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Паладійчук Ю.Б.
к.тех. наук, доцент
Вінницький національний аграрний університет, вул.. Сонячна, 3, Вінниця
ORCID: http://orcid.org/0000-0003-4257-9383
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ДОСЛІДЖЕННЯ ХАРАКТЕРИСТИКИ НАРОСТОУТВОРЕННЯ ПІСЛЯ ДЕФОРМАЦІЙНОГО ЗМІЦНЕННЯ ПРИ ДЕФОРМУЮЧОМУ ПРОТЯГУВАННІ

Paladiychuk Yu.B.
PhD, Associate Professor/
Vinnitsia National Agrarian University, Soniachna str., 3, Vinnytsia, 21008
ORCID: http://orcid.org/0000-0003-4257-9383

STUDY OF CHARACTERISTICS OF GROWTH FORMATION AFTER DEFORMATION STRENGTH DURING DEFORMING STRENGTH

Анотація.

Попереднє холодне деформаційне зміцнення суттєво знижує роботу деформації при обробці пластичних матеріалів різанням. Це дозволяє зменшити коефіцієнт усадки стружки, сил і температури різання, поліпшення напружено-деформованого стану стружко утворення, покращення оброблюваності металевих матеріалів, здатних зміцнюватись холодною деформацією, набуття виробами високих фізико-механічних та службових властивостей. Формування тіла наросту відбувається на початковій ділянці протягування з певного об'єму оброблюваного матеріалу, який переходить під дією деформацій зсуву і стиску в пластичний стан і практично закінчується після повного включення зубця протяжки в роботу. Довжину цієї ділянки можна визначити за характерним збільшенням товщини стружки на початку її валика. У контактному шарі стружки і поверхневому шарі деталі, які межують з наростом, відбуваються глибокі пластичні деформації, про що свідчить текстура і зростання мікротвердості.

Abstract.

Precold deformation hardening significantly reduces the work of deformation during processing of plastic materials by cutting. This allows to reduce the coefficient of shrinkage of chips, cutting forces and temperatures, improving the stress-strain state of chip formation, improving the machinability of metallic materials that can be strengthened by cold deformation, the acquisition of high physical and mechanical and service properties. The formation of the body of the growth occurs at the initial site of drawing from a certain volume of the processed material, which passes under the action of shear and compression deformations into a plastic state and almost ends after the full inclusion of the broach tooth in the work. The length of this section can be determined by the characteristic increase in the thickness of the chips at the beginning of its roller. Deep plastic deformations occur in the contact layer of chips and the surface layer of the part adjacent to the growth, as evidenced by the texture and growth of microhardness.

Ключові слова: *деформуюче протягування, пластичне деформування, стружкоутворення, наростоутворення, дільниця пластичного контакту.*
Keywords: *deforming drawing, plastic deformation, chip formation, growth formation, plastic contact section*

Introduction. The emergence of new structural, difficult to process materials poses new challenges for solving practical problems of machining them.

The cutting process is significantly affected by the cold deformation hardening of the material of the part by various methods, which precedes machining.

Cutting with preliminary plastic deformation provides improvement of chip formation conditions by rational change of physical and mechanical properties of the material of the cutting layer due to its strengthening before the cutting process.

One of the features of cutting drawing as a low-speed, and hence low-temperature (Θ = 120°…250°C) process is the obligatory growth. According to modern ideas, during the entire cycle of drawing the body of the growth has a stable shape and volume, undergoes only elastic deformations and is actually an additional cutting wedge with its own geometric parameters (γ, α, ρ, etc.), which differ significantly from geometric the parameters of the tool received at sharpening. Outgrowth is generated by the system "tool-detail" when adapting the latter to the specified cutting conditions. From the standpoint of our study, the growth should be considered as a phenomenon that significantly changes the stress-strain state of the chip formation zone and, as a result, affects the shrinkage (thickness) of chips, Pz force, chip roller diameter and allowable degree of chip groove filling. From a number of quantitative characteristics of the growth body in order to assess the contact phenomena on the anterior surface, the relationship between the radius of curvature $\rho_н$ and the length of the sole Cn with the length of the section of plastic contact C1 should be taken into account.

An important regularity of the chip formation process in the conditions of growth is that within the latter the tangential stresses are determined by the condition of plasticity, not the law of external friction, ie the intensity of tangential stresses is equal to the yield strength of the material [3, 8]. At the same time, outside the body of the growth, ie in the area of AbstractAbstractelastic contact of the chips with the front surface of the tool, the tangential stresses change according to the law of external friction. For the contact pressure, obviously, and in the case of cutting stretching will be fair patterns obtained by prof. Poletikoy M. [4].

Main text. In the machining of plastic materials, the separation of the material of the cut layer from the workpiece is preceded by its plastic deformation, when the main part of the cutting work is spent on plastic deformation of the removal metal [5].

The model of such a process for conditions when low cutting speeds and other factors contribute to intensive growth, high contact stresses and low temperatures, which is characteristic of cutting drawing, should be presented as follows (fig. 1, a). Prior to meeting the chip groove 1, the cutting process is stationary and proceeds with the formation on the front surface of the tool 2 of a stable body of growth 3, which is formed from the material 4 of the part, and is actually part of the cutting wedge with a real front angle $\gamma_н$. The shear zone 5, where the processed material is mainly in the plastic state, is inclined to the direction of the cutting speed V at an angle of shear Fzs and since the admissibility of replacing the bulk shear zone by one plane is proved in cutting conditions deformation, we apply this assumption to our model [6]. For contact phenomena on the front surface, the most suitable and convenient for calculations is the scheme of stress-strain state, proposed by prof. Poletikoy M.F. [4]. This means that the additional hardening of the chip material in this section can be neglected due to a small increase in hardening at the values AbstractAbstractof shear deformation exceeding the value of $\varepsilon \geq 5\ldots 10$. With such deformations, the chip material is already in a state close to the hardening limit. In the force diagram shown in fig. 3.1, a, presents only the forces acting on the front surface of the tool: Rc, RZn, RYn - respectively, the force of chip formation and its components, the value of which determines the angle of action; N, F - respectively normal force and friction force, the value of which determines the angle of friction η; Rzs - tangential force in the shear plane inclined to the direction of the cutting speed at an angle of shear Fzs; qn, τFn - respectively contact pressure and tangential stresses on the front surface. The chip shrinkage coefficient ξ for the cutting scheme under analysis is determined by the ratio of the chip thickness Z to the slice thickness Sz.

The shear angle Fzs and the action ω, as well as the actual angle $\gamma_н$ in combination with the tangential stresses τ_c in the shear zone (chip formation) determine the force of chip formation, which can be calculated or determined experimentally. In the first case (see fig. 1, a):

$$R_C = \frac{\tau_C S_Z a}{\cos(\Phi_{3C} + \omega)\sin \Phi_{3C}}, \quad (1)$$

where: a - is the width of the cut.

Thus, according to researches of prof. Rosenberg O.M. [7]:

$$\tau_c = 0.185\ HV. \quad (2)$$

The tangential force in the shear plane Rzs, in turn, can be calculated depending on:

$$Rzs = \tau_c\, \xi\, S_z\, a, \quad (3)$$

or determined on the basis of an experimental study of cutting forces:

$$Pzs = \frac{P_{Z_n} \cos(Fzs + \omega)}{\cos\omega}, \quad (4)$$

and taking into account the known dependence of Ph.D. Vinogradova O.O [2]:

$$\omega + Fzs = 43^0 \ldots 46^0 \approx \pi/4 \quad (5)$$

we get:

$$Pzs = \frac{0{,}7 P_{Z_n}}{\cos\omega}, \quad (6)$$

From fig.1, and it is seen that the angle of action can be determined experimentally from the dependence:

$$\omega = arctg \frac{P_{y_z}}{P_{Z_n}}, \quad (7)$$

and the shear angle, taking into account expression (3.6):

$$Fs = \frac{\pi}{4} - arctg \frac{P_{y_z}}{P_{Z_n}}, \quad (8)$$

Thus, having used and having applied to our conditions the known dependence of prof. Abuladze N.G. [1], we obtain the ratio between the angles Fzs, ω, η, $\gamma_н$:

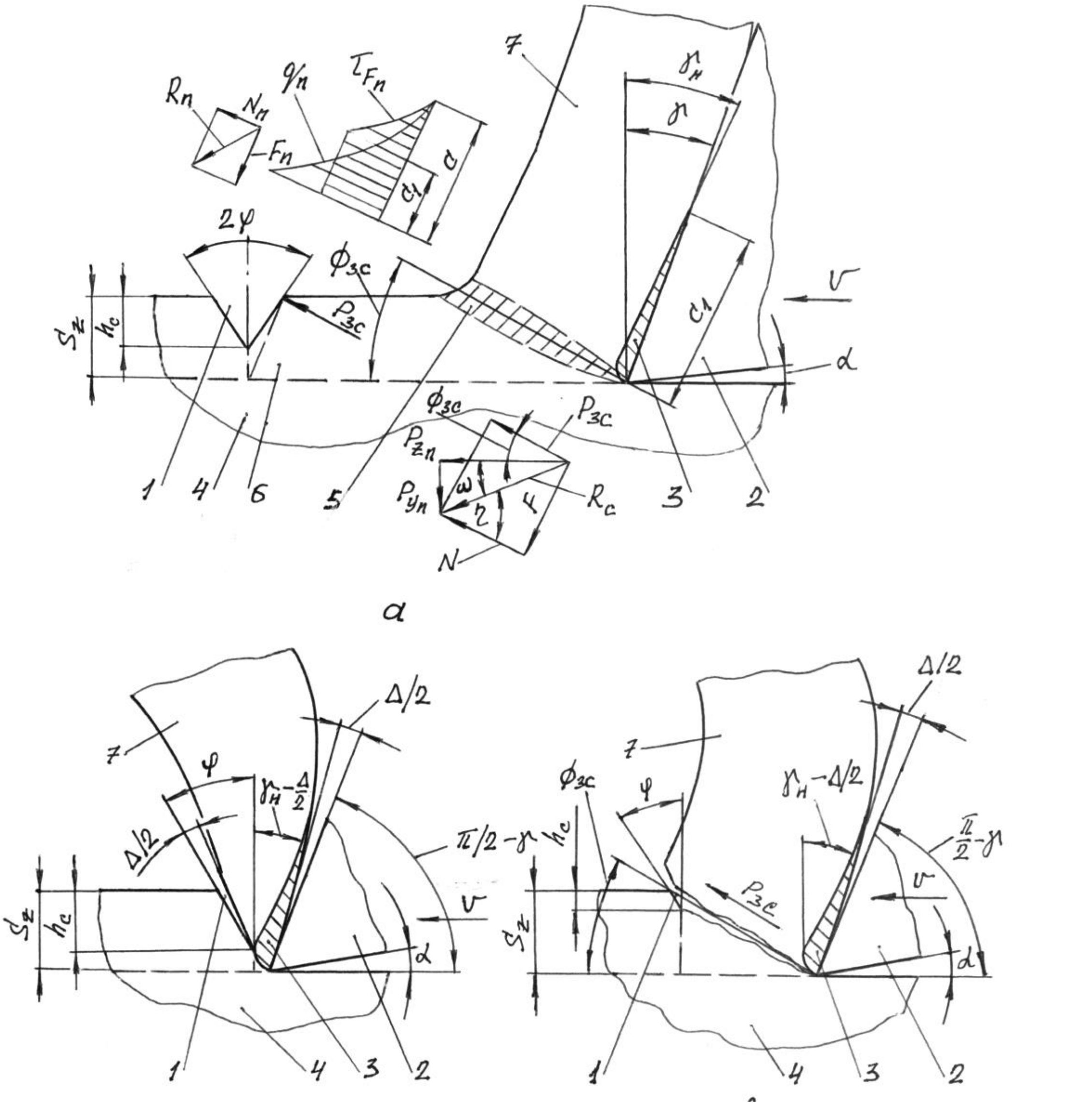
$$tgFzs = \frac{1 + tg\frac{\gamma_H}{2} - 1{,}8\cos\gamma_H tg(\omega + \gamma_H)}{1 - tg\frac{\gamma_H}{2} + 1{,}8\sin\gamma_H tg(\omega + \gamma_H)}, \quad (9)$$

where: η is the angle of friction

$$\eta = \omega + \gamma_н \quad (10)$$

The peculiarity of this calculation is the fact that for our conditions it is most difficult to determine the actual front angle, which is much larger than the front angle.

The study of the outer side of the drain chips on the "roots" of the chips shows that the surface of the chips in this part is characterized by the presence of "teeth", the height of which does not exceed 3%… 5% of the chip thickness. This phenomenon indicates the presence of micro-shifts between the individual elements of the chips, which, however, do not cause its destruction. However, in cases where the height of



b v

Fig. 1. Model of mechanics of chip breaking process by means of chip-splitting groove formed on workpiece allowance, at free orthogonal cutting at low speeds at cut thicknesses exceeding groove depth (Sz$\geq$hc): a - the process of stationary cutting, when the boundary of the chip formation zone has not yet reached the groove; b - the process of chip destruction for the case when Sz$\leq$hc; v - the process of destruction of chips, when Sz>>hc. 1 - chip-splitting groove; 2- cutting wedge; 3- body growth; 4- processed material; 5- shear zone (chip formation); 6- allowance; 7- shavings.

the "tooth" exceeds 10… 15% of the thickness of the chips, the process of transition from drain chips to chipping chips begins due to the concentration of shear deformation between the individual elements of the chips. In other words, there is a destruction of chips with a marked decrease in shear resistance τs. This phenomenon corresponds to the moment of meeting of the landslide zone with the chip-splitting groove.

When approaching the tool to the chip-splitting groove, two cases of change of the stress-strain state of the chip-forming zone and the cutting process as a whole are possible. In the first case, when $h_c \cong S_z$, ie when the depth of the groove is equal to or insignificantly less than the thickness of the cut (fig. 1, b), the cutting process is interrupted for a short time and all the phenomena that accompanied it disappear (shear zone, growth body , contact processes on the front surface, etc.). As for the body of the growth, according to research [4], it (this body) remains on the chips after the completion of the process of stretching without reducing the volume. The formation of the chip roller is completed and it (this roller) moves along the surface of the workpiece in the direction of movement of the tool tooth. The cutting forces instantly fall to zero, which is fixed by a dynamometer. In this case, it is important to withstand the following condition:

$$\varphi = \gamma_н + \Delta, \quad (3.12)$$

where: $\gamma_н$ - the front corner of the tool without growth; Δ - the angle that prevents the contact of the side walls of the groove when the chips are destroyed.

The essence of cutting with preliminary plastic deformation of the material of the cut layer consists in combining two processes - advanced plastic deformation (mandrel) and directly the cutting process (cutter, broach) [9]. Preliminary plastic deformation can be performed on the cutting surface or on the machining surface. Cutting with pre-plastic deformation together with a significant increase in the stability of the cutting tool can improve the performance of machining parts. In this case, the surface layer of the machining part acquires increased hardness, there are residual compressive stresses. Increase of stability and improvement of roughness of a surface - receive at drawing when before cutting teeth smoothing elements which carry out preliminary plastic deformation on a processing surface are established.

The cutting process is accompanied by friction of the processing material in the front and rear surfaces of the cutting part of the tool, which leads to the growth.

The growth body has a stable shape and volume, undergoes only elastic deformations and is actually an additional cutting wedge with its own geometric parameters, which are significantly different from the geometric parameters of the tool obtained during sharpening. Outgrowth is generated by the system "tool-detail" when adapting the latter to the specified cutting conditions. From the standpoint of our study, the growth should be considered as a phenomenon that significantly changes the stress-strain state of the chip formation zone and, as a result, affects the shrinkage (thickness) of the chips, the cutting force, the diameter of the chip roller.

The process of free orthogonal cutting of materials occurs under the conditions of counteraction of deformation hardening factors and shear thickness on the intensity of growth, so the effect of growth on the components of the stress-strain state of the chip formation zone is stable and constant throughout the stationary part of the cutting path. This is confirmed by photomicrographs of the chip formation zone, which are presented in fig. 2 and 3.

The process of cutting steel 35 in the state of delivery (fig. 2) is characterized by intense growth. The body of the growth consists of strongly deformed ferrite grains, along the contour of which you can trace the direction of deformation and determine the actual radius of curvature of the cutting wedge. The light sections of the deformation trajectory of ferrite grains are delimited by darker sections of deformed perlite. For the case under analysis, the outgrowth has the following main characteristics: rounding radius $\rho_н$ = 0,04 mm; height hn = 0.08 mm; front angle $\gamma_н$ = 26°; the length of the sole Ch = 0.22 mm with the length of the plastic contact C1 = 0.2 mm. The obtained quantitative characteristics of the growth body were subsequently used to assess the contact phenomena on the front surface of the tool.

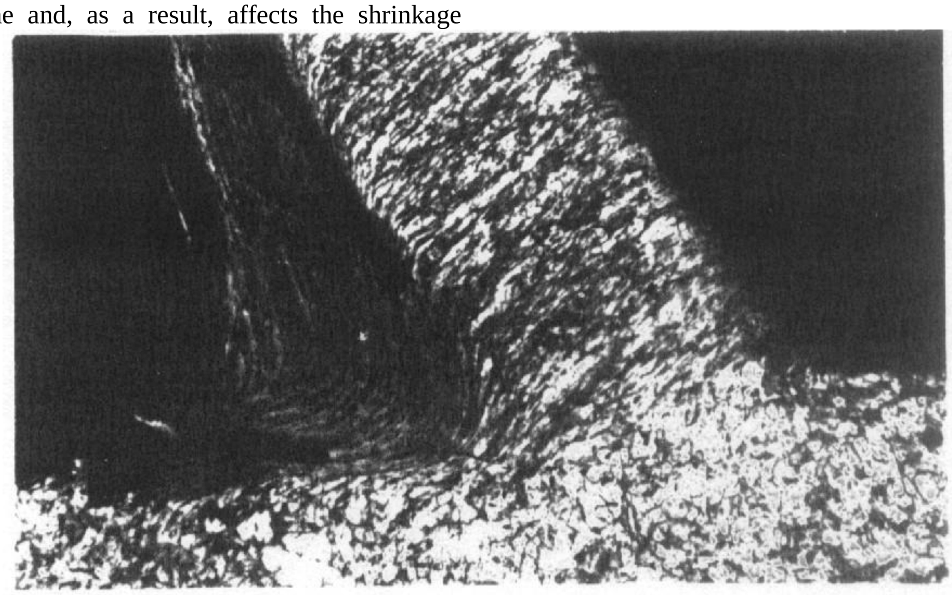


Fig. 2. Photomicrograph of the chip formation zone (X400) with free orthogonal cutting of steel 35 in the state of delivery (HV = 1600 MPa) at the actual cut width ai = 6.3 mm (a = 0... 12 mm): V = 0.13 m / s ; Sz = 0.05 mm; PI - steel P6M5, γ = 15°, α=20, λ =00, ρ = 7 mcm; medium - sulfofresol-R.

Studies have shown that the effect of deformation hardening by deforming drawing on the process of chip formation is significant and consists, first of all, in reducing the intensity of growth. This is confirmed by the figure. 3 is a photomicrograph of the chip formation zone obtained by free orthogonal cutting of steel 35 after strain hardening. When cutting hardened steel 35 outgrowth has the following characteristics: $\rho_н$ = 0.03 mm; hn = 0.06 mm; $\gamma_н$ = 34°; $C_н$ = 0.17 mm; C_1 = 0.15 mm.

The stress-strain state of the chip formation zone for the group of machined materials during cutting drawing in the conditions of variable allowance is characterized by a small difference between the maximum and minimum values AbstractAbstractof tangential stresses (within 15%… 30%), shear angles Φ = 25°… 35° and chip shrinkage coefficients. in length and thickness ξ = 2.2… 3.2 with a slight increase in its width (up to 2%), and the zone itself is narrowed to a size that allows without significant errors to approximate its plane.

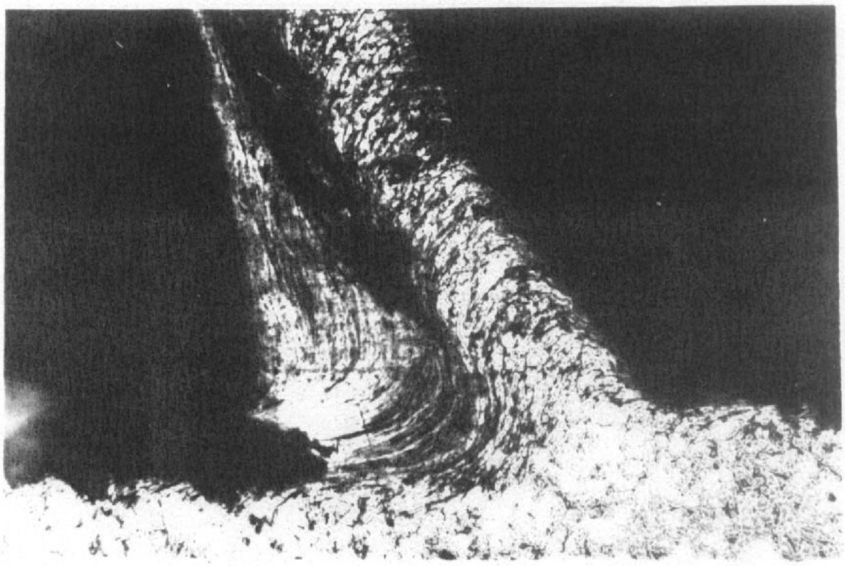


Fig. 3. Micrograph of the chip formation zone (X400) with free orthogonal cutting of steel 35 after HPD (HV = 2100 MPa) at the actual cut width ai = 6.7 mm (a = 0… 12 mm): V = 0.13 m / s; Sz = 0.05 mm; PI - steel P6M5, γ = 15°, α=20, λ = 00, ρ = 7mcm; medium - sulfofresol-R.

The study of contact characteristics on the front surface of the tool showed the following. In the case of cutting the studied steels in the state of delivery (fig. 2), the total contact length significantly exceeds the same characteristic for hardened steels (fig. 3). This also applies to the length of the plastic contact. So, for steel 35 the specified characteristics at drawing with identical modes for both cases are accordingly equal: C = 0,45 mm and 0,32 mm; C1 = 0.2 mm and 0.15 mm. The laws of distribution of tangential stresses along the contact of the chips with the front surface are similar for hardened and non-hardened steel. At the site of plastic contact, their value is constant, as determined by the plasticity of the processing material.

In fig. 4 shows the contact characteristics on the front surface of the tool with free orthogonal cutting of steel 35 in the state of delivery and after deformation hardening. The tangential stresses for steel after strain hardening are higher in this section. In the conditions of elastic contact, where there is no growth, the tangential stresses are gradually reduced along the entire length of the contact up to the separation of the chips from the front surface of the tool. The law of change of the coefficient of friction along the contact is determined by the combined influence of tangential stresses and contact pressure. Starting from the sections directly adjacent to the cutting edge of the tool, this coefficient increases and at the boundary of plastic and elastic contact increases by 2… 2.5 times. Further, the achieved values AbstractAbstractremain virtually unchanged.

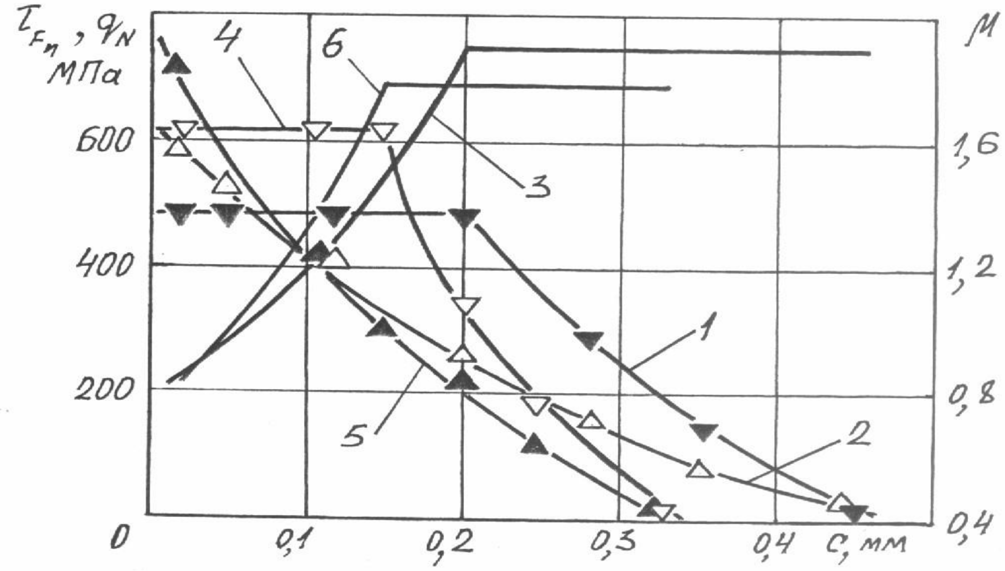


Fig. 4. Contact characteristics on the front surface of the tool with free orthogonal cutting of steel 35 (1, 2, 3 - HV = 1600 MPa; 4, 5, 6 - HV = 2100 MPa): qN - contact pressure (2, 5); τFn - tangential stresses (1, 4); μ - coefficient of friction (3.6); ai = 6.3 mm (1, 2, 3); 6.7 mm (4, 5, 6); V = 0.13 m / s; Sz = 0.05 mm; PI - steel P6M5, γ = 15°, α=20, λ =00, ρ = 7 mcm.

An important regularity of the chip formation process in the conditions of growth growth is that within the plastic contact section the tangential stresses are determined by the condition of plasticity, not by the law of external friction, ie the intensity of tangential stresses is equal to the yield strength of the part [2].

Conclusion. Studies have shown that the effect of deformation hardening by deforming drawing on the process of chip formation is significant and is to reduce the intensity of growth. The body of the growth consists of strongly deformed ferrite grains, along the contour of which you can trace the direction of deformation and determine the actual radius of curvature of the cutting wedge. The light sections of the deformation trajectory of ferrite grains are delimited by darker sections of deformed perlite.

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