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TECHNOLOGICAL OPPORTUNITIES FOR INCREASING THE MACHINE PARTS' OPERATIONAL CHARACTERISTICS

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Summary. An analysis of machine parts' frictional processing resulting in these parts' improved performance is effected. The influence of predominating technological parameters upon the metal's surface layers' characteristics forming has been investigated.

Key words: strengthening, surface firmed layer, heat conductivity, technological regimes, main parameters

INTRODUCTION

Modern equipment being completed with numerous automated units and systems in close and complex linking, that implies reliable operation of all the parts and units over the whole serviceability period. That task resolution includes as the main factor an increase in the quality of machine-building and repair industry enterprises through improving the machine parts' strengthening processing technology. Machine parts' workability essentially relies onto the metal's surface layer strength at alternating, impact, contact load and wearing under different operation modes. The progressive trends in machine building and repair technology consist in strengthening the thin surface layer of machine parts that permits economizing expensive alloyed steels, non-ferrous metals at the same time that mechanisms' life time extension and reliability increase, both reducing the production's energy input [Suslov 1987, Butakov and Sysoyev 1995]. The last tendency consists in an application of surface strengthening pulse technology methods with the use of high-concentration power sources. These methods' essence is that the relatively small metallic volumes are influenced with high-speed concentrated high intensity energy flows with further gradual cooling temperature. These specific conditions of processing allow obtaining the required physical chemical, antirust and operative characteristics of machine parts' surface layers. Such technological method is represented by frictional firming procedure. Under frictional firming the surface layers are subjected to complex structure-phase transformations with forming those strengthened layers featuring the series of specific physical and mechanical properties. Surface layers forming at high-speed frictional effort is mainly determined by thermal processes arising at frictional contact area [Yakimov *et al.* 1991, Kondakov and Vasilyev 1998, Gurey 2004, Mylko *et al*. 2004].

GOALS AND TASKS

With respect to the fact that the metallic surface layer forming process, the mechanism itself as well as its essential features are insufficiently studied, we have posed the goal of developing the technological principles for frictional firming of surfaces with the use of both physical and mathematical simulation of the mentioned process for the reason of the processed surface's and firmed layer's required parameters obtaining.

THE RESULTS

With the aim of investigating into the frictional processing predominating parameters' influence onto the firmed layer shaping process, we suggest a numerical analytical model developed as a thermal conductivity problem in the following way:

$$\frac{\partial^2 T}{\partial x^2}+\frac{\partial^2 T}{\partial y^2}=\frac{V\partial T}{\lambda\partial x};\qquad -\infty\le x<\infty,\qquad \partial<y<\infty \tag{1}$$

$$\lambda\frac{\partial T}{\partial y}=\begin{cases} q(x)=f\cdot V\cdot P(x), & \left[H(x)-H(x-2a^{*})\right] \quad \sum\limits_{k=o}^{n}\delta(x+Kl-V_u^2\cdot\tau) \\ hT, & -\infty<x<0\cup 2a<x<\infty \end{cases} \tag{2}$$

$$\mathrm{T(x,y)}\to 0 \qquad \text{then} \qquad \sqrt{x^2+y^2}\to\infty \tag{3}$$

Here with the denotations adopted are such:

- T – the processed surface temperature,
- λa – thermal physical indexes, respectively the heat conductivity and thermal conductivity,
- x, y – Cartesian coordinates,
- $2a^*$ - width of tool – to – processed surface contact,
- V – velocity of heating sector motion,
- $q(x)$ – intensity of frictional heat flow,
- f – frictional index,
- P – contact pressure,
- $H(x)$ – Heavyside's function,
- $\delta(x)$ – Dirac's function,
- K – number of tool's segments under friction (frictional disk sectors),
- l – length of segments under friction,
- V_u – tool velocity.

The sought case is such that due to high speed of heating at the expense of the significant thermal gradients in the direction, orthogonal to the heating section's motion, it is convenient to neglect the $\frac{\partial^2 T}{\partial y^2} = 0$ value at the condition that Penlais criteria would be $P_e = \frac{Va}{2k} > 20.$

Let us apply the Fourier integral transformation by the variable x, then the solution of heat conductivity boundary problem (1)-(3), will be obtained as follows:

$$T(\xi,\eta) = \begin{cases} 0; -\infty < \xi \le 0 \\ \frac{F}{\sqrt{\pi}} \int_0^{\varepsilon} G(\xi-\tau,\eta) P^*(\tau) d\tau, 0 \le \xi \le 1 \\ \frac{F}{\sqrt{\pi}} \int_0^{l} G(\xi-\tau,\eta) P^*(\tau) d\tau - \frac{B_i}{\sqrt{\pi}} G(\xi-\tau,\eta) T(\lambda) d\lambda, 1 \le \xi \le \infty \end{cases} \tag{4}$$

$$G(\xi,\eta) = \exp\left[-\frac{\eta^2}{4\xi}\right] / \sqrt{\xi}, \quad F = fVP_0 d / \text{к} \quad \xi = \frac{x}{2a}, \quad \eta = \frac{y}{d}, \tag{5}$$

$$P^* = P / P_o, \quad d = \sqrt{2ak / V}, \quad B_i = hd / k \tag{6}$$

where:

P_o – the contact pressure maximal value.

The integration of solution (4) at arbitrary uniform distribution of contact pressure P, is effected by the approximation method with the use of step functions' and section-like continuous functions' properties [Parkus 1963, Djidkov 1977]. It is shown that the formulation for non-dimensional temperature T*=T/F has the following structure:

$$T(\xi,\eta) = \frac{F}{\sqrt{\pi\delta\tau}} \sum_{i=0}^{n} P_i^* G_i^{(1)}(\xi,\eta) H(\xi), \qquad \begin{matrix} -\infty < \varepsilon < \infty \\ 0 \le \eta < \infty \end{matrix} \tag{7}$$

On the workpiece's surface, the contact pressure is distributed as:

$$P(x) = P_0 \left\{ \sqrt{1-(x-a)^2 / a^2} - 0.25\cos\left[5\pi(x-a)^2 / a^2\right] \right\}, \qquad 0 \le x \le 2a \tag{8}$$

there takes place a superposition of Hertz distribution and oscillatory distributions, this effect being specific for rough surfaces' contact.

The maximal value of contact pressure is increased at 25% above the corresponding value for Hertz distribution. At the same time the difference between the maximal temperatures amounts only to 4,5%. Therefore in the case of contact pressure distribution taking into account the effective surface micro-geometry with insignificant fluctuation, the maximal temperature evaluation should be effected with the use of elliptic distribution of heat flow intensity.

CONCLUSION

Therefore, after the effected research we obtained a resolution of the formulated problem that allows to find out the optimal correlation between the firmed layer depth and the controlling technological parameters, for the case of machine parts' frictional firming.

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