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Research of Thermal Phenomena During the Intermittent Processing Copper Bronze BrAZH9-4

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ABSTRACT

This paper presents the results of experimental and theoretical studies of the temperature in the cutting zone when processing non-ferrous metals and alloys cutting inserts made of synthetic corundum. It proved that with increasing speeds and increasing temperature of the feed at the top of the insert. Mathematical model of thermal conductivity for each element of the technological system is based on the generalized energy conservation.

Keywords: Corundum; face milling cutter non-ferrous metals; temperature; modeling.

INTRODUCTION

In modern conditions of production in developing products release minimal amounts inflate customers' requirements. In such circumstances, the most important task is to as quickly as possible the definition of rational parameters of cutting.

Currently, the part of individual researchers have made numerous experiments to obtain data on the determination of the resistance, temperature and other parameters of cutting .These experiments were tedious, require more time and cost of materials.

The magnitude of rational parameters of a thin non-ferrous metal treatment intermittent paramount influence the cutting temperature.

This paper presents the results of experimental and theoretical studies of the temperature in the cutting zone when processing non-ferrous metals and alloys cutting inserts made of synthetic corundum (sintekor).

It is known that single crystals when illuminated with light of a wavelength close to the intrinsic absorption edge, there is a considerable hardening of single crystal at the stage of plastic deformation in the temperature range 50-200 ^{0}C, charged braked by dislocations. This photoplastic effect was also observed in our studies [26, 34] when irradiated single crystals sintekor with orientation perpendicular to the main optical axis of cutting edge light source output of 300 ... 500 W, provide coverage in 1000 ... 3000 lux. Studies have shown that in the temperature range 130…200 ^{0}C there is an obvious increase in the durability of the single-crystal sintekor. The possibility of using a single crystal sintekor as cutting tools has led to the need to study the phenomena of heat and temperature in the cutting zone in order to prove a positive effect on the action photoplastic inserts of sintekor.

PROCESS

Estimation of the average temperature in the cutting zone is made through a scheme based on the method of the natural thermocouple. To measure its natural thermocouple composed of two pieces 2 made of different materials and isolated from each other, as well as the fixture by means of three insulating spacers 3.

During milling in place insulation blanks formed chips electrically comes into contact with the material of the two blanks, thus forming a natural one thermocouple. To improve the accuracy of measurement of the free ends of the thermocouple temperature was maintained at 0° C, corresponding

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to the melting point of pure ice, made from distilled water. For this purpose, the free ends of the thermocouple were immersed in separate beakers with distilled water and floating it with ice chips. Formed during the cutting process in the thermocouple thermoelectric driving force is amplified by an amplifier brand TA-5 and fed to the input light beam ray oscilloscope brand H-700. In the period from 2002-2009 years strengthening the thermoelectric motive force was carried out by means of the amplifier brand LA-UN16, with an automatic temperature compensation of the free ends of the thermocouple that allowed us to exclude the stabilization of the temperature of the free ends of the thermocouple.

Thermocouple calibration was performed by immersing the chips of the work piece materials that make up the natural thermocouple into the molten mixture of zinc with lead, whose temperature was 353, 2^0C.

In an example the two-parameter dependence of the temperature Θ on the top of the cutter from the cutting speed in the range of 88 to 703 m / min, feed in the range of 0.007 to 0.07 mm / tooth and depth of cut in the range of 0.02 to 0.2 mm bronze BrAZh9-4 cutting plate of sintekor[3].

Experiments have proven that with increasing speeds and increasing temperature of the feed at the top of the blade of the cutting insert, which coincides with the calculated data. The calculations were performed using the Mathcad 2000 PROFESSIONAL. Thus, we developed a method of determining the temperature at the top of the blade of the cutting insert according to the conditions of thin discontinuous non-ferrous metals and the cutting properties of the treated material, the geometric parameters of the blade insert, processing modes.

The first law of thermodynamics for the cutting process formulated as follows: the work is A_c spent on cutting the change of the total energy of cutting instrument $\Delta E_{c.t.}$ and work piece $\Delta E_{\det.}$, and on heating.

The first law of thermodynamics for the cutting process formulated as follows: cutting work A_c spent on the change of the total energy of the cutting tool $\Delta E_{c.t.}$ and work piece $\Delta E_{\det}$, as well as heating of the cutting tool $Q_{c.t.}$ and work piece $Q_{\det.}$ and loss of heat ΔQ to the environment with removable shaving. Subject to rule signs and, neglecting the potential energy position of the cutting tool and work piece, we write the equation of the first law of thermodynamics for the cutting process:

$$A_w = Q_{c.t.} + Q_{\det} + \Delta E_{c.t.} + \Delta E_{\det} + \Delta Q \quad [J] \tag{1}$$

Work of cut is determined by the following formula [189]:

$$A_w = (P_z \cdot v_{c.t.})\tau \quad [J] \tag{2}$$

Where P_z - the tangential component of cutting force, [H]; $v_{c.t.}$ - circumferential speed of the cutting tool (one-teeth cutter), [m/s]; τ - during steady state machining, [s].

Assuming that the lower and lateral surface of the work piece, and cutter tooth too, representing a plate of sintekor, heat insulated from the cutter holder, determine the amount of heat, going on heating the insert and the work piece [4]:

$$Q_{c.t.} = \frac{\lambda_{c.t.}}{в}(t - t')\tau \cdot a \cdot c \quad [J] \tag{3}$$

$$Q_{\det.} = \frac{\lambda_{\det}}{в'}(t - t')\tau \cdot (a')^2 \sin \beta \quad [J] \tag{4}$$

where $\lambda_{c.t.}$ and $\lambda_{\det.}$ - thermal conductivity material of the cutting tool and work piece respectively $W/(м \cdot к)$; $(a \times b \times c)$ - length, height and width of the work piece, respectively, [m]; $(a' \times b' \times c')$ - dimensions of the cutting insert, [m]; t - the average temperature in the cutting zone after a period of time τ, [^{0}C]; β - the apex angle of the cutting insert, [degree]; t' - temperature of insulated surfaces of the cutting edge and the work piece, [^{0}C]; $b' = \sqrt{(a')^2 + (a')^2} = a'\sqrt{2}$ [m] – diagonal cutting insert.

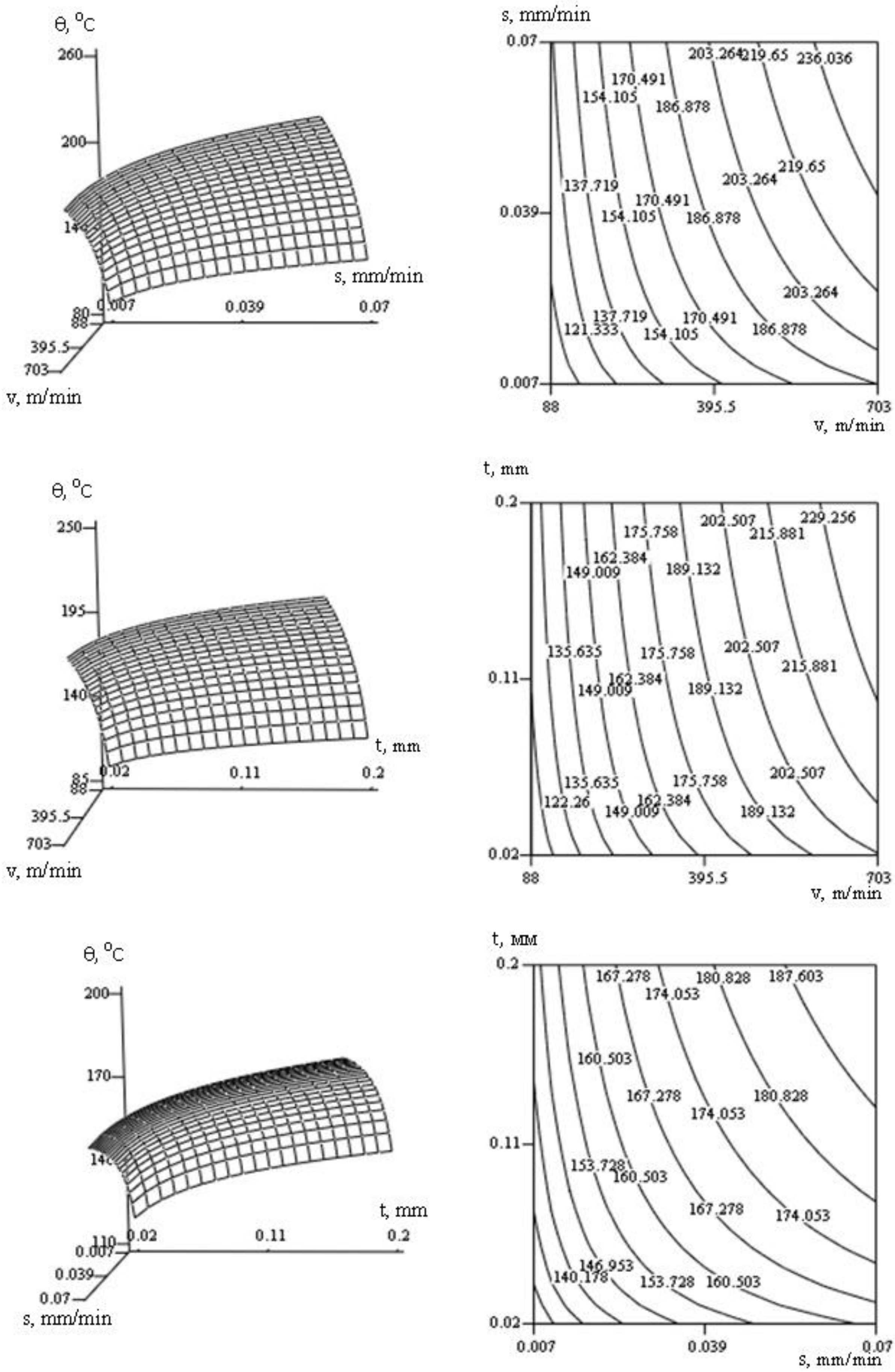

Fig2. *Dependence of the temperature of the cutting modes milling in the processing of bronze BrAZh9-4*

The change of the total energy of the cutting tool and the work piece is determined from the formula [5]:

$$\Delta E_{c.t.} = (\Delta E_{kin.})_{c.t.} + \Delta U_{c.t.} = \frac{m_{c.t.} v_{c.t.}^2}{2} + m_{c.t.} c_{c.t.} (t - t_0) \quad [J] \tag{5}$$

$$\Delta E_{\det.} = (\Delta E_{kin.})_{\det.} + \Delta U_{\det.} = \frac{m_{\det.} v_{\det.}^2}{2} + m_{\det.} c_{\det.} (t - t_0) \quad [J] \tag{6}$$

where $m_{c.t.}$ и $m_{\det}$ - weight, respectively, of the cutting tool and work piece, [kg]; $c_{c.t.}$ and $c_{\det}$ - mass heat capacity, respectively of the cutting tool and the work piece, $J/(kg \cdot K)$; t_0 - the initial temperature of the cutting tool or the work piece, [^{0}C]; $v_{\det}$ - moving speed of the work piece, $[м/c]$; $(\Delta E_{kin.})_{c.t.}$ и $(\Delta E_{kin.})_{\det.}$ - change in kinetic energy respectively of the cutting tool and the work piece, [J]; $\Delta U_{c.t.}$ и $\Delta U_{\det}$ - accordingly the change of internal energy of the cutting tool and the work piece, [J].

The loss of heat to the environment determined by the formula:

$$\Delta Q = \alpha (Q_{c.t.} + Q_{\det.}) = \alpha \cdot P_z \cdot v_{c.t.} \cdot \tau \tag{7}$$

where - the lobar portion of the heat goes to the heating of the cutting tool and the work piece. Substituting the expression (2), (3), (4), (5), (6) and (7) into equation (1) and solving for the average cutting temperature at obtain when $T' = T_0$:

$$t = t_0 + \frac{P_z \cdot v_{c.t.} \cdot \tau \cdot (1 - \alpha) - \frac{m_{c.t.} v_{c.t.}^2}{2} - \frac{m_{\det} v_{\det}^2}{2}}{\tau \cdot \left[\frac{\lambda_{c.t.}}{b} \cdot a \cdot c + \frac{\lambda_{c.t.}}{\sqrt{2}} \cdot a' \cdot \sin \beta \right] + m_{c.t.} \cdot c_{c.t.} + m_{\det.} \cdot c_{\det.}} \tag{8}$$

Problems of modeling of blade machining of metals and alloys require solution of the heat equation, written for the bodies involved in the processing and solved with appropriate boundary conditions .The one-dimensional heat equation is as follows [6]:

$$\partial t / \partial \tau = a \cdot (\partial^2 t / \partial x^2) + q_v / \rho \cdot c \,, \tag{9}$$

where τ - time a - coefficient of thermal diffusivity of the work piece material, t - the temperature at any point of the work piece, qv - power heat source.

The equations (9) to form more convenient from the point of view of the numerical solution. To this end, members of the (9) derivatives, approximately represented (approximated) derivatives in finite differences [7]:

$$\partial t / \partial \tau = (t_i^{k+1} - t_i^k) / \Delta \tau \tag{10}$$

$$\partial^2 t / \partial x^2 = (t_{i+1}^{k+1} - 2 t_i^{k+1} + t_{i-1}^{k+1}) / \Delta x^2 \tag{11}$$

Substituting equation (10) and (11) in (9), we obtain:

$$(t_i^{k+1} - t_i^k) / \Delta \tau = a \cdot (t_{i-1}^{k+1} - 2 t_i^{k+1} + t_{i+1}^{k+1}) / \Delta x^2 + q_v / \rho \cdot c \tag{12}$$

After some transformations, we obtain:

$$- t_{i-1}^{k+1} + (2 + s) \cdot t_i^{k+1} - t_{i+1}^{k+1} = s \cdot t_i^k + \omega \,, \tag{13}$$

Where - $s = \Delta x^2 / a \cdot \Delta \tau$; $\omega = \Delta x^2 \cdot q_v / a \cdot c\rho$; $i = 1,2,....,\ n - 1$; $k = 0,1,...,\ m - 1$

To $i = 1$ and $i = n - 1$ will have:

$$\begin{cases} -t_0^{k+1} + (2+s)\cdot t_1^{k+1} - t_2^{k+1} = s\cdot t_1^k + \omega \\ -t_{i-1}^{k+1} + (2+s)\cdot t_i^{k+1} - t_{i+1}^{k+1} = s\cdot t_i^k + \omega \quad ; i = 2,\ldots, n-2 \\ -t_{n-2}^{k+1} + (2+s)\cdot t_{n-1}^{k+1} - t_n^{k+1} = s\cdot t_{n-1}^k + \omega \end{cases} \tag{14}$$

For each layer, the system of equations (14) is a system of linear algebraic equations (n-1) with (n+1) unknowns.
The system is stable for otherwise there are certain instability.

Boundary conditions 3 of his race are as follows:

$$\begin{cases} (2\Delta x + 3\lambda/\alpha)\cdot t_0^{k+1} - 4\lambda/\alpha\cdot t_1^{k+1} + \lambda/\alpha\cdot t_2^{k+1} = 2\Delta x\cdot t_{av} \\ (2\Delta x + 3\lambda/\alpha)\cdot t_n^{k+1} - 4\lambda/\alpha\cdot t_{n-1}^{k+1} + \lambda/\alpha\cdot t_{n-2}^{k+1} = 2\Delta x\cdot t_{av} \end{cases} \tag{15}$$

Taking into account the boundary conditions (3.69) from (3.68) we get:

$$\begin{cases} [(2+s)\cdot\Delta x + (1+1{,}5s)\cdot\lambda/\alpha]\cdot t_1^{k+1} - (\Delta x + \lambda/\alpha)\cdot t_2^{k+1} = \\ = \Delta x\cdot t_{av} + (\Delta x + 1{,}5\,\lambda/\alpha)\cdot(st_1^k + \omega) \\ -t_{i-1}^{k+1} + (2+s)\cdot t_i^{k+1} - t_{i+1}^{k+1} = s\cdot t_i^k + \omega \qquad ; i = 2,\ldots, n-2 \\ [(2+s)\cdot\Delta x + (1+1{,}5s)\cdot\lambda/\alpha]\cdot t_{n-1}^{k+1} - (\Delta x + \lambda/\alpha)\cdot t_{n-2}^{k+1} = \\ = \Delta x\cdot t_{av} + (\Delta x + 1{,}5\,\lambda/\alpha)\cdot(st_{n-1}^k + \omega) \end{cases} \tag{16}$$

For the layer k+1 system (16), it represents a system (n+1) of equations with (n-1) unknowns. It can be solved by the methods of the left, right, and counter-sweep. We solve the system of equations (16) by using the right-hand sweep.

The system of equations (16) can be represented as follows:

$$\begin{cases} C_*\cdot t_1^{k+1} - t_2^{k+1} = f_1 \\ -t_{i-1}^{k+1} + C\cdot t_i^{k+1} - t_{i+1}^{k+1} = f_i \; ; i = 2,\ldots, n-2 \, , \\ C_*\cdot t_{n-1}^{k+1} - t_{n-2}^{k+1} = f_{n-1} \end{cases} \tag{17}$$

Where - $C_* = [(2+s)\cdot\Delta x + (1+1{,}5s)\cdot\lambda/\alpha]/(\Delta x + \lambda/\alpha)$ (18)

$C = 2 + s$ (19)

$f_1 = [\Delta x\cdot t_{cp} + (\Delta x + 1{,}5\cdot\lambda/\alpha)\cdot(s\cdot t_1^k + \omega)]/(\Delta x + \lambda/\alpha)$ (20)

$f_i = s\cdot t_i^k + \omega \; ; i = 2,\ldots, n-2$ (21)

$f_{n-1} = [\Delta x\cdot t_{cp} + (\Delta x + 1{,}5\cdot\lambda/\alpha)\cdot(s\cdot t_{n-1}^k + \omega)]/(\Delta x + \lambda/\alpha)$ (22)

Transforming the system of equations (17), we obtain:

$$\begin{cases} t_1^{k+1} = \alpha_1\cdot(t_2^{k+1} + \beta_2) \\ t_i^{k+1} = \alpha_{i+1}\cdot(t_{i+1}^{k+1} + \beta_{i+1}) \\ t_{n-1}^{k+1} = \alpha_n\cdot\beta_n \end{cases} \tag{23}$$

где - $\alpha_1 = 1/C_*$; $\beta_1 = f_1$; $\alpha_{i+1} = 1/(C - \alpha_i)$; $\beta_{i+1} = f_i + \alpha_i\cdot\beta_i$; $\alpha_n = 1/(C_* - \alpha_{n-1})$; $\beta_n = f_{n-1} + \alpha_{n-1}\cdot\beta_{n-1}$.

The procedure for solving the problem consists of forward and reverse sweeps. The direct testing them and determined coefficients, and inversely the temperature t.

To assess the effects of temperature source of heat in the work piece when the small milling procedure involves machining is realized in unsteady loading of inserts from sintekor, due to cutting conditions, physical and mechanical properties of the processed material, the instability of the processing, which is associated with the cyclical nature of the chip intermittent treatment, wear and tear on the back side of the cutting insert, as well as the temperature in the cutting zone [8]. A mathematical model of heat transfer process for each element of the technological system is based on the generalized law of energy conservation. For the purposes of the study of unsteady heat transfer process in the work piece to machine the heat equation of the form [7]:

$$\partial t/\partial \tau = a \cdot \left(\partial^2 t/\partial x^2 + \partial^2 t/\partial y^2 + \partial^2 t/\partial z^2\right) + q_v/\rho c \qquad (24)$$

We transform the equation (24) to a form more convenient from the point of view of the numerical solution. To this end, members of the (24) derivatives represented approximately finite-difference [7]:

$$\partial t/\partial \tau = (t_{i,n,m}^{k+1} - t_{i,n,m}^{k})/\Delta \tau \qquad (25)$$

$$\partial^2 t/\partial x^2 = (t_{i-1,n,m}^{k} - 2t_{i,n,m}^{k} + t_{i+1,n,m}^{k})/\Delta x^2 \qquad (26)$$

$$\partial^2 t/\partial y^2 = (t_{i,n-1,m}^{k} - 2t_{i,n,m}^{k} + t_{i,n+1,m}^{k})/\Delta y^2 \qquad (27)$$

$$\partial^2 t/\partial z^2 = (t_{i,n,m-1}^{k} - 2t_{i,n,m}^{k} + t_{i,n,m+1}^{k})/\Delta z^2 \qquad (28)$$

Substituting equation (25) - (28) in equation (24), after simple transformations we obtain:

$$t_{i,n,m}^{k+1} = [1 - 2\cdot(a\cdot\Delta\tau/\Delta x^2 + a\cdot\Delta\tau/\Delta y^2 + a\cdot\Delta\tau/\Delta z^2)]\cdot t_{i,n,m}^{k} + a\cdot\Delta\tau/\Delta x^2\cdot(t_{i-1,n,m}^{k} + t_{i+1,n,m}^{k}) + a\cdot\Delta\tau/\Delta y^2\cdot(t_{i,n-1,m}^{k} + t_{i,n+1,m}^{k}) + a\cdot\Delta\tau/\Delta z^2\cdot(t_{i,n,m-1}^{k} + t_{i,n,m+1}^{k}) + q_v\cdot\Delta\tau/\rho c \qquad (29)$$

$$x = i\cdot\Delta x,\ y = n\cdot\Delta y,\ z = m\cdot\Delta z,\ \tau = k\cdot\Delta\tau$$

If steps are selected so that the equation is simplified

$$t_{i,n,m}^{k+1} = (1 - 6\cdot a\Delta\tau/\Delta x^2)\cdot t_{i,n,m}^{k} + a\cdot\Delta\tau/\Delta x^2\cdot(t_{i-1,n,m}^{k} + t_{i+1,n,m}^{k} + t_{i,n-1,m}^{k} + t_{i,n+1,m}^{k} + t_{i,n,m-1}^{k} + t_{i,n,m+1}^{k}) + q_v\Delta\tau/\rho c \qquad (30)$$

Equation (30) is a basic calculation formula when determining the temperature of the preform being processed by milling. From the calculated output formula that the transition from the exact value of t to its approximate value is valid if the integration steps satisfy the relation:

$$0 \le [1 - 2\cdot(a\cdot\Delta\tau/\Delta x^2 + a\cdot\Delta\tau/\Delta y^2 + a\cdot\Delta\tau/\Delta z^2)] \le 1 \qquad (31)$$

If $\Delta x = \Delta y = \Delta z$, то (31) It simplified and takes the form:

$$0 \le [1 - 6\cdot(a\cdot\Delta\tau/\Delta x^2)] \le 1 \qquad (32)$$

The initial temperature is defined as: $t = f(x, y, z)$

The power of the heat source for the work piece is determined by the equation:

$$q_v = p_z\cdot v/V \qquad (33)$$

Where p_z - cutting force, v - cutting speed, V - the volume of the preform.

Initial dependencies to determine the temperature on the surface of the work piece are the boundary conditions.

The boundary conditions of the third kind on the outer surface of the work piece are as follows [9]:

$$\begin{cases} \lambda\cdot\partial t_{(0,y,z,\tau)}/\partial x + \alpha\cdot[t_{(0,y,z,\tau)} - t_{cp}] = 0 \\ \lambda\cdot\partial t_{(R_1,y,z,\tau)}/\partial x + \alpha\cdot[t_{(R_1,y,z,\tau)} - t_{cp}] = 0 \\ \lambda\cdot\partial t_{(x,R_2,z,\tau)}/\partial y + \alpha\cdot[t_{(x,R_2,z,\tau)} - t_{cp}] = 0 \\ \lambda\cdot\partial t_{(x,y,0,\tau)}/\partial z + \alpha\cdot[t_{(x,y,0,\tau)} - t_{cp}] = 0 \\ \lambda\cdot\partial t_{(x,y,R_3,\tau)}/\partial z + \alpha\cdot[t_{(x,y,R_3,\tau)} - t_{cp}] = 0 \end{cases} \qquad (34)$$

The boundary conditions of the fourth kind are as follows:

$$t_{i,0,m}^{k+1} = t_{cp} + \omega \cdot (k+1) \cdot \Delta\tau \tag{35}$$

After transformations we obtain:

$$\begin{cases} t_{o,n,m}^{k+1} = (a \cdot t_{av} - 0{,}5\,\lambda/\Delta x \cdot t_{2,n,m}^{k+1} + 2\,\lambda/\Delta x \cdot t_{1,n,m}^{k+1})/(\alpha + 1{,}5\,\lambda/\Delta x) \\ t_{R_1,n,m}^{k+1} = (a \cdot t_{av} - 0{,}5\,\lambda/\Delta x \cdot t_{R_1-2,n,m}^{k+1} + 2\,\lambda/\Delta x \cdot t_{R_1-1,n,m}^{k+1})/(\alpha + 1{,}5\,\lambda/\Delta x) \\ t_{i,R_2,m}^{k+1} = (a \cdot t_{av} - 0{,}5\,\lambda/\Delta y \cdot t_{i,R_2-2,m}^{k+1} + 2\,\lambda/\Delta y \cdot t_{i,R_2-1,m}^{k+1})/(\alpha + 1{,}5\,\lambda/\Delta y) \\ t_{i,n,0}^{k+1} = (a \cdot t_{av} - 0{,}5\,\lambda/\Delta z \cdot t_{i,n,2}^{k+1} + 2\,\lambda/\Delta z \cdot t_{i,n,1}^{k+1})/(\alpha + 1{,}5\,\lambda/\Delta z) \\ t_{i,n,R_3}^{k+1} = (a \cdot t_{av} - 0{,}5\,\lambda/\Delta z \cdot t_{i,n,R_3-2}^{k+1} + 2\,\lambda/\Delta z \cdot t_{i,n,R_3-1}^{k+1})/(\alpha + 1{,}5\,\lambda/\Delta z) \\ t_{i,0,m}^{k+1} = t_{cp} + \omega \cdot (k+1) \cdot \Delta\tau \end{cases} \tag{36}$$

where $i = 0,\ldots, R_1$, $n = 0,\ldots, R_2$, $m = 0,\ldots, R_3$, ω - coefficient, which depends on the material of the work piece.

For the study of unsteady heat transfer process in the work piece to machine implemented a model based on the finite difference method. Design method can be applied to solve problems related to the calculation of the temperature field at the finish milling blanks made of nonferrous metals and alloys. Two-dimensional heat conduction problem in differential form is:

$$c\rho \frac{\partial t}{\partial t} = \frac{\partial}{\partial x}\left(\lambda_x \frac{\partial t}{\partial x}\right) + \frac{\partial}{\partial y}\left(\lambda_y \frac{\partial t}{\partial y}\right) + q_v \tag{37}$$

where λ_x, λ_y - thermal conductivity in directions x и y; q_v - specific power source (drain) of the heat inside the body; $c\rho, \lambda_x, \lambda_y, q_v$ can be functions x, y and t ,those Cutting tool (work piece) body may be heterogeneous and the properties can depend on the temperature. The equation is applicable to both isotropic $(\lambda_x = \lambda_y)$, and to anisotropic $\lambda_x \neq \lambda_y$ bodies.

The initial condition $(\tau = 0)$

$$t(x, y, 0) = t_0(x, y) \tag{38}$$

Border conditions:

a) On the part of the boundary surface of the conditions:

$$\lambda_x \frac{\partial t}{\partial x} l_x + \lambda_y \frac{\partial t}{\partial y} l_y + q + \alpha_t (t - t_\infty) = 0 \tag{39}$$

b) a portion of the boundary surface S_2 setpoint:

$$t = t_0 \tag{40}$$

Combining S_1 and S_2 it forms a complete border S .Here l_x, l_y - the direction cosines of the vector normal to the surface; q - the specific density of the heat flux at the surface S_1; α_t - heat transfer coefficient; t_∞ - ambient temperature. If the boundary S_1 q and α_T equals to zero, then (39) reduces to:

$$\lambda_x \frac{\partial t}{\partial x} l_x + \lambda_y \frac{\partial t}{\partial y} l_y = 0 , \tag{41}$$

reflecting the absence of heat transfer across the border S_1. In the case of an isotropic body if - the normal to the surface, then this condition can be written as:

$$\frac{\partial t}{\partial n} = 0 , \qquad (42)$$

From a practical point of view the problem (37) - (41) is sufficiently complete to describe the thermal processes in metal cutting.

Determination of heat flux and temperature at the thin discontinuous non-ferrous metals and alloys cutting plates sintekors. Power (qv) of the heat flow to the cutting insert is experimentally in a plant comprising a lathe, bars of copper and aluminum, single-toothed end of the cutter sintekor, thermocouple and an oscilloscope [10, 4]. Due to the complexity of measuring the temperature at the edges of the blade end mill practical interest is the analytical study of the temperature field in the cutting insert.

For calculation formulas to solve differential equations of heat conduction

$$\frac{\partial t}{\partial t} = a\frac{\partial^2 t}{\partial R^2} + a\frac{\partial^2 t}{\partial z^2} + \varphi(R, z) \qquad (43)$$

If the boundary conditions:

$$\left.\frac{\partial t}{\partial R}\right|_{R=0} = 0 , \left.\frac{\partial t}{\partial R}\right|_{R=R_0} = -h_1 t\big|_{R=R_0} , \left.\frac{\partial t}{\partial z}\right|_{z=0} = -h_2 t\big|_{z=0} , \left.\frac{\partial t}{\partial z}\right|_{z=L} = -h_3 t\big|_{z=L}$$

and the initial condition $t\big|_{T=0} = 0$.

The function of the heat source φ(R, z) в (43) It simulates the appearance of heat in the processing zone. Assuming that most of the heat is released to the working surfaces of the cutting insert, the function of the heat source can be conveniently represented in the form:

$$\varphi = \frac{q_0}{cp}\left(\frac{R}{R_0}\right)\exp\left(-\left(z/l_1\right)^2\right) \qquad (44)$$

In these expressions: t - temperature at the point of the cutting insert, R and z - coordinate in the cylindrical frame, L - length of the insert, 2R0 - the outer diameter of the cutter, l_1 - blade length of the working part of the cutting insert, q_0 - density heat at R = 0 and z = 0, c - specific heat, ρ - density, h_1, h_2, h_3, - The given ($h = \alpha / \lambda$) heat transfer coefficients of working surfaces (rear and front) plates - thermal conductivity λ - Temperature coefficient conductivity material cutting plate. The temperature at this point of the insert, taking into account boundary and initial conditions, and the expression (43) can be written as:

$$t = \frac{2\sqrt{\pi q_0 l_1}}{\chi L}\sum_{k,m=1}^{\infty}\frac{\eta_k^2}{p(p+2)+\eta_k^2}\exp\left(-\frac{\eta_k^2 l_1^2}{L^2}\right)\times$$
$$\times\left(1+\frac{2p}{\sqrt{\pi\eta_k}}\int_0^{\frac{\eta_k l_1}{L}} e^{t^2}dt\right)\frac{2J_0(\mu_m)+\left(\mu_m-\frac{4}{\mu_m}\right)J_1(\mu_m)}{(\mu_m^2+h_l^2R_0^2)J_0^2(\mu_m)\lambda_{km}^2}\times \qquad (45)$$
$$\times\left(1+e^{-a\lambda_{km}^2 T}\right)\left(\cos\left(\eta_k\frac{z}{L}\right)+\frac{p}{\eta_k}\sin\left(\eta_k\frac{z}{L}\right)\right)J_0\left(\mu_m\frac{R}{R_0}\right)$$

Here $p = h_2 L$, η_c и μ_t - the roots of the characteristic equations, J0 and J1 - Bessel function of the 1-st kind of zero and first order, [4].

CONCLUSION

1. The need for the study of thermal phenomena in the area of cutting nonferrous metals and alloys cutting plates of sintekor due to the fact that the increase in wear resistance of inserts under the influence of light exposure takes place only in a certain temperature range.

2. Razrabotany mathematical model for calculating the average temperature in the cutting area based on the first law of thermodynamics, recorded for the solids involved in the machining process and the formulas for its calculation.
3. Identify the location of dangerous sections in the process of cutting non-ferrous metals and alloys inserts sintekor requires the development of analytical and numerical methods for calculating the local temperature, stress and strain in the cutting insert and the work piece.
4. The method of calculation of local strain and stress in the cutting insert of sintekor, based on the methods and sources of the differential equation of heat conduction.
5. Received plates sintekor through regular thermal regime.
6. A mathematical model for calculating the temperature on the surface of a formula to calculate the temperature at the top of the cutting inserts of sintekor work piece and non-ferrous metals and alloys based on the differential equation of heat conduction, and solved by the method of finite differences, finite elements and instant sources.
7. It is proved that the temperature in the cutting zone of nonferrous metals and alloys, cutting plates sintekor ranges from 120-200oS that FACT is challenging to increase wear plates exposed to light irradiation.

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