METHOD OF CONTACT STRESSES RESEARCH OVER SURFACES OF A CUTTER

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Calculation of cutting tool strength requires knowledge about distribution of contact loads (external stresses or specific loads) over a face and a flank surfaces of a wedge. They can be investigated experimentally by three methods: 1) by the optical polarization method, 2) by the method of interference, 3) by the method of a “split cutter” (sectional tool) [1].

The method of a “split cutter” allows to research distribution of contact loads (external stresses) with industrial cutting mode, but one demands creation of rigid dynamometer [1, 2]. In order to be sure about constant condition during experiments it is necessary to measure total components of a cutting force Pz (tangential component) and Py (radial component) by a lower level of elastic measuring elements 4 (Fig. 1). These forces are large and thickness of walls are large – measuring elements 4 are more rigid in comparison with the upper elastic measuring elements 3.

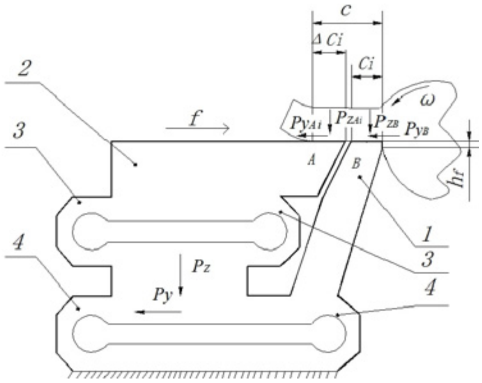

Fig. 1. The research of contact loads distribution over a face surface of the cutting tool by the method of the “split cutter” on a lathe with horizontal feed rate *f*

Upper level of elastic measuring elements 3 is used for measurement of force components Pz_A and Py_A which act on the surface of part A of the “split cutter”. This dynamometer is named as “four-component dynamometer for a split cutter” [1].

Specific contact loads are calculated as a ratio of an increment of forces over the plate A to an increment of area of this surface. For the free orthogonal cutting and for the rake angle $\gamma=0^o$ $Pz_{Ai}= N_{Ai}$, $Py_{Ai}= F_{Ai}$. We consistently displace the dynamometer with the cutter along periphery of the disk on the length l_i relatively the initial position, cut the disk and measure force components $Pz_{A\,i}$ and $Py_{A\,i}$ (Fig. 1).

The increment of the normal force over increment area with length $\Delta C'_{i+1}$ is a force on the plate A for the considered position minus force for the previous position: $\Delta N'_{A\,i+1} = N_{A\,i+1} - N_A$. Also for the tangential force $\Delta F'_{A\,i+1} = F_{A\,i+1} - F_{A\,i}$.

The ratio of these forces increment to the contact area increment is the specific normal and tangential cutting force over the increment of zone (i+1) (with the length $\Delta C'_{i+1}$). For the rake angle $\gamma=0^o$: $q_{N'\,i+1} = \Delta N'_{A\,i+1} / (\Delta C'_{\,i+1}\cdot b_c)$; $q_{F'\,i+1} = \Delta F'_{A\,i+1} / (\Delta C'_{\,i+1}\cdot b_c)$.

For very small displacement of the dynamometer along the disk periphery ($\Delta l_i \to 0$) the specific normal force $q_{N'\,i+1}$ over this area will be considered as a normal stress over rake surface σ ($\sigma_{i+1} \approx q_{N'\,i+1}$). Similarly for a shearing stress τ ($\tau_{i+1} \approx q_{F'\,i+1}$).

Elements 4 are deformed elastically under forces Pz_B and Py_B, which act on the plate B, and are shifted slightly lower and in the left direction (out from workpiece) together with the elements 3, which are mounted on the lower level of elastic measuring elements 4. Exceeding (projection) of the plate A relatively the plate B is not formed.

Research of contact load distributions over the flank-land with use of above scheme of cutting faces a problem of elastic deformation of measuring elements 3 (Fig. 2).

The force $Py_{A\,i}$ acts on the plate A and slightly displaces the plate A in the left direction (out from plate B) due to small rigidity of element 3, that leads occurrence exceeding the plate B relatively the plate A. The sharp projection of the plate B starts to cut off an additional chip from the surface of the disk. The slit between plates A and B is hammered that leads to violation of forces measurement and even to breakage of plates.

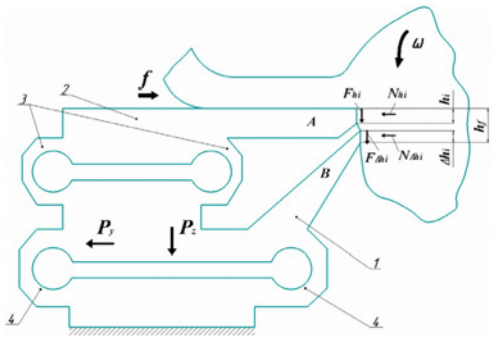

Fig. 2. The research scheme of contact loads distribution over the flank-land of the cutting tool by the method of the "split cutter" on a lathe with horizontal feed rate *f*

For elimination of the specified undesirable phenomena it is necessary to change the cutting scheme: research of contact loads over the flank surface is necessary to carry out on a horizontal milling machine with the vertical feed f of machine tool table (Fig. 3).

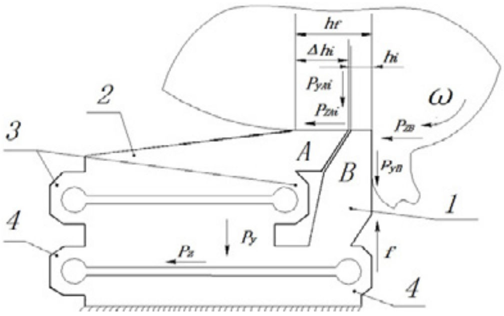

Fig. 3. The research scheme of contact loads distribution over the flank-land of the cutting tool by the method of the "split cutter" on a horizontal-milling machine with vertical feed rate f of a table

Forces Pz_B and Py_B act on the plate B over the face and some part of the flank-land surface of this plate. Elements 4 are deformed elastically and are shifted slightly lower and in the left direction (out from workpiece) together with elements 3, which are mounted on the lower level of elastic measuring elements 4. Exceeding plate A relatively plate B is not formed.

Force $Py_{A\,i}$ act on the plate A over an area with length Δh_i ($\Delta h_i = h_f - h_i$) of the flank-land and displaces plate A slightly lower than plate B due to small rigidity of elements 3. Exceeding plate A relatively plate B is not formed due to large rigidity of elements 4.

The ratio of forces increment $\Delta N'_{A\,i+1}$ and $\Delta F'_{A\,i+1}$ to the contact area increment is a specific normal and tangential cutting force over the area with the length $\Delta h'_{i+1}$:

$$q_{N'h\,i+1} = \Delta N'_{A\,i+1} / (\Delta h'_{i+1} \cdot b_{dc}) = \Delta P'y_{A\,i+1} / (\Delta h'_{i+1} \cdot b_{dc});$$

$$q_{F'h\,i+1} = \Delta F'_{A\,i+1} / (\Delta h'_{i+1} \cdot b_{dc}) = \Delta P'z_{A\,i+1} / (\Delta h'_{i+1} \cdot b_{dc}).$$

For $\Delta l_i \to 0$ a specific normal force $q_{N'h'\,i+1}$ can be considered as a normal stress σ_h ($\sigma_{h'\,i+1} \approx q_{N'h\,i+1}$). Similarly for a shearing stress τ_h ($\tau_{h'\,i+1} \approx q_{F'h\,i+1}$).

References

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2. Bogoljubova M.N. et al. Mathematical simulation and optimization of cutting modes in turning of titanium alloy workpieces // IOP Conference Series: Materials Science and Engineering. – 2016. – Vol. 124. – P. 012–045