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# THERMAL AREA IN CUTTING TOOL

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***Abstract:*** *The paper contains an appreciation regarding the actual stage of knowledge in metal splitting field from the viewpoint of tribologic aspects and defines main aspects related to cutting factors influencing tools wearing and lastingness. The paper shows a proposal of evaluation under dynamic conditions of thermal status, considering that based on temperatures known in cutting area, appreciation can be done about tools lastingness and a mathematic model of thermal status in this tribosystem.*

***Key words:*** *splinter, friction, heating, wearing.*

## 1. GENERALITIES

Tool wearing has a typical evolution, following a curve named wearing characteristic. Other factors which influence wear, as cutting speed *v,* advance *s*, etc., are represented through curve families (Fig. 1).

On a wearing characteristic, wearing intensity $I = \text{tg}\varphi$ can be defined as a value of slope characteristic in a certain point, and wearing average intensity $I_{med} = \text{tg}\varphi_{med}$ as a value of a slope which passes through origin and is tangent to wearing characteristic in wearing point of abrupt increasing. Due to a lot of experimental research there have been established relations between tool blade wearing and a range of factors which compete on cutting processes.

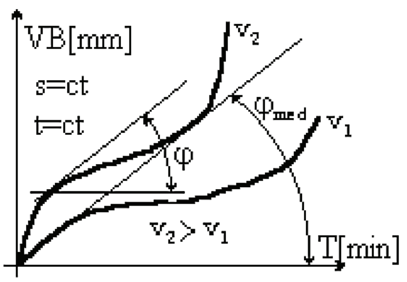


**Fig. 1.** Wearing characteristics family.

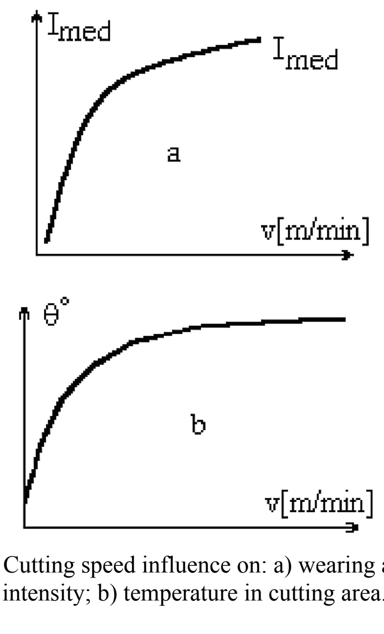


**Fig. 2.** Cutting speed influence on: a) wearing average intensity; b) temperature in cutting area.

On this basis we can conclude that cutting speed is the main factor which influences wear by means of temperature in the cutting area. For example, Fig. 2 shows the curves of wearing average intensity and temperature depending on cutting speed. Analysing the two curves, we notice they have the same shape and the temperature in cutting area is the main wearing factor.

## 2. ACTUAL STAGE OF RESEARCH ON TOOL WEARING FOR METAL SPLITTING

For metal splitting there have been determined empiric relations in order to appreciate tool splitting time when we know the work conditions, up to the maximum admitted blade wearing. These relations are used for planning tool necessary, for calculate splitting factors with a minimum cost and for an approximate optimisation of splitting conditions [2].

Researches in this field do not consider wearing mechanism, data being rather poor. For this reason there have not been explained a range of unusual behaviours ]impossibility of reproducing some phenomena which appear in conditions rather identical. For example, Solomon has reached to the conclusion that, irrespective of part material, from a certain speed there is no more growing of splitting temperature; even in his work a very significant decreasing of the temperature has been noticed (Fig. 3).

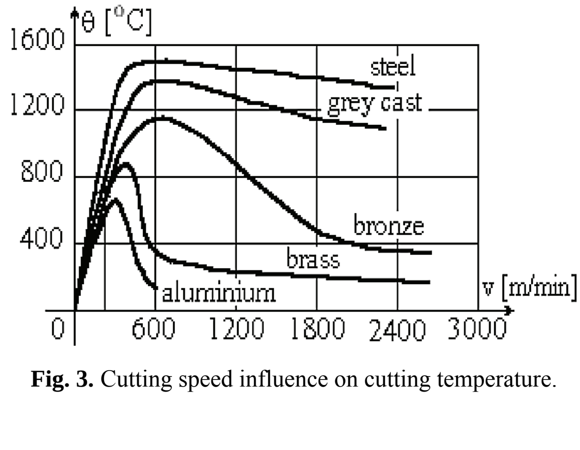


**Fig. 3.** Cutting speed influence on cutting temperature.

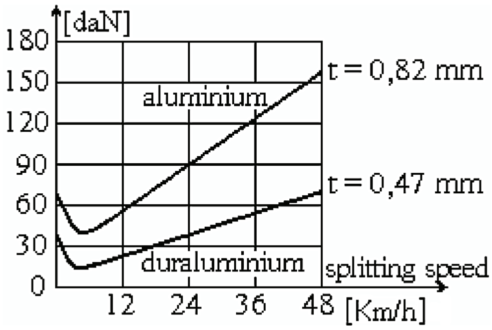


**Fig. 4.** Cutting force depending on speed to Kuznetov.

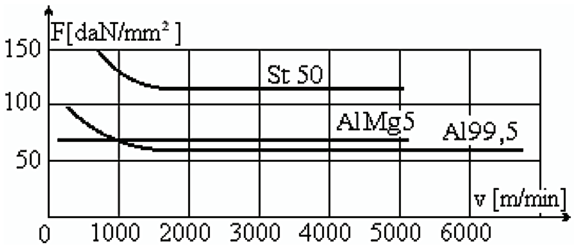


**Fig. 5**. Specific cutting speed depending on speed according to Richter and Schiffner.

Kronenberg found that steel splitting force first increases with the speed, then quickly decreases. Kuznetov found that for aluminium and duraluminium first force decreases while splitting force increases, then quickly increases – Fig. 4. Richter (in 1954) and F. Schiffner (in 1966) found that for aluminium (Al 99.5, AlMg5) and for steel (St50), first splitting force hyperbolically decreases with the speed, then remains constant, no matter how much increases splitting speed (Fig. 5).

Major contradictions appeared in the field of tool blade temperature and it's wear. J. B. Armitage and A. O. Schmidt in 1952 wanted to repeat Solomon trials using a saw milling machine – 200 mm diameter, 10 teeth plated with metallic carbons – which splitted OL42 steel with speed up to 2 500 m/min; they have shown that blades are used in less than a second and the mill becomes a rotating torch. Trials made in U.S.A. show that splitting steel with speeds of 60–80 m/min produce blue splinters – with a high temperature – but for speeds of 1 000–1 500 m/min and an increased tool advance, the splinters are white and cold [2].

It requires then a thoroughly approaching of wearing phenomenon, of it's factors which determine and influence it, in order to build up a model as close to real status as possible. We consider this approaching has to start by identifying and defining the forces which appear in splinter – blade tribosystem, by evaluating mechanic and thermal effects, and finally, by proposing wearing phenomenon model.

## 3. FORCES DURING CUTTING PROCESS

Cutting forces, according to Merchant model unanimously accepted as valid for all cutting situations, is shown in Fig. 6. Considering this model, we notice that forces generating source $Q_2$ act in point $M_2$ – splinter's pressure centre – with the position determined from forces balance acting upon the splinter:

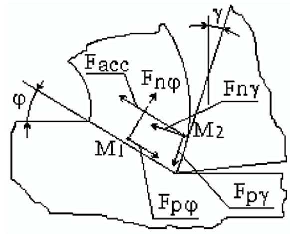


**Fig. 6.** Forces model for cutting.

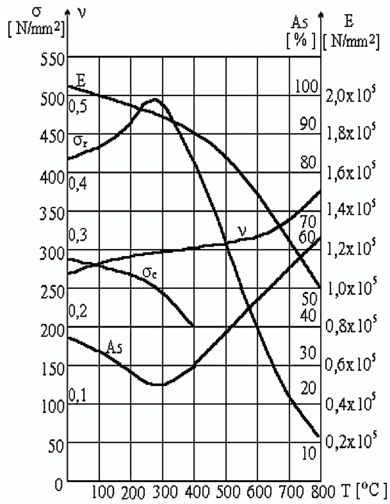


**Fig. 7.** Mechanic characteristics variation with temperature for steel $\sigma_r$ = 420 N/mm at temperature of 20°C.

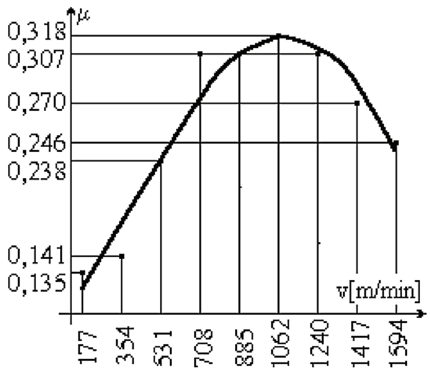


**Fig. 8.** Friction parameter variation depending on relative speed.

$$OM_2 = \frac{a \cdot \left[ F_{n\gamma} \cdot \sin(\varphi - \gamma) + F_{p\gamma} \cdot \cos(\varphi - \gamma) \right]}{2 \cdot \left[ F_{acc} \cdot \cos(\varphi - \gamma) + F_{n\gamma} \right] \cdot \sin\varphi} \qquad (1)$$

The effective calculation of the forces is to be done considering the characteristics of splinter material depending [1] on temperature (Fig. 7) and those of friction factor [5] depending on speed (Fig. 8).

## 4. THERMAL SOURCES DURING CUTTING

It is unanimous accepted the model of thermal source $Q_1$s shown in Fig. 9. Wasted mechanic work transforms almost entirely in heat as follows: in cutting area, mechanic work of plastic deformation generates source $Q_1$ and both in splinter – tool friction area – where appears source $Q_2$ – and in tool – working plan area, source $Q_2$.

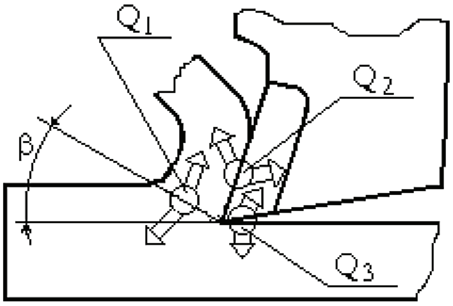


**Fig. 9.** Mechanic works transforming in heat.

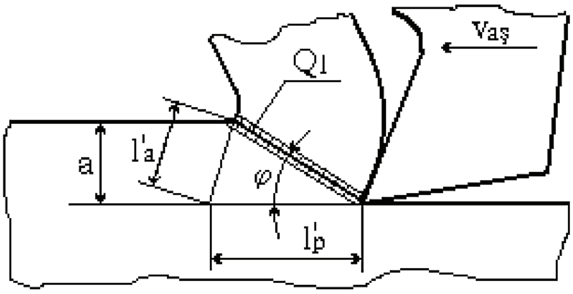


**Fig. 10.** The form of source Q in splitting plan.

Source $Q_1$ is considered to be in shape of an oblique strip directed on cutting plan, Fig. 10, moving through the splitted layer with the main cutting speed $v_{as}$ and remaining constant during cutting because of the elements of cutting which do not change.

$$Q_1 = \frac{L_{def.pl.f.}}{\tau} = \frac{1+\mu}{3\cdot E\cdot\delta}\cdot v_{a]}\cdot\sigma_c^2\cdot \mathrm{tg}\,\varphi \quad [\mathrm{W/m^3}] \qquad (2)$$

For source $Q_2$ is considered to be a parabolic distribution (Fig. 11) for which we have:

$$Q_2 = m\cdot u^2 + n\cdot u + o \quad [\mathrm{W/m^3}]. \qquad (3)$$

This heat comes from the friction between splinter and cutting plan for which we have:

$$P_f = F_f\cdot v_\gamma = \mu_\gamma\cdot F_{n\gamma}\cdot v_\gamma \quad [\mathrm{W}]. \qquad (4)$$

Source $Q_3$ is very small and in most cases it is neglected.

## 5. MATHEMATIC MODEL OF THERMAL STATUS IN SPLINTER – TOOL BLADE TRIBOSYSTEM

Knowing the heat sources and assuming that we know thermal intensities in surces, as power volume density in each source, $R_\varphi$, $R_\gamma$, $R_\alpha$, knowing measure unit [W/m$^3$], we can model the heat phenomenon in splinter, tool and part.

The differential equation of heat transfer by conduction is as follows :

$$\rho\cdot c\cdot\frac{\partial\theta}{\partial t} = \left(\frac{\partial^2\theta}{\partial x^2}\cdot\lambda_x + \frac{\partial^2\theta}{\partial y^2}\cdot\lambda_y + \frac{\partial^2\theta}{\partial z^2}\cdot\lambda_z\right) + \\ + R(x,y,z,t) \qquad (5)$$

applicable in volumes limited by the free plans of blade and splinter.

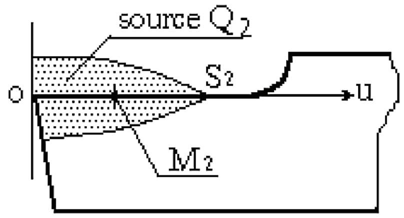


**Fig. 11.** Parabolic distribution of source $Q_2$.

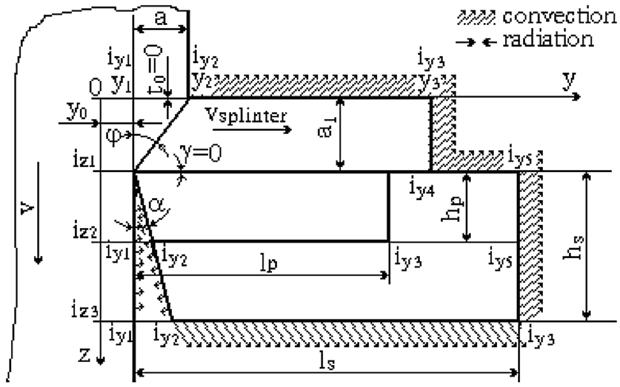


**Fig. 12.** Heat transfer the examined area and neighbouring areas.

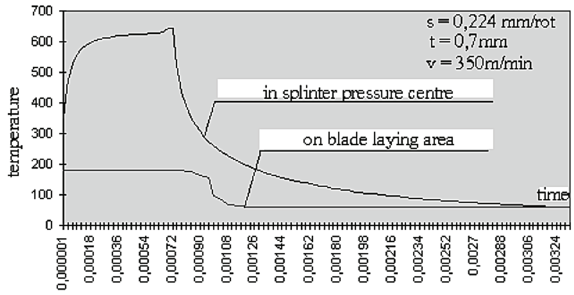


**Fig. 13.** Tool temperature variation with metallic carbure for discontinous cutting.

The equation is solved in *YOZ* plan (Fig. 12) considering that on *X* direction heat distribution is uniformly done.

For solving the system of equations regarding heat transfer, area $l_s x h_s$ is divided in area elements $\delta_y x \delta_z$, obtaining a number of junctions. Using the proposed mathematic model [3], for a definite cutting case, by means of computer simulation, there have been obtained the curves of temperature variation in escaping area and in tool blade (Fig. 13).

## 5. CONCLUSIONS

Based on the information from the speciality literature, so far it can not be approached a theoretical research regarding wearing phenomenon analysis on tool blade for definite cases.

Appreciation of wearing process as a dynamic one, and determination of a mathematic model which can permit an appreciation of thermal status in splinter - tool tribologic system may lead to reducing the efforts of assimilation in manufacturing of new types of tools.

Stand measurements have shown the dependence of the friction coefficient on the relative speed between the tribosystem elements, the dependence way being influenced by the nature of materials of the friction couple; it has been noticed a continuous decreasing dependence of friction coefficient on speed for steel-steel couples and a dependence with a maximum point for steel-metallic carbide couples.

Considering that friction in splinter-tool tribologic system is a noncoulombian one [3], and the fact that this friction influences especially heating and tool lastingness, researches on friction may lead to the conclusion of limiting or extending the working speed range for some definite case of part-tool materials, choosing the fields where friction decreases very much.

The most important thermal sources, such as the source created by plastic deformations in the cutting plane and the source created by the friction between the splinter and the tool blade escaping area, have intensities and distributions depending on the values of the splitting conditions parameters and on the splinter-blade couple. They heat the splitting area to temperatures non-homogeneous distributed, and the temperatures influences those materials constants related to heating sources intensity.

Thermal status in the splitting area is characterized by a maximum in the splinter pressure center on the escaping area, as long as, in the wear area (the laying area) the temperature is much lower.

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