RESEARCH OF THERMAL PROCESSES AT CUTTING WITH VARIABLE PARAMETERS AT THE UNSET HEAT EXCHANGE

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Abstract: *The method of calculation of thermal streams and temperatures in the cutting area at treatment with the variable terms of process is presented. Researches are executed for the terms of non-stationary and stationary process at the continuous and irregular cutting. Character and degree of depth, feed and cutting speed influence on thermal streams and cutting temperature at treatment with the in-out parameters of cut are set.*
Key words*: Thermal state, cutting tool, non-stationaryness, unset heat exchange, irregularity, blade top temperature*

The thermal state of the cutting tool determines efficiency of his use to a great extent. The modern tendencies of intensification of the cutting modes during exploitation of the cutting tool result in the substantial increase of his thermal loadings that determines actuality of tasks on their research.

Presently the methods of researches of the thermal state of the cutting tool are well enough developed in the conditions of the set heat exchange [1, 2, 3]. However in a number of cases at the brief or irregular cutting ignoring non-stationaryness of process is impossible. General theoretic conformities to the law of description of the thermo physical phenomena are known at the unset heat exchange do not take into account the features of functioning of the cutting tool and require substantial clarification. There is of both scientific and practical interest research of possibilities of theoretical description of the thermal state of the cutting tool and estimation of their temperature under various conditions exploitations.

The purpose of the presented work is creation of method of calculation of temperature of the cutting tool in the conditions of the unset heat exchange and also analysis on its foundation of influence of treatment terms on his thermal state.

A temperature in the cutting blade of instrument is formed under act of sources q_1 and q_2, closenesses of thermal streams on front q_1 and back q_2 surfaces of blade of instrument at the set heat exchange can be expected:

$$q_1 = \frac{K_1 K_3 \lambda_u - K_2 N_2 h + K_1 M_2 h}{K_3 K_4 \lambda_u + M_2 K_4 h - N_1 N_2 lh/\lambda_u}; \quad q_2 = \frac{(K_1 - K_4 q_1)\lambda_u}{N_2 h}, \tag{1}$$

$$K_1 = \frac{(1+c)\omega_{\ddot{a}} kb' q_{\ddot{a}}}{\lambda_{\ddot{a}} V} + \frac{K_{c1} q_{1T}}{\lambda_{\ddot{a}}}\sqrt{\frac{\omega_{\ddot{a}} kl}{V}}; \; K_2 = \frac{(1+c)\omega_{\ddot{a}} kb' q_{\ddot{a}} T_u}{\lambda_{\ddot{a}} V} + \frac{K_{c2} q_{2T}}{\lambda_{\ddot{a}}}\sqrt{\frac{\omega_{\ddot{a}} h}{V}};$$

$$K_3 = \frac{1{,}82 K_{c2}}{\lambda_{\ddot{a}}}\sqrt{\frac{\omega_{\ddot{a}} h}{V}}; \quad K_4 = \frac{1{,}3 K_{c1}}{\lambda_{\ddot{a}}}\sqrt{\frac{\omega_{\ddot{a}} kl}{V}} + \frac{M_1 l}{\lambda_u};$$

$$M_{1,2} = (4{,}88 + 2{,}64\eta_{1,2}^{0,5}\lg \eta_{1,2})\beta^{-0,85}; \;\; N_{1,2} = (0{,}04 + 0{,}02\,\eta_{1,2}^{0,6}\lg \eta_{1,2}) B_{1,2}(h/l),$$

where M_1, M_2, N_1, N_2 is dimensionless functions, determining heating of grounds on the front and back surfaces of blade of instrument; λ_∂, λ_u, ω_∂, ω_u is coefficients of heat conductivity and diffusivity of materials of detail and instrument accordingly; l is length of blivet in directions of tails of shaving; h is a wear on a back surface; a is a thickness of cut; a_1 is a thickness of shaving; k is a coefficient of shaving; V is cutting speed; c is a coefficient, taking into account heating of layers of metal of shaving for one turn of detail; $T_ä$ is a dimensionless function of distributing of temperatures in a detail, caused by the warmth of deformation; b' is a coefficient of relative amount of warmth, get-away in shaving.K_{c1} it is a coefficient, taking into account the law of distributing of closeness of thermal stream on a front surface (for the combined law K_{c1} = 0,77); K_{c2} is a coefficient, taking into account the law of distributing of closeness of thermal stream on a back surface (for the asymmetrical normal law K_{c2} = 0,55); q_{1T}, $q_ä$ - closenesses of thermal streams from forces of friction on the grounds of contact between shaving and front surface of blade of instrument, between the back surface of blade of instrument and detail, and also in the area of deformation; η - dimensionless width of cut: $\eta_1 = b/l$, $\eta_2 = b/h$ ($\eta_{1,2}>1$); $\beta = 90° - \gamma - \alpha$ - sharpening corner; $b = t/\sin\varphi$ - width of cut; t - cutting depth, φ - a main corner in a plan; $B_{1,2}(h/l)$ - special functions: $B_1(h/l) = 2{,}85 - 0{,}9(h/l)$, $B_2(l/h) = 2(l/h)^{0,54}$ if $\beta = 90°$.

The temperature field arising up in the blade of tool at the unset heat exchange is described as follows:

$$\Theta(x,y,z,\tau) = PT(\psi,\eta,\zeta,F_o) = \int_0^1 d\psi_u \int_{-\alpha}^{\alpha} \frac{\left(1 - erf\left[\frac{\sqrt{(\psi-\psi_è)^2+\eta^2+(\zeta-\zeta_è)^2}}{2\sqrt{F_o}}\right]\right)}{\sqrt{(\psi-\psi_è)^2+\eta^2+(\zeta-\zeta_è)^2}} d\zeta_u, \tag{2}$$

where $\psi = x/l$, $\psi_u = x_u/l$, $\zeta = z/l$, $\zeta_u = z_u/l$, $\eta = y/l$ - dimensionless coordinates; $\alpha = 0{,}5b/l$ - dimensionless width of cut; $F_o = \omega\tau/l^2$ - dimensionless criterion of time, or criterion of Fourier; $P = K_b\, ql/4\pi\lambda$ (K_b is a transition coefficient from unlimited space to the unlimited wedge) - size coefficientж $erf[u]$ – known modified function of integral of probability.

The temperature field arising up in the blade of tool at the set heat exchange is described as follows:

$$\Theta(x,y,z) = PT(\psi,\eta,\zeta) = \int_0^l d\psi_u \int_{-\alpha}^{+\alpha} \frac{d\zeta_u}{\sqrt{(\psi-\psi_è)^2+\eta^2+(\zeta-\zeta_è)^2}}, \tag{3}$$

In general case the change of temperatures in the tool blade in the period of the unset heat exchange can be described by a function from dimensionless time $m(Fo)$, the chart of which is presented on a fig. 2 [1]. For the practical use it is expedient to enter analytical description of this function:

$$m(F_o) = \begin{cases} 4\cdot 10^{-3} F_o, & if\ \ F_o \le 150; \\ 0{,}12 F_o^{0,33}, & if\ \ 150 \le F_o \le 300; \\ 4{,}3\cdot 10^{-5} F_o + 0{,}8, & if\ \ F_o \ge 300. \end{cases} \tag{4}$$

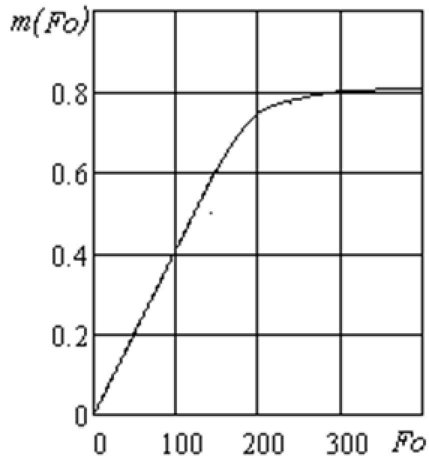

Fig.1. Graphs of change function of the tool blade temperatures at the unset heat exchange

For the account of features of forming of thermal streams at the unset heat exchange in dimensionless functions determining heating of grounds on the front and back surfaces of tool blade the function *m(Fo)*is entered: M_1 *m(Fo)*, M_2 *m(Fo)*, N_1 *m(Fo)*, N_2 *m(Fo)*.

Calculations were executed for the followings terms: the processed material is steel 45; □*в* = 750МПа; instrumental material Т15К6; parameters of chisels: corners in a plan - $\varphi = \varphi 1 = 45°$; front corner - γ =-7°; back corner - α = 7°; sharpening corner β = 90°; a wear on a back surface made h = 0,05 mm and h = 0,1 mm.

Graphs of change of closenesses of thermal streams on front q_1 and back q_2 tool surfaces for the different values of wear on the back surface of blade at the unset heat exchange presented on a fig. 2.

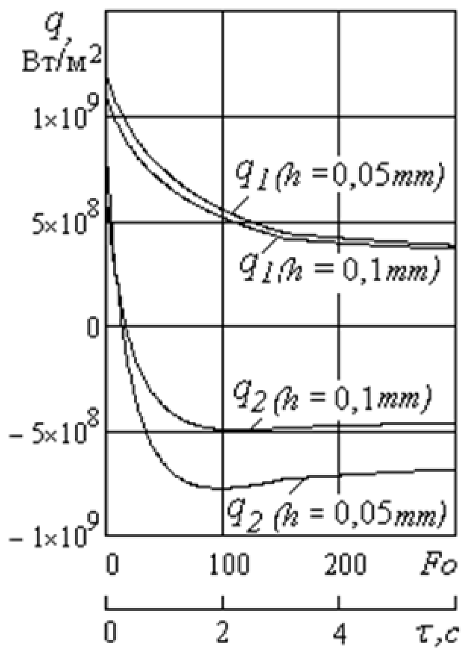

Fig.2. Graphs of thermal streams closenesses change on the front and back tool surfaces at the unset heat exchange

On graphic arts it is rotined along with dimensionless time *Fo* real time of cutting τ. Graphs testify that in initial moment of time thermal streams both on front q_1 and on back q_2 tool surfaces very great. They decrease in time and then stabilized, that testifies to the set process of heat exchange. With the increase of wear on the back surface of thermal streams closeness on a back surface diminishes considerably, on a front surface does not change practically.

Temperatures on front Θ_{nn} and back Θ_{3n} surfaces of tool blade formed under act of thermal streams q_1 and q_2 are determined as follows:

$$\Theta_{ïï} = \left(\frac{q_1 l}{\lambda_{è}} M_1 + \frac{q_2 h}{\lambda_{è}} N_2 \right) m(Fo);$$

$$\Theta_{çï} = \left(\frac{q_2 h}{\lambda_{è}} M_2 + \frac{q_1 l}{\lambda_{è}} N_1 \right) m(Fo). \qquad (5)$$

The cutting temperature is middle temperature on the front and back surfaces of blade Θ_{cp}:

$$\Theta_{cp} = \frac{\left(\Theta_{ïï}\, l + \Theta_{çï}\, h\right) m(Fo)}{l + h}. \qquad (6)$$

Graphs of change of middle temperatures on the front and back tool surfaces for the different values of wear on the back surface of blade (h = 0 and h = 0,1 mm) at the unset heat exchange presented on a fig. 3.

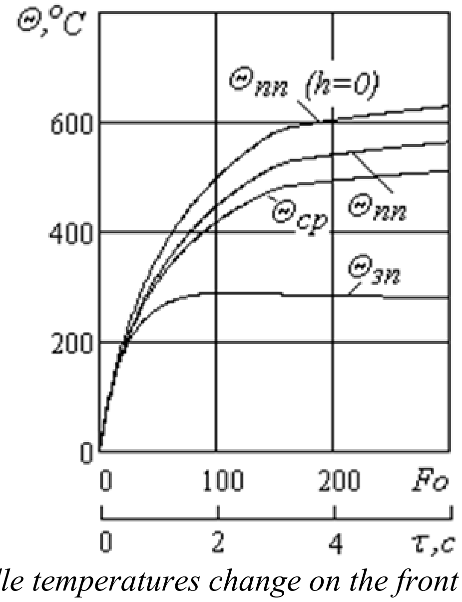

Fig. 3. Graphs of middle temperatures change on the front and back tool surfaces

During working as a tool with wear on a back surface h = 0 a middle temperature is determined only temperatures on the front surface of blade and considerably higher than temperatures observed at presence of wear on a back surface. With appearance of wear on a back surface there are negative thermal streams on a back surface, which reduce a middle temperature, which becomes less than, than temperature on a front surface.

The graphs of change of temperature of cutting for the different values of cutting speed V – *a)* (S = 0,1 *mm/ob*) and cutting feed S – *b)* (V = 90*m/min*)at the unset heat exchange are presented on a fig. 4.

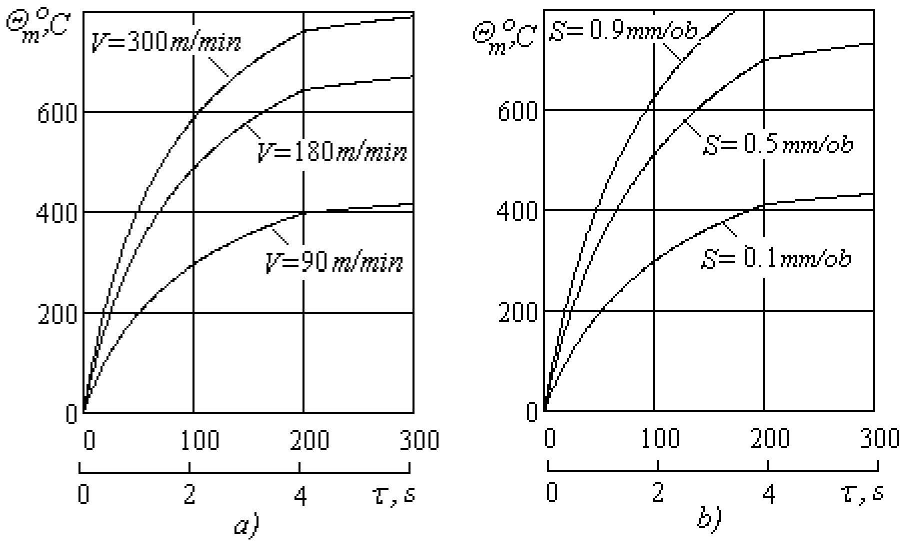

Fig. 4. Graphs of cutting temperature change for the different values of cutting feed V – a) and cutting feed S and cutting feed S – b)

The executed calculations allow setting character and degree of influence of cutting speed and feed on the cutting temperature.

Conclusions. Thus the developed method and also created software of calculation allow to determine thermal streams and temperatures in the cutting area at the unset heat exchange.

In the presentedwork on the basis of analysis of thermal streams in the cutting conformities to law of forming of thermal streams and cutting temperatures are set at the unset heat exchange and also the method of determination of middle temperature on the contact surfaces of blade is developed The method can find a wideuse for determination of thermal streams and cutting temperatures at the different types of tooling and foremost at the irregular cutting.

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