachment vehicles.

Keywords: *mechanical availability, vehicles, border detachment, estimation.*

Goroshko A.V., Royzman V. P. **Refined methods of statistical data processing**

Handling statistical data is an essential component to solving the problems of monitoring the state of border security, assessment and prediction of the sources and nature of the threats and challenges to national interests at the state border of Ukraine, development and study of the border agency, techniques calculation needs men and equipment necessary for the effective performance of assigned tasks, study methodologies to assess the efficiency of the management structures of the (sub) state border protection , reliability, technical means of protection of the state border, and others.

In contrast to the known method adopted by the authors propose to treat the data, suggesting that the observation made by “emissions” are those of the individual modes and distribution law really is not unimodal and polymodal.

The method is presented and processed empirical density distribution as a superposition of features unimodal density distribution (mixing) with the a priori probabilities (weights).

The authors propose a method based on decomposition of mixtures approximation of probability density by the method of least squares interpolation or some dotted-set.

The paper presents a method of processing refined empirical statistical data representing the distribution law as polymodal mixture unimodal laws. The method can reveal the internal structure of the data, taking into account possible polimodal law and their distribution, along with a reasonable selection step histogram gives the rules for dealing with such data.

In subsequent publications, the authors will describe the method for assigning confidence intervals for polymodal distribution laws and their practical application to determine the acceptable values of observational data.

Keywords: *statistical processing, distribution law, polymodal, the mixture distribution laws.*

Danyk Yu. H., Shestakov V. I., Chernyshuk S. V. **Approach to cyberthreats classification**

Nowadays cyberthreats became most dangerous for normal functioning of critical infrastructures of whole countries. Effectively counteraction to these threats demands deep analysis of their nature and systematization. Majority of modern researchers consider cyberthreats in context of information security or data

protection and don’t take into account peculiarities of management processes witch take place in information systems. But complex nature of cybernetic systems demands to consider such threats as threats to management processes. Purpose of this paper is to develop existing approaches to cyberthreats classification with regard to management process peculiarities in order to systematize existent in this subject area knowledge for their further appliance in cyberthreats modeling and development of methods and countermeasures for cyber security of citizens, society and whole country.

According to accepted definition of cyberthreats it’s suggested a set of their classification features witch determined by characteristics of certain cybernetic system and its elements; peculiarities of management, communication and information processing in such systems; properties of signals and information transmission medium (path); capabilities of threat sources. As result we succeessed to singularize following classification features: cybernetic system type; targeted system element; used for cyberthreat realization vulnerabilities of system or its elements; cyberthreat source placing; method of cyberthreat realization; cyberthreat transmission medium; premeditation; origination; occurrence repetition; hiding; dimensions of treats realization impact; management hierarchy; practicality of realization; time of occurrence; conditionally.

For suggested features noncrossing classes are determined and influence of cyberthreats categorization on determined classes to cybersecurity effectiveness is substantiated. All classes are summarized in general classification scheme for better understanding of their structure.

As result applied classification scheme makes it possible to describe each cyberthreat as a set of quantitative and quality characteristic, witch can be used for modeling and further identification of these threats.

Developed classification provide for possible addition and embranchment to subclasses for convenient determination of cyberthreats list for certain cybernetic system depending from level of necessary detalization. In order to demonstrate mentioned properties of suggested classification the possibility of its application for information and control systems is showed.

Suggested classification is not contradictory to existing one and consider complex nature of these threats. It’s based on most important for defense and counteraction features. Chosen features guarantee completeness and clarity of classification.

Developed classification scheme can be take as a basis for further researches in field of cyberthreats detection technologies in order to timely reaction to these threats and eliminate their escalation.

Because of constant transfiguration of modern cybernetic systems and modification of processes, witch take place in these systems, actuality of classification can be achieved only by permanent addition and revision which should be conducted on regular basis.

Keywords: *classification, cyberthreats, criterion of classification, counteraction.*

Yevdokhovych B.V. **Substantiation of methodological approach to sample evaluation and selection of thermal surveillance devices for state border protection**

Under modern conditions when the world market provides a wide range of new models of thermal imaging technology there is a need for solving the scientific problem to develop a methodological approach to the evaluation and selection of the best samples matching the "efficiency (quality) – cost" criterion. The results of solving this problem enable to provide the best selection of sample thermal imaging technology with tactical and technical characteristics that could potentially meet the requirements (which relate to the thermal imaging equipment) in order to effectively perform the tasks in a particular area of the state border and to avoid unreasonable resource expenditures.

Present conditions and prospects for threats and risks development on the State Border of Ukraine require continuous increasing of demands for the mathematical apparatus being used to substantiate the selection of complex technical systems for special purposes (CTSSP). This is due to the high cost of present modernization projects of CTSSP, costly resources for their execution (e.g., time and finances), high risk of making wrong decisions and serious consequences of them in the development and management of projects.

In order to solve the problems of comparative evaluation and selection of CTSSP being used at the manufacture, transport, in the military sphere, in the course of the state border protection, etc., the hierarchy analysis method (HAM) is often used. However, the use of HAM has several disadvantages, including the following: the complexity, the labor input for calculations, and the subjectivity of weighty coefficients definition for the indicators being compared.

In order to eliminate drawbacks of HAM the use of image processing method (IPM) has been proposed which is based on the model formation to compare alternatives for class ideal images ("ideal" alternative).

Based on this, the purpose of the article is to analyze the existing approaches and to substantiate the proposed methodological approach to evaluation and selection of sample thermal surveillance devices for border protection.

The algorithm to select samples of CTSSP based on the image processing method implemented in DSS NooTron has been offered which enables to solve the problem of classification, multicriterion and comparative analysis of alternatives and their selection. The main stages of the IPM algorithm include the formalization of the input and resulting variables, development of neural network; at this stage the substitution of improved pattern in the resulting function; the correction of the weight vector is carried out and the Chebyshev polynomials are computed; the alternatives are introduced into the resulting function for image recognition.

In order to test the proposed approach being based on IPM the task on selecting the best sample of the proposed thermal surveillance devices to use for protection of the state border in a specific area of responsibility of a border guard service department has been solved.

To confirm the results of calculations and compare the obtained variants being based IPM the calculation of this problem has been carried out using the

hierarchy analysis method. According to the results obtained by calculations the article concludes that it is possible to utilize the image processing method for comparative evaluation and selection of samples of thermal surveillance devices. The comparison of these methods with respect to their potential for solving selection problems has revealed their advantages and disadvantages.

The conclusions of the article substantiate the reliability of result obtained from the application of the image processing method for compara tive evaluation and sample selection of thermal surveillance devices and the feasibility to apply methods being considered in combination.

Keywords: *substantiation, thermal imaging technology, decision making, state border protection.*

Kryzhnyi A. V., Hurskyi T. H., Klimovich S. O. **The analysis of characteristics of radio communication systems with code division multiple access**

Modern telecommunication systems are widely using broadband signals. The main advantages of using them compared to narrowband are high anti-jammingness, low probability of the process of information transmission (high secrecy), increased security when transmitting data, the ability of digital processing of the received signals and code division multiple access scheme.

The advantages of broadband signals making them very attractive for use in special telecommunication systems of military organizations, reliable operation of which shall be provided in a complex radio-electronic environment, primarily due to the possible of jamming. Spreading of the signal's spectrum is performed in two main ways:

frequency hopping spread spectrum (FH), which involves changing the carrier frequency within a given band between individual frequency channels;

direct spread spectrum signals (DSSS), which is done by encoding each bit of information flow unique pseudo-random sequence (PRS). Using DSSS in perspective special telecommunication systems seem more promising.

The purpose of the paper is to analyze the characteristics of existing standards, using wideband signals by direct spread and determine the feasibility of their use in advanced wireless communication systems special purposes.

The main characteristics of the CDMA standards include: basic frequency bands of base and mobile station; width of the spectrum; clock frequency of PRS; type of modulation; features of multiple access; types of orthogonal and spreading code sequences; types of anti-jamming coding with parameters: limit the length of the code sequence K and rate R; the length of the frame; interleaving scheme; power control scheme and it's accuracy; search method cell of the mobile station; synchronization scheme; compatibility with other standards.

Given the need to ensure work in active radio-electronic suppression, using known standards in the special telecommunication systems is unpractical. The first, characteristics of signals commonly known, which simplifies the task of efficient jamming at the stages of entering and maintaining communication. Knowing the structure of the spreading sequence noise producer may, by correlation analysis to quickly determine the parameters of the effective interference. Secondly, the rate

of spreading of the signal in the existing CDMA-standards is relatively small, so the gain of the receiver processing accordingly small. Therefore, the frequency band occupied by known standards are not used narrowband systems. Increased base that would reduce power spectral density of the signal will operate broadband and narrowband radio communication systems practically without mutual influence.

In the future there is a need to develop own standards using the technology of direct spread spectrum, which should provide for the maximum possible spreading; the possibility of adaptive changes in the parameters when the quality of communication is deteriorating, particularly as a result of jamming; increased secrecy, efficiency and reliability of the entry in the communication.

Keywords: *radio communication, radio access, broadband signals, direct spread spectrum systems, code division multiple access, special purpose system.*

Kupriyenko D. A. **Basic concepts and categories in the area of border security**

The article deals with the basic concepts and categories in the area of border security “border security”, “border policy “. In the context of current scientific and political debate focuses on the direct relationship of national security by addressing issues related to the definition and operation of the state border, as well as ensuring its protection and the protection security of border areas that are adjacent to it. This causes the orientation of scientific research towards the formation of a single view on the phenomenon of border security, the development of mechanisms for its security and, finally, study the theoretical and methodological foundations of border policy.

Research in the Ukraine border security problems only initiated. The analysis of scientific publications show that despite considerable interest in the abovementioned problems observed lack of elaborated conceptual and categorical apparatus, hence the need for further conceptualization of border security. An important component of national security and its specific form is border security, which characterizes the degree of protec tion of the territorial integrity and sovereignty of the state in all spheres of social life and human activity, human rights and freedoms in the border area, which is achieved by early detection, prevention, neutralization real (potential) internal and external threats (real dangers) and ensuring sustainable development of border areas, the transparency of the state border to carry out cross-border activities and traveling people.

The main focus of border security is border policy as a deliberate and coordinated activities of state agencies, local governments, community organizations and individuals that aims to ensure the sovereignty, territorial integrity and inviolability, implementation and defense of national interests and national security in its border area.

Keywords: *national security, border security, border security, border policy, system.*

Podolian O.Yu. **He transport conditions analysis of vehicles operating in the units of the State Border Guard Service of Ukraine**

At the present stage of development of the autotechnical provision system of the Border Guard Service has become quite urgent, regarding the question of automobiles selection with high fuel efficiency and environmental friendliness for the border guard units. Best values of these parameters represent automobiles with combined (hybrid) power plants.

Decision regarding border guard units equipment with vehicles having hybrid power plants requires careful study. This is due to the high cost of the "hybrids" themselves and what concerns creation and establishment of the operating system.

On the other hand, the results of simulation of an automobile operation with a hybrid power plant show that its efficiency directly depends on the conditions of functioning. Therefore, there is a need for a detailed study of the parameters of conditions of automobiles functioning in the regions of border guard units location to determine the expected level of effectiveness of these vehicles samples usage in the process of operational activity.

Conducted scientific research to find information as for determining conditions of border guard units automobiles functioning to assess prospects for use of hybrid propulsion systems gave no positive results. Accordingly, as the purpose of this study were defined formalization of operating vehicles transport conditions in the regions of location of border guard units and justification of the most important parameters to ensure their opportunity to further evaluate the effectiveness of use of vehicles with hybrid power plants by border guard units.

This research paper defines the main parameters of the transport conditions of vehicles functioning in the border guard units regions location. In particular: the amount of passenger and cargo capacity required for these vehicles, the maximum speed of their movement, fuel endurance; probable average speed; probable value of the rate of increase of fuel costs on the route, as well as allowable annual cost resource. The results obtained are intended for use in evaluating the effectiveness of the vehicles with hybrid power plants by border guard units. In the future, it is of interest to research into the rest of conditions of factors of hybrid cars functioning, that can considerably influence the efficiency of their use in the border guard units operational service activity.

Prokopenko E. V. **Study of adaptive routing methods**

In the modern conditions of the development of the State Border Guard Service of Ukraine information corporate performance is one of the most important methods to increase management efficiency. Therefore, today the development of telecommunications networks and information systems in the State Border Guard Service of Ukraine is an objective necessity and carried out taking into account the global trends in the construction and integration of networks, equipment and services provider. This trend requires the introduction of equipment and technologies that meet modern international standards, guidance and indicators of quality of service.

To ensure the quality of service of telecommunication systems they are required to have a mechanism that allows fast and lossless agents to deliver data from one user to another. One of the main locations is in the given routing mechanism. Properly organized in conjunction with the routing component access control overloading streams and fully guarantee the quality of a network. At present, the telecom network of the State Border Guard Service of Ukraine used the method of static routing that provides input and change of address tables manually by the network administrator. In this method of routing there are several defects that significantly reduce the efficiency of network service.

Due to continuous growth of information transmitted and its heterogeneity of content and physical nature and complexity of expanding departmental telecommunications network it is an urgent task to develop dynamic (adaptive) methods of information management. From the speed of data acquisition and, ultimately, operational decision-making depends on the solution of this problem in many respects.

Recently, a very active research area developed Natural Computing. They combine mathematical methods, which laid down the principles of natural mechanisms of decision-making:

geneticalgorithms;
evolutionprogramming;
neuralnetwork computing;
DNA computing;
cellular Automata;
antcolony algorithms.

These mechanisms orient flora and fauna towards adaptation to their environment over millions years. Simulated self-organization is the foundation of the colony, antsalgorithms optimization – a new promising method of natural computing.

A colony of ants is considered as a multi-agent system in which each agent (ant) operates independently following very simple rules. In contrast, almost primitive behavior of the agents, the behavior of the whole system goes surprisingly very reasonable. This allows you to recommend the use of ant algorithms to solve complex problems routing – choosing the optimal route of complex telecommunications networks.

Keywords: *natural computing, ant colony, pheromone, multi-agent system, the routing algorithm.*

Royzman V. P., Shinkaruk O. N. **Analysis of the current state of the problem of ensuring the strength reliability of electronic products, used in the ministry of internal affairs and the border service of Ukraine**

In connection with the place having breakdowns or failures of electronic equipment (due to mechanical effects), which is operated on the vehicles used in particular in the Border Guard Service of Ukraine and Ministry of Internal Affairs of Ukraine, the article analyzes the current state of the problem of ensuring the strength reliability of electronic equipment. Directed destabilizing factors that

affect electronic equipment, given the characteristics of vibrations acting on the equipment installed on mobile objects, provides statistics failures caused by mechanical effects. Interest are materials about MTBF of electronics in the United States. Draws attention to the defects of capacitors, which occur due to failures in 61 % of cases and resistors in nearly 30 % of cases. Do conclusion about the need to develop experimental and computational methods and tools for investigation of dynamic strength and creating effective remedies electronic products from mechanical influences.

Keywords: *electronic equipment, strength, vibration, capacitors, and reliability.*

Royzman V. P., Shinkaruk O. N. **Rapid method wheel balancing vehicles without removing it from the work axis in operational conditions at operating speed**

Due to the fact that the automotive electronics, consisting armed Border Service of Ukraine and the Ministry of Internal Affairs operated in off-highway and off-road, because it dents drives uneven tire wear, dirt and other buildup comes fast wheel imbalance and increase the vibration that creates discomfort the driver and the passengers, leading to the destruction of certain parts and reduce the reliability and operating life. Therefore, the actual method is to create a rapid rebalancing wheels, if needed, could be performed in any location of the vehicle at any time and would not need balancing machines. Given that some cars have the ability to untwist lifted car wheel from a car engine, the method for balancing a vehicle wheel in operation without removing the wheels working axis and operational speed. In addition, this method is much more accurate than the methods of balancing on balancing machines. In this article the testing method for balancing the wheels on the car UAZ.

Keywords: *balancing, wheel, wheel axle, imbalance and vibration.*

Salnikova O. F., Bilokur M. O., Hapeeva O. L. **Problems of application of scientific and technical products after completion of scientific and research works**

The questions about legal acts (RED – Research and Development) of armament and military technology (AMT) development (modernization) to order of the Department of Defense of Ukraine are the questions of urgent importance and are determined by the following criteria:

all kinds of military or dual-use are the property of Ukraine and should be used in further researches;

high cost of military production and the availability of use restriction military stamps require of its accurate accounting and preservation.

The development (modernization) of AMT is performed according to the state purpose-oriented defense programs of the Armed Forces of Ukraine AMT development (hereinafter – SPODP AMT) on grounds of government contracts (agreements) with RED fulfilment for AMT development (modernization) that are concluded between Department of Defense of Ukraine and subjects of businesses

activity of all forms of property that are defined as executors of these works in accordance with the laws of Ukraine. The order of execution and adoption of RED (phases, sub-phases of RED) is established by national (international) standards of development and organization system of the production of AMT (hereinafter – the standards DOSP) and other regulations on these issues. The problems settlement that cannot be solved by applicable standards, are accomplished according to the state contracts (agreements) of RED fulfilment.

It is known that in Ukraine, in the Soviet time, the strong scientific, technical and industrial potential in the defense sector was accumulated. After the independence of Ukraine structural subdivisions were formed: the Committee of the Research and Development of Armament of Ministry of Defense of Ukraine, which took the functions of the customer of Scientific and Technical Products (STP) concerning the development of AMT in the interests of the military department.

The problem of preservation of scientific, technical and industrial potential that the defense enterprises of military and industrial complex (MIC) had, is arise before Ukraine. To ensure their orders, the administration of the defense department concluded agreements (contracts) of RED fulfilment to develop the specimen of AMT. The Committee of the Research and Development works in conjunction with the Ministry of Machine Building, the MIC (military and industrial complex) and conversion (the predecessor of the current Ministry of Industrial Policy) the Plan of transitions (such those that were left from Soviet time) of RED was formed and was approved on the state level. This document was the basis for RED plan that is approved by the Department of Defense of Ukraine and was given to the Department of Economy and Department of Finance of Ukraine.

The all mentioned failings should be addressed to the legal framework by modifying of existing legal documentation in accordance with the above algorithm. The other way is used in the leading countries of the world: it foresees that property rights for STP, which was established by the results of the RED and paid by the state, are transmitted due to prearranged pay to enterprises-executors of RED or enterprises-manufacturers of serial production and these enterprises due to the creation of new specimens of AMT created on the basis of this STP and related deductions (taxes) to the state budget to compensate for the state expenses of RED fulfillment. If the company-executor of RED is successful and profitable in the market, it will always be interested in getting the right property for their scientific and technical products, which can be used in accordance with current legislation in the future (for example – in the development of new specimens), taking into consideration that such STP is the basis for the development of production technologies or services giving, including high technology and dual-use technologies. Thus, the obtaining of ownership to such STP opens the path of further development for enterprise-executor of RED or other enterprise-producer of serial specimens of AMT. And conversely, if the enterprise-executor of RED refuses to acquisition of ownership of their scientific and technical products, and

for Department of Defense of Ukraine it can be a reason for conclusion concerning of that enterprise incapability to create high technologies or dual-use technologies.

Keywords: *scientific and technical products, defense industrial complex, scientific and research, research and engineering works***.**

Sobchenko V. A. **Analysis of methods for evaluating reliability of complex technical systems during their operation**

Technical means of border protection is one of the significant elements of the detecting violation system of the border. In recent years, the major powers of the world make intensive improvement of advanced technologies in radio electronics, automation. Modern devices, systems and complexes for their frontiers protection were created on their basis. Practice shows that the current model of state border security requires greater use of innovative technical means of border protection such as thermal imagers, modern radars and signaling means.

By the year 2015 border protection units will have been equipped with modern technical facilities of border protection according to the Concept of the State Border Guard Service of Ukraine. However, maintaining the efficiency of technology requires huge expenses. Therefore, improvement of the existing exploitation systems to provide the required technique reliability level in a limited funding is important issue.

The scientific article concerns the analysis of existing research methods of complex technical systems reliability during their operation given. It gives the following results: common deficiencies of existing methods and non-compliance with the conditions of use of the state border protection highlighted. In addition, the possibility of using an individual approach to assess the reliability of complex technical systems used in the state border protection was justified.

The existing methods of research of reliability do not allow carrying out a variety of calculations with high precision and efficiency. It greatly limits their usefulness for the study of different technical systems reliability when they change.

As a result of the research the existing methods are reduced to determining the reliability parameters. They are common for similar equipment models and should take into account the largest possible number of terms of use. Although it is possible to determine the individual approach of reliability parameters for each technique sample with adequate maintenance provided, and considering the high cost of modern technical systems exploitation.

Keywords: *reliability, complex technical system, mobile thermal complex methods of reliability analysis*.