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RESEARCH REGARDING CUTTING TOOL BLADE TRIBOLOGY

Assoc.Prof.Dr.Eng. Daschievici Luiza
Assoc.Prof.Dr.Eng. Ghelase Daniela,
"Dunarea de Jos" University of Galati

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 splitting factors influencing tools wearing and lastingness. The paper presents a proposal of evaluation under dynamic conditions of thermal status, considering that based on temperatures known in splitting area, appreciation can be done about tools lastingness and a mathematic model of thermal status in this tribosystem.

1. INFLUENCES OF SPLITTING CONDITIONS FACTORS ON TOOLS WEARING

Tool wearing has a typical evolution, following a curve named wearing characteristic. Other factors which influence wear, as splitting speed *v,* advance *s*, etc., are represented through curve families, Fig. 1 [5].

On a wearing characteristic, wearing intensity

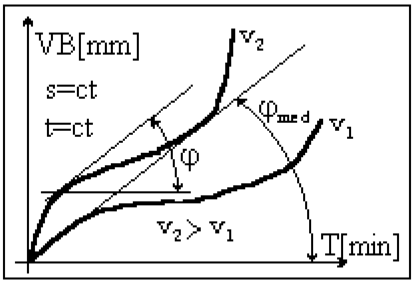

Fig. 1 Wearing characteristics family

$I=tg\varphi$ can be defined as a value of slope characteristic in a certain point, and wearing average intensity $I_{med}= tg\varphi_{med}$ 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 have been established relations between tool blade wearing and a range of factors which compete on splitting processes. On this basis we can conclude that splitting speed is the main factor which influences wear by means of temperature in the splitting area. For example, fig. 2 [5] shows the curves of wearing average intensity and temperature depending on splitting speed.

Analysing the two curves, we notice they have the same shape and the temperature in splitting area is the main wearing factor.

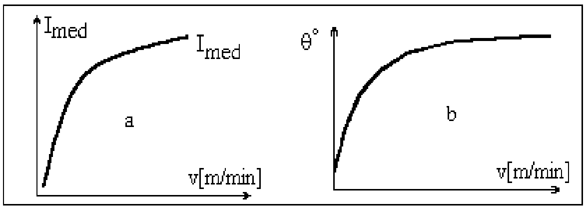

Fig.2 Splitting speed influence on: a) wearing average intensity
b) temperature in splitting area

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

For metal splitting 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 [1], [3]. Researches in this field do not consider wearing mechanism, data being rather poor. For this reason have not been explained a range of unusual behaviours regarding wear reducing for very high speed or the 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 [1].

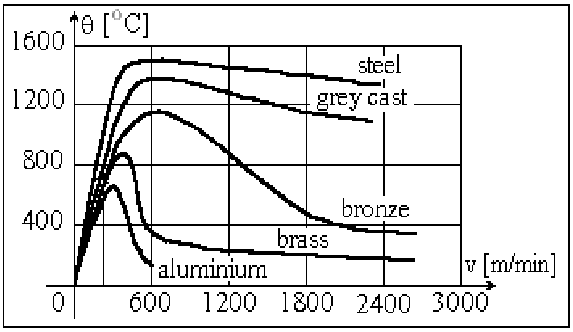

Fig.3 Splitting speed influence on splitting temperature.

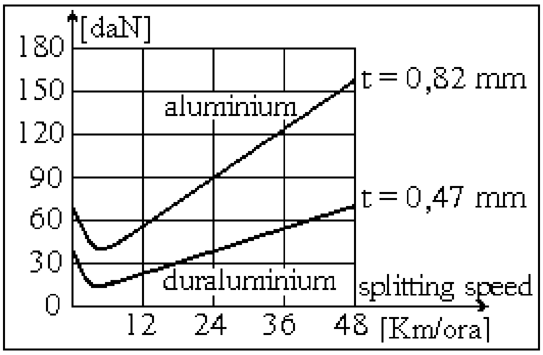

Fig. 4 Splitting speed depending on speed to Kuznetov

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 [4]. Richter and F. Schiffner 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 [6].

Major contradictions appeared in the field of tool blade temperature and it's wear. J.B. Armitage and A.O. Schmidt 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 2500 m/min; they have

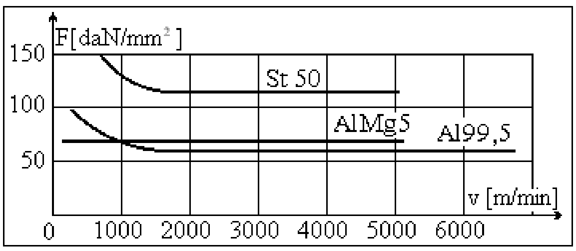

Fig.5 Specific splitting speed depending on speed according to Richter and Schiffner.

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 1000 - 1500 m/min and an increased tool advance, the splinters are white and cold [1].

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. THE RESEARCH METHODOLOGY AND THE UTILIZED MANNERS

Among the considered objectives, there can be mentioned:

- the research of dynamic phenomena
- the research of thermal and wear phenomena

It was necessary to develop a physical model of the phenomenon in order to perform the researches; in fact, the phenomenon is a conventional image of the real status, representing the basics of mathematical modeling. The model has mathematical equations, functionally describing the physical model, and through it, the real phenomenon. For mathematical model solving, difficult to be analytically solved, there have been used numerical methods to obtain solutions for the differential equations.

The stages covered for phenomenon modeling are, as follows:

- splitting area forces modeling, based on Merchant model for free orthogonal splitting, fig. 6 [5], where is taken into consideration the fact that the splinter is balanced by two categories of external and internal forces
- heating sources modeling

It is thought that the heating source consists both by the non-conservative mechanical work wasted by plastic deformation in the cutting plane area and by the non-conservative mechanical work from the friction on the escaping and on the laying tool area.

- heat dispersing modeling. The heat disperses into a non-homogeneous environment consisting of splinter, blade and tool body, each having different caloric coefficients, both as value and temperature dependence.

Solving the problem of heat dispersing under transitory conditions and in a heterogeneous environment leads to temperature knowing for every moment and in each point of the considered environment.

The theoretical study program, including the above-mentioned models, materialized in a very complex physical and mathematical computer model, enables the researching of the influence of different factors, such as:

- the parameters of the splitting conditions (speed, advance, depth)
- tool blade material
- the splitting manner (continuous or interrupted).

As previously shown, the friction in the splitting area takes place under very particular conditions, such as high pressures, relative high-speed values, no lubrication. The bibliographical research shows that coulombian friction is an exaggerated approximation of dry friction.

As long as a realistic mathematical model is desired, the friction model for the splitting area should have a friction coefficient depending on speed for the couple splinter-blade.

By mathematical modeling, the differential equation for heat conducting is:

$$\rho \cdot c \cdot \frac{\partial \theta}{\partial t} = \lambda \cdot \left(\frac{\partial^2 \theta}{\partial x^2} + \frac{\partial^2 \theta}{\partial y^2} + \frac{\partial^2 \theta}{\partial z^2} \right) \quad (1)$$

that for an anisotropic and non-homogeneous material generally turns to:

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

where:

ρ - material density (kg/m^3);

c - material specific heating (J/kgK);

λ_x, λ_y, λ_z - material thermal conductivity (W/mK).

The integration of the differential equation (3) is analytically difficult to solve, and the specialty literature does not offer exact solutions for each practical case. To obtain an analytical result, the following solution is used:

$$\theta(t, x, y, z) = T(t) \cdot F(x, y, z) \quad (3)$$

replacing it in heat equation (2) leads to:

$$\rho \cdot c \cdot \frac{\partial T}{\partial t} \cdot F(x,y,z) = T(t) \cdot \left[\lambda_x \cdot \frac{\partial^2 F(x,y,z)}{\partial x^2} \right] + T(t) \cdot \left[\lambda_y \cdot \frac{\partial^2 F(x,y,z)}{\partial y^2} + \lambda_z \cdot \frac{\partial^2 F(x,y,z)}{\partial z^2} \right] \quad (4)$$

Heat exchanges inside and on the areas of the tribosystem the mathematic model, knowing the border conditions, extremely difficult to be analytically described, materializes elements and that is why numerical integration is preferred, the most suited being the finite differences method.

The friction coefficient used by the computing program was experimentally determined by using energetic methods.

The results obtained for the friction coefficient

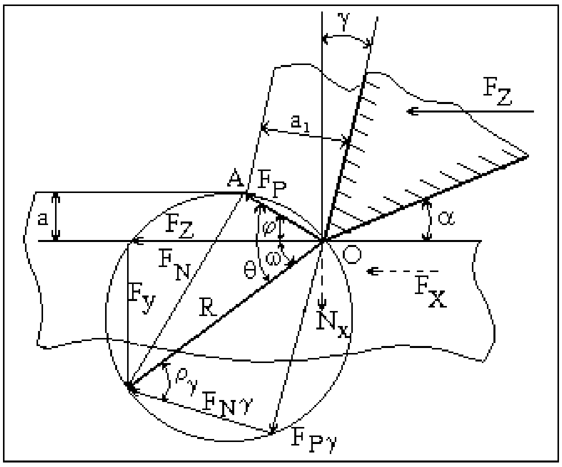

Fig.6 Splitting area forces based on Merchant model for free orthogonal splitting

clearly led to the conclusion that, in this case, the friction is non-coulombian. Its dependence on speed is shown in fig. 7 [7], [3].

The present paper also uses the results obtained by a classical research regarding tool wear, results taken out from a research project performed for manufacturing assimilation of metallic carbide cutting plates. These results were synthesized in wearing diagrams, VB = f(T), for some specific processing cases. These wear curves, continuous in time, enabled the study of wear evolution correlated to the suggested mathematical modeling.

Taking into account the fact that the speed mostly determines process thermal status, with implications on cutting tool wear, it was considered necessary to be analyzed for the heating process, especially on the laying area, in order to diminish the implications and wear reducing.

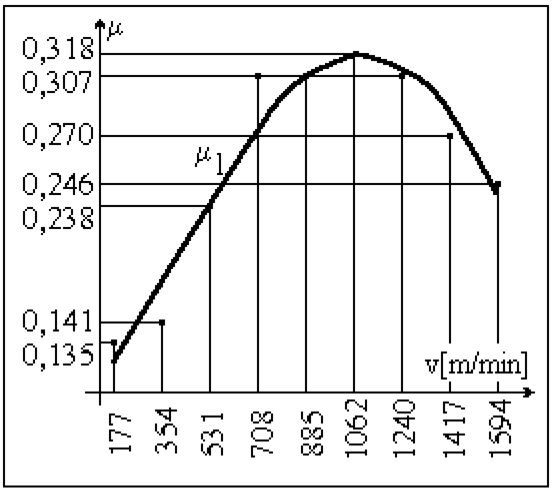

Fig. 7 The variation of friction coefficient on relative speed

By solving the mathematical model using the specialized developed program, thermal areas are obtained; when analyzing for different splitting processes, with the required parameters v, s and t, appreciations on wear and durability of splitting tools can be stated. The obtained data can be used to trace a curve for temperature dependence on speed, as shown in fig. 8 [2].

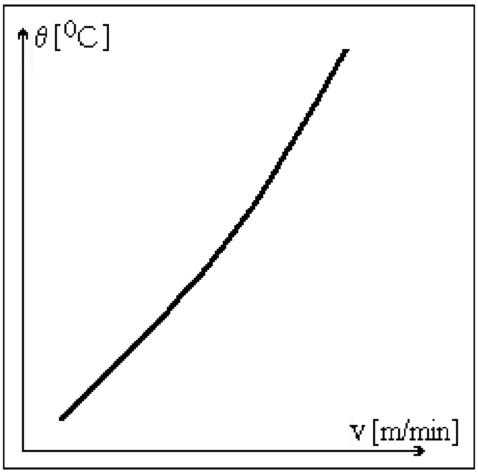

Fig.8 The variation of temperature on the splitting speed

Notice the similitude between θ°[C] = f(v) curve and I_{med}=f(v) curve, fig. 9; a direct relation I_{med}=f(θ°C) for case (P10) can be stated, as shown in fig. 10.

Diagram analysis concludes that there is a good proportionality of wear medium intensity with the maximum temperature of splitting process, an experimentally stated fact, also presented by the specialty literature.

Experimental and theoretical researches

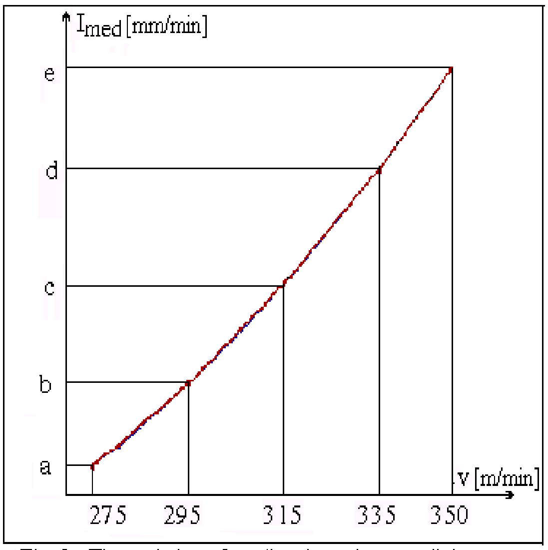

Fig. 9 The variation of medium intensity on splitting speed

4. CONCLUSIONS

Based on the performed studies, a series of conclusions have been stated, among which are, as follows:

- the friction between splinter and tool blade is, for certain, a dry friction;
- 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;
- 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;
- it has been stated a dependence relation between a parameter characteristic tool blade wear, such as wear medium intensity, and splitting area temperature; the relation is, with pretty small deviations, a directly proportional dependence one; thus, by measuring the tribosystem temperature, the wear medium intensity can be evaluated, at least for the splitting process.

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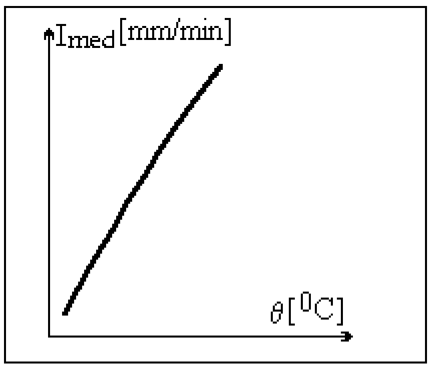

Fig.10 The variation of medium intensity on maximum temperature

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