（№.２　２００１年１０月１日号目次）

特集：ロシア極東コムソモリスク・ナ・アムーレにおける 技術開発研究　その２

今号では№.１に引き続き、コムソモリスク・ナ・アムーレ工科大学における技術開発研究をご紹介いたします。

Ⅱ．技術文献

コムソモリスク・ナ・アムーレ工科大学（つづき）

⑧等方性の混成抵抗媒質モデル開発のためのアプローチの進展

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短評：

異質微小粒子の力学におけるモデリングの諸問題が考察されている。エネルギーの関数が、応力テンソルの成分のフーリエ級数として表されている。ここで表されたものは、一次近似においては古典的な弾性ポテンシャルと一致し、以降の近似では、混成抵抗粒子の非線形挙動の影響を考慮した修正を含んでいる。モデルの物質定数を決定する方法が考察され、また、ねずみ鋳鉄の変形に関する比較グラフの分析が行われている。

報告：

DEVELOPMENT METHOD OF CREATION MODELS ISOTROPIC HETEROGENEOUSLY RESISTING MEDIUMS[1]

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Occurrence of many new constructional materials with inhomogeneous structure, described by nonlinearity of behaviour even at small deformations, and their wide prevalence in practical using stimulates development of mathematical modeling in continuum mechanics generally and, in particular, development of governing equations, permitting consider given deviation from the linear law of behaviour. From this point of view most universal is the method, consisting in presentation function elastic energy of model isotropic medium as Fourier series on components of strain tensor [1-3]. This method allows to receive governing equations with number of items, necessary for the account of nonlinear behaviour materials with a required exactness. However universality of the given method allows, not losing generality, to present elastic potential as series on components of stress tensor, that was not carried out, however to nowdays. In the given research the possibility of such presentation and also identification the obtained model are examined.

Using results of research [3], we present function of elastic energy W as series

$$W(\sigma)=\sum_{n=0}^{\infty}\sum_{l=0}^{\infty}\overline{a}_{ln}L_n^{\alpha}(r)\cdot\Xi_K^{l}(\sigma) \qquad (1)$$

where $L_n^{\alpha}(r)$ – polynomials Lagger with $\alpha\geq 2$, $\Xi_K^{l}(\mathbf{x})$ – orthogonal basis functions of rotation group n-dimensional space $SO(n)$. Presentation of polynomial Lagger [4] allows to select more easy forms of common expansion (1). The greatest interest represents expansion of the second degree of homogeneity

[1] Research carried out by financial boost RFBR (project 01-01-00921) and Ministry of Education Russia (project E00-4.0-123).

$$W(\sigma) = r^2 \sum_{l=0}^{\infty} a_l^{(m)} \Xi_K^l(\sigma) \tag{2}$$

where r – position vector of point in space of stresses. The basis functions $\Xi_K^l(\mathbf{x})$ are given by expressions

$$\Xi_K^l(\mathbf{x}) = \prod_{j=0}^{n-3} \left\{ C_{k_j - k_{j+1}}^{\frac{n-2-j}{2} + k_{j+1}} \left(\cos\theta_{n-j-1}\right) \sin^{k_{j+1}} \theta_{n-j-1} \right\} \cdot \cos k_{n-2}\theta_1 , \quad k_{n-2} \geq 0$$
$$\Xi_K^l(\mathbf{x}) = \prod_{j=0}^{n-3} \left\{ C_{k_j - k_{j+1}}^{\frac{n-2-j}{2} + k_{j+1}} \left(\cos\theta_{n-j-1}\right) \sin^{k_{j+1}} \theta_{n-j-1} \right\} \cdot \sin k_{n-2}\theta_1 , \quad k_{n-2} < 0$$

where the symbol K designates sequence of integers $\left(k_1, ..., \pm k_{n-2}\right)$, and $l \equiv k_0 \geq k_1 \geq ... \geq k_{n-2} \geq 0$, $x = \left(x_1, x_2, ..., x_n\right)$, $C_l^p(x)$ – polynomials Hegenbauer, having an integral presentation

$$C_l^p(\cos\varphi) = \frac{\Gamma(2p+l)}{2^{2p-1}\Gamma^2(p)} \int_0^{\pi} \left(\cos\varphi - i \sin\varphi \cos\theta\right)^l \sin^{2p-1}\theta d\theta ,$$

and the connection between cartesian and spatial polar coordinateses looks like

$$\begin{cases} x_1 = r \sin\theta_{n-1} \sin\theta_{n-2} ... \sin\theta_2 \sin\theta_1 \\ x_2 = r \sin\theta_{n-1} \sin\theta_{n-2} ... \sin\theta_2 \cos\theta_1 \\ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \\ x_{n-1} = r \sin\theta_{n-1} \cos\theta_{n-2} \\ x_n = r \cos\theta_{n-1} \end{cases}$$

$$r_{n-j}^2 = x_1^2 + x_2^2 + ... + x_{n-j}^2 , \quad \frac{x_{n-j}}{r_{n-j}} = \cos\theta_{n-j-1} , \quad \frac{r_{n-j-1}}{r_{n-j}} = \sin\theta_{n-j-1}$$

For the considered problem the space is six-dimensional, as the stress tensor is symmetrical. The account the isotropic character of medium allows to reduce considered space to three-dimensional space principal values of stress tensor. Then the basis functions Ξ_K^l coincide with spherical Y_l^m [5].

The evaluation expressions of basis functions, their further substitution in (2), superposition of the requirement invariance of the form W concerning rotation group and overdenote coefficients allows to receive the following presentation of elastic potential

$$W(\sigma)=\frac{\alpha_1}{2}J_1^2+\alpha_2 J_2-\alpha_3 J_1\sqrt{J_2}+\alpha_4\frac{J_3}{\sqrt{J_2}}+\alpha_5\frac{J_1^3}{\sqrt{J_2}}+$$
$$+\alpha_6\frac{J_1^4}{J_2}+\alpha_7\frac{J_1 J_3}{J_2}+\alpha_8\frac{J_1^2 J_3}{J_2\sqrt{J_2}}+\ldots \tag{3}$$
$$J_1=\sigma_{ij}\delta_{ij},\ J_2=\sigma_{ij}\sigma_{ij},\ J_3=\sigma_{ij}\sigma_{jk}\sigma_{ki},$$

where α_i – material constants of model (3). The governing equations of this model, according to equalities $\varepsilon_{ij}=\partial W/\partial\sigma_{ij}$, look like

$$\varepsilon_{ij}=\left(\alpha_1-\alpha_3/\psi+3\alpha_5\psi+4\alpha_6\psi^2+\alpha_7\kappa^3/\psi+2\alpha_8\kappa^3\right)\cdot J_1\delta_{ij}+$$
$$+\left(2\alpha_2-\alpha_3\psi-\alpha_5\psi^3-\alpha_4\kappa^3-2\alpha_6\psi^4-2\alpha_7\psi\kappa^3-3\alpha_8\psi^2\kappa^3\right)\cdot\sigma_{ij}+ \tag{4}$$
$$+3\left(\alpha_4+\alpha_7\psi+\alpha_8\psi^2\right)\frac{\sigma_{ik}\sigma_{kj}}{\sqrt{J_2}}+\ldots$$
$$\psi=J_1/\sqrt{J_2},\quad \kappa=J_3^{1/3}/\sqrt{J_2}$$

The parameters ψ and κ were entered into relations (4) also, as ξ and η in [1]. Generally speaking, the obtained model does not coincide with the model given in researches [1, 2], however, it is possible to assume about similar exactitude of prediction nonlinear behaviour of microinhomogeneous materials taking into account identical initial premises of these models conclusion. In that specific case governing equations (4) coincide with classical

$$\varepsilon_{ij}=\alpha_1 J_1\delta_{ij}+2\alpha_2\sigma_{ij},$$

where the compliances are defined through constants of Lame λ and μ in the following way

$$\alpha_1=-\frac{\lambda}{2\mu(3\lambda+2\mu)},\quad \alpha_2=\frac{1}{4\mu}$$

For affirming identification of model it is necessary to develop procedures of definition of unknowns material constants and to plot comparative diagrams of behaviour some microinhomogeneous materials. Consider the elementary models with elastic potential, in which nonzero are α_1, α_2, α_3, α_4.

The most prime and precise testing for definition of mechanical properties microinhomogeneous materials are the experiences on uniaxial tension-compression. The results of these experiences are given as values of components stress tensor $\sigma_i^{\pm}$ and tensor of strains $\varepsilon_i^{\pm}$, where the sign "+" means tension, "–" – compression, i = 1, 2. Then the set of equations for definition material constants looks like

$$\varepsilon_i^{\pm} = \left(\alpha_1 - \alpha_3 / \psi^{\pm}\right) \cdot J_1^{\pm} \delta_{ij} + \left(2\alpha_2 - \alpha_3 \psi^{\pm}\right) \cdot \sigma_i^{\pm} + 3\alpha_4 \frac{\sigma_i^{\pm 2}}{\sqrt{J_2^{\pm}}}, \quad i = 1, 2 \qquad (5)$$

The system (5) is a set of the linear algebraic equations. In that specific case it is overdetermined, and for it equalization used least-squares method. In case using governing equations with other nonzero constants α_j the datas of other experiences are necessary, for example, simple shear or biaxial uniform tension. The adding of experience results on simple shear allows to define already seven unknowns constants.

For completeness of research the numerical calculations on definition of material constants were carried out and plotted comparative diagrams of behaviour the typical representative of considered class materials – grey cast iron at stationary value to temperature of deformation 293 K. The algorithm calculation of material constants was designed and the program in software Mathcad was composed, results of calculations as the comparative diagrams loading of grey cast iron are given in fig. 1, 2. The characters designate the following species strain deformation: a) uniaxial tension; b) uniaxial compression; c) simple shear; d) biaxial uniform tension; e) a biaxial nonuniform tension with the ration of principal tensile stress 0,5.

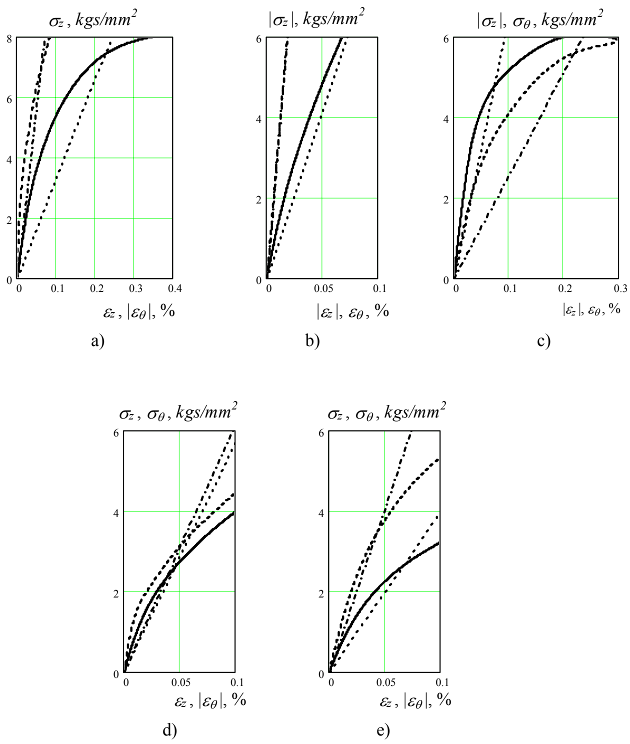

Fig. 1

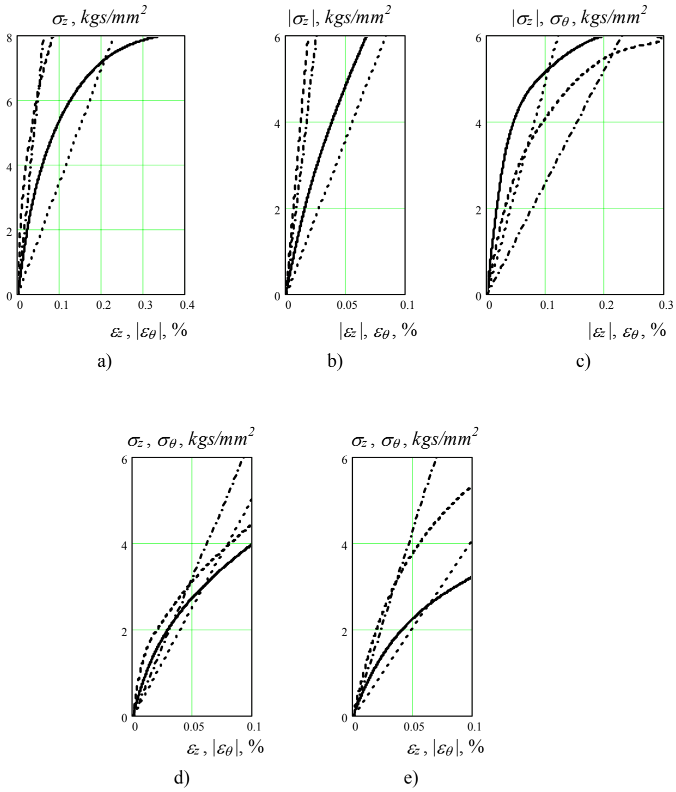

Fig.2

The continuous and dot plots display a modification of axial strains at loading for the experiment and model (4) accordingly, dashed and dash-dotted are for tangential strains also for experiment and model (4) accordingly. In a fig. 1 for calculations the model with constants α_1, α_2, α_3, α_4 was used, and in fig. 2 – model with α_1, α_2, α_3, α_4, α_5, α_6, α_7 was used. In these figures the good congruence of the plots for axial and for tangential strains are observed. It is necessary to mark the account by the given model of the basic aspect nonlinearity behaviour for microinhomogeneous materials – discrepancy of the diagrams for different species mode of deformation.

Thus, it is possible to make a conclusion, that we received the presentation of elastic potential as Fourier series on components of stress tensor. The procedure of calculation for material constants of model was offered by results of standard experiences on uniaxial tension-compression and simple shear and it was plotted the comparative diagrams of behaviour grey cast iron.

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⑨コーティングした材料を使ったコンピュータ設計

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短評：
不均質な複合材料による複数の層からなるコーティングを施した材料の、複雑な応力下における強度を求めるための、相間エリアの挙動と残留応力を見込んだ上で、強度規準および断片ごとに均質な(piecewise homogeneous)物体のための境界要素法に基づいた計算方法が紹介されている。ネットワークで結ばれたワークステーションで並行して計算をさせることのできる、コーティングのある物体の自動計算プログラム・パッケージが説明される。

報告：

COMPUTER DESIGNING of MATERIALS With COATINGS[2]

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At an estimation of safety factor of compositions of a type the basis - coating usually is necessary to take into account a way of their connection, for example, soldering or welding connection of any performance. For such bodies can be characteristic thin heterogeneous interphase layers and various sort of interphase structures imperfection caused by features of technological character with intensive physico-chemical processes on border of the partition of phases. By consideration of tasks of contact interaction of such structures it is necessary to take into account these deviations from ideal contact, which result in imperfection of conditions of a continuity of vectors of displacements and stresses at transition through interphase area.

To the present time the criteria for comparison of the characteristics of durability of a material are revealed at elementary loadings with its plastic deformation strength and stretching in conditions of action of complex system of stresses. The parameters of the stressed state are established also, on which conditions the intensity of processes causing exhaustion of durability of a material depends. The statistical aspects of durability and feature of behaviour of materials in conditions of the high temperatures are taken into account. Such criteria practically correctly reflect conditions of a limiting state of the given structures at the complex homogeneous stressed state.

In real temperature power modes of operation of materials with coatings in a composition there can be essentially heterogeneous complex stressed state with large gradients of stresses. Thus the calculation of durability is connected to calculation of distribution a stress tensor's components in researched areas of a basis and coating.

Development of methods and algorithms of calculation of the stressed-deformed condition of bodies with coatings usually use the transformation of a task to research of deformation of plates laying on rigid or linear - deformable basis. The choice of vari-

[2] Research carried out by financial boost RFBR (project 01-01-00921) and Ministry of Education Russia (project E00-4.0-123).

ant of mechanical model for the description of properties of a coating (in usual, it is plates Kirhgofa-Lyava or Reyssnera-Timoshenko and their modifications), it appears, it can essential influence final result. It, in turn, can result in incorrectness of the decision, deforming a true picture of interaction a coating with a basis and distribution in them of stresses. In connection with given inadequacy the various specifications of the classical applied theories are offered at the description of properties of a coating, which can be effective at the decision of particular tasks. The development of these specifications on multi-layer heterogeneous coatings or on real, more complex constructions, than layer, strip, sphere or cylinder, encounters, as a rule, on while insuperable difficulties. At the same time basic advantage of the specified equations of deformation of a coating as thin-walled elastic element considers their affinity to the equations of the theory of elasticity in the qualitative and quantitative attitudes at the decision of the given class of tasks.

The calculation of the stressed state in a basis and in multi-layer heterogeneous or composite coating can from the beginning be carried out on the basis of the equations of the theory of elasticity without use of the applied theories of thin-walled elements.

Presence of large gradients of stresses in a coating and basis for many working bodies and units of friction of modern machines raise appeal of methods of a boundary element, in which the calculation of distribution of stresses is based on the exact analytical decisions of the equations of the theory of elasticity [1, 2].

The technique of calculation of durability of materials with composite and multi-layer coatings is offered at the complex stressed state based on criterion of durability and on an indirect method of a boundary element for piecewise-homogeneous bodies, in a general case allowing to calculate bodies with several arbitrary located areas with different elastic constant ν And E, in view of behaviour interphase areas and residual stresses.

The task of the theory of elasticity for materials with coatings is based on consideration of a piecewise-homogeneous body Ω, consisting from homogeneous phases Ω_n, so $\Omega = \bigcup_n \Omega_n$ and $\Sigma_{n,m} = \Omega_n \bigcap \Omega_m$ - surface of the partition of phases Ω_n and Ω_m, $n, m = 1, \ldots, N$. The description of the stressed-deformed condition of a body Ω is carried out by a vector of displacement $\vec{U}(u, v)$, deformation tensors $\varepsilon = (\varepsilon_{ij})$ and stresses $\sigma = (\sigma_{ij})$ for each phase.

The basic relationships at flat deformation are the following equations of balance of phases both expression for deformations and stresses:

$$\begin{aligned} \frac{\partial \sigma_{xx}^{(n)}}{\partial x} + \frac{\partial \sigma_{xy}^{(n)}}{\partial y} = 0, \\ \frac{\partial \sigma_{xy}^{(n)}}{\partial x} + \frac{\partial \sigma_{yy}^{(n)}}{\partial y} = 0, \end{aligned} \tag{1}$$

$$\varepsilon_x^{(n)} = \frac{\partial u^{(n)}}{\partial x}, \; \varepsilon_y^{(n)} = \frac{\partial v^{(n)}}{\partial y}, \; \varepsilon_{xy}^{(n)} = \frac{1}{2}\left(\frac{\partial u^{(n)}}{\partial y} + \frac{\partial v^{(n)}}{\partial x}\right), \tag{2}$$

$$\sigma_x^{(n)} = \frac{2G^{(n)}}{1-2\nu^{(n)}}\left[\left(1-\nu^{(n)}\right)\varepsilon_x^{(n)} + \nu^{(n)}\varepsilon_y^{(n)}\right],$$

$$\sigma_y^{(n)} = \frac{2G^{(n)}}{1-2\nu^{(n)}}\left[\left(1-\nu^{(n)}\right)\varepsilon_y^{(n)} + \nu^{(n)}\varepsilon_x^{(n)}\right], \tag{3}$$

$$\sigma_{xy}^{(n)} = 2G^{(n)}\varepsilon_{xy}^{(n)},\ \sigma_{zz}^{(n)} = \nu^{(n)}\left(\sigma_{xx}^{(n)} + \sigma_{yy}^{(n)}\right).$$

In expressions (2), (3) $u^{(n)}$, $v^{(n)}$ - displacements accordingly on axes x and y of rectangular Cartesian system of coordinates with basis $\left(\vec{e}_x, \vec{e}_y\right)$, $G^{(n)}$ and $\nu^{(n)}$ - shear modulus and Poisson's ratio of a material of phase n. The statement of a task is finished by the formulation of boundary conditions on an external surface of a body $\partial\Omega$ and conditions on surfaces of the partition $\sum_{n,m}$. If the adjacent phases work in common, the vectors of displacements and stresses at transition through surfaces of the partition change continuously and

$$\vec{U}^n = \vec{U}^m,\ \vec{P}^n = \vec{P}^m \text{ on } \sum_{n,m}, \tag{4}$$

where $\vec{U} = u\vec{e}_x + v\vec{e}_y$, $\vec{P} = \left(\sigma_{xx}n_x + \sigma_{xy}n_y\right)\vec{e}_x + \left(\sigma_{yy}n_y + \sigma_{xy}n_x\right)\vec{e}_y$, $\vec{n} = \left(n_x, n_y\right)$ - normal in a point of a surface $\sum_{n,m}$.

The fundamental decision $H_{ij;k}(Q, q_0)$, $I_{ik}(Q, q_0)$ of task (1) - (3) in case of a homogeneous infinite plane is given in [3], due to which the stresses and deformations calculate under the formulas

$$\sigma_{ij}^{(n)}(Q) = \int_{\partial\Omega'^{(n)}} H_{ijk}^{(n)}(Q, q_0) f_k^{(n)}(q_0)\, dl,$$

$$\varepsilon_{ij}^{(n)}(Q) = \int_{\partial\Omega'^{(n)}} I_{ik}^{(n)}(Q, q_0) f_k^{(n)}(q_0)\, dl$$

where $H_{ijk}^{(n)}(Q, q_0)$, $I_{ik}(Q, q_0)$ - Green's function of influence $(i, j, k = x, y)$, which describe stresses and deformations in an internal point Q of phase n $\left(Q \notin \partial\Omega^{(n)}, Q \notin \sum_{n,m}\right)$, caused by action of unit force enclosed in a point q_0 of a boundary or contact contour $\partial\Omega'^{(n)}$, $q_0 \in \partial\Omega'^{(n)}$, $\partial\Omega'^{(n)} = \partial\Omega^{(n)} + \sum_{n,m}^{\pm}$, $n, m = 1, 2, \ldots, N$. Thus the boundary elements located on the side $\sum_{n,m}^{+}$, reversed to a phase $\Omega^{(n)}$, and on the side $\sum_{n,m}^{-}$, reversed to an adjacent phase $\Omega^{(m)}$, same contact $\sum_{n,m}$ coincide with each other. The functions $f_k^{(n)}(q_0)$, named by fictitious loadings, are from system $(n, m = 1, \ldots, N)$ equations [4]

$$\frac{1}{2} f_k^{(n)}(q) + \int_{\partial\Omega^{(n)}} H_{ijk}^{(n)}(q, q_0) n_j(q) f_k^{(n)}(q_0)\, dl_{q_0} = P_k^{(n)}(q),$$

$$\int_{\partial\Omega^{(n)}} I_{ik}^{(n)}(q, q_0) f_k^{(n)}(q_0)\, dl_{q_0} = u_k^{(n)}(q), \tag{6}$$

$$\frac{1}{2} f_k^{(n)}(q) + \int_{\Sigma^+_{n,m}} H_{ijk}^{(n)}(q,q_0) n_j(q) f_k^{(n)}(q_0) dl_{q_0} =$$

$$= \frac{1}{2} f_k^{(m)}(q) + \int_{\Sigma^-_{n,m}} H_{ijk}^{(n)}(q,q_0) n_j(q) f_k^{(m)}(q_0) dl_{q_0},$$

$$\int_{\Sigma^+_{n,m}} I_{ik}^{(n)}(q,q_0) f_k^{(n)}(q_0) dl_{q_0} = \int_{\Sigma^-_{n,m}} I_{ik}^{(m)}(q,q_0) f_k^{(m)}(q_0) dl_{q_0}.$$

The system of the integral equations (6) with use of quadrature formula of rectangles is resulted in system of the linear algebraic equations, which, after multiplication to the transposed matrix of coefficients, can be solved by a Zeydel's method [5].

At the decision of tasks by the given algorithm it is necessary to deal with the ill-conditioned systems of the linear equations (owing to use at record of conditions of continuity of the integral equations of the first sort)

$$\sum_{j=1}^{N} a_{ij} x_j = b_i, \qquad i = \overline{1, m}; \qquad m \ge n, \tag{7}$$

where b_i - observed values of loadings containing an error of the square-law form δ, i.e. $\|b - \bar{b}\| \le \delta$, here $\bar{b}$ - exact value of loadings; a_{ij} - known coefficients of a matrix; x_j - required values. As it is usual b_i are given with an error, in a general case the system (7) is disjoint, i.e. has not the decision. Square-law approximation to the decision (7) in this case is searched. As initial given (boundary loadings) initially contain a mistake, there is a set of the decisions, satisfying to condition

$$\|Ax - b\|^2 \le \delta^2. \tag{8}$$

Thus, owing to instability of a task, among these decisions there can be such, which as much as strongly differ from exact. It causes necessity of use of the appropriate methods of the decision of incorrect tasks. Fundamental reception of the decision of such systems of the equations is the A.N. Tikhonov's regularization method [6].

As there is a set of the decisions of system, which satisfy (8), it is necessary from this set to choose the decision meet the certain requirements. In it the basic idea of regularization method consists. By Tikhonov, the given task is transform to minimization smoothing parametrical functional

$$f(x) = M^{\alpha}[x, A] = \|Ax - b\|^2 + \alpha\|x\|^2, \tag{9}$$

where $\alpha = \alpha(\delta > 0)$ regularization parameter, coordinated with an error of the input data δ.

Thus, the initial task (7) is replaced other, close (at small α) to it by a task (9). Thus is proved, that the decision (9) is regularize, and, hence, stable.

Let's state algorithm of the decision of a task (9), realized in a complex of program, which consists of repeated formations and decisions of systems of the linear equations by final methods. The algorithm contains external and internal cycles, which provide examination of a condition, indicative of reception of the regularity decision of system (7).

External cycle: a sequence, meet to zero, $\{\alpha_p\}$ here is formed, on which elements the minimization of functional (9) is made. As such the sequence is taken a geometrical progression $\alpha_{p+1} = \mu\alpha_p$, $p = 0,1,2,\ldots$, $\mu < 1$. After a choice next $\alpha = \alpha_p$ the transition to an internal cycle follows.

Internal cycle. Provides search of a minimum of functional (9) at the fixed value $\alpha = \alpha_p$. It is possible to show, that the minimum of functional at $\alpha = \alpha_p$ provides the decision of system:

$$\left(AA^* + \alpha_p E\right)x = A^* b + \alpha_p,$$

where A^* transpose of matrix A, E - unit matrix.

After that the transition to an external cycle follows.

As criterion of a choice of regularize approximations the complex of program uses Tikhonov-Glasko criterion [7], not requiring knowledge of value of an input error δ:

$$\alpha_{onm} = \min_p \max_j \left| x_j^{\alpha_{p+1}} - x_j^{\alpha_p} \right|.$$

With the purposes of testing the received algorithms the following task for a non-homogeneous body was solved. The considered area (fig. 1) consists of a ring $a \le r \le b$ with elastic constant ν_1 and G_1 inside a round aperture of radius $r = b$ in a large plate with elastic constant ν_2 and G_2. The internal surface of a ring is under action of normal stresses $\sigma_{rr} = -p$, and the plate is free from stresses on infinity.

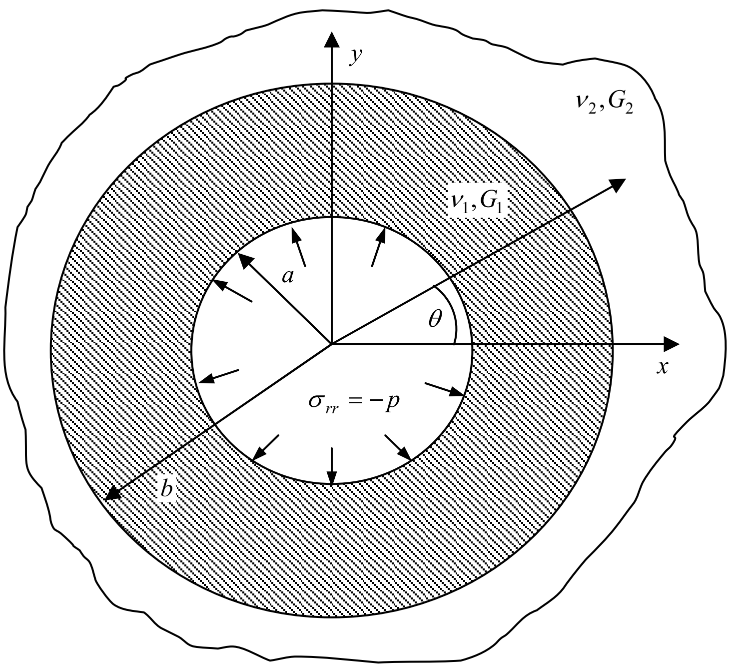

Fig. 1. Task about the stresses state of an internal

The decision of this task is defined through radial and tangential stresses under the formulas:

$$\left.\begin{aligned} \sigma_{rr} &= \frac{1}{1 - a^2/b^2}\left[\left(pa^2/b^2 - p'\right) - \left(p - p'\right)a^2/r^2\right] \\ \sigma_{\theta\theta} &= \frac{1}{1 - a^2/b^2}\left[\left(pa^2/b^2 - p'\right) + \left(p - p'\right)a^2/r^2\right] \end{aligned}\right\} \quad a \le r \le b$$

,

$$\left.\begin{aligned} \sigma_{rr} &= -p' b^2/r^2 \\ \sigma_{\theta\theta} &= +p' b^2/r^2 \end{aligned}\right\} \quad r \ge b,$$

where $p' = \dfrac{2(1-\nu_1)pa^2/b^2}{2(1-\nu_1)+(G_1/G_2-1)(1-a^2/b^2)}$.

The numerical decision of this task is received at the following values of parameters: $a/b = 1/2$, $\nu_1 = \nu_2 = 0.25$, $G_1 = 2000$, $G_2 = 1000$ and $|p| = 8$. The circular borders $r = a$ and $r = b$ were divided into 100 elements everyone. The results of calculations are compared to the analytical decision, where a continuous line - theoretical decision, point - numerical (fig. 2).

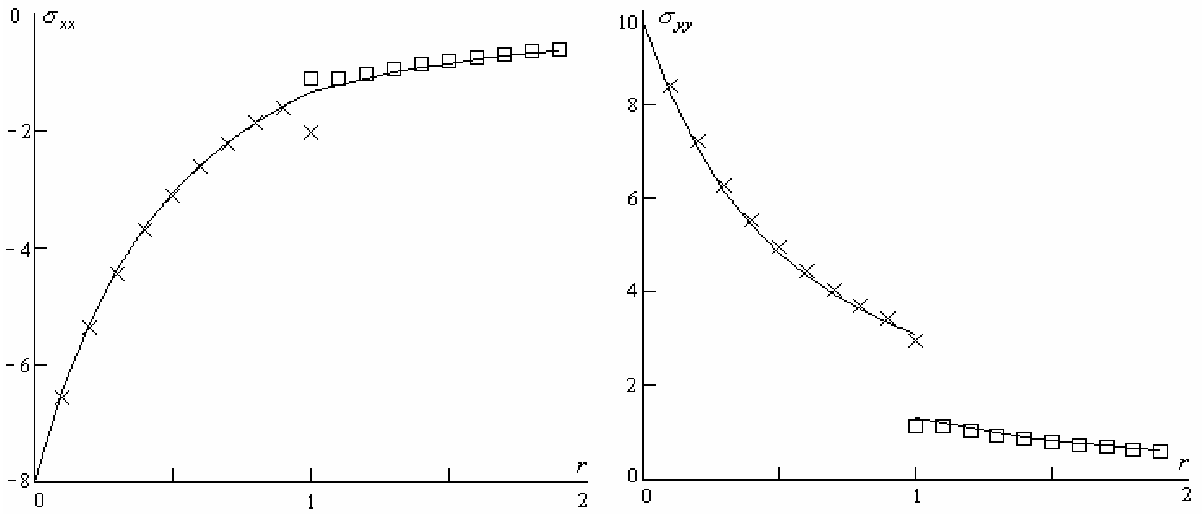

Fig. 2 Comparison of theoretical and numerical results

At the decision of modern practical tasks any widespread numerical methods arise rather large systems of the equations, which decision in acceptable time limits frequently not under force to any modern personal computers. Growing complexity of soluble tasks causes it first of all. At modeling bodies with coatings the described complex of the programs has arisen a similar problem. So, for example, at the decision of some tasks related to calculation of stressed state of bodies with coatings, the systems of the linear equations reach 3000-4000 thousands equations, that for the usual personal computer frequently not under force. The decision of even more complex tasks on personal computer becomes simply impossible. It has caused development of a complex in one direction - updating of mathematical algorithm and its program realization with the purpose of involving in computing process not one, and many computers (workstations) (fig. 3), i.e. creation of a complex of the distributed calculations.

The basic computing complexity is represented with the decision of system of the linear equations by a method of regularization, since it is related to repeated formation and decision of systems by final methods. Thus the complex offers as use of the parallel mathematical algorithms, and distribution of separate independent blocks of all algorithms (at an inefficiency use of the parallel mathematical algorithms) between several machines in a network.

At last, in view of growing need of available computer support for realization of model calculations and, in particular, calculation of the stressed state of materials with various coatings, the uniform complex of the programs including the listed above opportunities was created. To number of positive qualities of a complex it is possible to attribute an opportunity of the automatic formulation of a task, simultaneously with its maximum detailed description, construction of the color and black-and-white diagrams of the stressed state, complete automation of computing process. The basic block diagram and description of modules of a complex are presented in a fig. 3:

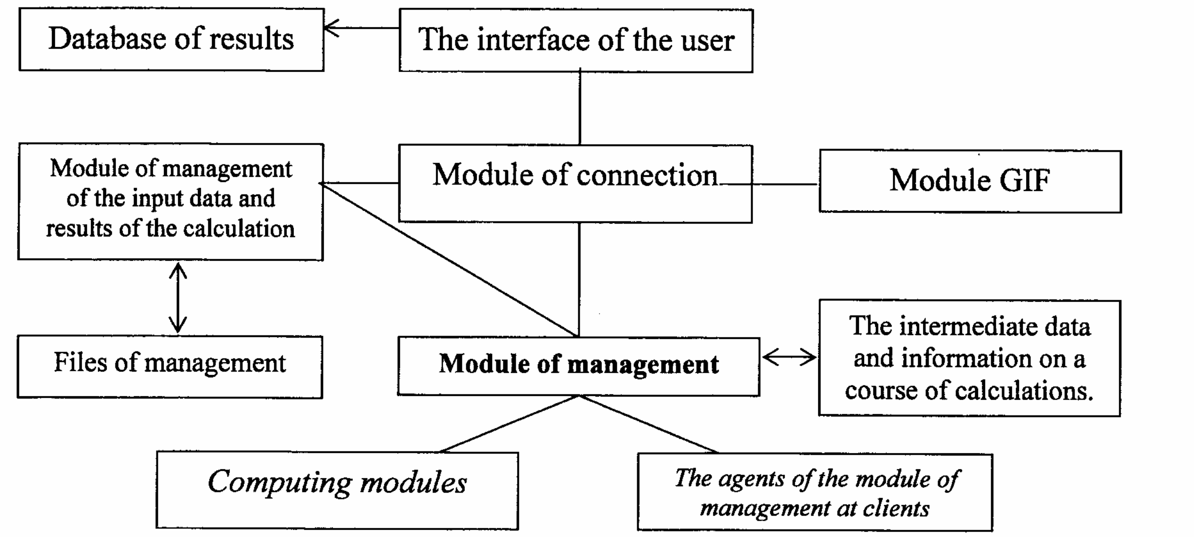

Fig. 3. Structure of a complex of the programs

1. Interface of the user. Is the graphic program for Windows and is intended for input data, describing a task, control information and output of results of the calculation.
2. Module GIF. Realizes preservation of the stressed state diagrams (color and black-and-white as isoline) in a graphic format GIF.
3. Module of communication. Is the auxiliary module deciding a number of auxiliary tasks and facilitating creation of user interface.
4. Module of management of the input data. Realizes operations of storage and processing of input data given particular computing tasks.
5. Module of account. Represents three groups of fineer modules:
    - Server: realizes logic of distribution of calculations on separate workstations and is central storehouse of results of the account;
    - Client modules: are duplicated on separate workstations and realize logic of network interaction, operate resources of the machine and local account;
    - Calculation modules: actually realize numerical algorithms and located on separate workstations together with client modules.

In figure the gray color designates modules, which are executed on a main workstation, being the center of the information gathering and management of workstations included in calculation. On last the modules marked on the diagram by italics are executed.

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⑩航空機の輪郭をなす部材の有望な多軸制御加工法とそのアルゴリズム

Kuzmin A.O., Mogilnikov E.V., Oleinikov A.I.

短評：
ツールのさまざまな回転を組み合わせることで曲面を成形する新装置の有望なスキームがいくつか考察されている。これらのスキームをもとに、NC 制御工作機の加工制御データを 5 分の 1 で済ませる
ことのできる、円筒面と円錐面の近似アルゴリズムが開発された。

報告：

PERSPECTIVE MODES AND ALGORITHMS MULTICOORDINATE DEVOLATILIZATION CONTOURFORMATION DETAILS OF AIRPLANE

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To the present time the technology of program's handling is the most effective technology of shapeforming for composite curvilinear surfaces contourformation details with application of mathematical models [1]. The usage of mathematical model of surface allows considerably to reduce the nomenclature of mounting and to lower labouriousness of its manufacture as contrasted to by manufacture binding of mounting on loft-sample-master form method. Non-loft production of articles becomes basis of serial production in aircraft construction and it is base for preparation of the programs for numerically controlled machine tool on manufacture of details, reducing twice periods of posing article and in 3-4 times of cost on posing.

However realization of technologies of program's handling with using of electronic models contours objectively stipulate sharp magnification amount of works on preparation of automatized production and programs. The preparation of the controlling information at handling details on numerically controlled machine tool usually is carried out with using algorithms of linear approximation [2, 3]. As is marked in [4], such method differs large volume of the controlling information, that can have subzero effect for accuracy and velocity of handling.

The wide introduction numerically controlled machine tools, automation of cutting processes stimulates development of new perspective modes of handling, permitting application of other laws of interpolation, which, allow to reduce labouriousness mathematical preparation of the controlling programs and to raise accuracy.

We consider the schemes of new devices for shaping of curvilinear surfaces by method adding gyrations of the instrument around of the parallel and intersected axes in zone of handling (fig. 1, 2).

The axis OS_2 can rotate concerning axis OS_3, the axis OS_1 of the instrument can rotate concerning axis OS_2. All axes are parallel to each other (angle $\alpha = 0$, a fig. 1) or they are situated at the angle of $\alpha > 0$ and intersected in point O (fig. 2). At rotational concerning OS_3 the axis OS_2 is situated on generatrix of the cylinder or cone according to the foundation C_2. At rotational concerning OS_2 the axis OS_1 is situated on generatrix of the cylinder or cone according to the foundation C_1. We designate through W_i angular velocities of rotation about an axis OS_i. One of the important parameters for given schemes is the quotient of velocities $W_2 / W_3 = k$. The made surface on planes, bounding detail, exactly corresponds to given, at milling by the indicated mode however negative factor is the lack designed algorithms interpolation of surface contourformation details.

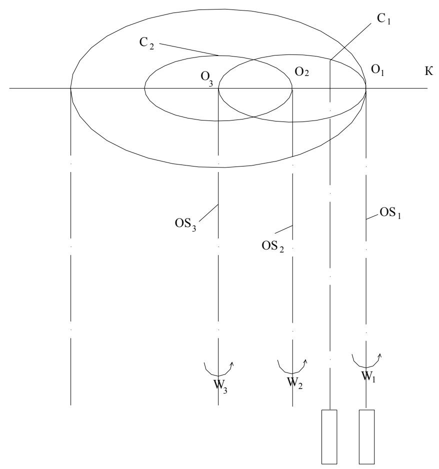

Fig. 3

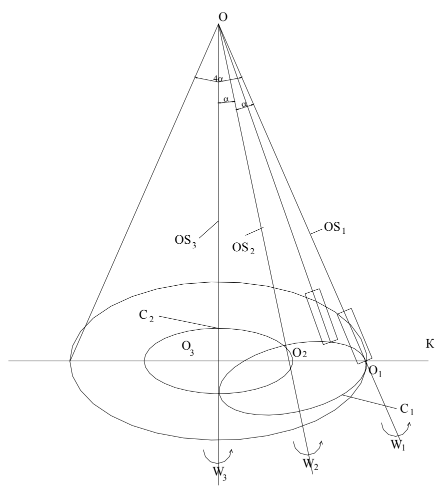

Fig. 4

In our research the algorithms of the programs handling cylindrical and conic surfaces on the basis of these new kinematic schemes are given.

The scheme figured in a fig. 1 is used for handling cylindrical surfaces. The given scheme allows organizing gyrations axes with different values coefficient of quotient of angular velocities k.

The equations motion point of axis OS_1 look like

$$\begin{cases} x = R(\cos\beta + \cos(\beta(k+1))) \\ y = R(\sin\beta + \sin(\beta(k+1))) \end{cases} \tag{1}$$

where R is radius of circles C_1 and C_2, β is angle of rotation OS_2 rather OS_3, $\gamma = k\beta$ is angle of rotation OS_1 rather OS_2.

The guiding cylindrical surface is situated on some plane $z = const$ and set by the equation $y = f(x)$, and its generatrix is parallel this plane. Under the guiding we shall further understand its equidistant curve located apart and equal to half diameter of miller.

We accept point with coordinates for the point of handlings the beginning, then the initial positions of axes are defined

$$\gamma_0 = 2\varphi, \quad \beta_0 = \delta - \gamma \tag{2}$$

where $\varphi = arccos\left(\sqrt{x_0^2 + y_0^2} / R\right)$, a $\delta = arctg(y_0 / x_0)$.

The pair of numbers (γ_0, β_0) uniquely determinate a position of axes. Let's assume, that the miller during handling is displaced from the right to the left against hour arrow. Then we give an increment x_0, equal $-h$, where h is step of approximation. Evaluating $y = f(x_1) = f(x_0 - h)$, by the formulas (2) we shall discover (γ_1, β_1). Thus, the miller will pass some path with coefficient quotient of velocities, equal

$$k = \frac{\gamma_1 - \gamma_0}{\beta_1 - \beta_0} \tag{3}$$

For definition deviation path section from a guiding $f(x)$ cylindrical surface it is required to select criterion of deviation. As those we take the following

$$\Delta = \frac{1}{\beta_1 - \beta_0} \int_{\beta_0}^{\beta_1} \left| f(x_u) - y_u \right| d\beta < \varepsilon \tag{4}$$

where ε is greatest possible error, and x_u, y_u are defined by the formulas

$$\begin{cases} x_u = R(cos\,\beta + cos(\beta + \gamma_0 + k(\beta - \beta_0))) \\ y_u = R(sin\,\beta + sin(\beta + \gamma_0 + k(\beta - \beta_0))) \end{cases} \tag{5}$$

If the step h is selected very small, so $\Delta << \varepsilon$, then x_0 is possible to reduce sequentially by increments $-2h$, $-3h$, …, evaluating the appropriate errors so long, as Δ will not exceed ε. Then as the first point of approximation we accept the last one, for which the inequality (4) is valid. Guessing the found point as initial, we'll apply the indicated algorithm and it will be applied as long, as a grid of approximating points won't fill all guiding.

The scheme, figured in a fig. 2, is used for handling conic surfaces.

The guiding conic surfaces is situated in plane $z = R_d$ and it is given by the equation $y = f(x)$ (term "guiding" is used as the mentioned above). Let consider projections of axes OS_1 and OS_2 from beginning of coordinates on this plane. We receive scheme similar the previous one put the lengths of rungs already are variables, depending on angles inclination of axes OS_1 and OS_2 to an axis z.

We accept the point with coordinates (x_0, y_0, R_d) for a point of handlings beginning, then the initial positions of axes are defined by angles:

$$\beta_0 = \theta_0 - \sigma_0, \quad \gamma_0 = \pi - arccos\left(\frac{cos\,\delta_0 - cos^2\,\alpha}{sin^2\,\alpha}\right) \tag{6}$$

where β_0 is angle of rotation OS_2 concerning OS_3, $\gamma_0 = k\beta_0$ is angle of rotation OS_1 concerning OS_2, and

$$\theta_0 = arctg(y_0 / x_0), \quad \sigma_0 = arccos\left(ctg\alpha \cdot tg\frac{\delta_0}{2}\right), \; \delta_0 = arctg\left(\sqrt{x_0^2 + y_0^2} / R_d\right)$$

Similarly giving the increment $-2h$, $-3h$, … to x_0, we shall get points of approximation. For selection of required increment we enter the criterion of deviation:

$$\Delta = \frac{1}{\beta_1 - \beta_0}\int_{\beta_0}^{\beta_1} \left| f(x_d) - y_d \right| d\beta < \varepsilon \tag{7}$$

where

$$x_d = R_d\frac{x}{z}, \quad y_d = R_d\frac{y}{z}, \quad z = R_d$$

$$\begin{aligned}
x &= R \cdot \big(sin\,\alpha \cdot cos\,\alpha \cdot cos\,\beta \cdot cos(\gamma_0 + k \cdot (\beta - \beta_0)) - \\
&\quad sin\,\alpha \cdot sin\,\beta \cdot sin(\gamma_0 + k \cdot (\beta - \beta_0)) + cos\,\alpha \cdot sin\,\alpha \cdot cos\,\beta\big) \\
y &= R \cdot \big(sin\,\alpha \cdot cos\,\alpha \cdot sin\,\beta \cdot cos(\gamma_0 + k \cdot (\beta - \beta_0)) - \\
&\quad sin\,\alpha \cdot cos\,\beta \cdot sin(\gamma_0 + k \cdot (\beta - \beta_0)) + cos\,\alpha \cdot sin\,\alpha \cdot sin\,\beta\big) \\
z &= R \cdot \left(cos^2\,\alpha - sin^2\,\alpha \cdot cos(\gamma_0 + k \cdot (\beta - \beta_0))\right)
\end{aligned}$$

$$k = \frac{\gamma_1 - \gamma_0}{\beta_1 - \beta_0}$$

As the angle of inclination OS_1 to an axis z is not constant, therefore for handling conic surface of height h_f millers are necessary with height, not smaller than the value (for lack of the "dead" parts of the surface). The value h_f is evaluated by the formula

$$h_f = \frac{R_d + h_{пов}}{cos\,\delta_{max}} - \frac{R_d}{cos\,\delta_{min}} \tag{8}$$

where δ_{max} and δ_{min} accordingly the greatest and least angles of the inclination OS_1 to an axis z, the conic surface is restricted to planes $z = R$ and $z = R + h_{пов}$.

The given algorithms allow essentially to reduce volume of the controlling information. For example, during the handling of an elliptic element of detail this volume is diminish col in five times in comparison with linear interpolation.

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⑪材料押出しの計算メカニズム

Mogilnikov E.V., Oleinikov A.I.

短評：

金属等の可塑材料の押出しプロセスの計算モデリングの基礎となるのは、表面力の強さを評価するための汎用的な変分法を実現するアルゴリズムの集合である。ワーキング・プレッシャーなどのプロセス中のエネルギーや力といった変数の計算に加え、速度場、変形場および応力場が解明される。これらの場を解析することは、プレス製品の品質向上、機械装置や押し出し、ブローチ削り、絞り、据込み、鍛造などの工程の最適化に役立つ。例として、1 軸と 2 軸の横押出しの計算および摩擦力の単位圧力値に及ぼす影響の解析が紹介されている。

報告：

NUMERICAL MECHANICS OF EXTRUSION METAL[3]

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It is not always is possible to find the precise solution of problem in plastic theory [1], for example, method of slip lines, on account of series reasons such as composite geometry of area, nonfulfillment of boundary conditions in stresses or speeds and etc., therefore large development was received the approximate methods of the solution, in particular, method of upper-bound estimate, founded on the extreme theorems of plastic theory [2-5].

Problem definition. Let's describe a problem definition [4]. Let's consider some solid, occupying volume V, restricted surface $S = S_F + S_u$. On part of solid surface S_F the effort F_n presets; components last on axes x_i (i = 1, 2, 3) we shall designate through X_i, on part of solid surface S_u the speed V_0 presets; its components we shall designate through u_{0i}.

Let σ_{ij} – some field of stresses, satisfying to differential equilibrium equations inside solid (in area V)

$$\sigma_{ij,j} + f_i = 0, \quad i = 1, 2, 3 \qquad (1)$$

and equilibrant with given on boundary S_F by loads X_i:

[3] Research carried out by financial support RFBR (project 01-01-00921) and Ministry of Education Russia (project E00-4.0-123).

$$\sigma_{ij} n_j = X_i \text{ на } S_F, \quad i = 1, 2, 3 \tag{2}$$

Hereinafter the mediums, for which value of shearing stresses are considered, and, therefore, value of intensity shearing stresses can not surpass some value

$$s_{ij} s_{ij} \le 2\tau_s^2, \quad s_{ij} = \sigma_{ij} - \delta_{ij}\sigma, \quad \sigma = \frac{1}{3}\delta_{ij}\sigma_{ij}, \quad i = 1, 2, 3 \tag{3}$$

In our research the cartesian system of coordinates will be used, f_i – components of volumetric force, τ_s – yield strength at shear, n_j –components of external single normal to surface S.

We shall enter some kinematically possible field of speeds u_i, satisfying to given conditions on part surface S_u

$$u_i = u_{0i} \quad \text{на } S_u, \quad i = 1, 2, 3, \tag{4}$$

and condition of incompressibility in V

$$\delta_{ij}\xi_{ij} = 0, \quad i = 1, 2, 3 \tag{5}$$

where ξ_{ij} – tensor of speed strain

$$\xi_{ij} = \frac{1}{2}\left(\frac{\partial u_i}{\partial x_j} + \frac{\partial u_j}{\partial x_i}\right) \tag{6}$$

Hereinafter connection between stresses and speeds can be arbitrary.

Then upper-bound estimate of power surface forces on S_u [4, 5]

$$\begin{aligned} \int \sigma_{ij} n_j u_{0i} dS_u \le \int \frac{1}{2\mu}\left(2\tau_s^2 + \mu^2 \xi_{ij}\xi_{ij}\right) dV + \sum_{p=\overline{0,n}} \int \frac{1}{2\nu_p}\left(\tau_s^2 + \nu_p^2 [u]_p^2\right) dS_p - \\ - \int X_i u_i dS_F - \int f_i u_i dV \equiv G(\mu, \nu, u_i) \end{aligned} \tag{7}$$

where μ, ν_p – any positive piecewise continuous functions in V and on slip surface S_p, $[u]_p$ – speed jump on S_p.

If on boundary S_u the shearing stress $\tau_0 = \mu_{tr}\tau_s$ presets, where μ_{tr} – friction coefficient, that in case, when index p is peer null, in (7) is necessary to substitute integrand on

$$\frac{1}{2\nu_0}\left(\mu_{tr}^2 \cdot \tau_s^2 + \nu_0^2 [u]_0^2\right)$$

All further reasoning are conducted similarly.

It is further supposed, that $X_i = 0$, $f_i = 0$, $i =$ 1, 2, 3, and μ, ν_p – piecewise constant functions.

For minimization of functional and searching of unknowns functions μ, ν_p and u_i the following iterative process is applied

$$
\begin{aligned}
&G\left(\mu^n, \nu_p^n, u_i^n\right) \geq \min_{\mu} G\left(\mu\ , \nu_p^n, u_i^n\right) = G\left(\mu^{n+1}, \nu_p^n, u_i^n\right) \geq \min_{\nu_p} G\left(\mu^{n+1}, \nu_p, u_i^n\right) = \\
&= G\left(\mu^{n+1}, \nu_p^{n+1}, u_i^n\right) \geq \min_{u_i} G\left(\mu^{n+1}, \nu_p^{n+1}, u_i\ \right) = G\left(\mu^{n+1}, \nu_p^{n+1}, u_i^{n+1}\right)
\end{aligned}
\tag{8}
$$

Surfaces S_p break area V on final number of subregions: $\bigcup_{\alpha=1}^{k} V_\alpha = V,\ k < \infty$. Expression μ_α – value μ on V_α. Then the functional (7) can be written to view

$$
G\left(\mu_\alpha, \nu_p, u_i\right) = G_1\left(\mu_\alpha, \nu_p\right) + G_2\left(\mu_\alpha, \nu_p, u_i\right) \tag{9}
$$

where

$$
\begin{aligned}
&G_1\left(\mu_\alpha, \nu_p\right) = \frac{\tau_s^2}{2}\left(\sum_{\alpha=1}^{k} \frac{2mes\left(V_\alpha\right)}{\mu_\alpha} + \sum_{p=0}^{n} \frac{mes\left(S_p\right)}{\nu_p}\right), \\
&G_2\left(\mu_\alpha, \nu_p, u_i\right) = \frac{1}{2}\left(\sum_{\alpha=1}^{k} \mu_\alpha \int \xi_{ij}\xi_{ij} dV_\alpha + \sum_{p=0}^{n} \nu_p \int [u]_p^2 dS_p\right), \\
&mes\left(V_\alpha\right) = \int dV_\alpha\ , \quad mes\left(S_p\right) = \int dS_p\ .
\end{aligned}
\tag{10}
$$

Expressions μ_α^{n+1} и ν_p^{n+1} in iterative process

$$
\mu_\alpha^{n+1} = \left(\frac{2\tau_s^2 mes\left(V_\alpha\right)}{\int \xi_{ij}^n \xi_{ij}^n dV_\alpha}\right)^{1/2}, \quad \alpha = \overline{1,k} \tag{11}
$$

$$
\nu_p^{n+1} = \left(\frac{\tau_s^2 mes\left(S_p\right)}{\int \left[u^n\right]_p^2 dS_p}\right)^{1/2}, \quad p = \overline{0,n} \tag{12}
$$

Then functions u_i^{n+1} are finding from the solution of problem

$$
G_2\left(\mu_\alpha^{n+1}, \nu_p^{n+1}, u_i^{n+1}\right) = \inf_{u \in U} G_2\left(\mu_\alpha^{n+1}, \nu_p^{n+1}, u_i\ \right) \tag{13}
$$

where U – set of kinematically possible speeds.

In case of plane problem the finite element method is applied [6]. Let V – some flat area with boundary S on plane (x, y); (u,v) – components of vector speed on axes x и y, φ – stream function. Then the condition of incompressibility (5) enters

$$\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}=0,$$

The components of speed are connected with stream function by ratio

$$u=\frac{\partial \varphi}{\partial y}, \quad v=-\frac{\partial \varphi}{\partial x},$$

and then the condition of incompressibility is executed identically.

Then varied part of functional (9) is given by

$$G_2(\mu_\alpha, \nu_p, u_i)=\sum_{\alpha=1}^{k}\mu_\alpha\int\left\{\frac{1}{4}\left(\frac{\partial^2\varphi}{\partial y^2}-\frac{\partial^2\varphi}{\partial x^2}\right)^2+\left(\frac{\partial^2\varphi}{\partial x\partial y}\right)^2\right\}dV_\alpha+$$
$$+\sum_{p=0}^{n}\frac{\nu_p}{2}\int\left(\left[\frac{\partial\varphi}{\partial y}\right]^2+\left[\frac{\partial\varphi}{\partial x}\right]^2\right)dS_p\equiv J(\mu_\alpha, \nu_p, \varphi) \quad (14)$$

Let area V divided into set of rectangular lagrangian finite elements $\bigcup_{\alpha=1}^{k} V_\alpha = V,\ k<\infty$, with nine points on each element. Boundaries of elements V_α are considered as surface of possible gaps of speed S_p. On each element we shall enter in consideration basic functions φ_l^α, $l = 1, \ldots, 9$, appropriate to points.

Then stream function φ determines as linear combination of basic functions

$$\varphi=\sum_{i=0}^{N-1} b_i\varphi_i \quad (15)$$

where b_i – unknowns coefficient, φ_i – basic function, appropriate i point on element, N – total of finite elements.

Substituting (15) in (14), differentiating and equating null private derivatives, we receive the system of linear algebraic equations concerning b_i. Having solved it, we find coefficients μ_α and ν_p by the formulas (11), then again we decide the system and so long, last two values of functional will be not differed from each other on some small quantity, then the iterative process are ceased.

The processes consider lateral extrusion of metal through rectangular matrix: the ingot is extruded between two driving towards one another presses-stamps (fig. 1); the ingot is extruded in the container by one press-stamp (fig. 2). Both problems are reduced to plane deformation, as it is supposed, that the sizes of ingots in z-dimension are much greater of the sizes in direction axes x and y.

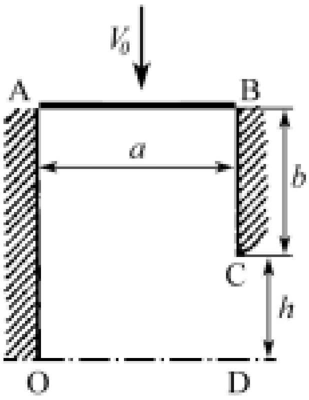

Fig. 1

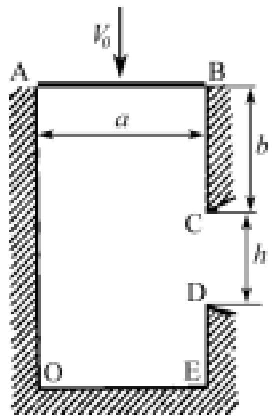

Fig. 2

In both cases the presses-stamps are moved with speed $V_0 = 1$. Through a width of the container is denoted, through b – distance from press-stamp to hole, through c – distance from hole to the bottom of container, through $2h$ and h, accordingly, – width of hole.

Then the boundary conditions are entered on the appropriate sides AO, AB, CD, OD, DE for considered problems in the following form:
for problem at fig. 1:

$$AO:\ \frac{\partial\varphi}{\partial y} = 0; \qquad AB:\ -\frac{\partial\varphi}{\partial x} = -V_0;$$

$$BC:\ \frac{\partial\varphi}{\partial y} = 0; \qquad OD:\ -\frac{\partial\varphi}{\partial x} = 0$$

for problem at fig. 2

$$AO:\ \frac{\partial\varphi}{\partial y} = 0; \qquad AB:\ -\frac{\partial\varphi}{\partial x} = -V_0;\ BC:\ \frac{\partial\varphi}{\partial y} = 0;$$

$$DE:\ \frac{\partial\varphi}{\partial y} = 0; \qquad OE:\ -\frac{\partial\varphi}{\partial x} = 0$$

The amount of pressure p_s want to determine, divided by yield strength τ_s and area contact of the tool and ingot.

The data of calculations are adduced in tab. 1, 2 accordingly for the first and second problems. The streamlines are obtained for each problem (fig. 3, 4).

Table 1

№ iteration	1	2	3	4	5	6
p_s / τ_s, smooth	8.15	6.99	6.44	6.10	5.86	5.68
p_s / τ_s, rough	9.13	8.12	7.70	7.48	7.34	7.24

Table 2

№ iteration	1	2	3	4	5	6
p_s / τ_s, smooth	9.42	7.75	7.05	6.65	6.39	6.21
p_s / τ_s, rough	10.46	8.94	8.38	8.10	7.93	7.83

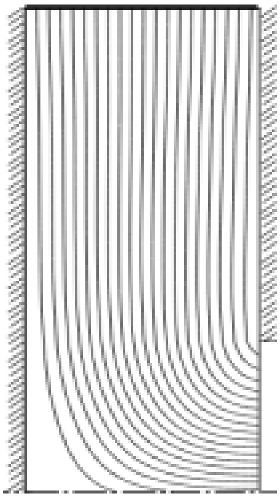

Fig. 3

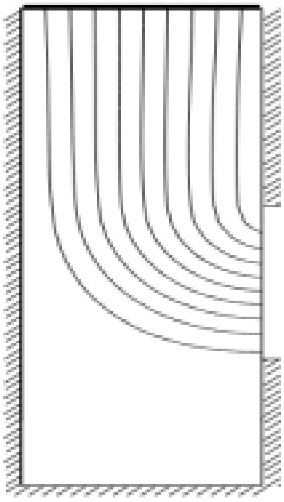

Fig. 4

In the tables the values of specific pressure p are adduced, divided on yield strength at shear τ_s. The sizes of areas: $a = 2$, $h = 2$, $b = 4$ for first problem; $a = 2$, $b = 4$, $h = 4$, $c = 4$ for second problem. For each problem two cases were considered – when the walls of the container and press-stamp are absolutely smooth and rough.

It is possible to mark, that at identical geometry of considered areas value of specific pressure, expended for deformation of ingot at two-side extrusion is less, than at unilateral extrusion on 6 % and 8 % accordingly for cases with absolute smooth and rough surfaces.

The obtained results can be utilised in technological calculations of flanging processes with tubular filler in different industries, for example, aircraft construction, mechanical engineering, shipbuilding and many other.

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⑫磨耗を考慮した切削工具の緊張状態の進展に関する計算モデルの構築

Kabaldin Yu.G., Oleinikov A.I., Kuzmin A.O.

短評：
境界エレメント（BEM）法に基き、磨耗によって圧痕および面取部が発達する際の切削工具の緊張状態がどう変化するかが研究されている。

報告：

COMPUTING MODELING of EVOLUTION of the STRESSED STATE of the CUTTING TOOL In view Of WEARINGS

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Researches and development of new tool materials nowadays proceed. These researches are directed on development of such materials, which have high hardness and endurance, and also sufficient strength, since it determines serviceability of a tool material.

The urgency of the given researches proves to be true as necessity of creation of more durable and reliable tools, and increase of quality of processing of details about their help.

Last confirms by that during processing the initial surface of the tool owing to wearing changes, namely, the geometrical parameters of the tool cutting edges change. Thus, functionability of the tool and quality of processing to a great extent depend on current values of kinematic geometrical parameters of cutting edges and ranges of their change during cutting. It is known, that, for example, the deviation of value of a front rake of a cutting wedge on five grades against its best value can lower stability of chisels three times, hobs - twice; the deviation of value of a clearance angle on five grades can call reduction of stability of chisels twice, of hobs - five times and to result in chipping cutting edges in case of further increase of clearance angles [1]. Owing to last the disastrous loss of machining accuracy is possible. Therefore at an estimation of machining accuracy it is necessary to take into account kinetics of wearing and margin of safety of the tool.

The most often reason of failure of a cutting instrument is the brittle failure and loss of the form in connection with plastic deformation of a cutting wedge. But, as a rule, to this stage the natural wear on forward and back surfaces of the tool will precede.

During cutting the blade of a cutting tool subjects to diverse mechanical loads and scuffing by a worked material.

In the present activity the research was made, the purpose which one is the influence determination of cutting tool wedge wearing during its activity on character of a stressed state in cross-section of the tool.

On the basis of the given information it is supposed to determine reasons of development of destruction.
For the effect registration of the tool wearing on a stressed state of the cutting tool cross-section subject to given normal and tangent efforts (a fig. 1), experimentally obtained by Vereshaka A.S. [1]

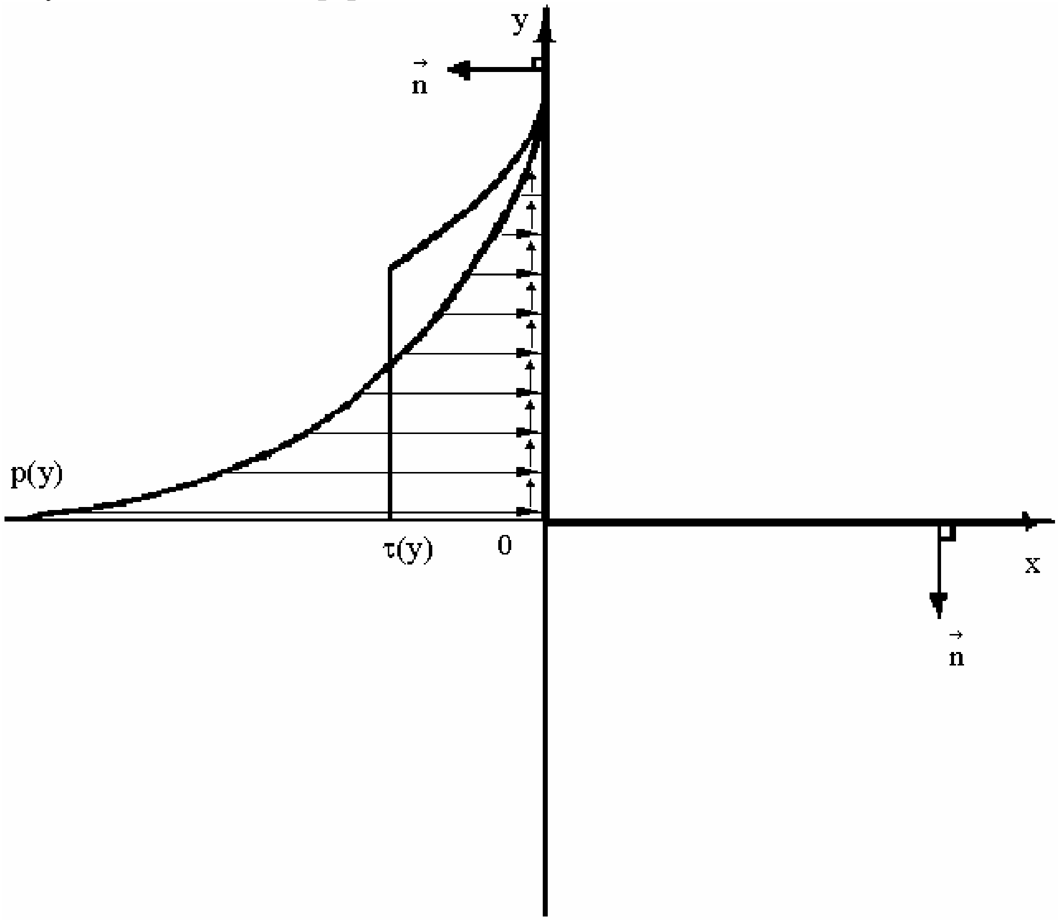

Fig. 1 «Distribution normal and shearing stresses on contact pads of a cutting tool»

and two problems are resolved:

1. Calculation of a stressed state of the tool right at the beginning of activity;
2. Calculation of a state of stress of the tool after 20 minutes of continuous operation;

The calculations were conducted numerically through a created software package constructed on the basis of an indirect method of boundary elements [2].
As outcomes the diagrams of a function of destruction for the data of two tasks (fig. 3, 4 accordingly) are shown. Function of destruction here is understood as criterion of limiting state of a tool material up to temperatures T < 600C by the way, offered by A.A. Levedev [1976]:

$$F_p \equiv 0.24\tau + 0.76\sigma_{max} 0.8^{1-\frac{\sigma}{\tau}} = \sigma_в,$$

where $\tau = \sqrt{\frac{1}{2}\left[(\sigma_x - \sigma_y)^2 + (\sigma_y - \sigma_z)^2 + (\sigma_z - \sigma_x)^2\right] + 3\sigma_{xy}^2}$,

$\sigma = \sigma_x + \sigma_y + \sigma_z$,

$\sigma_z = \nu(\sigma_x + \sigma_y)$.

The figures 3, 4 represent the diagrams created by a designed software package and reflecting calculation of a function of destruction in rectangular area of the tool with the given size. Components of stresses or function of destruction in each point of the tool is compared to one of the thirty equal numerical intervals dependent on a difference between maximum and minimum value of an appropriate function in area and expressed in kgf / mm2. The predetermined colour is assigned to each interval and on the diagram points from one interval of values are shown by one colour.

The conformity of intervals and colours is shown as the panel in the left part of the diagram.

In the fig. 3 values distribution diagram of the function of destruction is shown, which one takes place for new not worn tool in the beginning of work. According to this diagram, there are two centers of wearing propagation: first and most important is formed in top of the tool on a cutting edge, second - less intensive, on a forward edge apart 0.6 mms from top (square of a grid indicated in figure, has the size 1 x 1 mm). The destruction from these zones is distributed to a forward edge (in fig. 3 the paths of possible destruction is indicated by directional curves). The obtained character of distribution of function of destruction confirms the experimental data and causes creation of a lune of wearing on a forward edge of the tool. To the 20-th minute of the tool activity the lune of wearing takes the form, indicated on a fig. 4, on which one it is shown by white area.

From a fig. 4 it is visible, that at the given stage of the tool activity the center of propagation of its further wearing and possible destruction is the top (cutting edge) hard-alloy insertion of the tool. Thus probably further propagation of a lune of wearing, which one results in a flattening of its bottom, and also destruction of a back surface of the tool.

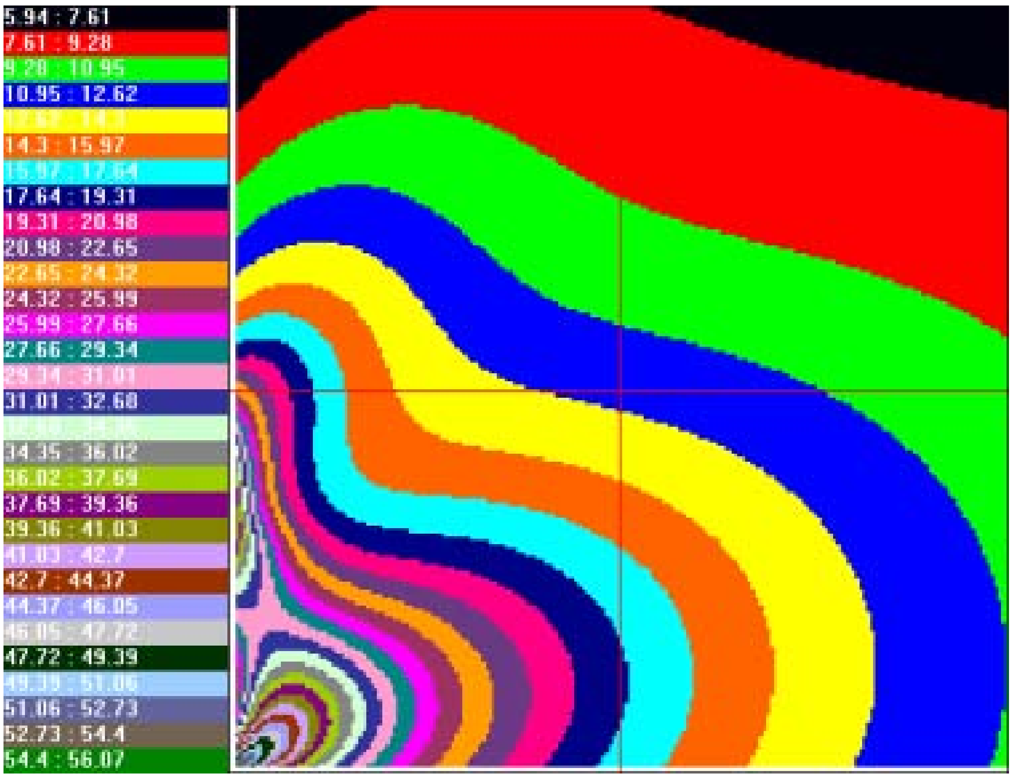

Fig. 3. The diagram of function of destruction for the tool in beginning of work.

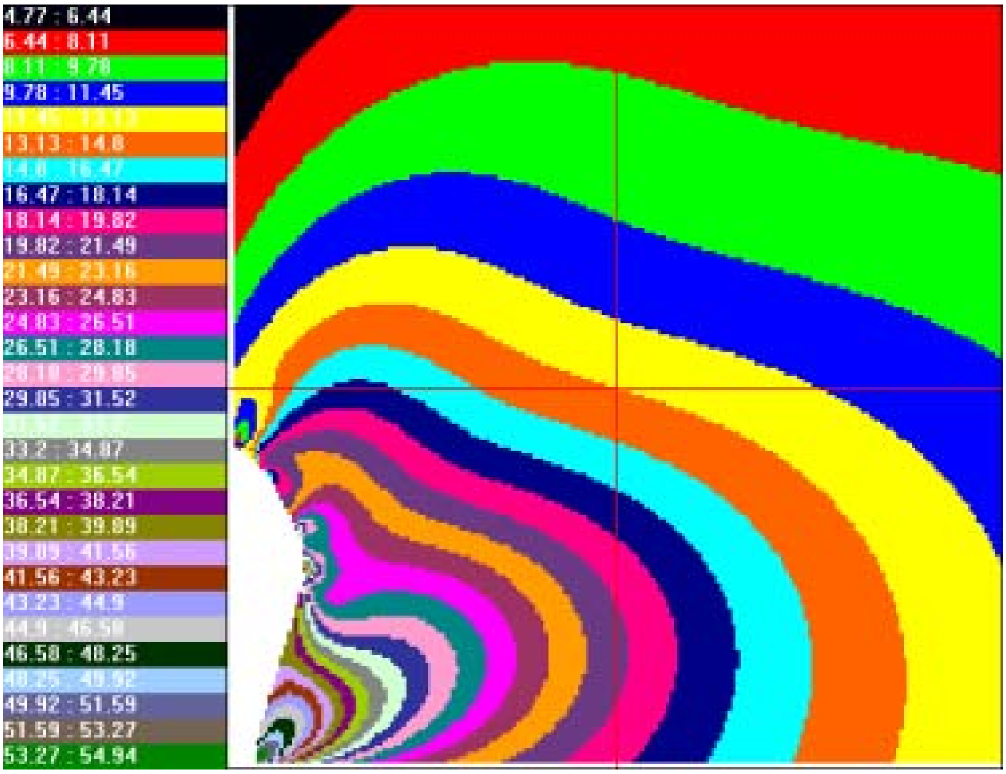

Fig. 4. The diagram of function of destruction for the tool after 20 minutes.

On the basis of the given researches the following conclusions are made:

1. The new results about distribution of operational stresses in the tool are received in view of its wear process.
2. The features of a stress distribution are determined, which one arises owing to wearing of a forward edge of the tool.
3. The most probable reasons and mechanism of wearing or destruction of the tool are established, which one can be prescribe in development of the guidelines on increase of endurance and quality of processing.

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⑬用途の異なる強誘電複合ポリマー
Zatouli A.I.

要点：

重近年電分野では、強誘電ポリマーないしは強誘電ゴムからなる電磁波を防止するコーティングや被覆材料の利用が盛んになっている。こういった材料の性質の研究により、その重要な特徴が明らかになってきた。

充填された誘電物質と充填材の化学的性質のために、複合材料はトラップ効果を発揮し、「ホット」な電子の中和層として利用することができる。この層は、ペースト、ラッカー、糊、塗料タイプの被膜などのかたちで形成することができる。材料のトラップ効果は、おもに充填材のタイプと構造により決定される。

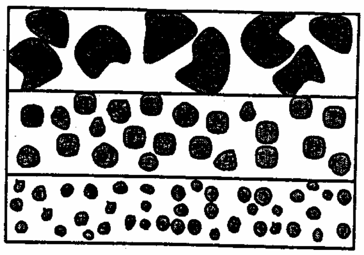
さらにまた、複合材料は強誘電性充填材により高い相対誘電率をもつために、誘電的に分離されたなかではεにしたがって電場が再配置される。コーティングする層の数を調節することで誘電率を段階的に変化させることができ、それに伴って電場強度を変えることができる。ポリマーマトリックスのなかに分散度の異なる充填材を入れるか（図１）、または２種類以上の充填材の割合や分散度を変えることで、新たな可能性が生まれる。

上記以外にも、外部からの電極の分極化と一定の配向性のドメイン構造を形成することにより誘電率を上げることができる。

充填材の母材にエラストマーとゴムを使う方法もある。誘電･圧電ゴムの研究はまだあまりされていないが、こうした材料を使えば、ホース状のピエゾセンサーを作ることができる。

母材としてのポリマーやゴムは複合材料に、強誘電体のもっていない可塑性を与えることができる。とはいえ、こうした複合材料の開発にはかなりの困難が伴う。そのなかでも最大の困難は、高い誘電率(ε)と可塑性を同時にもつコンポジットをつくることができないことである。さらにまた、充填率を上げると強度が低下し、複合材料の誘電正接が増加する。

図１　分散度の異なる充填材の入った複合材料の多層コーティング



要点（英文）：

COMPOSITE ELECTRICAL ENGINEERING POLYMER MATERIALS OF VARIOUS APPLICATIONS

Zatouli A. I.

In resent years anti-emission layers and coverings are actively used in high-voltage technical devices (machinery), they being made on the basis of seignettecontaining polymers or rubbers. The study of such materials characteristics revealed a number of irnportant properties in them.

Due to seignette-filling and in accordance with the chemical nature of the filler, composites of that kind display a trap effect and thus can be utilized as layers neutralizing "hot" electrons. Such layers may be used in the form of paste, varnish, glue, paint coating, etc. The trap effect of these materials is mainly explained by the type of the filler and its structure.

Besides, due to the seignettefillers, composite materials have hightened relative dielectric penetrability values, which results in re-distribution of electric field according to ε within the dielectric insulation. Using stratum application, it is possible to obtain the graded regulation of dielectric penetrability and, accordingly, of electric tension. Intersting apportunities appear, if to inject into the polymer matrix the filler with different dispersion (see figure 1) , or to vary the compound and dispersion of two or more fillers.

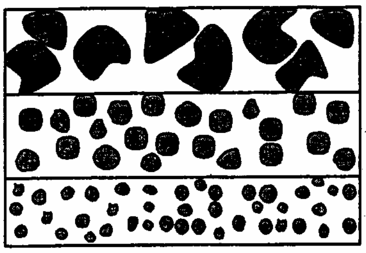
Apart from this, an increase in dielectric penetrability is possible due to the outer polarization and formation of blast furnace structures of certain orientation.

Variants are interesting of elastomer and caoutchouc application as the basis for filling. Seignette-piezo-rubbers have not jet been well-studied, but they give the opportunity to create extensive piezosensors in the form of hosed cables.

Polymer and rubber bases provide a composite with plasticity, which seignette-electric materials do not possess. Elaboration of such composite materials, however, meet a number of difficulties. The most serious of them is impossibility to create composites, possessing both high ε values and high plasticity at the same time.

Besides, a high filling degree results in the reduction of electric endurance and angle tangent extension of dielectrical loss of composite materials.

figure 1 Stratum application of a composite material with a filler of various dispersion



⑭工業用発電機の３相電圧自動安定化装置と無効電力補償装置の開発原理

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要点：

工業･農業および民生用電気設備の信頼性は、ユーザーに供給される電力の品質に大きく左右される。

電力の品質をあらわす主要な指標は、ユーザーである機器の電源入力端子における電圧偏差と電圧変動である。ここで注意したいのは、最終ユーザーに供給される電力は大抵の場合、一般的には負荷時の変圧比を調整する機能のない、最大出力が 1000 kVA までの 10/0.4 kV および 6/0.4 kV の逓降変圧器によってつくられることである。このことが 0.4 kV を使用する機器の電源品質の悪化の原因となるため、瞬断を起こさずに電圧を安定にするような方法を考えなければならない。

レポートでは、供給側の電圧と、振幅と位相が負荷電圧に応じて変化する昇圧器の２次巻き線のひとつないし複数の電圧を代数的に加算（ベクトル加算）する方法による、３相電圧の自動安定化装置のつくり方をいくつか考察している。アルゴリズムを装置が実現する方法として、給電電源と同期している周波数変換器から１次側に給電される昇圧器を１個ないし数個もつ電圧ブースト回路を採用するが、これには周波数変換器を直に使う方法、DC 回路を間に入れて使う方法、高周波回路を間に入れて使う方法の３つのオプションが紹介されている。

この電圧自動安定化装置は、負荷時の相電圧の許容偏差が 0.5%以下、電圧復帰時間が 0.1 秒未満、出力電圧カーブの調波係数が許容値内にあるといった特徴がある。加えて、負荷により消費される無効電力の一部が補償される。

要点（英文）：

PRINCIPLES OF DESIGN OF AUTOMATIC THREE-PHASE VOLTAGE STABILIZATION SYSTEMS AND REACTIVE POWER COMPENSATION FOR INDUSTRIAL APPLICATIONS

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Reliability and efficiency of industrial agricultural and domestic electrical equipment operation are closely associated with quality of electric power brought to a consumer.

Basic parameters determining the quality of electric power are deviations and oscilations of voltage on terminals at a consumer's. It should be mentioned that power supply of most electricity consumers is implemented with step-down transformers of 10/0.4 kV or 6/0.4 kV voltage and up to 1000 kV･A power which are, as a rule, not equipped with devices for regulating gain under load. This involves falling of quality of 0.4 kV consumers' power supplying and requires development of additional measures for stabilizing voltage without interruptions in power supplying.

In the paper, various designs of automatic three-phase voltage stabilization systems are considered, which are based on algebraic (vector) summation or sub-traction of supply voltage and one or several voltages of secondary windings of the voltage-additive transformer(s); amplitude and phase of the latter voltages are generated in dependence of the voltage value on a load. For algorithm implementation in the systems, voltage-additive channel is employed, consisting of one or several voltage-additive transformers which primary windings are powered from cycloconverters synchronized with supply line. Versions are presented containing direct cycloconverters as well as cycloconverters with imtermediate DC unit or high-frequency unit.

Automatic stabilization systems are characterized with permissible deviations of phase voltage on a load, not exceeding 0.5%, deviations compensation response of up to 0.1 sec. long and permissible armonics coefficient of output voltage waveform. In addition, partial compensation of load-consumed reactive power is performed by the devices.