IOP Conf. Series: Materials Science and Engineering **1018** (2021) 012010 doi:10.1088/1757-899X/1018/1/012010

The role of the friction process in abrasive grain micro cutting technology

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Abstract. The process of micro-cutting with abrasive grain - complicated tribological phenomenon. The removal of the chip-shaped material from the surface of the semi-finished product is accompanied by elastic and plastic deformations of the surface, with heat releases and phase changes. One of the features of the grinding process and other types of abrasive processing, is that the removal of the chip especially takes place with negative front angles. According to [1] the average value of the front cutting angle values is within the limits - (46.6… 56.9). To the geometric parameters of the distant layer that characterizes the cutting process can be attributed: the thickness and width of the cut and the shrinkage of the chip. A series of scientific and manual works on cutting materials can be objected to the fact that in the process of deformation at cutting which is characterized by the coefficient of shrinkage of the chip a physical-mechanical influence has the characteristic of the processed material, the value of advance, depth of cutting and other parameters.

1. Introduction

Even in the middle of the last century, the authors [1, 2] remarked that when analyzing the mechanics of cutting materials, there is a wrong physical explanation of the phenomena and an incorrect determination of the main influencing factors. The authors assumed that the main role in the value of plastic deformation belongs to the coefficient of friction. The influence of cutting regimes and physical-mechanical properties of materials on the value of plastic deformation of the removed layer, determined by the shrinkage of the chip, can be expressed only by the corresponding influence on changing the coefficient of friction of the chip on the cutting surface of tools.

Experimental research [3, 4] confirms the above. In the development of the above we can add that the local value of the coefficient of friction within the contact area "tool-chip" is not constant. Depending on the purpose of the research, we can examine only the most requested areas of contact of the abrasive grain with the chip. Because, the discussion takes place about the formation of the chip, so the main role is given to the plane of separation of the front and back surface of the granule, ie - the cutting edge of the tool.

The results of experimental research related to the determination of the shear force at grinding are known [5]. Models of cutting forces are known [6, 7] they have an essential value in determining the friction force, and can explain the processes of friction, cutting and the formation of wrinkles on the surface of the part (figure 1) [8]. The increase of the cutting depth is accompanied by the increase of the cutting forces, as a result tempering increases and there are changes in the structure and hardness

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of the part, attempts have been made to describe mathematically [9] the value of the influence of cutting forces on the process of forming residual stresses. .

Decreasing the cutting forces and the cutting depth leads to an increase in the influence of friction [10]. Consequently, the volume of heat in the cutting area increases, which leads to the appearance of thermal stresses, which can be determined by the expression [10, 11]:

$$\sigma = \frac{E}{1-\mu}\lambda(t_{\phi} - t) \tag{1}$$

where: E - Yung module; μ - Poisson's ratio; λ - thermal coefficient; t_{φ} - average temperature; t - current surface temperature.

It is known that along the cutting line the normal stresses reach the maximum values and the tangential ones are equal to zero, ie the friction forces are missing.
After the transformation the expression (2) will have the form:

$$\frac{\mu_1+\mu_2}{1-\mu_1\mu_2} < \frac{\eta cos\gamma}{1-\eta cos\gamma}. \tag{2}$$

2. **Mathematical model**

In the paper [3] it was demonstrated that the rotating hyperboloid is a figure that better fits the shapes of the abrasive grain and can be used to model geometry. This is also mentioned in the authors' work [3]. Then the value of the front angle on the surface of the abrasive granules and in the plane of the main sections at the level of the semi-finished section can be determined from the following expression [4]:

$$\frac{1}{\cos\gamma} = \pm\sqrt{\frac{\rho^2}{a^2(2\rho + a_z \mathrm{tg}^2\gamma_3)} + \mathrm{tg}^2\gamma_3 + 1}, \tag{3}$$

where: ρ - radius of rounding of the cutting edge (radius of the tip of the hyperboloid); a_z- depth of purchase with a single grain; γ_3 - the front angle of the abrasive granule, determined by the position of the asymptotes of the hyperboloid - the model of the granule section ($\gamma_3 = \varepsilon / 2$, ε - the angle between the asymptotes).

By transforming expression (2), it follows that,

$$\pm\sqrt{\mathrm{tg}^2\gamma + 1} = \pm\sqrt{\frac{\rho^2}{a^2(2\rho + a_z \mathrm{tg}^2\gamma_3)} + \mathrm{tg}^2\gamma_3 + 1},$$
$$\frac{1}{\cos\gamma} = \pm\sqrt{+\mathrm{tg}^2\gamma + 1}:$$

$$\mathrm{tg}^2\gamma = \frac{\rho^2 + 2\rho a_z \mathrm{tg}^2\gamma_3 + a_z^2 \mathrm{tg}^4\gamma_3}{a_z(2\rho + a_z \mathrm{tg}^2\gamma_3)}, \tag{4}$$

$$\mathrm{tg}\gamma = \frac{\rho + a_z \mathrm{tg}^2\gamma_3}{\sqrt{a_z(2\rho + a_z \mathrm{tg}^2\gamma_3)}}, \mathrm{tg}^2\gamma = \frac{(\rho + a_z \mathrm{tg}^2\gamma_3)^2}{a_z(2\rho + a_z \mathrm{tg}^2\gamma_3)}, \gamma = -\mathrm{arctg}\left(\frac{\rho + a_z \mathrm{tg}^2\gamma_3}{\sqrt{a_z(2\rho + a_z \mathrm{tg}^2\gamma_3)}}\right),$$

$$\text{where } \gamma = \in \left(\frac{\pi}{2}; 0\right) \tag{5}$$