calculated tolerance T_{Ai} in the table of tolerances corresponds to the eleventh (11) or lager grade of tolerance the task can be solved.

If calculated tolerance T_{Ai} corresponds to the ninth (9) or more exact grade of tolerance it is necessary to change locating (technological datum) without attempts to solve a dimensional circuit since in a workpiece machining the probability of deriving of reject (invalid part) is great.

REFERENCES

1. Скворцов В.Ф. Основы размерного анализа технологических процессов изготовления деталей: учебное пособие. 2-е издание. Томск: Издательство Томского политехнического университета, 2009. -90 с.
2. Косилова А.Г., Мещеряков Р.К Справочник технолога-машиностроителя Том 1. - Москва «Машиностроение», 2003. – 943 с.

CONTACT LOADS ON SURFACES OF WORN OUT CUTTER IN STEEL MACHINING

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For calculation of a cutting tool strength, it is necessary to know not only component forces of cutting, but also distribution of contact loads on rake and flank surfaces [1-5]. This task is especially important for rough cutting by the worn out cutting tool. Wear on a flank surface leads to appearance of a chamfer on a flank surface (flank-land) and the big contact loads leading to a tool failure.

The method of a “section tool” is used for research of contact stresses distribution [1-5]. It is very labour-consuming and demands the use of rigid, special four-component dynamometer. Therefore research was carried out for defining the parametres of contact loads distribution which can be used for loading of cutting tool for calculation of cutting tool strength.

Research of force dependences was executed in turning a workpiece made from a steel 40X with hardness HB 220 and ultimate tensile stress

σ_{UTS}=1000 MPa by a cutter with a cutting plate made from cemented carbide T15K6. The principal edge angle in the plan φ=45 °, the end cutting-edge angle φ_1=45 °, the side-rake angle γ = +5 °, the side-relief angle α = 12 °, the angle of the principal cutting edge inclination λ=0 °, artificial chamfer length h_f was varied from zero to 0.95 mm with a constant clearance angle α_h=0 °.

For elimination of a variance in the depth of cut t after each cutting the real (actual) depth of cut t_{act} (mm) was calculated. Actual specific force of cutting was calculated for tangential component P_z:

$$q_{Pz\ act} = P_{z\ act} / (s \cdot t_{act})\ \text{(MPa)}. \qquad (1)$$

Then the more precisely defined cutting force $P_{z\ pr}$ was calculated for adjusted depth of cut t_{adj}:

$$P_{z\ pr} = q_{Pz\ act} \cdot t_{adj} \cdot s\ \text{(N)}. \qquad (2)$$

This precisely determined force $P_{z\ pr}$ was used for construction of graphs of cutting force dependence from the feed rate s, the depth of cut t and the length of a chamfer on a flank surface h_f.

For research of influence of feed rate s on a specific tangential component of cutting force $q_{Pz\ act}$ (MPa) corresponding graphs have been constructed (Fig. 1). Similar equations were used for calculation of more precisely determined components $P_{x\ pr}$ and $P_{y\ pr}$.

In our research the precisely determined resultant force of cutting force components, acting in horizontal plain XOY, P_{xy} was also calculated:

$$P_{xy\ pr} = (P^2_{x\ pr} + P^2_{y\ pr})^{½}. \qquad (3)$$

Using this equation (3) the specific cutting force $q_{Pxy\ pr}$ was calculated:

$$q_{Pxy\ pr} = P_{xy\ pr} / (s \cdot t_{adj})\ \text{(MPa)} \qquad (4)$$

Graph of this specific cutting force $q_{Pxy\ pr}$ dependence on feed rate s is presented in Fig. 1. Increasing feed rate s causes reducing the specific cutting forces q_{Pz} and q_{Pxy}.

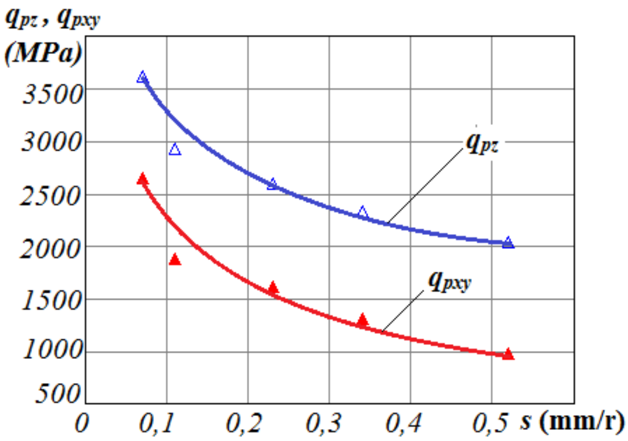

Fig. 1. Influence of feed rate s (mm/r) on specific cutting forces (MPa) in steel 40X machining. t = 2 mm; v = 2 m/s; hf = 0.29 mm

By results of graphs of cutting force components P_z and P_{xy}, the forces $P_{z\,r}$, $P_{xy\,r}$, acting on the rake surface of the cutter, have been selected by the method of extrapolation on a zero chamfer of a flank surface ($h_f \to 0$ mm). Using these components of cutting force $P_{z\,r}$ and $P_{xy\,r}$ the normal N and the tangential (shear) F forces on the rake surface were calculated with the account of the principal angle on the plan φ and the side-rake angle α.

These forces were used to create epures of normal σ and shear τ contact stresses on the rake surface of the cutting tool (Fig. 2) based on the law of contact stresses distribution, received by us [1, 3] and other scientists [2, 4, 5]. When constructing the drawing, the condition to be met is as follows :

$$N = \int_0^c \sigma_{xi} \cdot dx \ \ \text{(N)}, \qquad (5)$$

$$F = \int_0^c \tau_{xi} \cdot dx \ \ \text{(N)}, \qquad (6)$$

where σ_{xi} – is normal contact stress in a considered point i from a cutting edge on a rake surface of a cutting tool (MPa); τ_{xi} – shear contact stress in a considered point i from a cutting edge on a rake surface of a cutting tool (MPa); c – is length of contact of a chip with a rake surface of a cutting tool (mm).

By results of our experiments it was acknowledged that the greatest normal contact stress on the rake surface $\sigma_{max} \approx 1900…2300$ MPa, depending on feed rate s, that is approximately 2 times more than ultimate tensile strength of a steel 40X. The parametres σ_{max}, σ_{const}, τ_{max}, l_0 and l_1 of contact stresses on the rake surface of a cutter (Fig. 2) were calculated.

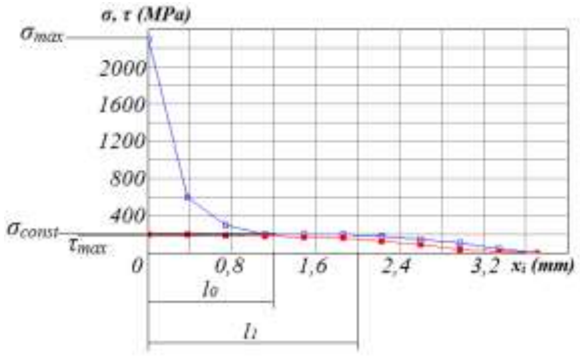

Fig. 2. Parametres of contact stresses epures on the rake surface of the cutter. Abscissa – is distance from a cutting edge along a rake surface x_i (mm). Ordinate – is contact stress on a rake surface (MPa)

On Fig. 3 experimental points are presented and graph, after their calculation by program MathCAD to rectilinear dependence is constructed.

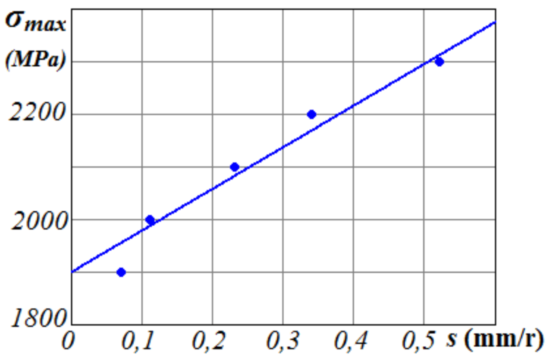

Fig. 3. Feed rate s (mm/r) influence on magnitude of the greatest normal contact stress at a cutting edge in steel 40X machining.

Shear contact stress τ on a rake surface in steel machining on the area with length $l_1 = c_1$ (mm) does not vary at moving far from the cutting edge, which confirms plastic character of a chip contact with a rake surface. Magnitude $\tau_{max} \approx 200$ MPa is equal to shear strength of this steel at a temperature nearby 700 °C that corresponds to knowledge about the processes occurring on a rake surface [1, 3, 4, 5].

In our opinion, equations experimentally determined for steel 40X are possible to use also for other brands of steel when the continuous chip is forming. A major factor which influence on contact stresses is ultimate tensile strength UTS (σ_{UTS}) (MPa).

Considering that in our experiments the steel with $\sigma_{UTS} = 1000$ (MPa) was being machined, we offer for calculation of epures' parametres on the rake surface of the cutting tool (see Fig. 3) to use following equations:

$$c \approx 10 \cdot a \text{ (mm)} \quad (7)$$

$$l_1 \approx 0.55\, c \text{ (mm)} \quad (8)$$

$$\sigma_{max} = 792 \cdot s + 1.9 \cdot \sigma_{UTS} \text{ (MPa)} \quad (9)$$

$$\sigma_{const} = -183 \cdot s + 0.289 \cdot \sigma_{UTS} \text{ (MPa)} \quad (10)$$

$$\tau_{max} \approx 0.2\, \sigma_{UTS} \text{ (MPa)} \quad (11)$$

Graphs of flank-land length h_f influence on cutting force components were used for construction of contact stresses epures on the flank-land. We believed that change of chamfer length slightly influences the forces acting on the rake surface [1-11], and epures do not depend on flank-land length h_f at α_h=0 ° [1, 3].

Normal specific contact load on the chamfer $q_{N\,h}$ (MPa) (or normal contact stress on the chamfer σ_h (MPa) when $\Delta h_f \rightarrow 0$ mm) was calculated as a ratio of an increment of normal force on a flank-land ΔN_h (N) to an increment of the area of the flank-land ($\Delta_{area} = \Delta h_f \cdot b$), i.e. $q_{Nh} = \Delta N_h / (\Delta h_f \cdot b)$, where Δh_f – is an increment of length of the flank-land (mm), b – is width of contact of a chamfer of a cutting tool with a workpiece surface (mm). The shear specific contact load on the chamfer q_{Fh} (MPa) (shear contact stress on the chamfer τ_h (MPa) when $\Delta h_f \rightarrow 0$ mm) was calculated as a ratio of an increment of shear (tangential) force on the flank-land ΔF_h (N) to an increment of the area of the flank-land, i.e. $q_{Fh} = \Delta F_h / (\Delta h_f \cdot b)$.

Distributions of contact stresses on a flank surface chamfer in steel 40X machining are presented in the Fig. 4.

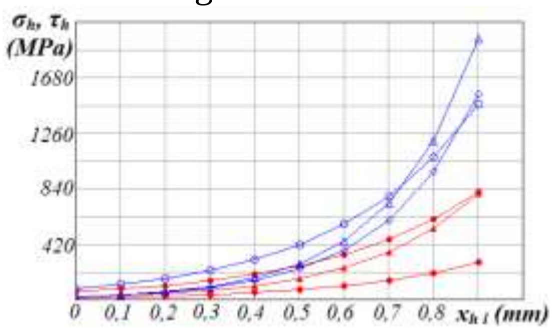

Fig. 4. Distribution of normal σ_h (◊, Δ, ○) and shear τ_h (♦, ▲, ●) contact stresses (MPa) on a flank-land of a cutter in steel 40X machining. γ = 5 °, φ = 45 °, v = 2 m/s, t = 2 mm.

◊, ♦ - s=0.34 mm/r; Δ, ▲ - s=0.23 mm/r; ○, ● - s =0.11 mm/r.

Abscissa – is distance from a cutting edge along a flank surface chamfer $x_{h\,i}$ (mm)

At a cutting edge contact stresses are almost equal to zero, and at moving far from the cutting edge they are essentially increased on an exhibitor. It is connected with a sag mn_1j of cutting surface under the influence of a radial component cutting force on the rake surface $P_{y\,r}$ in machining of the materials forming a discontinuous chip (Fig. 5) [3].

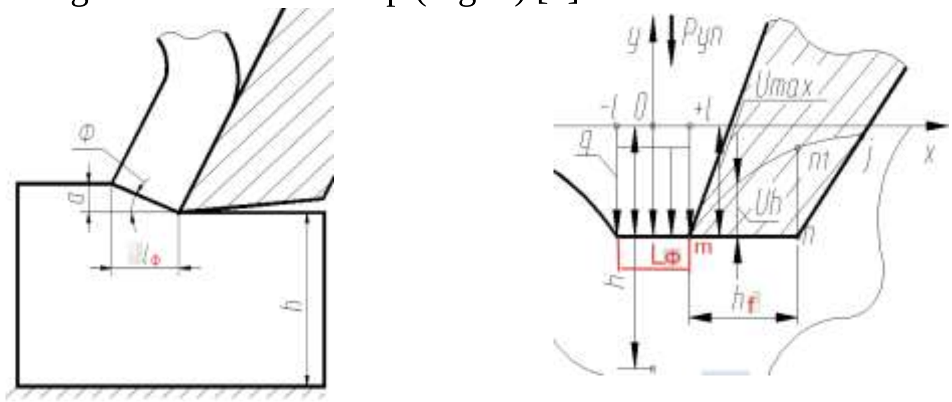

Fig. 5. The sag of the reference surface mn_1j under a radial component of cutting force on a rake surface P_{yr} (P_{yn})

With increasing feed rate s the radial force on a rake surface $P_{y\,r}$ is increased, but a length of projection of a conditional shear plain on a transient surface l_Φ is also increased.

$$l_\Phi = a \cdot \text{ctg}\,\Phi \text{ (mm)}, \qquad (12)$$

where Φ is shear angle (°).

Specific normal load $q_{Py\,r} = P_{y\,r} / (l_\Phi \cdot b)$ (MPa) is thus diminished, and the wave length of a sag is increased. This in appearance, a paradoxical hypothesis proves to be true by results of our experiments, i.e. with increase of feed rate s contact stresses at a cutting edge are diminished.

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REFERENCES

1. Kozlov V., Zhang J., Cui J., Bogolyubova M. Split Cutter Method for Contact Stresses Research over Flank Surface of a Cutter // *Key Engineering Materials*. *Trans Tech Publications*, (Switzerland), 2017, v. **73,** pp. 252-257.

2. Hu J., Chou Y. K. Characterizations of cutting tool flank wear-land contact // *Wear,* 2007, v. **263,** (7-12 SPEC), pp. 1454-1458;
3. Kozlov V. N. Flank Contact Load Distribution at Cutting Tool Wear // *Proceeding of the7th International Forum on Strategic Technology*, IFOAT2012, 2012, v. **2,** pp. 147-151.
4. Полетика М.Ф. Контактные нагрузки на режущих поверхностях инструмента. Москва: Машиностроение, 1969. – 148 с.
5. Развитие науки о резании металлов /В.Ф. Бобров, Г.И. Грановский, Н.Н. Зорев и др. – М. Машиностроение, 1967. – 416 с.
6. Васильев Д.Т. Силы на режущих поверхностях инструмента // Станки и инструмент. – 1954 – № 4. – с. 1-5.
7. Кравченко Б.А. Силы, остаточные напряжения и трение при резании металлов. Куйбышев: Куйбышевское книжное издательство. 1962. - 179 с.
8. Artamonov E.V., Chernyshov M.O., Pomigalova T.E. Improving the Performance of Composite Bits with Replaceable Inserts // Russian Engineering Research, 2017, v. **37**, No. 4, pp. 348–350.
9. Proskokov A. V. and Petrushin S. I. Chip Formation with a Developed Plastic-Deformation Zone // *Proceeding of the7th International Forum on Strategic Technology*, IFOST2012, 2012, v. **2.** pp. 173-177.
10. Afonasov A. and Lasukov A. Elementary Chip Formation in Metal Cutting // *Russian Engineering Research,* 2014, v. **3,** pp. 152-155.
11. Artamonov E. V., Vasil’ev D. V., Kireev V. V., and Uteshev M. Kh. Mechanics of Chip Formation in Cutting // *Russian Engineering Research,* 2017, Vol. 37, No. 5, pp. 450–454.

CALCULATION OF TECHNOLOGICAL DIMENSIONS

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The designation of TP represents a multialternative task, the correct solution of which requires realization of a number of calculations. In the beginning of designation kinds of processing of blank surfaces and methods of achievement of their accuracy appropriate to the requirements of the drawing, type of manufacturing and equipment, existing in the machine shop, previously are defined or established.