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STUY REGARDING THEORETICAL ASSIGNING THE MACHINING FORCES BASING ON THE THEORY OF PLASTICITY

Ştefan MIHĂILĂ[1], Ioan PANTEA[1], Radu MĂRIEŞ[1], Maria MADA[2],

University of Oradea[1] "Ioan Ciordaş" Technical College Beiuş[2]
E-mail: mihailasna@yahoo.com

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Abstract:

The process of machining can be explained on the basis of the chosen model of the material and the processes of creating the chip taking into consideration the plasticity of the machined material. The method of creating the chip which is presented in this paper defines the actual process of material machining allowing to calculate the forces in the timing process.

1. STRESSESON THE PLANE OF SHEAR

Generally speaking, it may be stated that according to the theory of plasticity machining may take place only then, when the force affecting the material reaches the value at which (in given conditions and temperature) the cutting stress τ_φ on the path of shear will be achieved that will equal the shearing stress at the compression or tension withstand test of the material and correspond with achieving the Re yield point..

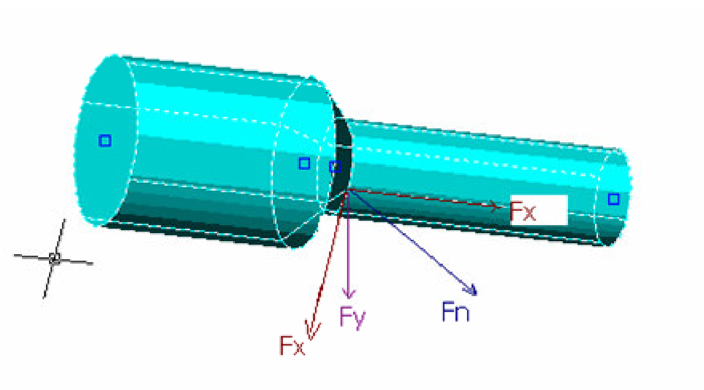

Fig. 1 The taken geometrical model

$$\tau = \frac{(\sigma_1 - \sigma_2)}{2}\sin 2\varphi \tag{1}$$

$$\tau_\varphi=\sigma_1 \cos^2 \varphi+\sigma_2 \sin^2\varphi \tag{2}$$

It is also known that, in the examined model, the cutting stresses on the phat of shear take the maximum vaule, that the angle between the main normal stresses and the cuting stressb is 45^0 which clearly defines the directions of the axes of the main stresses in the chip Figure 2 and the cuttingss τ_φ is defined by the dependence[5]:

$$\tau_{\phi_{max}} = \frac{(\sigma_1 - \sigma_2)}{2} \quad (3)$$

Therefore, for the given machining conditions, after the shearing stress of the path of shear reaches the value τ_φ =0,5 Re, basing on the model of creating the chip with one plane of shear, a continuous process of deformation and strengthening the material will begin, which may căuşe a rise of the stress tangent to the critical value $\tau_{\varphi kr}$ =0.5 Rm.

Irrespective of the physical-mechanical propertres of the machined material and the value of the machined material and the value of the machining velocity V_2 , V_x , V_Y the thickness of the machined layer g and tool rake angle y_n , the shearing stresses along the proof plane of shear BD may change from the value which is equal to the half of the yield point to the $\tau_{\varphi kr}$= 0,5 Rm value, whilst normal stress may take different values.

Normal stresses σ_φ on the plane of shear depend on the tool rake angle y_n and the friction factor μ of the chip on the friction surface, and they may change their value along the proof friction stress from negative to positive Figure 5.

The directions and values of the main stresses mav be defined with the use of the known vaule of the chip s dshearing stress in the plane of shear and the equeation of the theory of plasticity (1)n ,(2) for the flat state of stresses treated as superposition of the sttresses along perpendicular directions Figure 2

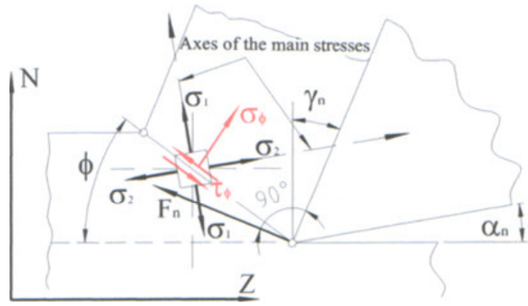

Fig. 2. The stress pattern of the chip on the plane of shear

2. THE MODEL OF THE MACHINING OF THE CHIP

In the taken model of machining the material which thickness equals *h* - Figure3, in the normal plane there was assumed a relocation of the material with respect to the knife from the point *A* to *B* on the Δl distance under the influence of the working of the *F* force later called the force of creating the chip. This force causes the corner point *A* of the machined layer lying at the beginning of the fillet (the machining plane) relocate along the slip line over the Δp value up to the *C* point lying on the stress plane of the tool.

The same picture of shear strain may be observed on the outer surface of the machined material which *E* point is relocated to the *F* point of the free chip surface. At further relocation of the tool over the next Δl value the above presented process repeats and it is treated as constant relocations of the thin surfaces of the material on the proof plane of shear without any disarrangement of the connectivity of the relocated chip layers. The Δp distance is called the absolute slip.

In order to answer the questions of what causes the relocation of the machined layer along the proof plane of shear and when this relocation starts, it is necessary to consider the forces working upon the machined layer from the side of the rake plane of the tool Figure 3.

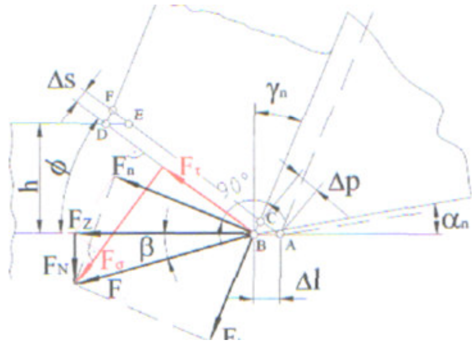

Fig.3. The model of the forces pttern in the machining zone for the model of Creating a chip with one plane of shear.

The tool works upon the machined layer with a normal force to the F_n stress plane; this force causes the stress force $F_n = \mu F_n$ (where *p.* is the friction factor between the chip and the tool, which takes the values of the (0 to 0.5) range depending on the contact conditions).

The sum of the forces F_n and F_t gives a force called the *F* force of creating the chip, inclined to the machining layer with the β operating angle. The cut layer of the Δs thickness is compressed with the $F\sigma$ force and cut with the F_τ.force. Therefore, the force of creating the chip may be divided into the F_σ force which is perpendicular to the proof plane of shear and the component $F\tau$ working along that plane.

Moreover, the force of creating the chip may be divided into two component machining forces in the adopted frame of reference F_z and F_N.

In the case of orthogonal machining, the cutting force on the proof path of shear equals:

$$F\tau = \tau \cdot b \frac{h}{\sin \varphi} \tag{4}$$

where:

h - the thickness of the machined layer in normal intersection,

$$h = f \,.\, sin\, \chi \tag{5}$$

b - the width of the machined layer:

$$b = \frac{g}{\sin X} \tag{6}$$

g-the machining depth

f- the rate of feed

X- the main angle of attaching the tool

The total force of the creating the chip equals:

$$F = \frac{\tau_\varphi \cdot h \cdot b}{\cos(\beta+\varphi) \cdot \sin \varphi} \tag{7}$$

The value of the angle of the chip's slide may be determined using the criterion of the system s minimal energy.

$$\frac{\partial F}{\partial \phi} = \tau \cdot b \cdot h = \frac{\cos(2\varphi+\beta)}{\cos^2(\beta+\varphi) \cdot \sin^2 \varphi} = 0 \tag{8}$$

The equation numer 8 is staisfied when the chip s solide angle equals:

$$\varphi = \frac{\pi}{4} . \frac{\beta}{2} \tag{9}$$

In order to reduce the number of the unknowns and determine the φ angle in the function of the chip's coefficient of friction over the tool's stress layer and the rake angle y_n, according to the -Figures it may be written:

$$\varphi = \frac{\pi}{4} . \frac{arctg \mu . \gamma n}{2} \tag{10}$$

Where: μ - the chip's coefficient of friction over the tool's stress layer may take the values from $\mu=0$ up to μ=0.5, depending on the kind of the cutting fluid, the rake angle and the layer's condition. Moreover, it follows from the –Figures 3 that:

$$F_z = cos\,\varphi - F_N . sin\,\phi \tag{11}$$

$$F_Z = \frac{\tau_{\varphi.n.b}}{cos(\beta + \varphi). sin\,\varphi} . cos\,\beta \tag{12}$$

$$F_Z = \frac{\tau_{\varphi.n.b}}{cos(\beta + \varphi). sin\,\varphi} . sin\,\beta \tag{13}$$

After taking into account the main angle of attaching the x cutting layer, the components of the cutting forces equal:

$$F_Z = \frac{\tau_{\varphi.n.b}}{cos(\beta + \varphi). sin\,\varphi} . sin\,\beta . sin\,\chi \tag{14}$$

$$F_Z = \frac{\tau_{\varphi.n.b}}{cos(\beta + \varphi). sin\,\varphi} . sin\,\beta . cos\,\chi \tag{15}$$

So forth received dependencies (12), (13), (14) and (15) allow for clear defining of the forces being the components of the cutting force.

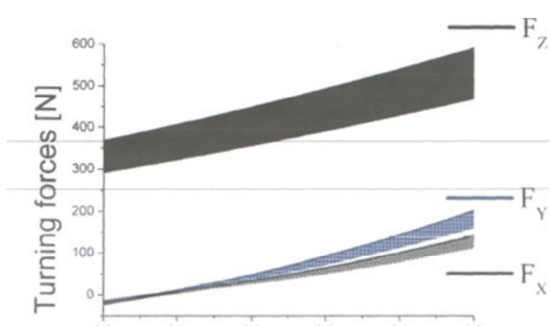

Fig. 4. The change of the machining forces for the 40H steel in the function of the change of the coefficient of fiction ju and the changeable value of the shearing stress τ_{φ}.

For the purpose of better presentation of those dependencies hypothetical calculations for the material 40H steel of the parameters Rm=980MPa, Re=780Mpa were used. And for those the values of the cutting forces in the process of turning with the angle of attaching the main cutting edge $\kappa = 35°$, the machining depth g=2mm and the rate of feed f=0.2mm/turn were calulated. Allthe forcesweredetermined of friction μ and the changeable value of the aherearing stress.

$$\tau_{\varphi} = \frac{Re}{2} \rightarrow \frac{Rm}{2}$$

As it can be seen on the graph, when the coefficient of friction μ is small enough and the rake angle y_n is small even the opposite turn of the normal force to the machined layer is possible, which agrees with the statement that the normal stresses in the chip may be both positive and negative .

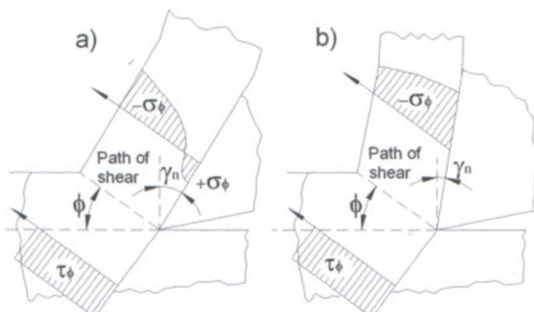

Fig. 5. The change of the stress value in the chip in depending on the tool rake angle y_n. a)big rake angle b) small rake angle.

3. CONCLUSIONS

According to the theory of plasticity the value of shearing stress during the chip deformation process may change from minimum value, which corresponds to the yield point, up to a maximum value, which represents the Rm-tensilestrengh of the given material.

Theerefore, it is allowed to assume that for the machining process, in which a totally discontinuous chip is prduced, the shearing sress on the path of shear achieves $\tau_{\varphi kr}$ =0.5 Rm the maximum value.

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