ANALYTICAL PARAMETERS DETERMINATION OF CUTTING POWER TENSION

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Abstract: *analytically identified components of the cutting force, cutting and conventional stress conditions reduction for blade and grinding. Substantiated conditions for transition from the cutting process to the process of plastic deformation of the material being processed without the formation of chips.*

Keywords: cutting process, grinding, cutting force, processing productivity

1. INTRODUCTION

Of the various materials processing technologies based on the use of various forms of energy, it is necessary to highlight the mechanical machining materials processing technologies [1, 2], which are characterized by the lowest power consumption and highest processing capacity and ensure high quality and accuracy of machined surfaces. Cutting processes materials are widely used in manufacturing and in the coming years won't lose its significance. Their further development is of great practical importance to improve the accuracy, quality and machining performance. Accordingly in the work considered questions analytical determination of parameters of the power intensity of the cutting process and the conditions of reduction applied to the blade and grinding.

2. ANALYTICAL RESEARCH

The cutting process is directed destruction of the surface layer of the treated material under the action of the load arising from contact with the cutting tool. This load is called the theory of cutting the cutting force. Usually it is resolved into two components - the tangential P_z and radial P_y (fig. 1):

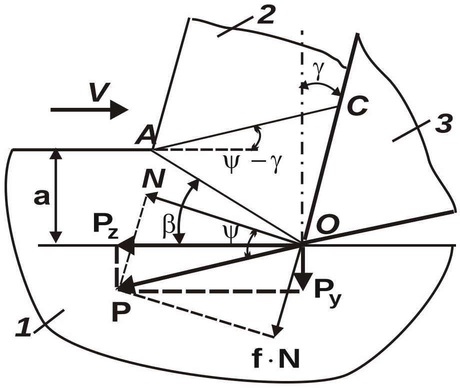

Fig. 1: Design scheme of the cutting process: 1 - processed material, 2 - chips, 3 - cutting tool

$$P_z = \sigma \cdot S = \sigma \cdot \frac{Q}{V_{cut}}; \qquad (1)$$

$$P_y = \frac{P_z}{K_{cut}} = \frac{\sigma}{K_{cut}} \cdot \frac{Q}{V_{cut}}, \qquad (2)$$

where σ - conventional voltage cutting; S - the cross sectional area of cut; $Q = S \cdot V_{cut}$ - processing performance ; V_{cut} - cutting speed; $K_{cut} = P_z / P_y$ - coefficient of cutting.

The most important condition of efficiency of the cutting process is to increase processing performance Q. On the basis of the converted according (1): $Q = \frac{P_z \cdot V_{cut}}{\sigma}$, this is achieved by increasing parameters P_z, V_{cut} and reduction σ. Obviously, the increase of the tangential component cutting force P_z limited durability of the cutting tool, and increase the cutting speed V_{cut} - his resistance due to the temperature factor. The possibility of reduction of nominal voltage cutting σ connected with the contact management processes, taking place on the front and back surfaces of the instrument. Therefore, parameters σ and P_z due mechanics, the cutting speed V_{cut} - the thermophysics of the cutting process. However, this separation is very relative, because the parameters σ and P_z also temperature depends on cutting and they must learn how to position mechanics, and from a position of Thermophysics of the cutting process.

About the effectiveness of processes for mechanical and physical-technical materials processing judged by the value of energy consumption E, equal to the work expended on a unit volume of material removal V. Presenting the work A, necessary for removing bulk material V, at machining and volume V as $A = P_z \cdot l$; $V = l \cdot S$ (where l - length of cutting path , м; S - the cross sectional area of cut , м^2), energy consumption $E = A/V$ determined

$$E = \frac{P_z}{S} = \sigma. \qquad (3)$$

As can be seen, when machining (cutting, cutting and abrasive tools) energy intensity E numerically equal to the conventional stress cutting σ.

To determine σ should consider a simplified analytical model of the cutting process (fig. 1), according to which the material removal occurs by shifting elements formed along the conditional chip shear plane, located at the angle β to the direction of movement of the tool. Under the influence of forces P_z and P_y in the shear plane shear stress occurs τ. To determine the position of the shear plane of the material conditional (contingent shift angle material β) it is necessary to project the components of the cutting force P_z, P_y and set the shear stress τ:

$$\tau = \frac{sin\beta}{a \cdot в} \cdot \left(P_z \cdot cos\beta - P_y \cdot sin\beta\right) = \frac{P_y}{a \cdot в} \cdot \left(0{,}5 \cdot K_{cut} \cdot sin2\beta - sin^2\beta\right), \qquad (4)$$

where $a,\ в$ - accordingly, thickness and width of cut , м.

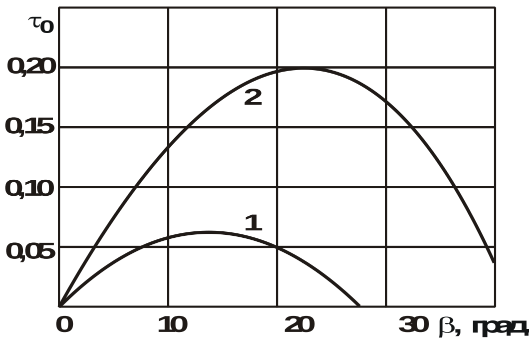

Fig. 2: Dependency τ_0 on the angle β: 1 - K_{cut} =0,5; 2 - K_{cut} =1.

Shear stress τ, based on dependencies (4), has the most from conditional shift material β. On the fig. 2 graphically the character of change of the function $\tau_0 = 0{,}5 \cdot K_{cut} \cdot sin2\beta - sin^2\beta$, a member of the dependence (4).

The extreme value β is determined from the necessary conditions of extremum $\tau'_\beta = 0$:

$$tg2\beta = K_{cut}. \qquad (5)$$

As you can see, the relative shift of the material clearly depends on the coefficient of cutting K_{cut}: with increasing angle β increases.

Radial component cutting force P_y is determined from the dependence (4) with relation (5) on condition $\tau = \tau_{sh}$:

$$P_y = \frac{a \cdot в \cdot \sigma_{st}}{K_{cut}^2} \cdot \left(1 + \sqrt{1 + K_{cut}^2}\right), \qquad (6)$$

where $\tau_{sh} \approx 0{,}5 \cdot \sigma_{st}$ - tensile strength the shift of the processed material, Н/м^2; σ_{st} – tensile strength at compression of processed material , Н/м^2.

Tangential component cutting force $P_z = K_{cut} \cdot P_y$ and conditional voltage cutting $\sigma = P_z / a \cdot в$ are defined:

$$P_z = \frac{a \cdot в \cdot \sigma_{st}}{K_{cut}} \cdot \left(1 + \sqrt{1 + K_{cut}^2}\right); \qquad (7)$$

$$\sigma = \frac{\sigma_{st}}{K_{cut}} \cdot \left(1 + \sqrt{1 + K_{cut}^2}\right). \qquad (8)$$

Specific components of the cutting forces describes dependencies:

$$P_{z_{sp}} = \frac{P_z}{a \cdot в \cdot \sigma_{st}} = \frac{1}{K_{cut}}\left(1 + \sqrt{1 + K_{cut}^2}\right); \qquad (9)$$

$$P_{y_{sp}} = \frac{P_y}{a \cdot в \cdot \sigma_{st}} = \frac{1}{K_{cut}^2}\left(1 + \sqrt{1 + K_{cut}^2}\right). \qquad (10)$$

From dependences (9) and (10) it follows that the parameters $P_{z_{sp}}$ and σ identical, asdescribes the same addiction. The analysis calculated based on the dependencies (9) and (10) values $P_{z_{sp}}$ and $P_{y_{sp}}$, which is shown in fig. 3, shows that, subject to the K_{cut} = 1parameters $P_{z_{sp}}$ and $P_{y_{sp}}$ equal, as provided K_{cut} <1 и K_{cut} >1 fair accordingly conditions $P_{z_{sp}} < P_{y_{sp}}$ и $P_{z_{sp}} > P_{y_{sp}}$. As is known, the condition K_{cut} < 1 implemented for abrasive processing, but the condition $K_{cut} > 1$ – at the blade processing. Therefore, when sanding the greatest influence on the process parameters has a radial P_y component cutting force, but when the blade processing - tangential P_z component cutting force. Thus the components of the forces at the edge processing ($K_{cut} > 1$) less than for abrasive processing ($K_{cut} < 1$), that indicates the possibilities of improving the accuracy and quality of cutting edge tools. This pattern is due to the smaller values of the conditional voltage cutting $\sigma = P_{z_{sp}}$, which provided $K_{cut} \to \infty$ seeks to adopt the values σ_{st} (fig. 3). In this case the conditions of chip formation comply with the terms of straightforward destruction of the sample at its compression.

Express the ratio of cut K_{cut} through the components of the cutting force N и $f \cdot N$, appearing on the front surface of the tool (fig. 1) [3]:

$$\begin{cases} P_z = N \cdot cos\gamma + f \cdot N \cdot sin\gamma, \\ P_y = -N \cdot sin\gamma + f \cdot N \cdot cos\gamma, \end{cases} \tag{11}$$

where f - the coefficient of friction on the front surface of the tool; γ - cutting angle of the tool.

Whence

$$K_{cut} = ctg(\psi - \gamma) = \frac{1 + f \cdot tg\gamma}{f - tg\gamma}, \tag{12}$$

where $f = tg\psi$; ψ - conditional friction angle on the front surface of the tool.

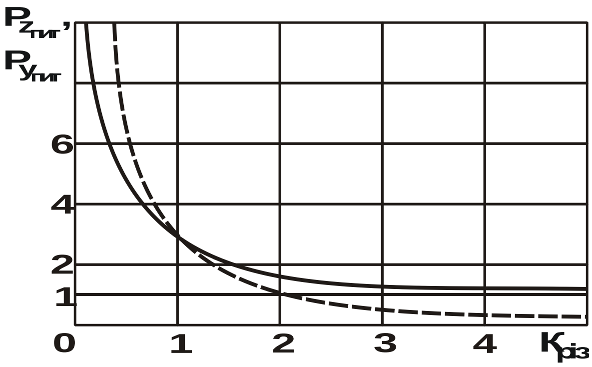

Fig. 3: Dependency $P_{z_{sp}}$ (the solid line) и $P_{y_{sp}}$ (the dotted line) rate cuts K_{cut}.

Graphically, the dependence (12) shows on the fig. 4. The coefficient cutting K_{cut} - plus, changes in limits from 0 up to 0.

Comparing dependence (5) and (12), the obtained dependence for calculation of the conditional shift material β:

$$\beta = 45° + \frac{\gamma - \psi}{2}. \tag{13}$$

Angel $\omega = \psi - \gamma$ is called the angle of the. So the options P_z, P_y and σ can be expressed also through the angle of the $\omega = \psi - \gamma$:

$$P_z = a \cdot в \cdot \sigma_{st} \cdot \left[tg(\psi - \gamma) + \sqrt{tg^2(\psi - \gamma) + 1} \right]; \tag{14}$$

$$P_y = a \cdot в \cdot \sigma_{st} \cdot tg(\psi - \gamma) \cdot \left[tg(\psi - \gamma) + \sqrt{tg^2(\psi - \gamma) + 1} \right]; \tag{15}$$

$$\sigma = \sigma_{st} \cdot \left[tg(\psi - \gamma) + \sqrt{tg^2(\psi - \gamma) + 1} \right]. \quad (16)$$

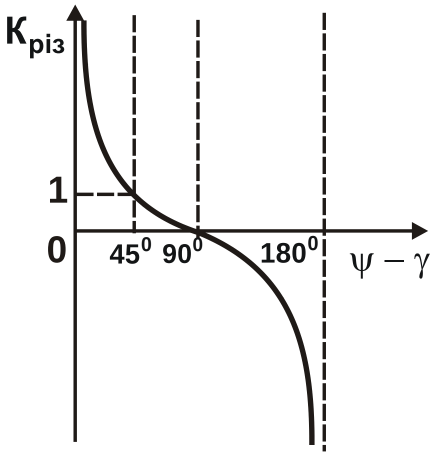

Fig. 4: Dependency K_{cut} from the angle $\psi - \gamma$

Obviously, edge processing is implemented, provided $\omega = \psi - \gamma < 45^0$, and abrasive treatment on condition $\omega = \psi - \gamma > 45^0$ (given the negative values of angle γ – condition $\omega = \psi + \gamma > 45^0$).

From dependence (5) and fig. 4 it follows that the condition $K_{cut} \to \infty$ (or $\sigma \to \sigma_{st}$) performed at an angle of actions $\omega = \psi - \gamma \to 0$ (or condition $f = tg\gamma$).

Most simply, this condition is realized when processing the diamond tool, because diamond has the lowest coefficient of friction f with the processed material. This explains the possibility of a significant reduction of forces in diamond turning, which takes place in practice.

In dependencies (14) – (16) the angle of the $\omega = \psi - \gamma$ you must look at the positive. Obviously, with the increase in the angle-action $\omega = \psi - \gamma$ parameters P_y, P_z and σ increase. For them reduce it is necessary the positive angle of the tool γ increase, and the friction angle ψ (coefficient of friction f) reduce.

At values $tg(\psi - \gamma) > 1$ radial component cutting force P_y more tangential component cutting force P_z. This is possible when the angle of action $(\psi - \gamma) > 45°$, sowith a relatively large contingent angle of friction $\psi > 45°$ and small value $\gamma \approx 0$, or negative values of the front angle γ, then the angle actions $\omega = \psi - \gamma$ will be obviously more $45°$.

The last case is implemented, for example, when cutting with abrasive and diamond grains grinding wheel [4]. The more the degree of dulling of grains, the more negative the front angle γ and the higher the ratio P_z / P_y. This is consistent with the practice of cutting. It is established experimentally that when the blade processing is executed, as a rule, condition $P_z > P_y$, so $tg(\psi + \gamma) > 1$.

At the initial moment of treatment (at the moment of cutting blade tool in the processed material), when almost no friction generated chip with the front surface of the tool($\psi \approx 0$), tangential component cutting force P_z more, than at the steady state cutting process, when there is friction chip with the front surface of the tool and $\psi > 0$. This is because in the first case, when $10° < \gamma < 40°$ values $tg(\psi - \gamma)$ more, than in the second case, at $10° < \psi < 40°$ – $tg(\psi - \gamma) \to 0$ .The lowest value P_z is reached at $\psi = \gamma$.

Increase P_z at the moment of cutting tool in the material can be one of the factors determining the low efficiency of the instrument for discontinuous cutting. The presence of forces P_y at the steady state cutting process allows essentially to reduce P_z and improve the efficiency of the instrument.

Negative values of the front corner of the instrument γ (and zero) tangential component cutting force P_z at the moment of cutting is less, than at a steady process of cutting. Consequently, the use of instruments with a negative front corners of the fundamentally changes regularities tensions process, excludes increase P_z at the moment of cutting. According to (14) - (16) with relation (5) and trigonometric transforms simplified and take the form:

$$P_y = \frac{a \cdot в \cdot \sigma_{st}}{tg\,2\beta \cdot tg\beta}; \quad P_z = \frac{a \cdot в \cdot \sigma_{st}}{tg\beta}; \quad \sigma = \frac{\sigma_{st}}{tg\beta}. \qquad (17)$$

As you can see, the options P_y, P_z, σ quite clearly depend on conditional shift material β. The more β, the less P_y, P_z, σ and effectively cutting process.

At grinding (K_{cut} < 1), looking forward corner cutting grain circle γ negative [5], dependency (14) – (16) can be simplified

$$P_z = \frac{2 \cdot a \cdot в \cdot \sigma_{st}}{K_{cut}}; \quad P_y = \frac{2 \cdot a \cdot в \cdot \sigma_{st}}{K_{cut}^2}; \quad \sigma = \frac{2 \cdot \sigma_{st}}{K_{cut}} = 2 \cdot \sigma_{st} \cdot tg(\psi + \gamma). \qquad (18)$$

on condition $(\psi + \gamma) \to 90^0$ rightly $\sigma \to \infty$. In this case the cutting process (chip disposal) is not implemented, only the elastic-plastic deformation of the material without the chip formation. Therefore, the process of cutting edge cutting and abrasive tools may be made, provided $\omega = \psi + \gamma < 90^0$. Using this condition, you can scientifically grounded approach to the selection of optimum processing conditions, including processing methods, mode settings cutting tool characteristics, etc. Thus, in the solution of important topical the problem of determination of parameters of power tension cutting process, and the conditions of decrease in relation to edge cutting machining and grinding.

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