（No.１　２００１年９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１

今号より３号にわたりロシア極東のハバロフスク地方、主としてコムソモリスク・ナ・アムーレとハバロフスクにおける産学共同による技術開発研究に的を絞り、コムソモリスク・ナ・アムーレ工科大学、コムソモリスク・ナ・アムーレ航空機製造工場、ハバロフスク工科大学、極東科学アカデミー機械工学研究所による機械製作、電機技術、材料、航空機製造に関した技術開発の研究をご紹介いたします。

Ⅰ．コムソモリスク・ナ・アムーレについて

コムソモリスク・ナ・アムーレ市は、ロシア極東のハバロフスク地方に位置し、ハバロフスク市から北東に 356km。自動車道路では 404km。アムール河の下流、左岸に沿って 20km 以上にわたり市を形成する。アルール河とバム鉄道が通る交通の要衝。人口 29 万 2,500 人（2000 年 1 月 1 日現在）。ハバロフスク地方行政区では、ハバロフスク市に次ぐ第 2 の都市であり、ロシア極東全体（716 万人）でもハバロフスク(60 万 6,600 人)、ウラジオストク(60 万 3,400 人)、に次ぐ第 3 の都市。

コムソモリスク・ナ・アムーレは、1932 年に市となり、1932 年から 1939 年にかけて航空機製造工場と造船所が建設され、1941 年から 1945 年にかけてアムール製鋼所が建設されて以来、ソ連時代は軍需工業都市として発展。外国人の立ち入りが禁止されていた。現在ではハバロフスク地方の工業生産高の 40%（1999 年）を占め、航空機製造業、造船、鉄鋼業、建機、精油所などの主要企業が集中する極東最大の工業都市となっている。1998 年には同市の工業総生産の 74%、雇用人口の 38%を製造業が占め，主要な経済基盤となっている。1998 年の同市の GDP は 74 億 5,220 万ルーブルで、前年度比 36.5%増。工業生産高は 1996 年以降プラス成長で、1999 年の工業生産高は対前年比 27%増。コムソモリスク・ナ・アムーレの主要企業は以下のとおり。:

≪機械製造≫：

コムソモルスク・ナ・アムーレ航空機製造工場：スホイ戦闘機 Sukhoi-27,30（中国に輸出し、従業員を増やすなど活況）、水陸両用機 "Be-103"、民間機"Sukhoi-80"を製造。

分社化企業："Stils"社（モーターボート "Amur" "Strela"、ヨット、スクーター、子供用自転車、医療用チャンバー、スノーモービルを製造）。"Avest"社（韓国 LG のライセンスによる TV、ラジオ、その他家電品のアセンブリー、ボイラー、サハリン１および２用の機器製造）。

アムール造船所：創業以来、ソ連時代には潜水艦を製造。1996 年 11 月には、ハバロフスク地方の企業としては初めて"Sakhalin-2" 大陸棚石油ガス開発プロジェクト "Moliqkpaq" 掘削設備の一部を製造。最近では、多目的河川海洋用貨物船 "Volga"（5,500 トン），サルベージ用タグボート、小型漁船 (135 トン)、ハング・グライダーを製造。

アムールリトマシ（Amurlitmash）：鋳造設備製造（ショット・ブラスト　バレル他）。
コムソモリスク電機工場（Komsomolsky Electro-Technical Plant）：極東で唯一、自動車用バッテリーを製造、その他プラスチック製品を製造。
ポドマ（Podma）：1959 年に設立。クレーン製造、電動トレストルクレーン（昇降能力 12.5 トン、 スパーン 32 m）の製造を計画中。
エクスポ（EKSPO）：多目的ポンプ、航空機やタンクローリ車等への給油装置を製造。

≪製鉄≫

旧アムール製鉄所：極東唯一の製鉄所として極東地域の需要を充足してきたが、1996 年に倒産後、設備プラントごとに以下の独立企業として分割。外資を導入し、内外の需要増を背景に生産は向上している。

アムールメタル（Amur-metal）：圧延製品、棒材、線材、アングル、コの字形型材
アムールスターリ・プロフィール（Amurstal-Profil）：ガードレール、建設用他型鋼
極東圧延工場（Fareastern Stal）：棒材、アングル
スタルハ（Stal-Ha）：韓国との合弁、圧延材

≪林業・製材≫

フローラ（Flora）：材木の輸出、丸太、製材加工
ボストーク（Vostok）：建材等製材加工

≪その他≫

コムソモリスク製油所：サハリンのオハからパイプラインで供給される石油を精製。
エルコム（Elcom）：溶接用電極製造
コムソモルカ（Komsomolka）：縫製工場、1989 年 JUKI の設備を導入。日本、韓国にも輸出
コムソモルスクエネルゴジルストロイ（Komsomolskenergozhilstroi）：産業施設・住宅・パイプライン建設
エレクトロスヴャーズ（Electrosvyaz）：通信（国営）
ロスネット（Rosnet）：プロバイダー（民間）

コムソモリスク・ナ・アムーレ工科大学について

コムソモリスク・ナ・アムーレ工科大学は 1955 年に設立。教師、研究助手の総数は 380 人。うち科学博士号および博士候補を持つ教授の数は 163 人。教授 5 名がロシア科学アカデミー会員。コンピューター学部、電気工学部、航空機製造・造船学部、土木工学部、人文科学学部、経済・経営学部、環境・化学工学学部がある。

工科大学の特徴は、造船、航空機製造、機械製作、冶金、石油精製等の地元企業と古くから産学共同研究等を行う、極東で唯一の航空機製造学部があり、主として機械製作等の技術者を養成し地元企業に輩出している点にある。主要な専門技術分野は、機械製作、造船、冶金、材料学、航空機製造、電機技術関係である。

学術・技術開発研究の成果として、１）機械製作では、切削工具等にコーティングを施し耐摩耗性を高める方法の開発。２）機械製造･製作では、ニュウロンモウ、不確定ロジックに基礎をおいた操作方法の研究。３）造船では、新しい強度の計算方法、新しい船舶のユニットその他構造物の強度の計算方法の開発。４）冶金では、非鉄金属から新しい方法でビレットを取り出す精錬方法の研究、音響放出信号の処理を基礎にした製品の検査方法の開発。５）航空機製造分野では、圧力をかけて金属を加工し部品を作る加圧加工方法などの技術開発研究がある。

①高能率機械加工プロセスに関する数学・計算モデルの構築

Kabaldin Yu.G., Oleinikov A.I.

短評：

切削工具との接触点近傍の塑性変形帯における鋼およびチタン合金のミクロおよびレントゲン構造の分析結果が論述・検討されている。塑性変形帯中の各ゾーン、すなわち表面層融解、無定形化、拡散機構およびマルテンサイト機構による多晶変態の各ゾーンが定義され、ついで圧力下で生ずる外部摩擦による接触層の融解モデルが提案されている。このモデルにより、融解層の厚さを評価することが可能となった。発生した融解部との接触における（切削工具の）摩擦および振動挙動は融解金属の特性に左右されることが解明され、融解層における接触波の計算モデルが提案されている。また、定常波および単独波の発生条件が定義・検討されている。

報告：

Mathematical and computational modeling High-performance processes of a machining

KABALDIN Y.G., OLEINIKOV A.I.

Introduction. For the last time an universal approach in the study of a machining was offered [1]. On the basis of this method an experimental information about regularities of a time-space ordering and ascertaining presence of dissipative structures in cutting systems was explored and analyzed. The processes of ordering arise due to interaction of a great number of elementary subsystems. Bonding contact pads of the instrument with the work material are the most important. In turn, this system is a multiscaled non-linear dynamic system having its own intrinsical time-space ordering.

Such a way, at near-contact material layers of an instrument and its part level coming into being of rotational structures of metal motion in the cutting edge of shavings and periodic structures of a contingence of a layer to be cut with instrument’s forward surface is ascertained. At a level of phases and grains components forming contacting materials structures of new phases in a material being processed (for instance, trostite-perlite-ferrite in a sole of a growth from steel) and local separation (tearing off) structures of carbide grains in a surface layer of the instrument as well may arise. On a crystal’s scale one could see the formation of fragmented dislocation structure in hard alloy’s grains and also regular slipping strips. Self-formation of these structures takes place in oscillating fields of instrument’s and perform’s vibration by action of a great loadings according to the scheme pressure + shear.

Formation of similar structures in bodies of friction was also observed during experiments [2]. It results from [2] that increasing of pressure entails a transition from a slippage of contact to plastic shear. Under this instead of so-called tooth contacts structures as an areas of a high pressure taking up compressive forces arise. In such an areas the laminar nature of a plastic flow gets broken and rotational structures of a plastic particles driving come into being. Being generated by critical velocity of a plastic deformation, mentioned areas auto- accelerated extend with augment of shear and dissimilarity of stress on the contact velocity and also relax in a few seconds further.

Thus the adduced results of experimental investigations testify to origin of multiscale dissipative dynamic structures on contact instrument-work material. Their research is obviously connected with investigation of the dynamics of origin and evolution of a new structure. In the [2] there is a description for some of conditions of appearance of structures of irregular pressure in plastic contact. In the [3] the classification description of a wear of bonding contact pads of the instrument is fulfilled: adgesionly-fatigue, abrasive, chemical-abrasive, diffusive and oxidizing. In the [4] the molecully-mechanical theory of friction and the theory of fatigue outwearing explicates which assume sliding contact are developed.

In this work, according to the approach [1], mechanisms of a synergetic of evolution of new structures at the all-scale levels of outwearing of cutting tool's surfaces on the basis of the theory of a melting and solitons are considered.

1. A mathematical model of a metal's melting in cutting edge layer.

Let's consider a cutting wedge (fig 1.1) pressed by force P to a strip being dissected by the wedge on two parts and driven from a stationary value by speed U.

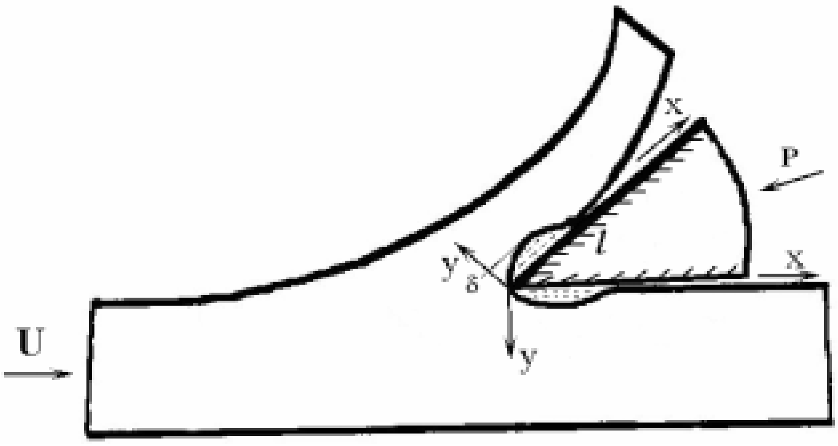

Fig. 1.1

At wedge's friction against mobile dissected parts of a strip (cuttings and the work surface) heat is getting out that involves melting of a metal in cutting edge layer by width δ.

When speed of cutting U is enough all the fluid in the layer is entrained by these parts of the strip in the direction of their motion. Owing to viscosity the speed of particles of a melt is converting in a zero on a surface. The transition from zero speed on a wedge to full speed U on the external boundary of a layer is getting accomplished in a very lamina of a melt. In this layer the velocity gradient in a perpendicular to cutting edges direction is too large and viscosity influences on flow of a melt very much. According to experimental data the width of a melt δ is very small against size of bonding contact pads of a wedge and dissected parts of the strip.

In the case in point one may reckon the melt an incompressible fluid as usual. Then the mass of a melt affluent in unit of volume is equal to a mass of a melt implied from the same volume. Therefore continuity equation (incompressibility) of a melt looks like

$$\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}=0, \tag{1.1}$$

where u and v – are components of melt speed along an axis x and y (fig. 1.1).

The dynamical equations of a melt express equality of product of a particle mass of a fluid on its convection acceleration taking into account migrations of particles, and forces, operating on it stipulated by pressure and viscosity.

Within bounds of δ-layer temperature differential is small and in fact coefficient of viscosity μ is constant in all layer. Then the Navier-Stokes equation of driving of a melt in a layer in a direction of an axis x looks like:

$$\rho\left(u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}\right)=-\frac{\partial P}{\partial x}+\mu\left(\frac{\partial^2 u}{\partial x^2}+\frac{\partial^2 u}{\partial y^2}\right) \tag{1.2}$$

in a direction y:

$$\rho\left(u\frac{\partial v}{\partial x}+v\frac{\partial v}{\partial y}\right)=-\frac{\partial P}{\partial y}+\mu\left(\frac{\partial^2 v}{\partial x^2}+\frac{\partial^2 v}{\partial y^2}\right) \tag{1.3}$$

As the width of a melt δ is small, and the speed v is equal to zero on cutting tool (CT), the transversal flow rate of a melt has the order δ. That's why magnitudes $\partial v/\partial x$ и $\partial^2 v/\partial x^2$ and have the same order δ in a layer. The parallel to CT velocity component by virtue of viscosity is equal to zero too on the wall of CT. On the boundary $y=\delta(x)$ of a melt in treated metal this component coincides a cutting speed U. Therefore magnitude $\partial u/\partial y$ has the order $1/\delta$ and magnitude $\partial^2 u/\partial y^2$ – order $1/\delta^2$. Taking into account these estimations for a lamina of a melt obviously one may lower an addend $\partial^2 u/\partial x^2$ as a small against $\partial^2 u/\partial y^2$ in an equation (1.2).

The similar estimations of addends of an equation (1.3) without taking into consideration small addends it's transformation into following simple equality

$$\frac{\partial P}{\partial y}=0 \tag{1.4}$$

It derives from a condition (1.4), that the value of pressure in a layer doesn't depend on coordinate y, i.e. in a transverse to a layer direction the magnitude P remains constant in fact and in every point of a perpendicular to a surface CT section the value of pressure is the same in a melt. Taking into account equality (1.4) and mentioned estimations of addends Prandle's equation for a boundary layer derives from (1.2):

$$\rho\left(u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}\right)=-\frac{\partial P}{\partial x}+\mu\frac{\partial^2 u}{\partial y^2} \tag{1.5}$$

The considered flow of a melt is not isothermal. The heft flow lays out mechanical flow. For the sake of determination of temperature's distribution in a layer it's necessary to connect dynamic equations of motion with a heat conduction equation. The heat balance of a driven particle of a melt is determined by its internal energy, thermal conduction, convection of heat by means of flow and origin of heat owing to internal friction. The equation of an energy balance answers a thermodynamic energy conservation law. According to this law the change of the total of magnitudes internal and kinetic energy of a particle is equal to the total of powers of forces, affixed on it and flow rate of energy brought from the outside to a particle. In our problem we consider the flow of heat being proportional to a lapse rate of temperatures T according to the Fourier's law as an external source of energy. The power of internal forces is calculated as a dot product of viscous stresses tensor and tensor of strain rates. At a melt incompressible all of this power turns to heat in an irreversible way. The change of internal energy is proportional to a change of temperature when heat capacity at constant volume C_v is a constant of proportionality. A values of thermal conductivity k in the Fourier's law and heat capacity C_v are constant in a narrow layer practically. Such a way the equation of heat (energy) spreading in a layer looks like

$$\begin{gathered}\rho C_v\left(u\frac{\partial T}{\partial x}+v\frac{\partial T}{\partial y}\right)=k\left(\frac{\partial^2 T}{\partial x^2}+\frac{\partial^2 T}{\partial y^2}\right)+\mu\left\{2\cdot\left[\left(\frac{\partial u}{\partial x}\right)^2+\left(\frac{\partial v}{\partial y}\right)^2\right]+\right.\\ \left.+\left(\frac{\partial v}{\partial x}+\frac{\partial u}{\partial y}\right)^2-\frac{2}{3}\left(\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}\right)\right\}\end{gathered} \tag{1.6}$$

At small width of a melt the addends containing magnitudes $\partial^2 T/\partial x^2$, $\partial u/\partial x$, $\partial v/\partial y$ and $\partial v/\partial x$ in an equation (1.6) are small in contrast to remaining terms. Therefore one may record an equation of heat's distribution in a narrow layer in the simpler way:

$$\rho C_v\left(u\frac{\partial T}{\partial x}+v\frac{\partial T}{\partial y}\right)=k\frac{\partial^2 T}{\partial y^2}+\mu\left(\frac{\partial u}{\partial y}\right)^2 \tag{1.6}$$

Thus, the flow equations of a melt in a shear zone of CT represent a continuity equation (1.1), equation of motion (1.5) and energy equation (1.7), which will be rewrote in the form of the following system:

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

$$\rho\left(u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}\right)=-\frac{\partial P}{\partial x}+\mu\frac{\partial^2 u}{\partial y^2} \tag{1.8}$$

$$\rho C_v\left(u\frac{\partial T}{\partial x}+v\frac{\partial T}{\partial y}\right)=k\frac{\partial^2 T}{\partial y^2}+\mu\left(\frac{\partial u}{\partial y}\right)^2$$

The equations (1.8) to be integrated at boundary conditions of an adhesion of a viscous melt to CT's edges

$$u=0\ ,\ v=0,\ \text{at}\ \ y=0 \tag{1.9}$$

On the boundary between a fluid and work material $y=\delta(x)$ is component of speed u which is parallel to an edge in proportion to cutting speed U,

$$u=kU,\ \text{when}\ \ y=\delta(x) \tag{1.10}$$

The density of metal being melted varies just a little so we may consider a fluid density in a layer δ to be equal to the one of work material.

On the boundary of a melting the temperature field should fit a condition of equality to a melting temperature of metal $T_{пл}$, and perpendicular to the edge heat flow component must be equal to an entrained effective melting heat quantity

$$T=T_{пл},\ \ k\frac{\partial T}{\partial y}=-\rho uL, \tag{1.11}$$

Effective melting heat L is equal to the total of a real melting heat $\mathbf{L}'$ and heat needed to increase initial temperature of treated metal from $\mathbf{T}'$ to $T_{пл}$,

$$L=L'+c\left(T_{пл}-T'\right), \tag{1.12}$$

where c – is metal thermal capacity.

The surfaces of edges in our problem may be considered to be heat-insulated, so

$$\frac{\partial T}{\partial y}=0\ \ \text{at}\ \ y=0 \tag{1.13}$$

Equality to zero of a bed depth of a melt in a conterminous to vertex CT index point should be added to conditions (1.9) - (1.13):

$$\delta=0\qquad \text{at}\ \ x=0 \tag{1.14}$$

Such a way the mathematical sample of shear and melting zone is obtained which is represented by system (1.8) of a melting layer equations and boundary conditions (1.9) - (1.14).

2. When it's cutting the major role belongs to processes in a layer to be cut off and to once on a perform's job surface nearby a cutting edge. In cutterside layers an intensive strain and transfering of a mechanical energy in thermal one take peace.

The crude estimate of rising metal's temperature may be got as result of (2.1)

$$\Delta T = \frac{\tau_s \gamma}{C_v}, \tag{2.1}$$

where τ_s – yield stress, γ – plastic deformation of relative shear and C_v – heat capacity when v is constant.

Having put $\tau_s = 3 \cdot 10^5 \, N/m^2$, $C_v = 5000 \, J/(m^3 K)$ and $\gamma = 20$, as it is when strains of relative shear nearby a forward edge take peace, we obtain $\Delta T = 1200K$, that is close to a melting temperature (1500 C°).

The question if a thin molten layer in an environ of a cutting edge can be formed will be considered in the base of the classical laws of viscosity and heat interchange by using of integral methods for a boundary layer.

In general when molten metal's flowing along a wall the width of a temperature boundary layer δ_T exceeds the one of a viscous bound layer δ_μ because of a Prandtle number Pr's smallness. In the case in point a molten layer's width δ_H may exceed or be equal to a viscous layer's δ_μ. Let's define conditions that allow both of these cases separately for back and forward edges of the tool.

Back edge

If $\delta_H \geq \delta_\mu$ for any x_1 (see fig. 2.1), the viscous boundary layer progresses as if it did in incompressible viscous fluid in an environ of a front edge of a plate while stream's moving along this so long as the incident flow's speed may be considered to be constant and equal to cutting speed U present problem. So one may use a precise solution of equations (1.1), (1.5) for a similar Blasius's problem [5] that gives

$$\delta_\mu \approx 5\sqrt{\frac{\mu x_1}{\rho U}}, \tag{2.2.}$$

where μ – dynamic viscosity, ρ – density.

Viscosity of fluid metals near a melting temperature $\mu \approx 2.5 \cdot 10^{-3}$ Pa $\cdot$ s. The speed's reference magnitude in the case in point is equal to $U = 10 \, m/s$. It follows from (2.2) that

$$\frac{\delta_{\mu}}{\sqrt{x_1}} = 5\sqrt{\frac{b}{Re_b}}, \qquad \frac{\delta_{\mu\,max}}{b} \approx \frac{5}{\sqrt{Re_b}} = 0.03 \tag{2.3}$$

where $Re_b = \frac{Ub\rho}{\mu}$ – Reynold's number, b width of a bevel of a wear.

For the sake of molten layer δ_H 's estimation we'll analyze pursuant to an equation (1.6) and (1.9), (1.11) conditions the balances of heat in an integral approximation:

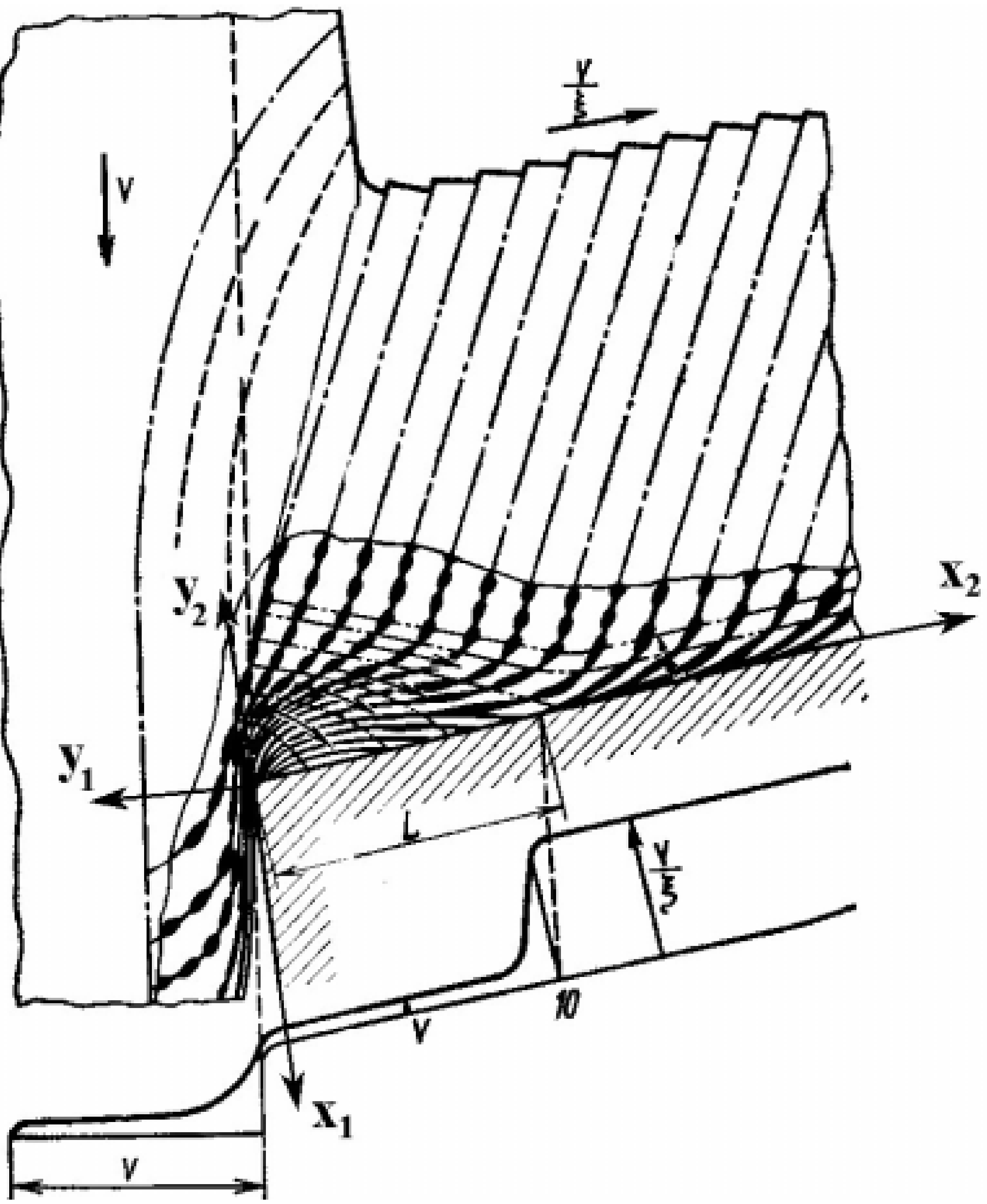

Fig. 2.1. The flow’s scheme of layer to be cut and work surface.
(In a drag of figure - graph of distribution of speeds in parallel to edges)

$$d\int_{0}^{\delta_H} \rho u C_v T dy_1 \approx dx_1 \int_{0}^{\delta_\mu} \mu\left(\frac{\partial u}{\partial y_1}\right)^2 dy_1$$

Meanwhile the internal energy of a molten layer C_vT represents basically melting heat, so the heat balance is:

$$d\int_{0}^{\delta_H} \rho u L' dy_1 \approx dx_1 \int_{0}^{\delta_\mu} \mu\left(\frac{\partial u}{\partial y_1}\right)^2 dy_1 \quad (2.4)$$

Here L' – specific melting heat, $\mu(\partial u/\partial y_1)^2$ – volumetric heat source manufactured by viscous friction. The left part of equation (2.4) is an increment on x_1 of heat flow entrained by molten metal as a latent heat of a melting. In approximated equality (2.4) it's considered that $L' \approx C_v T$ and heat needed to increase metal's temperature to melting one, it's additional heating after being smelted-down, and heat transfer through breaking points of the upper and lower bounds of a layer δ_H as well aren't taken into account. That's why width's estimations of δ_H obtained below may be taken for the upper once.

In case $\delta_H > \delta_\mu$ we may consider the velocity profile in a viscous boundary layer to fit a distribution for a laminar flow:

$$u \approx 0{,}3Uy_1\sqrt{\frac{U\rho}{\mu x_1}} \qquad (2.5)$$

So there's an equation linking widths of a molten and viscous boundary layer through a back edge

$$\delta'_H - \frac{\delta_H}{4x_1} = \frac{U}{3L'}\sqrt{\frac{\mu U}{\rho x_1}} \cdot \frac{\delta_\mu}{\delta_H} \qquad (2.6)$$

Having accounted change δ_μ to fit relations (2.2), we'll get an equation for a molten layer width's definition

$$\delta'_H = \frac{\delta_H}{4x_1} + \frac{5\mu U}{3\rho L'} \cdot \frac{1}{\delta_H} \qquad (2.7)$$

Next relation answers to this equation

$$\delta_H = 2\sqrt{\frac{5\mu U}{3\rho L'}}\sqrt{x_1} \qquad (2.8)$$

If x = b then (2.8) involves the next estimation:

$$\delta_{H\max} \approx 2\sqrt{\frac{5}{3L'\mathrm{Re}_b}}b \qquad (2.9)$$

The obtained relation (2.8) and estimation (2.9) are right under condition that width of a molten layer exceeds the one of a viscous boundary layer. Let's find a condition for a cutting speed's magnitude, which allows to implement the mentioned mode. To make it an equation (2.6) should be rewrote as follows:

$$\left(\frac{\delta_H}{\delta_\mu}\right)' = \frac{1}{4x_1}\frac{\delta_H}{\delta_\mu} + \frac{U}{3L'}\sqrt{\frac{\mu U}{\rho x_1}}\frac{1}{\delta_H} - \frac{\delta_H}{\delta_\mu^2}\delta'_\mu \qquad (2.6')$$

Let's consider the derivative sign in the left part of equation for a point, when $\delta_H = \delta_\mu$. As the derivative is positive so width of a molten layer grows along x_1 faster than one of viscous boundary layer.

By using (2.2) it follows from (2.6 ') that $\delta_H \geq \delta_\mu$ when

$$U^2 \geq 4L' \qquad (2.10)$$

For iron $L' = 280 \cdot 10^3\ \mathrm{J/kg}$ and $\delta_H \geq \delta_\mu$ when $U > 1000\ \mathrm{m/s}$, for cuprum $L' = 200 \cdot 10^3\ \mathrm{J/kg}$ and $U \geq 600\ \mathrm{m/s}$, for a lead $L' = 20 \cdot 10^3\ \mathrm{J/kg}$ and $U \geq 300\ \mathrm{m/s}$.

Let's analyse a case $U \leq 2\sqrt{L'}$, when $\delta_H = \delta_\mu = \delta$. A boundary-layer profile of speeds we'll consider to be linear. The integral balance of heat generated and entrained will look the next way:

$$\delta(0{,}5\delta\rho L'U) \approx \mu\delta\left(\frac{U}{\delta}\right)^2 dx_1$$

Having fulfilled some relevant transformation we'll get the next:

$$\delta' = 2\frac{b}{\delta} \cdot \frac{U^2}{L'\mathrm{Re}_b} \qquad (2.11)$$

The next relation fits this equation:

$$\delta = 2\sqrt{\frac{b}{\mathrm{Re}_b}\frac{U}{\sqrt{L'}}}\sqrt{x_1}\,, \qquad (2.12)$$

It results from (2.12) that

$$\frac{\delta_{max}}{b} = 2\frac{U}{\sqrt{\mathrm{Re}_b L'}}$$

Having put $b = 10^{-3}$ m in iron when a cutting speed $U = 10\ \mathrm{m/s}$ it results that $\delta_{max} \approx 0{,}25$ mcm.

Let's estimate temperature in a boundary layer. A heat flow being extracted by molten metal from a cut [0, x_1], is evaluated under the formula

$$Q = 0{,}5\delta\rho L'U = \frac{U^2\rho L'}{\sqrt{L'\mathrm{Re}_b}}\sqrt{bx_1} \qquad (2.13)$$

When the edge is heat-insulated the heat flowing in the direction of a metal layer in which a melting takes place is determined as follows:

$$q = \frac{dQ}{dx_1} \approx \lambda\frac{\Delta T}{\delta/2} \qquad (2.14)$$

where $\lambda = \mu C_p/\mathrm{Pr}$ – thermal conductivity, C_p – specific heat, Pr – Prandtle number, $\Delta T = T - T_{пл}$, T – average temperature in a boundary layer.

It results from (2.13) and (2.14) that

$$\Delta T \approx \frac{1}{2}\frac{U^2}{C_p}\mathrm{Pr} \qquad (2.15)$$

According to (2.15) molten metal's overheating temperature is constant through a bevel of a back edge. A rate for fluid aluminum ($C_p = 1084\,\mathrm{J/(kg \cdot K)}$; $\mathrm{Pr} = 0{,}037$) entails $\Delta T \approx 0{,}002°\mathrm{K}$, so overheating in a layer is completely inappreciable and its mean temperature is practically equal to a temperature of a melting.

Forward edge

In case $\delta_H > \delta_\mu$ for every x_2 the viscous boundary layer progresses as if it did in incompressible viscous fluid in an critical point environ when stream's flat running against a wall as one may consider a critical point to be disposed on a cutting edge (fig. 2.1). So we may use a precise solution for equations (1.1), (1.5) in a similar problem [5], that involves:

$$\delta_\mu = 2{,}4\sqrt{\frac{\mu l}{\rho k_c U}} \qquad (2.16)$$

where k_c – factor of truncation of a cuttings, l – length of a so-called stagnant zone (fig.2.1).

According to (2.16) a viscous boundary layers width doesn't depend on coordinate x_2, i.e. it doesn't vary through an edge within an interval *l*. Formula (2.16) may be rewrote as follows

$$\frac{\delta_\mu}{l} = \frac{2{,}4}{\sqrt{\mathrm{Re}_l}} \qquad (2.17)$$

where $\mathrm{Re}_l = \dfrac{k_c U l \rho}{\mu}$ – Reynold's number for a forward edge.

In case cutting speed's 10m/s the formula (2.17) entails

$$\frac{\delta_\mu}{l} \approx 0.01$$

Then let's account a case which may be realized when cutting speed's being customary or namely when the molten layer $\delta_H = \delta_\mu = \delta$ is boundary. So, similarly to (2.12), there's a relation

$$\delta = 2\mathbf{k}_c\mathbf{U}\sqrt{\frac{1}{\mathbf{L}'\,\mathrm{Re}_l}}\sqrt{\mathbf{x}_2} \qquad (2.18)$$

and formula

$$\frac{\delta_{max}}{l} = 2k_c\frac{U}{\sqrt{L'\,\mathrm{Re}_l}},$$

that involves $\delta_{max} = 95\mathrm{mcm}$ in iron as $k_c = 0.5$, $U = 10\mathrm{m/s}$, $l = 2.5\cdot10^{-3}\mathrm{m}$, i.e., according to (2.12), the molten layer's width on a forward edge may exceed the one on a back edge more than fourfold. Thus, as it was in (2.15), one may conclude that metal isn't overheated to temperature exceeding one of a melting in molten layer.

Friction stresses in melting site of a back edge are

$$\tau_з = \frac{1}{b}\int_0^b \mu\left(\frac{\partial u}{\partial y_1}\right)_{y_1=0} dx = 0.5\sqrt{\mu U\rho L'}. \qquad (2.19)$$

Similarly for a forward edge

$$\tau_п = \frac{1}{l}\int_0^l \mu\left(\frac{\partial u}{\partial y_2}\right)_{y_2=0} dx = 0.5\sqrt{\mu k_c U\rho L'}. \qquad (2.20)$$

In case $U = 10\mathrm{m/s}$ for iron it'll be

$$\tau_ç = 3700\frac{N}{m^2}, \qquad \tau_ï = 2600\frac{N}{m^2}.$$

3. Computational simulation of influence of magnitude of pressure on parameters of oscillations of a chisel. The description of unsteady planes motion of an incompressible fluid is set by values of a velocity term $\vec{u} = (u, v)$, density ρ and pressure *p*, which are functions of explanatory variables – time *t* and Cartesian coordinates (x, y). The initial systems are consisting of one differential equations of continuity representing law of conservation – **law of conservation of mass (volume)**

$$div(\vec{u}) \equiv \frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} = 0, \qquad (3.1)$$

and equation of impulses (equation of a momentum) – **conservation of momentum law**

$$\vec{u}_t + (\vec{u} \cdot \nabla)\vec{u} + \frac{1}{\rho}\nabla p = \vec{g}, \qquad (3.2)$$

where $(\vec{u} \cdot \nabla) = u\frac{\partial}{\partial x} + v\frac{\partial}{\partial y}$, $\nabla p = (p_x, p_y)$ – lapse rate of pressure in the given point of a layer, ρ – density of a layer, $\vec{g} = (0, -g)$ – vector of a density of mass forces, $g = const$.

As the density is fixed and original vorticity is equal to zero, so the equation of impulses (3.2) may be integrated with Cauchy - Lagrange integral as result

$$\Phi_t + \frac{1}{2}|\nabla\Phi|^2 + \frac{p}{\rho} + gy = b(t) \qquad (3.3)$$

when $b(t)$ is an arbitrary function of time. One may account this function to be equal to zero without violations of a generality because in the case of point a speeds potential as a function $\Phi = \Phi(t, x, y)$ connected with components of a velocity term by potential ratio: $u = \frac{\partial\Phi}{\partial x}$, $v = \frac{\partial\Phi}{\partial y}$ exist.

The continuity equation (3.1) for potential movements turns to an equation of the Laplace

$$\Phi_{xx} + \Phi_{yy} = 0 \qquad (3.4)$$

Thus, the system of vectorial equations (3.1), (3.2) is reduced to two scalar equations (3.3), (3.4).

Edge conditions. In order to describe particular movement it's necessary that a solution of these equations in the given area, restricted by the instruments surface and melts boundary in treated metal should be looked for. We'll consider the layer being analyzed to have even bottom conterminous to the boundary between the layer and solid metal. When cutting speed is high enough every particles of a layer is carried away by perform in a direction of its driving relative to the tool. So the tool's oscillation may arise as a result of its slipping along the wave contact boundary with a layer and oscillation of vertex of a cutting wedge in so with transiting on the boundary of a layer by waves. The transition speed of these waves develops of a cutting speed V and natural speed V_k of their spreading on a layers contact surface.

The plane $y = 0$ having a boundary condition with an edge condition of not seeping leak is picked out as a bottom

$$v \equiv \Phi_y = 0 \qquad (3.5)$$

On contact to the tool the pressure $P = P(t, x)$ operates and the kinematic condition of a coherence of a layers particles driving speeds on mentioned contact and layers boundary itself is answered. Thus there're two conditions on a contact with the tool:

$$(h_t + uh_x)_{y=h} = 0, \quad p|_{y=h} = P, \qquad (3.6)$$

where the first equality expresses the kinematic condition, and second expresses dynamic one. Meanwhile the surface of a layers contact with the tool is described by an equation $y = h(t, x)$. As the pressure's expressed by potential taken from the Cauchy

- Lagrange integral (3.3), the condition on tools contact with the surface may be written by way of the potential

$$\left(h_t + \Phi_x h_x\right)_{y=h} = 0, \quad \left(\Phi_t + \frac{1}{2}\left|\Phi_x^2 + \Phi_y^2\right|^2 + gy\right)_{y=h} = -\frac{P}{\rho} \tag{3.7}$$

The mathematical sample presented allows to analyze contact pressures $P(t, x)$ influence on molten metal's wave driving performances.

The solution of a problem (3.4), (3.5), (3.7) being set is reduced to an equation originating from conditions (3.7). The value φ of potential Φ on the boundary $y = h$ is entered. Substitution of this function in (3.7) involves two equations for φ and h functions, coming out which are written the following way

$$h_t + h_x\varphi_x + h\Delta_2\varphi = 0,$$

$$\varphi_t + \frac{1}{2}\left(\varphi_x^2 + \varphi_y^2\right) + gh + \frac{P}{\rho} = 0,$$

according to theory of a shallow water [6].

The solution of these equations may be got under Bussineska & Kortevega – de Freez's approximation. However fixed of driving by which a velocity terms and pressures fields don't depend on time are steady.

The fixed wave process represents the stiffened dynamic configuration. It takes much time to work out the steady flow as it's an approximated sample piece of actual movement.

The fluid stream is described by functions $h(x, y)$ and $\Phi(x, y)$. For this class of flows the conservation laws are answered

$$\int_0^h \Phi_x dy = a \tag{3.8}$$

$$\int_0^h \left(\Phi_x^2 - \Phi_y^2\right)dy = gh^2 + 2\left(\frac{P}{\rho} - b\right)h + c \tag{3.9}$$

with given constants a, b, c, where a – expenditure of a material in a layer, $\mathrm{m^2/s}$; b – Bernoulli's constant, $\mathrm{m^2/s^2}$; c – with - density function of impulse through a layer, $\mathrm{m^3/s^2}$; $P = P(x, y)$ – pressure profile on the boundary of a layer with the instrument, $\mathrm{N/m^2}$.

The second approximation following from the equations shallow water theory reduced a problem set to an equation describing the tool with a melt contacts profile.

$$\frac{a^2}{3}h'^2 = -gh^3 + 2\left(b - \frac{P}{\rho}\right)h^2 - ch - a^2 \tag{3.10}$$

An equations (3.10) solution describes so-called cnoidal waves (that are expressed by the way of an elliptic function cn heeding contact pressure *P*.

The external parameters of waves *a, b, c* are reduced to two dimensionless:

$$\sigma = \frac{3}{4}\cdot\frac{gc}{b^2}, \quad \theta = \frac{27}{8}\cdot\frac{g^2a^2}{b^3}, \tag{3.11}$$

which allow to get an equation (3.10) in the dimensionless form

$$y'^2 = -y^3 + 3\left(1 - \frac{P}{\rho b}\right)y^2 - 3\sigma y + \theta . \qquad (3.12)$$

In an equation (3.10) new variables are entered according to substitution

$$h = \frac{2}{3}\frac{b}{g}y, \quad x = \frac{a}{\sqrt{2b}}\bar{x} \qquad (3.13)$$

The functions $y(x)$ required is got from an equation (3.10) as a quadrature and set by the formula

$$y = y_2 + \left(y_3 - y_2 cn^2\left(\frac{1}{2}\sqrt{y_3 - y_1}\bar{x}, k\right)\right), \qquad (3.14)$$

where the module k is determined by equality: $k^2 = (y_3 - y_2)/(y_3 - y_1)$.

On a fig. 3.1 - 3.7 the wave movements of a layer profiles by different contact pressures are shown. Meantime the contact pressure changes answered the sinusoidal law, i.e. decremented from the maximum value to the minimum one first and then returned to a primal value being augmented.

Analysis of results obtained shows that by contact pressures values being maximum the regular periodic waves having quite large frequency (fig. 3.1) are to be observed. By contact pressure getting reduced some oscillation frequency increasing and considerable abatement of an oscillation frequency take place (fig. 3.2-3.6). By the given changes of aircraft attitude periodicity of waves to be conserved but by reaching some minimum pressure the contacts wave structure to be rebuilt namely solitary waves of max amplitude called solitons (fig. 3.4) replace the regular periodic waves.

The results obtained may be applied to solution origin of a growth gears construction.

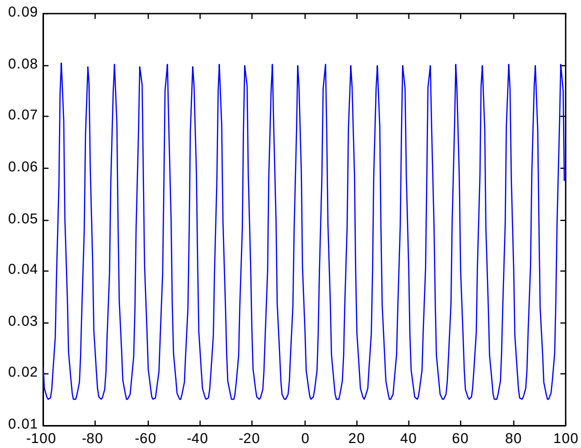

Fig. 3.1

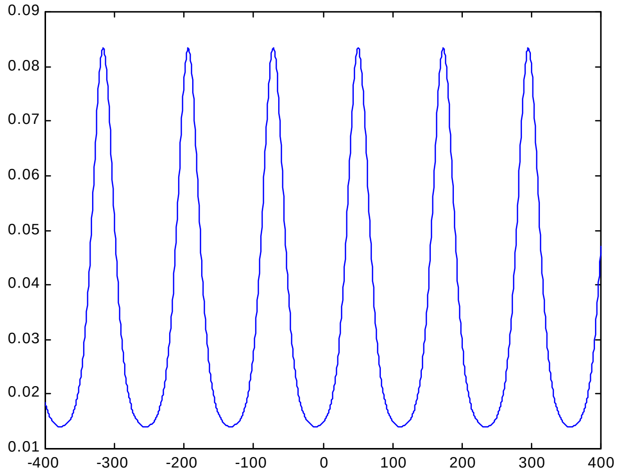

Fig. 3.2

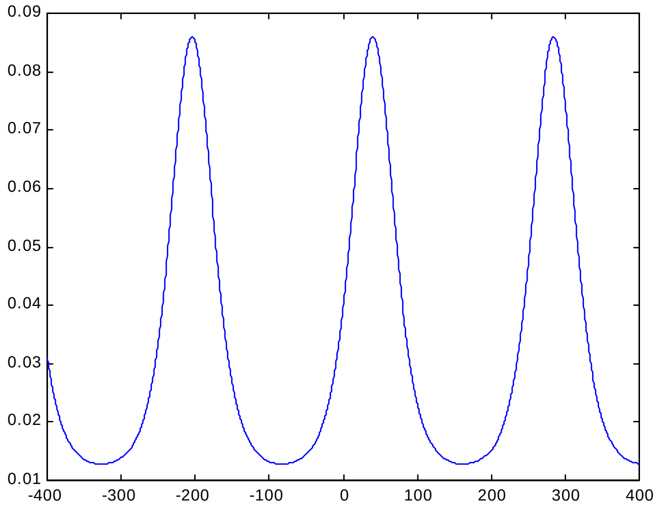

Fig. 3.3

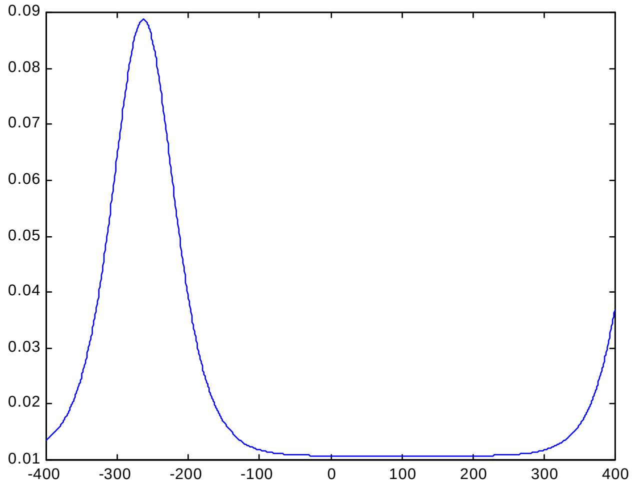

Fig. 3.4

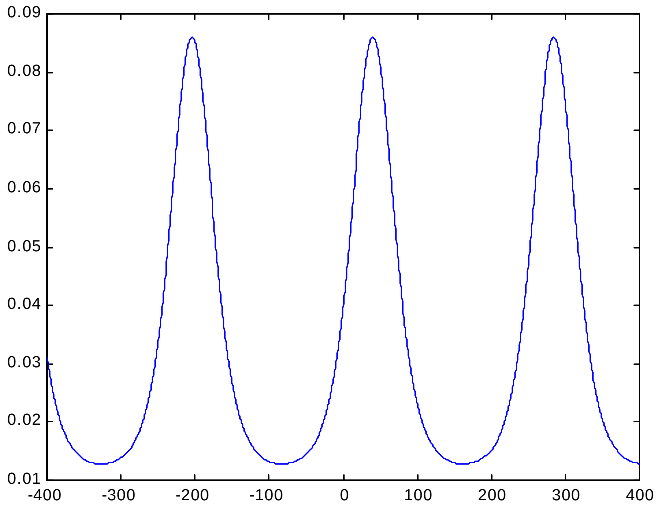

Fig. 3.5

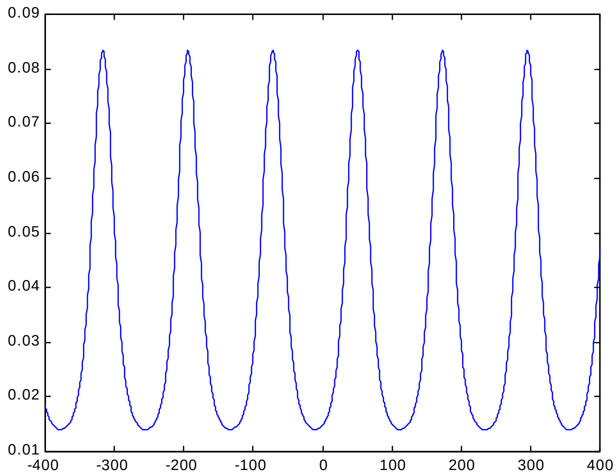

Fig. 3.6

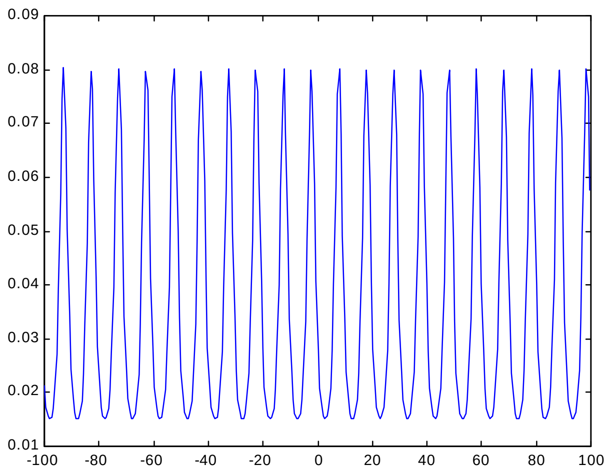

Fig. 3.7

The results of investigation presented to be used when cuttings arising process and steadiness of processes of a machining processes [7] control systems being worked out.

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②クラックの生じた物体の破壊の計算モデリング

Oleinikov A.I., Magola A.S.

短評：

クラックのある物体の破壊という固体力学における実際的な課題を解決するためには、境界要素法の一種で不連続変位法と呼ばれる方法が効果的である。この方法を用いたコンピュータ･プログラムが、コンパイラー言語の C++で開発されている。このプログラムでは、ひとつ以上のクラックのある材料に、クラックと本体の境界に任意の荷重をかけたときの挙動をモデル化することができる。このプログラムの有効性を試すなかで、切削工具の切れ刃にひとつ以上のクラックが生じたときの応力変形挙動を調べるために実験的に計算を行った。クラックの進行状況の計算モデリングにより、例えば、切れ刃の破壊メカニズムや破壊プロセスの解明が可能となる。

報告：

Numerical modeling of fracturing of solids with cracks.[1]

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Now, for a solution of different engineering and technical problems the numerical methods implemented on the computer are widely used. Among the numerical methods of a solution of boundary value problems it is good itself has recommended a boundary elements method. Many practical problems of a fracture mechanics of a rigid body concern bodies, which containing narrow cutaways, similar to a slit or a cracks. For problems of such type effectively to apply variant of a boundary elements method termed by a method of displacement discontinuity, which based on an analytical solution of a problem on an infinite plane x, y, the displacements in which undergo constant on magnitude a discontinuity within the limits of finite segment [1]. This solution will match to an asymptotic of stressed at apex of crack.

On a base of the given method the computer program written on the high level language C ++ (with usage of the compiler MS Visual C ++ 6.0) was implemented. Having user interface of full value agreeable to the standards of modern applications written for MS Windows 95/98/NT/2000/ME, the given program allows to calculate such performances as discontinuities U_x, U_y and stresses σ_{xx}, σ_{yy}, σ_{xy}, and also, on a base already available, principal stresses $\sigma_{\max}$, $\sigma_{\min}$ and $\tau_{\max}$, which are evaluates by the formulas:

$$\sigma_{\max} = 1/2\left(\sigma_{xx} + \sigma_{yy}\right) + \sqrt{1/2\left(\sigma_{xx} - \sigma_{yy}\right)^2 + \sigma_{xy}{}^2}\ ,$$

$$\sigma_{\min} = 1/2\left(\sigma_{xx} + \sigma_{yy}\right) - \sqrt{1/2\left(\sigma_{xx} - \sigma_{yy}\right)^2 + \sigma_{xy}{}^2}\ ,$$

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

$$\tau_{\max} = \sqrt{1/2\left(\sigma_{xx} - \sigma_{yy}\right)^2 + {\sigma_{xy}}^2}\,.$$

and fracture function:

$$F_r = 0{,}24\,\tau + 0{,}76\,\sigma_{\max} \cdot 0{,}8^{1-\sigma/\tau}\,,$$

where

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

$$\sigma_z = \nu\left(\sigma_x + \sigma_y\right),\quad \sigma = \sigma_x + \sigma_y + \sigma_z\,.$$

As an example with the help of the given program the task about an infinite body with a crack testing intrinsic pressure was solved. This task is assign by the following

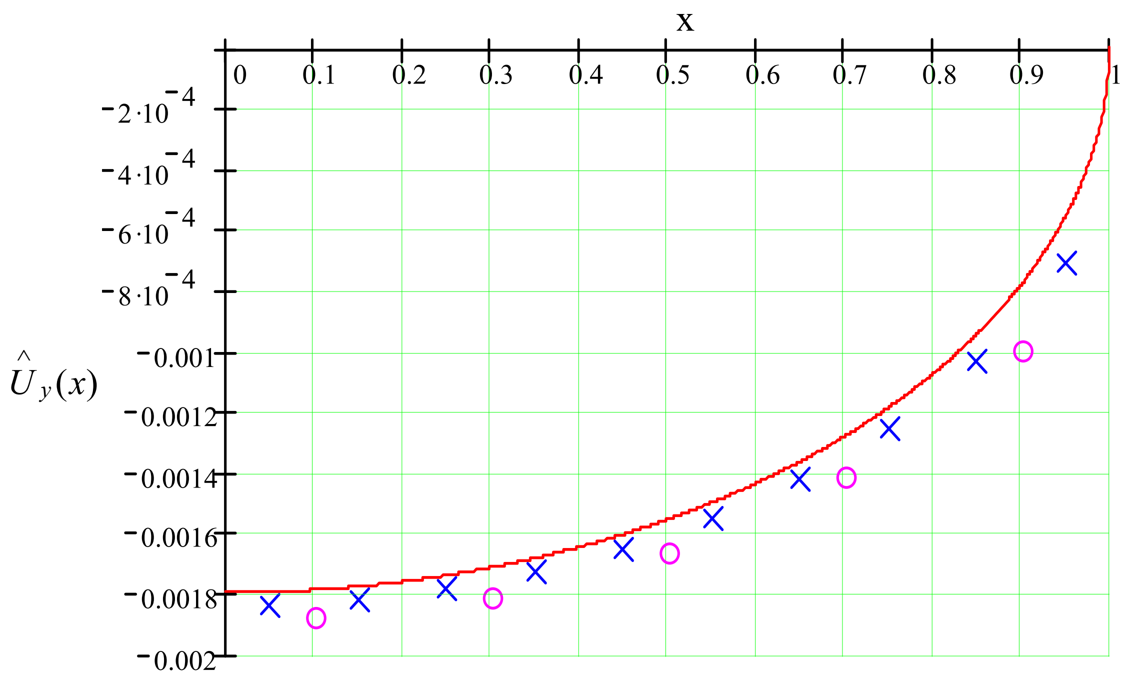

Fig.1. Numerical and analytical solution for distribution of displacement discontinuities.

conditions:

$$\sigma_{xy} = 0,\ -\infty < x < \infty,\ y = 0,$$

$$\sigma_{yy} = -p,\ |x| < b,\ y = 0,$$

$$u_y = 0,\ |x| \ge b,\ y = 0.$$

Besides, on infinity all discontinuities and stresses are equal to zero. An analytical solution of this task for distribution of relative normal stresses along a crack (i. e. for summarized disclosure) is determined by the formula

$$\hat{u}_y(x) = -\frac{2(1-\nu)}{G}\,pb\left(1 - x^2/b^2\right)^{1/2} \tag{1}$$

For $b = 1$, $\nu = 0.1$, $p = 1$, $G = 10^3$ and at separation of a crack on 10 and 20 boundary elements was obtained solution, which is represented in a fig. 1. On it are figured the graph of exact distribution of displacement discontinuities, which was defined according to (1), and the points (in a figure they are marked are figured as daggers for 20 boundary elements and as circles for 10 boundary elements) approximate solution obtained with the help of the program. From a fig. 1 it is possible to conclude, that the method of displacement discontinuity overstate values of relative stresses of surfaces of a crack, but in accordance with magnification N (i.e. number of boundary elements) the results come nearer to exact solution.

Having received a solution on boundary, the program further allows to evaluate stresses σ_{xx}, σ_{yy}, σ_{xy} and discontinuities u_x, u_y in any area beyond the bound of a crack.

Thus, the program allows to model behavior of a material containing one or more cracks, under action of arbitrary loads on the bound of a material and crack.

As input data of the program the following performances appear: the coefficient of Poisson and Young's modulus describing physical properties of body, condition of a symmetry, initial stresses, geometry of an outline and (or) crack(s), type of boundary conditions (in stresses, in displacements or blended) both normal and tangents of a component of stresses and (or) displacements (depending on a type of boundary conditions) and, at last, coordinates of rectangular area (in the given version area rectangular, but given circumstance is not limitation and in further the possibility of the representation of area of the arbitrary form) outside of boundary can be implemented, in which it is required to calculate stresses both displacements and amount of points in the given rectangle on a horizontal and vertical, in which the stresses and displacements will calculate.

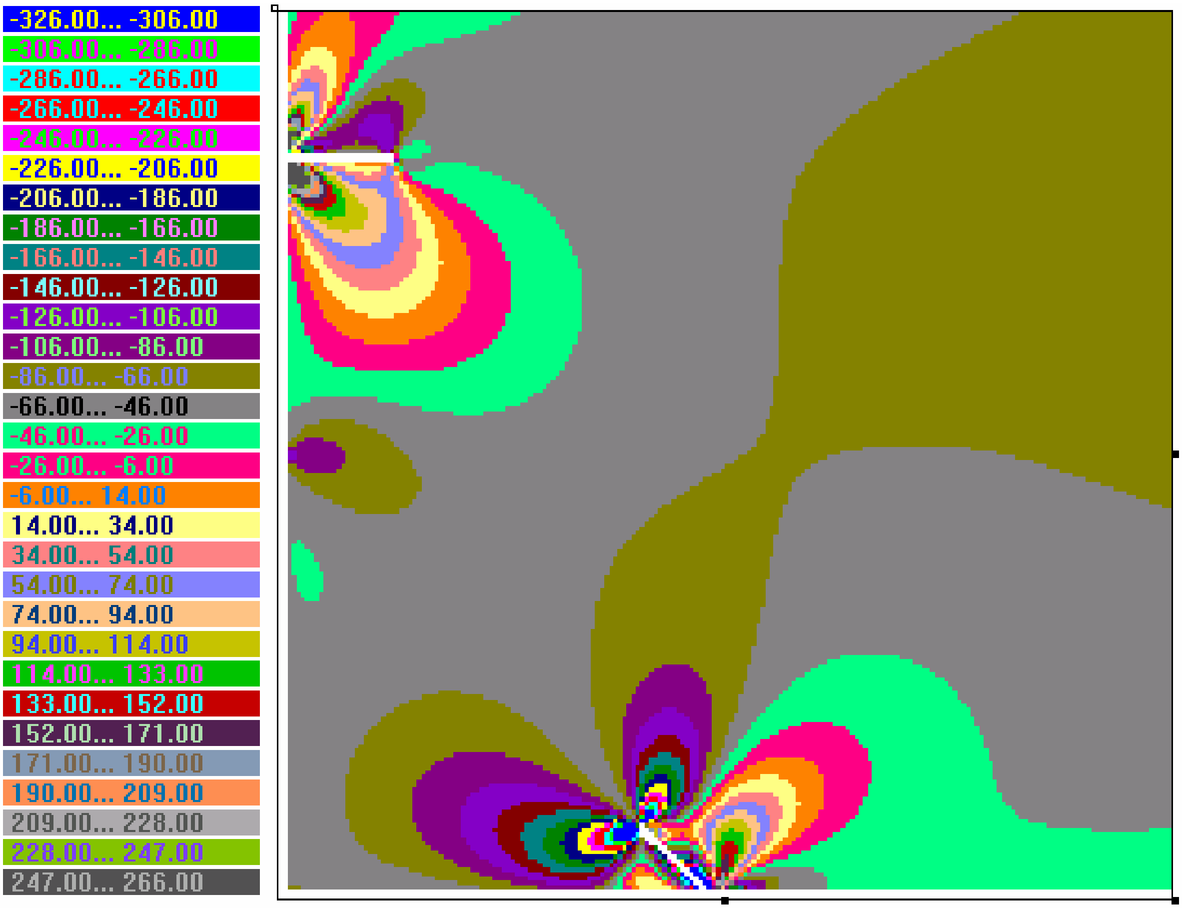

Fig.2. Diagram of σ_{xy} in color.

Geometry of an outline and crack (one or more), and also normal and the tangents of a component are introduced as customary strings the containing functions of one argument (x or y) and further brought strings of the formulas are treated by the program, using the special module permitting on the noted formula to receive a value of the function at any argument. Thus, knowing the function circumscribing an outline or a crack, it is possible to set the arbitrary forms of an outline and cracks.

As output data the program produces a set of color or only contour (at the request of the user) diagrams of each of the listed above performances (displacements and stresses) in an arbitrary scale. The diagrams are created by the following principle: there are minimum and maximum values of each component the obtained interval of values is divided on an amount of colors and each of obtained subintervals the color and further is put in correspondence, depending on that in what of subintervals the value of the component in each concrete point of area out of bounds hits, all points everyone by particular color are mapped. In case of the contour diagrams the lines bounding areas obtained subintervals are mapped only. As an example the diagram σ_{xy} in color (fig. 2) and contour variant of the same diagram (fig. 3) for the task about corner of the cutting tool with two microcracks for an edge is reduced. In a case, when the contour diagrams for definition are created where to be this or that range of values, the following mechanism is used: using a mouse pointer, it is possible, click-

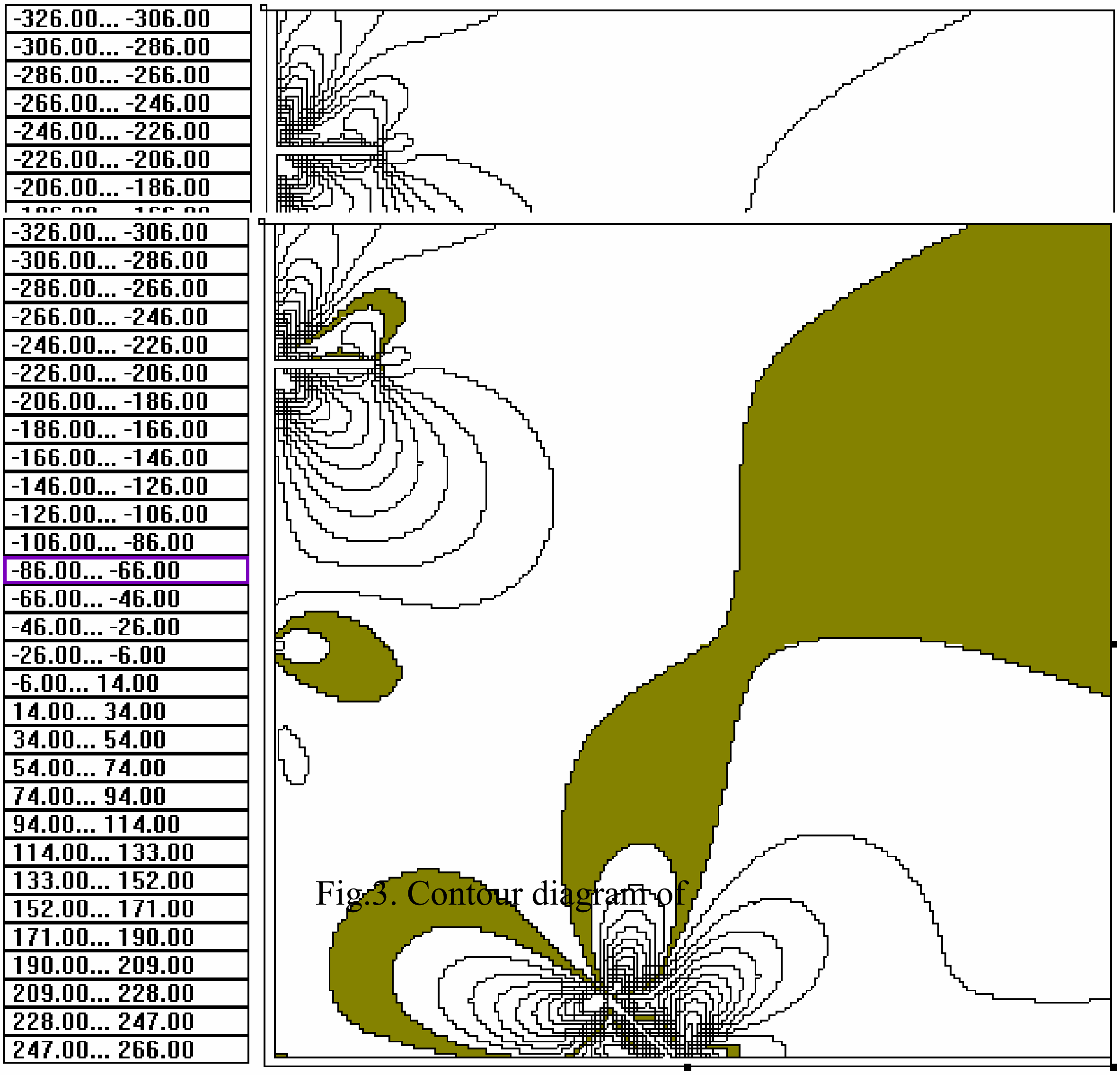

Fig.4. Contour diagram of σ_{xy} with selected interval.

ing on for the necessary interval, to see interesting area, isolated by particular color (fig. 4).

All brought in input data can be saved in separate files, which in appropriate way, register in an operating system (MS Windows). Any of the obtained diagrams is possible is to saved in the file of the BMP-format (bitmap).

At build-up of the contour diagrams it is very difficult to foresee and «to "force" the program properly to place scores of each of subintervals and consequently in the program the small designer permitting to place is implemented to translocate and to delete scores. The obtained diagram it is possible, again, or to save the file of the special format, by the defined given program (that it was possible to change arrangement of scores), or to save in the BMP-file.

Researching facilities of the given program, the computing experiments were carried out with the purpose of study of a stressed-deformed state for an edge of the cutting tool at origin in it of one and more cracks. The numerical modeling of development of these cracks has allowed to describe the mechanism and to research the process of fracturing of a cutting edge.

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③周波数によって回転数を制御する誘導電気駆動装置のエネルギー特性の分析と最適化

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要点：

固定子に加えられる交流電圧の振幅および周波数を変化させることによって回転子の回転数を制御する、周波数制御式誘導（非同期）かご型電動機をベースとした電気駆動装置は、各種の製造用機械設備の自動制御式駆動装置として広く実用に供されている。

駆動装置全体および原動機である電動機自体の機能を決定する仕様項目のうち、特に重要な意義を有するのが電動機（この場合は誘導電動機）のエネルギー特性に関する各指標である。これらの特性指標としては何よりもまず効率と力率が挙げられる。長時間一定の条件で稼動する駆動装置にとっては、これらの指標の最適化こそが、電動機（の機械部分）におけるエネルギー損失を抑えるという視点からも、また、給電網・電動機の電源要素におけるエネルギー損失を抑え、消費電流を低減させるという視点からも、有利な条件となる。

本レポートでは、電源電圧の振幅および周波数を変化させることによって回転子の回転数を制御し、一定の条件下で稼動する誘導電動機について、その効率と力率の最適の組み合わせを分析し、そうした組み合わせが可能か否かが検討されている。またこれに関連して、効率と力率の積からなる誘導電動機の統合的エネルギー指標の概念が導入されている。これは、電動機のエネルギー特性が向上すると、いずれの場合も効率と力率の積が最大（すなわち１）に近づくという事実を考慮に入れたものである。

上記の統合的エネルギー指標を概念導入し、一定条件下で稼動する誘導電動機についてこの指標を最適化することにより、電動機の制御に関するある法則を得ることができる。この法則とは、すべりの絶対値に対する電源電圧の相対周波数の関係式として表わされ、誘導電動機の効率と力率との合理的組み合わせを可能とするものである。この関係式を用いれば、電動機の固定子に加えられる交流電圧の振幅および周波数それぞれの変化法則を合成によって策定し、誘導電動機を原動機とする周波数制御式の電気駆動装置のシステム構造とその制御系各要素の特性を確定することが可能となる。

こうして合成された電気駆動装置のシステムを数字モデル化し、研究したところ、このシステムが一定条件下での稼動時において優れたエネルギー特性を有するものであること、および、誘導電動機を原動機とする周波数制御式電気駆動装置の開発に今回得られた制御法則を実地利用することが目的にかなった企図であること、が明らかとなった。

要点（英文）：

ANALYSIS AND OPTIMIZATION OF ENERGETIC CHARACTERISTICS OF FREQUENCY-REGULATED ASYNCHRONOUS ELECTRIC DRIVES

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Electric drives based on asynchronous engines with short-circuited rotor the rotation velocity of which is guided by changing amplitude and voltage frequency of the stator are widely used in practice as executive automatized drives for different production machinery.

From the list of technical and economic characteristics which define the efficiency of electric drive as a whole and its engine as well, of great importance are energetic indices of an asynchronous electric engine in this case. To the latter we should refer efficiency and factor of power. For the drives operating mainly in long-set routines, the optimization of these indices ensures certain advantages as in view of decreasing losses in engine as well as in elements of power source for the asynchronous engine and circuit, decreasing additional load of them with electric currents consumed by the engine.

The paper presents analysis and examination of the possibility for providing optimum combination of Efficiency and Power Factor of the asynchronous engine in static routine of work with amplitude-frequency regulation by the rotational velocity of its rotor. In connection with this we introduce the occasional notion of the generalized energetic index of Asynchronous Engine that is determined as product of Efficiency and Power Factor taking into consideration the fact that the best energetic characteristics of the engine identically correspond to the largest (closer to 1) values of these quantities.

The generalized energetic index accepted in our work and its optimization in static routine of work of asynchronous engine enabled to deduce the law of regulation of the engine as dependence of absolute sliding from relative frequency of feeding voltage ensuring rational combination of efficiency and power factor of the engine. Using this dependence enables to synthesize the corresponding laws of changing amplitude and frequency of the voltage for the engine's stator, to define the structure of the frequency-regulated electric drive system with executive asynchronous engine and characteristics of the regulation system elements.

The investigation of the digital model of the synthesized system of electric drive confirmed its increased energetic indices in static routine of work and expediency of using the laws of regulation obtained in practice of constructing frequency-regulated electric drives with asynchronous engines.

報告：露文のみ有るため、本号では掲載しません。
但し、露文報告を入手希望の場合は、ロ東貿に御照会ください。

④交流電気機械系の作動態様のエネルギー特性を示す各座標を測定するセンサーと、周波数制御式誘導電動機の研究・開発作業におけるこれらセンサーの利用

A.R.Kudelko, A.V.Guschin, I.P.Dudchenko
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要点：

交流を用いた電気・機械エネルギー変換の各要素およびシステムのエネルギー特性指標を実験調査し、これら各指標を最適化した周波数制御式（交流電圧の振幅・周波数によって回転数を制御する）の誘導電気駆動装置を開発するには、変換器、電動機、駆動装置全体のエネルギー座標を示す信号を発生させ捉えることが必要となる。

このレポートでは、かご型誘導電動機を原動機とする交流電圧振幅・周波数制御式電気駆動装置を例にとって、交流を用いた電気・機械エネルギー変換の各要素およびシステムの作動態様のエネルギー特性を示す各座標を測定するセンサーの開発に関する諸問題が検討されている。直接測定可能な第 1 座標センサーが内容定義され、その信号を、周波数変換器、原動機、電気駆動装置全体の作動態様を特徴づける信号に変換する機構のアルゴリズムと構造が紹介されている。

第 1 座標として利用されるのは、固定子の電圧および電流（それらの変動周波数、通常および瞬間値）、回転子の回転数および固定子予備コイルを用いて測定された起電力、である。

次に電気駆動装置の負荷作動態様に関する情報（信号）を確保するためのアルゴリズム、力率、効率、それらの積、電圧・電流相差など、そのエネルギー特性指標が検討されている。

誘導電動機を原動機とする周波数制御式電気駆動装置の研究・開発のために開発された装置を用いた例が紹介されている。

要点（英文）：

SENSORS OF COORDINATES CHARACTERIZING ENERGETICS OF ROUTINE OF WORK OF ELECTROMECHANICAL SYSTEMS A. C. AND THEIR USAGE IN INVESTIGATION AND CONSTRUCTION OF FREQUENCY – REGULATED ASYNCHRONOUS ELECTRIC DRIVES

A. R. Kudelko, A. V. Gushchin, I. P. Dudchenko
(Komsomolsk–on–Amur State Technical University, Russia)

Experimental research of energetic indices and characteristics of elements and systems of electromechanical transformation of a. c. energy, and also the development and creation of frequency-regulated asynchronous electric drives with optimization of their energetic indices account for the necessity of forming signals which characterize energetic coordinates of transformers, executive engines and electric drive systems as a whole.

The Report considers the questions of coordinate sensors construction which characterize energetics of routine of work of elements and systems of electrome-

chanical transformation of a. c. energy citing as an example a frequency-regulated drive the executive organ of which is an asynchronous engine with a short-circuited rotor. The sensors of initial coordinates have been determined, they are subjected to direct measurement; the algorhythms and transformational structures of signals into signals received from them which characterize the energetics of the routine of work of the frequency converter, engine, electric drive as a whole.

Voltage and currents of the stator (their frequency, acting and instant moments), rotor's rotation velocity and also emf of stator gained with the help of additional windings on the engine's stator – are used as primary coordinates. The examination is also given to the algorhythms of getting information (signals) characterizing the loading routine of electric drive, its energetic characteristics – coefficient of power, efficiency, their product, phase differencies between voltage and current, and other parameters.

There are presented here examples of using the developped devices for investigation and construction of systems of frequency-regulated electric drive with asynchronous engines.

⑤整流器直流側の力率の改善

Kuznetsov V.P.

要点：

相制御式のサイリスタ整流器の主な欠陥のひとつに、出力電圧低下時の急激な力率悪化がある。この欠陥を克服するさまざまな方法が時期を違えて提起されてきた。これらの方法はすべて、無効電力を補償するための追加的装置を用いるか、あるいは、サイリスタの自然および強制スイッチングなど、通常の相制御とは異なるサイリスタ制御法を用いるかのどちらかの主要グループに分類できる。いずれにせよ、基本的にこれらの方法はすべて汎用性を持たず、サイリスタ変換器が特定の条件で稼動している場合にのみ利用可能である。

このレポートではサイリスタ整流器の力率改善を目指すオリジナルな方法が提案されている。この方法は、整流器ブリッジ回路の各ゲートの半分に分流コンデンサを接続するもので、この場合、コンデンサは、無効電力の補償を目的とする通常の分流コンデンサのように交流側に配置はせず、直流側とする。コンデンサの充電電流は無効電力の先行成分となり、サイリスタ整流器が形成する後発成分を補完する。

この方法は、外部落下特性、すなわち電圧ではなく電流給電条件で稼動する装置に最も適合したものである。これら装置としては、めっき設備、溶接機、蓄電池用充電器がある。この方法は特許を受けている。

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要点（英文）：

AC RECTIFIER POWER COEFFICIENT IMPROVEMENT

V.P. Kuznetzov

One of the main phase controlled thyristor rectifiers disadvantages is that of sharp power coefficient deterioration at output voltage drop. Many times there were offered to consideration a number methods to cross this disadvantage. The whole set of the methods can be divided into two main groups:

- Use of complementary devices aimed for reactive power compensation.
- Use of specially purposed methods of thyristor control different from an ordinary phase one;

Regarding the second case thyristors may be switched by means of either natural or forced commutation. Anyway all the aforesaid methods are generally not of unique nature and are used for rectifiers processing under certain conditions only.

Proposed bellow is the original method of thyristor rectifiers' power coefficient improvement. The subject of the method lies in the fact that capacitors shunting half of the rectifier-type bridge valves are to be connected up. This way the capacitors are not AC (which is a usual method of reactive power compensation) but DC connected. Capacitors' recharge current causes a reactive power advance component, that compensates the exfoliating one, produced by a thyristor rectifier.

This method is the most convenient to be used for packages with dropping external characteristics, i.e. for those processing in the regime of current source not voltage. The packages referred may be those with electroplating and welding equipment as well as storage batteries charging devices. The described above method has been granted with a patent.

Supplemential information

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⑥材料の変形過程を調べ、材料の限界特性を予測するツールとしての発振音波

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短評：

チタン合金 OT-4 の試片を１軸方向に引張ったときに生じる組織欠陥の成長を、最新の音波発振方法により観察した結果を紹介。音響像の分析により、合金の変形と破壊が生じるメカニズムに応じた、合金中における破壊の蓄積過程の観察が可能であることが示されている。

短評（英文）：

Acoustic emission as a tool of research the process of deformation and prediction the limit material characteristic

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There are results of research of defect structure evolution in titanium alloy samples "OT-4" with one-axis stretching and using modern achievement of the acoustic emission method in the paper. Possibility of consideration the stages of process of damage accumulation in alloy, connected with change of mechanism of deformation and destroying alloy, with acoustic emission method is shown.

報告(露文)：露文のみ有るため、本号では掲載しません。

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⑦四象限制御トランスーサイリスタ式電圧補償器、同無効電力補償器の設計原理

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短評：
無効電力の補償を行い、動力学的特性を向上させ、外寸･重量を改善するために、直流回路を持つ量産型周波数コンバータをベースにしてつくる、電源に同期したサイリスタ･コンバータを用いて、昇圧トランスの周波数･振幅･位相を連続的に制御する方法が提案されている。新しい装置では、負荷電圧の調節（安定化）と電源の無効電力の補償という、相互に補完しあう機能が実現されている。理論的研究と実証的研究の結果が掲載されている。

報告：

PRINCIPLES OF MAKING TRANSFORMER- AND THYRISTOR- BASED COMPENSATORS OF VOLTAGE DEVIATIONS AND REACTIVE POWER WITH FOUR-QUADRANT CONTROL

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In this paper smooth pulse, magnitude and phase control of a booster transformer by means of thyistor converter synchronized with supply network i s proposed to ensure reactive power compensation and to improve dynamic characteristics, mass and sizes. The converter has a DC circuit and is made on basis of commercially produced frequency converter. In the new device two mutually complementary functions are combined: regulation (stabilization) of load voltage and the network's reactive power compensation.

The necessity to proliferate means of consumers voltage stabilization and supply network reactive power compensation is clearly defined with requirements of power quality and its economy. The solution of this problem acquires particular urgency for power supply systems with extended power transmission lines and variable nature of the load. This can be attributed to all the industrially developed countries with vast territories and considerable distances between consumers and power supply centers .

Unlike devices known in the world practice in the proposed device two complementary functions are combined : complete compensation of reactive power and stabilization of voltage independently of supply network external characteristic slope and the value and the character of the load.

Four- quadrant forming of the additional voltage vector in the orthogonal coordinate system has simple realization and better shape of the output voltage . Besides, this way in comparison to vector forming in polar coordinates also has a disadvantage . In case of orthogonal coordinates two booster transformers are used, and their total power is proportional to the arithmetical sum of the square triangle's sides , and at the same time in case of polar coordinates one transformer is used , and its power is proportional to the geometrical sum of the same square triangle's sides.

This fact enables decreasing mass and sizes of the transformer equipment of the device when using polar coordinates.

As for complexity of inverters control and the compensator regulation unit the following should be mentioned: in case of orthogonal coordinates the inverters control system is more complex, and in case of polar coordinates so does the unit of the whole device regulation.

Control system performs an operation of shifting of control pulses' phases on outputs. Control pulses on I st and 2nd outputs are shifted respectively by angles a and p-a in regard to initial phase P . which is regulated by unit regarding network's voltage.

The first and the second three-phase inverters convert the rectified voltage to two AC voltages .

The vectors of the first harmonics of these voltages are shifted by common initial phase P in regard to network's voltage. One of these vectors is regulated in phase by angle a, and the other is regulated by angle p-a. Due to the fact that inverters and are connected with secondary windings of the transformer on both sides, to the windings is applied the difference between the inverters' output voltages or the sum of conjugate complex vectors with phase a, which are presented in a complex plane rotated by angle P regarding networks' voltage. During the process of stabilization of the output voltage, when the output voltage is lower (higher) than the previously set (for example, nominal) level the recuperative rectifier operates in rectifier (inverter) mode and enables the transformer and the whole device to operate in voltage adding (voltage subtracting) mode with consumption of additional energy from the network (with recuperation energy to the network) .

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