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VYACHESLAV F. BEZJAZYCHNYJ [*],
ALEXANDER N. SUTYAGIN[*]

Technological providing of surface layer quality parameters during the machining

Key words

Friction, wear, surface layer, quality parameters, machining.

Summary

The article describes the problem of friction unit surface layer parts wear resistance assurance based on control of geometrical and physic mechanical properties to be formed the machining.

1. Introduction

Machine components wearing is characterised by destruction of a contact surface layer in which physicochemical alterations and fatigue changes occur as a result of the surface interaction of mated parts. Wearing destruction has an accumulative character and grows out of repeated accumulation of damages; therefore, the wear resistance is rather sensitive to insignificant changes of materials properties.

The normal operation of a unit is characterised by the minimal wear rate of the material and the simultaneous forming of balanced geometrical (roughness) and physicomechanical (rate of the mechanical hardening of a surface layer) parameters of a surface layer of machine components (according to research of A.A. Matalin, V.S. Kombalov, A.G. Syuslov et al.). The duration of break-in

[*] Rybinsk State Academy of Aviation Technology named after P. A. Solovjev, 152934, Rybinsk, Yaroslavl region, St. Pushkin, 53, Phone Office: (4855) 222091, Fax: (4855) 213964, E-mail: root@rgata.ru.

period of interfaced machine components depends upon the difference between the initial quality parameters and optimal parameters of the surface layer. Therefore, during manufacturing of vital units, optimal quality parameters of the surface layer are to be technologically provided on the surfaces of the machine components.

Existing techniques of wear rate calculation have the following differences:

- In some of them the wearing ratio is estimated according to the specified quality parameters of the surface layer.
- In others wearing ratio is estimated according to the specified machining modes.

This does not provide the forming of balanced quality parameters of a surface layer of the machine components, which are necessary for normal operation of the unit. So it is necessary to develop a mathematical model that matches technological machining conditions with balanced quality parameters of a surface layer of machine components.

2. Theoretical parts

Any crystal body possesses inner and surface energy. Changing of an inner energy is determined by the formula of specific energy of deformation Δw accumulated in the material as a result of dislocation forming (according to research of M.A. Prokofiev, RSAAT)

$$\Delta w = f\left(HV, HV_0, \alpha_0, G\right) \tag{1}$$

where G – a displacement module of an examined material; α_0 – parameter of interdislocation interaction; HV – a microhardness of a surface layer of an examined part at the specified depth; HV_0 – a microhardness of a undeformed material.

As a result of the interaction of the interfaced parts, new surfaces are formed which are followed by energy release γ_{ef}, consumed in formation [1]

$$\gamma_{ef} = f\left(F, Rz, HV\right) \tag{2}$$

where F – normal force of friction pair elements interaction; Rz – an altitude of irregularities of an examined surface profile.

As a result of the break-in process of interfaced machine components, the surface of a part obtains such physical conditions and such a structure that provides minimal potential energy of the surface layer, i. e. becomes the stable system that allows minimal dissipation of energy at such conditions. The geometrical (roughness) and physicomechanical (microhardness) quality parameters of a surface layer formed in this way are called balanced.

According to the first law of thermodynamics, the work of friction force, taking into consideration the conditions of obtaining a balanced state is expressed as

$$W_{fr} = f\left(f, F, S_{fr}, V_W, Rz_{bal}, HV_{bal}, HV_0\right) \quad (3)$$

where W_{fr} – friction work; f – a friction coefficient; S_{fr} – friction track; Rz_{bal} – balanced roughness of the interfaced surfaces of the components; HV_{bal} – balanced microhardness of a surface layer of an examined part at the specified depth; V_W – the volume of a worn material.

Taking into consideration, that expression $\frac{V_W}{S_{fr}}$ represents the value of wear rate J_V, correlation between wear rate and balanced parameters of a roughness and a rate of a mechanical hardening of a surface layer of machine components is defined as

$$J_V = Kj\frac{fF3\pi S_{fr}Rz_{bal}2\cdot 10^{-3}\cdot\left[HV_0(N_{bal}+1)\right]^{1,19} - 4F^2}{\frac{3\pi}{\alpha_0^2 G}S_{fr}Rz_{bal}\cdot 2\cdot 10^{-3}\cdot\left[HV_0(N_{bal}+1)\right]^{1,19}\left[0,32\cdot HV_0\cdot N_{bal}\right]^2} \quad (4)$$

where J_V – wear rate, m^3/m; Kj – proportion ratio depending on physicomechanical properties of a material; f – friction ratio of materials of a friction pair; α_0 – parameter of interdislocation interaction.

Using the formula for correlation between surface roughness, the rate of mechanical hardening and technological requirements of machining [2, 3], and the correlation between wear rate and technological requirements of machining is formulated as

$$J_V = f\left(Kj, f, F, S_{fr}, \alpha_0, r, HV_0, h_c, \sigma_B, \sigma_{B_E}, p_1, t, \tau_p, B_{Cr}, \gamma\right) \quad (5)$$

where $p_1 = f\left(a_1, b_1, c\rho, \theta, \rho_1, a, \lambda_p, \beta, \varepsilon, V, \lambda, \alpha, \tau_p, b, a_2, B_{Cr}, b_2, \gamma, x, \delta_1\right)$; h_c – depth of a mechanical hardening; V – a cutting speed; t – a cutting depth; τ_p – plastic displacement resistance of the treated material; λ and λ_p – thermal conduction of treated and tool materials; θ – a melting temperature of a treated material; α and γ – rear and front angles of the cutter; φ и φ_1 – principal and auxiliary angles of the plane; β, ε – cutter pointing angle and vertex angle of the plane; r – radius at a cutter tip of the plane; ρ_1 – radius of a rounding of a cutting edge of a cutter; δ_1 – value of wearing of a cutter on a rear surface; σ_B – ultimate stress limit of a treated material; a – temperature conduction of a treated material; σ_{B_E} – ultimate stress limit of electric steel taken as a standard sample; $c\rho$ – specific volume thermal capacity of a treated material; a_1 –

thickness of cut; b_1 – width of cut; b – the summary length of cutting edges; $V_{Cr} = \frac{cB_{Cr}^{x} D_{Cr}^{z}}{G_{Cr}^{y} (1 - \sin\gamma)^{0,73}}$ – dimensionless group; $B_{Cr} = \frac{Va_1}{a}$ – dimensionless group; $G_{Cr} = \frac{\lambda_p}{\lambda} \beta \cdot \varepsilon$ – dimensionless group; $D_{Cr} = a_1/b_1$ – dimensionless group; a_2, b_2, c, ξ, χ, x, y, z – the values depending on properties of treated and tool materials.

3. Experimental conditions, results and discussion

Analysis of the results of calculated and experimental definition of the wear rate of samples (materials grades: 52100, D 4, Nichrome V) in balanced state conditions of a surface layer has shown that a lapse of calculation for the developed relation (4) does not exceed 12 % with correction coefficient *Kj* for different groups of materials. As a result of the analysis of the experimental data, it has been discovered that value of coefficient *Kj* characterises the ability of a material to resist plastic deformation and destruction during the friction process. Using degree approximation of experimental values, the following expression for definition of coefficient *Kj* is obtained:

$$Kj = 20 \cdot \left(\frac{\sigma_B}{\sigma_{0.2} \cdot \delta} \right)^{-4,14} \tag{6}$$

where $\sigma_{0,2}$ – yield strength conditional with the tolerance on value of plastic deformation at stressing 0.2 %; δ – extension strain.

On the basis of the obtained relations, the technique of machining conditions calculation providing of machine components surface layer wear resistance is offered. Algorithm of the developed technique is shown on Fig. 1.

The algorithm operation consists in following:

1) Initial data input: displacement module of an examined material *G*, microhardness of a undeformed material HV_0, normal force of interaction of elements of a friction pair *F*, friction ratio of materials of a friction pair *f*; parameter of interdislocation interaction α_0;
2) Using Formula (4), wear rate and balanced surface layer quality parameters (rate of the mechanical hardening of a surface layer and roughness) are calculated;
3) The choice of treatment (turning, milling, etc.), according to part geometry, required accuracy of the machining and the machined surface quality.

Machining conditions (Unit 1, Unit 2) are calculated based on algorithms designed by scientists of Rybinsk State Academy of Aviation Technology [4].

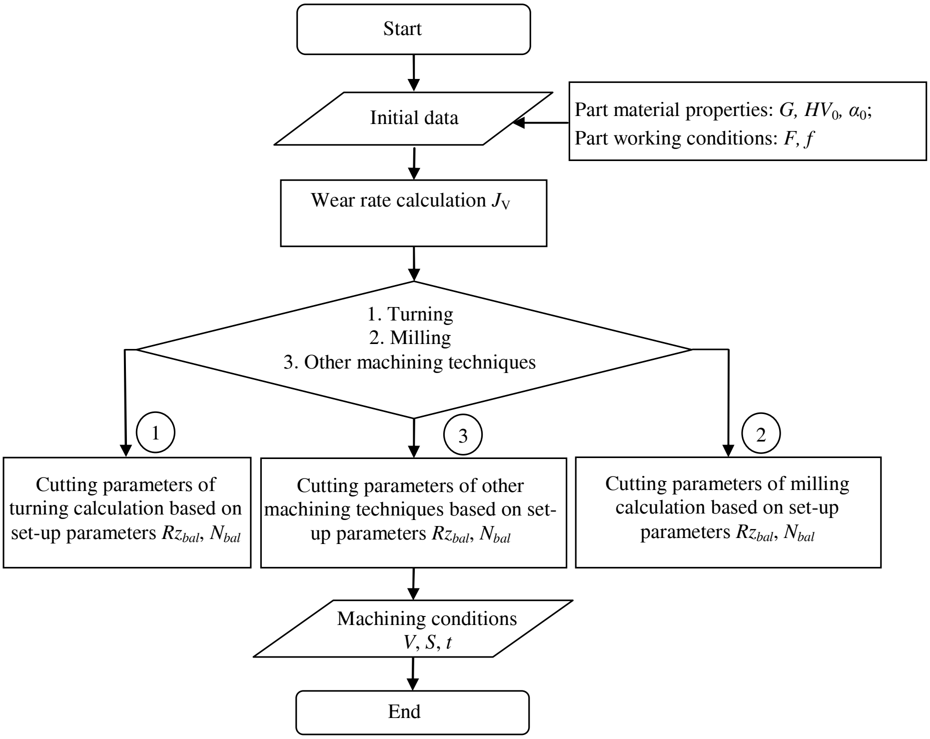

Fig. 1. Algorithm of machining condition calculations of machine components surface layer wear resistance

Relations of wear rate and cutting parameters of turning, which permit the calculation analytically of wear rate dependent on chosen cutting parameters, to assign or adjust treatment conditions providing the forming of the balanced geometrical and physic mechanical properties of machine component surface layers are obtained (Tab. 1).

Tab. 1.

Parts material	Relations of wear rate and cutting parameters of turning
52100	$J_V = 3,71 \cdot 10^{-8} S^{0,054} V^{0,85} t^{-0,12} r^{-0,069} \varphi^{-0,69} F^{0,95}$
150 Cr 14	$J_V = 2,945 \cdot 10^{-8} S^{0,024} V^{0,428} t^{-0,046} r^{-0,077} \varphi^{-0,909} F^{0,907}$
D 4	$J_V = 3,294 \cdot 10^{-9} S^{0,17} V^{0,15} t^{-0,09} r^{-0,13} \varphi^{-0,05} F^{0,89}$

In Tab. 1: S – feed, mm/rev. Equations adequately describe the process at S = 0.05...0.08 mm/rev; V = 0.1...0.2 m per sec.; t = 0.25...0.4 mm; φ = 45 … 60 °; r = 0.3 … 1 mm; F = 100 … 500 N; a dry friction; elastic character of interaction; contact temperature no more than 120°C.

4. Conclusion

The developed algorithm of treatment condition calculations for providing machine components surface layer wear resistance allows technologist in the processing design stage to determine machining conditions providing forming of the balanced geometrical and physical-mechanical properties of machine component surface layers, permitting the reduction of running-in time of machine components.

References

[1] Kascheyev V. N. Phenomena of the metals friction contact zone. Moscow. 1978. 213 p.
[2] Bezjazychnyj V. F., Kozhina T. D., Konstantinov A. K. Moscow. 1993. 184 p.
[3] Bezjazychnyj V. F., Krylov V. N., Poletaev V. A. Automatization of the gas-turbine engines manufacturing process. Chapter 1. Moscow. 2005. 560 p.
[4] Bezjazychnyj V. F., Kozhina T. D., Volkov S. A. Industry registration certificate №3452 “Machining conditions of turning providing parts performances”. Moscow. 2004. 1 p.

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