Research of Changeability of Cutting Process Parameters at turning of the Shaped Surfaces

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Abstract. Conformities to law of changeability of the tool geometrical parameters, parameters of cut section, parameter of the chip formation, cutting forces, cutting temperature and machining surface roughness at machining of the shaped surfaces are set.

There is researched character of change of the working edge angle, cutting face edge angle, width and thickness of cut section, cutting speed on position of blade top on the convex and concave shaped surface.

The analytical dependences of the chip contraction coefficient, cutting forces, cutting temperature and machining surface roughness on the cutting speed and feed are certain. The method of determination of the cutting forces, thermal streams and cutting temperature at turning of the shaped surfaces is created taking into account changeability of the geometrical parameters and parameters of cut section. There are set coefficients, which allow expecting these parameters in any point of the convex and concave shaped surfaces.

The method of account of the cutting process parameters changeability at optimization of the cutting regimes at turning of the shaped surfaces on the criterion of maximum productivity is developed. With the use of method of the linear programming analytical dependences of the optimum-cutting regime from the turning parameters taking into account variable limitations on cutting forces, cutting temperature and machining surface roughness are definite.

Introduction

Upgrading quality of machines details with achievement of the maximally possible productivity of machining is a major task of modern engineer. Among the various types of machines details surfaces it is occupied the special place the shaped surfaces machining of which is very difficult.

Providing of quality of machines details making the working surface of which is limited by the shaped type is an intricate technological problem. Machining of the shaped surfaces requires the difficult kinematics of relative motion of blank and cutting tool and characterized by the variable values of technological parameters, which determine the machining terms.

Presently the questions of providing of exactness at turning of the shaped surfaces are most studied [1]. Information on the ground of choice of rational parameters of cutting process taking into account the features of the shaped surfaces machining absents practically.

The tasks of the productivity increase are most grounded decide based on optimization of the cutting regims on the criterion of maximum productivity. The known methods of determination of the optimum of cutting regims do not take into account changeability of parameters of the shaped surfaces treatment that requires their further development [2]. Based on analysis of rough and finish turning [3, 4] the necessity of account of the limitations on the cutting forces, cutting temperature and machining surface roughness are grounded, and similarly limitations for the roughness of the treated surface, which in the case of the shaped surfaces machining, are variable and require the special approaches for their determination.

The purpose of represented work is installation of conformities to law of change cutting forces, cutting temperature and machining surface roughness at turning of the shaped surfaces taking into account changeability of the tool geometrical parameters, parameters of cut section, parameter of the chip formation.

General Information

At turning of the shaped surfaces, there are variables working edge angle, parameters of cut section and cutting speed along curved surface. As a result the physical parameters of cutting process: chip contraction coefficient, cutting force, cutting temperature and machined surface roughness are variable. Conformities to law of change of working edge angles are presented in fig. 1.

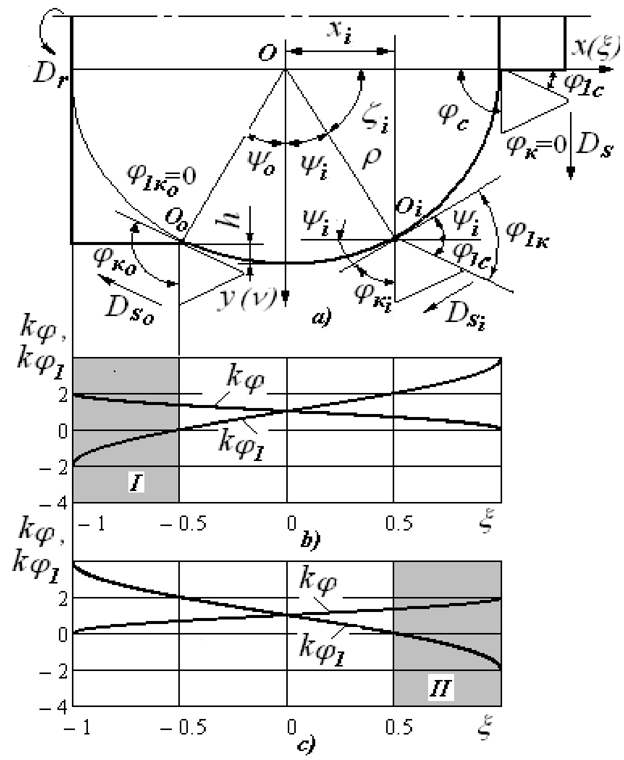

Fig. 1. Chart of determination of working edge angle – *a)* and charts of their change at turning of convex – *b)* and concave – *c)* shaped surfaces

Example of determinations the working cutting edge angle φ_K and cutting face edge angle φ_{1K} is resulted for a convex surface (fig. 1a) with the permanent radius of curvature ρ (generatrix the surfaces of rotation is an arc of circumference, a center of the accepted system of co-ordinates is the center of curvature, that by the center of circumference). Machining is executed by an instrument with a trihedral plate for which static working edge angle are $\varphi_C = 90^o$; $\varphi_{1C} = 30^o$. Position of blade top on the indicated curved surface is determined by the instantaneous corner of turn ψ_i, which for convex ψ_{i1} and concave ψ_{i2} surfaces are calculated as follows: $\sin \psi_i = x_i/\rho$; $\psi_{i1} = \arcsin(\xi_i)$; $\psi_{i2} = \arcsin(-\xi_i)$ ($\xi_i = x_i/\rho$ is a dimensionless co-ordinate).

Working cutting edge angle φ_K and cutting face edge angle φ_{1K} are determined in relation to direction of feed motion D_{Si} by the instantaneous turn corner ψ_i: $\varphi_{Ki} = \varphi_C - \psi_i$; $\varphi_{1K} = \varphi_{1C} - \psi_i$.

General conformities to law of change of working cutting edge angle φ_K and cutting face edge angle φ_{1K} along a dimensionless co-ordinate ξ by comparison to the values of these corners in a point, proper to beginning accepted system of co-ordinates, can be described by the dimensionless coefficients $k_\varphi(\xi) = \varphi_K(\xi)/\varphi_K(0)$, $k_{\varphi 1}(\xi) = \varphi_{1K}(\xi)/\varphi_{1K}(0)$:

$$k_\varphi(\xi) = \frac{\varphi_C - \arcsin(\xi)}{\varphi_C - \arcsin(0)} = \frac{\varphi_C - \arcsin(\xi)}{\varphi_C}; \quad k_{\varphi 1}(\xi) = \frac{\varphi_{1C} + \arcsin(\xi)}{\varphi_{1C} + \arcsin(0)} = \frac{\varphi_{1C} + \arcsin(\xi)}{\varphi_{1C}} \qquad (1)$$

Charts of dimensionless coefficients k_φ, $k_{\varphi 1}$,, characterizing the relative changes of working cutting edge angle $\varphi_K(\xi) = k_\varphi(\xi)\varphi_C$ and cutting face edge angle $\varphi_{1K}(\xi) = k_{\varphi 1}(\xi)\varphi_{1C}$ along a dimensionless co-ordinate ξ are presented in the fig. 1b and fig. 1c.

The feature of machining of convex curved surface is possibility of machining the same instrument of surface to the point O_0, for which $\varphi_{1Ko} = 0$. Dimensionless co-ordinates of point O_0: $\xi_0 = -\sin(\varphi_{1C})$; $\nu_0 = -\cos(\varphi_{1C})$. Maximal possible for machining dimensionless depth convex and concave surfaces can be calculated as $h/\rho = 1 - \cos(\varphi_{1C})$. Shaded area *I* (fig. 1b) corresponds to the area of impossible machining this tool of convex surface; shaded area *II* (fig. 1c) corresponds to the concave surface. It is set that at machining of convex curved surface working edge angle φ_K decreases and face edge angle φ_{1K} increases. At machining of concave curved surface working edge angle φ_K increases and cutting face edge angle φ_{1K} decreases.

Geometrical parameters of cut section thickness *a*, width *b* depend on technological parameters feed *S*, cutting depth *t* and working edge angle φ_K. At machining of curved surfaces the cutting depth *t* remains permanent, in this connection the width of cut *b* changes depending only on working cutting edge angle φ_K: $b(\xi) = t/\sin(\varphi_C - \arcsin\xi)$.

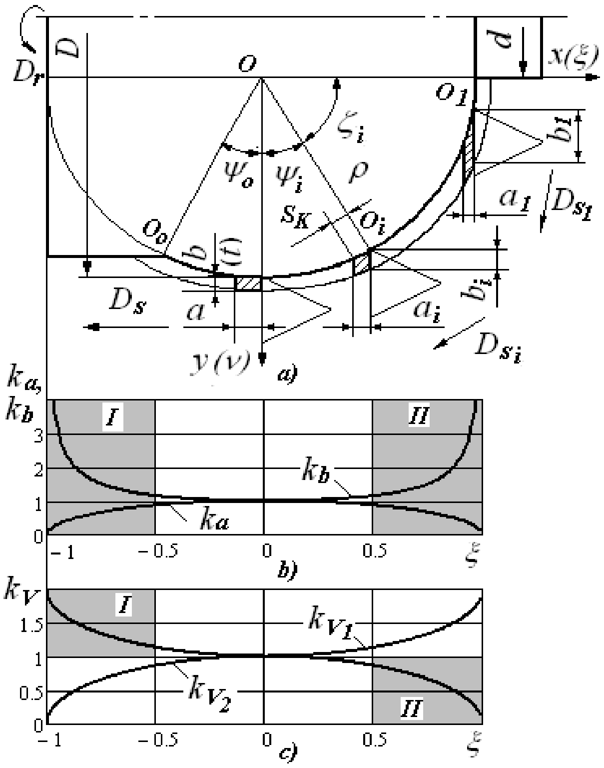

Fig. 2. Chart of determination of parameters of cut section – *a)* and charts of their change – *b)*, and charts of change of cutting speeds– *c)* at turning of convex and concave shaped surfaces

In the case of treatment on machine-tools with NC*,* with permanent contour speed of feed S_K, cutting thickness a changes depending on a working cutting edge angle φ_K: $b(\xi) = t/sin(\varphi_C - \arcsin\xi)$.Conformities to law of change of parameters of cut section and cutting speed are presented in fig.2.

General conformities to law of change of cutting parameters and cutting speed along a dimensionless co-ordinate ξ can be described by dimensionless coefficients $k_a(\xi) = a(\xi)/a(0)$, $k_b(\xi) = b(\xi)/b(0)$, $k_V(\xi) = V(\xi)/V(0)$:

$$k_a(\xi)=\sin(\varphi_C-\arcsin(\xi))/\sin(\varphi_C); \quad (2)$$

$$k_b(\xi)=\sin(\varphi_C)/\sin(\varphi_C-\arcsin(\xi)); \quad (3)$$

$$k_V(\xi)=1\mp[((1-\cos(\arcsin(\xi)))/2\delta)], \quad (4)$$

$\delta = D/\rho$ is a dimensionless diameter of the shaped surface in a point, proper to beginning accepted system of co-ordinates; sign «-» corresponds to the convex surface, sign «+» corresponds concave surface.

The set coefficients allow expecting cut section parameters and cutting speed in any point shaped surface $a(\xi) = k_a(\xi)a$, $b(\xi) = k_b(\xi)b$, $V(\xi) = k_V(\xi)V_D$.

Charts of dimensionless coefficients k_a, k_b, k_V, characterizing the relative changes of thickness and width of cut, and also cutting speeds along a dimensionless co-ordinate ξ by comparison to the values of these parameters in a point, proper to beginning accepted system of co-ordinates, presented on the fig. 2b and fig. 2c (δ = 0,5). Shaded areas *I* (fig. 2b, fig. 2c) correspond to the area of impossible treatment this instrument of protuberant surfaces; areas *II* – concave.

On the basis of the set conformities to law of change of working cutting edge angles, parameters of cut section and cutting speed at turning of the shaped surfaces conformity to law of change along curved generatrix of chip contraction coefficient $k(\xi)$, cutting forces $P_z(\xi)$, cutting temperatures $\Theta(\xi)$ and machining surface roughness $R_a(\xi)$ are investigational:

$$k(\xi)=C_k k_k(\xi)V^{n_k}S^{y_k}t^{x_k}; \; k_k(\xi)=k_V(\xi)^{n_k}; \quad (5)$$

$$P_z(\xi)=C_P k_P(\xi)V^{n_p}S^{y_p}t^{x_p}; \; k_P(\xi)=k_V(\xi)^{n_p}; \quad (6)$$

$$\Theta(\xi)=C_\Theta k_\Theta(\xi)V^{n_t}S^{y_t}t^{x_t}; \; k_\Theta(\xi)=k_V(\xi)^{n_t}; \quad (7)$$

$$R_a(\xi)=C_R k_R(\xi)V^{n_r}S^{y_r}t^{x_r}; \; k_{Ra}(\xi)=k_V(\xi)^{n_r}, \quad (8)$$

Fig. 3. Charts of change of the chip contraction coefficient – *a)*, cutting forces and machining surface roughness – *b)*, cutting temperatures – c) at turning of convex and concave shaped surfaces

C_i, x_i, y_i, n_i are coefficient and indexes of degree of influence of cutting speed V, feed S and depths t on the chip contraction coefficient k, cutting forces P_z, cutting temperatures Θ and machining surface roughness R_a accordingly.

General conformities to law of change of the indicated parameters of cutting process along a dimensionless co-ordinate ξ by comparison to the values of these parameters in a point, proper to beginning accepted system of co-ordinates, can be describe by dimensionless coefficients:

k_i: $k_k(\xi) = k(\xi)/k(0)$, $k_P(\xi) = P(\xi)/P(0)$, $k_\Theta(\xi) = \Theta(\xi)/\Theta(0)$; $k_R(\xi) = R_a(\xi)/R_a(0)$:

Charts of dimensionless coefficients k_k, k_P, k_Θ, k_R are presented on a fig. 3 (for the terms of treatment of construction steels the values of indexes are accepted n_k = -036; n_P = -0,15; n_t = 0,53; n_r = -0,15). It is set because of the conducted researches that the parameters of cutting process in the different points of the shaped surface differentiate substantially. There are maximal values of the chip contraction coefficient, cutting forces and temperatures at turning of convex surfaces take place in a point, proper to beginning accepted system of co-ordinates. For concave surfaces the chip contraction coefficient and cutting force are in a point, proper to beginning accepted system of co-ordinates, have a minimum value.

The results of calculation of actual temperatures of cutting [3] testify that at machining of shaped surfaces of value of temperatures in separate points can substantially exceed the possible level of 800ºC that not walked around to take into account at the choice of rational terms of machining. At machining with a permanent contour feed S_K the decline of cutting temperature to possible can be carried out due to the choice of optimum cutting speed V_o [4]. General conformities to law of change of optimum cutting speed along a dimensionless co-ordinate ξ can be described by dimensionless coefficients $K_V(\xi) = V_o(\xi)/V_o(0)$:

$$V_{\hat{\imath}}(\xi) = \left(\Theta / C_\Theta k(\xi) t^{x_t} S_{o2}^{y_t}\right)^{1/n_t} = K_V(\xi) V_o; \quad K_V(\xi) = k_V(\xi)^{-1} = 2\delta / \left[2\delta \mp \cos(\arcsin(\xi))\right]. \quad (9)$$

It is set coefficient $K_V(\xi)$, which allow expecting optimum cutting speed in any point of the convex and concave shaped surfaces

Conclusion

Based on setting conformities to law of changeability of the cutting process parametrers at machining of the convex and concave shaped surfaces the method of determination of the cutting forces, thermal streams and cutting temperature is created taking into account changeability of the geometrical parameters and parameters of cut section. There are set coefficients, which allow expecting these parameters in any point of the convex and concave shaped surfaces.

The method of account of the cutting process parameters changeability at optimization of the cutting regimes at turning of the shaped surfaces on the criterion of maximum productivity is developed. With the use of method of the linear programming analytical dependences of the optimum-cutting regime from the turning parameters taking into account variable limitations on cutting forces, cutting temperature and machining surface roughness are definite.

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