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SIMULATION OF THE DISTRIBUTION OF THE WORKING LOADS OF THE CRANKSHAFT AND THE TECHNOLOGY OF STRENGTHENING FRICTION SURFACES

МОДЕЛЮВАННЯ РОЗПОДІЛУ РОБОЧОГО НАВАНТАЖЕННЯ КОЛІНЧАТОГО ВАЛА ТА ТЕХНОЛОГІЇ ЗМІЦНЕННЯ ПОВЕРХОНЬ ТЕРТЯ

The durability and reliability of vehicles, parts and mechanisms depend on many factors, and the main one is the quality of each individual part. As defined in many information sources [1, 2], quality indicators have a multidirectional, complex composition — from material, chemical composition, micro and macrostructure, technologies, processing modes, surface layer condition, etc. to physical and mechanical properties. In the modern production of machine-building parts, it is necessary to take into account the steady increase in loads (speed, temperature, aggressive environment) on the mechanisms and parts that make up the entire machine-building product. In recent years, differentiated or combined treatments of the surface layer of parts have become widespread, contributing to the emergence of gradients in the structural-phase state, and, accordingly, to the uneven structure of the material.

Keywords*: modeling, physico-chemical processes, structural-phase state, combined treatments, strengthening parts, hardening treatment technology.*

Довговічність і надійність роботи автомобілів, деталей і механізмів залежать від багатьох факторів і основним з них є якість кожної окремої деталі. Як визначалося у багатьох інформаційних джерелах, показники якості мають багатовекторний, комплексний склад — від

матеріалу, хімічного складу, мікро і макроструктури, технологій, режимів обробки, стану поверхневого шару і т.п. до фізико механічних властивостей. В сучасному виробництві деталей машинобудівного комплексу необхідно враховувати не уклінне зростання навантажень (швидкість, температура, агресивне середовище) на механізми і деталі, що складають цільний продукт машинобудівного призначення.

В останні часи набули поширене використання диференційовані або комбіновані обробки поверхневого шару деталей, що сприяють виникненню градієнтів структурно — фазового стану, а відповідно і нерівномірної структури матеріалу. При необхідності суттєвого зміцнення поверхневого шару і твердості матеріалу необхідно попередньо проводити обробку для отримання відповідних структур (мартенситу, карбідів, нітридів, боридів та т.ін.), що забезпечує задані властивості.

Для оцінки стану поверхневого шару деталей із сталі 45 необхідно урахувати наступні фактори: геометричні параметри розмірів, шорсткість поверхні деталі, мікроструктуру і твердість зношених поверхневих шарів.

***Ключові слова**: моделювання, фізико-хімічні процеси, структурно-фазовий склад, комбіновані обробки, зміцненні поверхні, зміцнюючи теплові обробки.*

Problem's Formulation

If it is necessary to significantly strengthen the surface layer and harden the material, it is necessary to pretreat it to obtain the appropriate structures (martensite, carbides, nitrides, borides, etc.) that provide the specified properties. To assess the condition of the surface layer of 45 steel parts, the following factors must be taken into account: geometric dimensional parameters, surface roughness of the part, microstructure and hardness of the worn surface layers [1, 2]. One of the main components for determining the real loads on a part is the objective distribution of operating loads (a set of torques and force loads on each local fragment of the part), which is shown in Fig. 1.

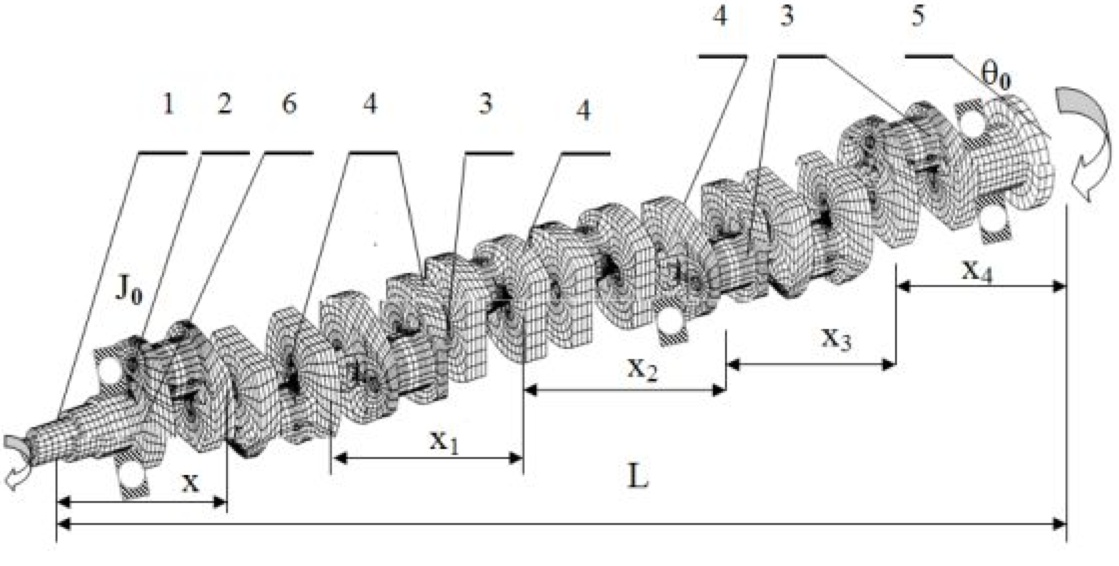

Fig. 1. Load diagram of the camshaft: 1 —shank; 2— bearing; 3— shaft; 4 — counter weight; 5— flange; 6 — main shaft journal; 7 — connecting rod journal

Hence, by differentiation, we find the torque equation

$$M_x(x,t) = \sum_{n=1}^{\infty} M_x(0) \cos r_n x \cdot \sin \omega_n t.$$

Analysis of recent research and publications

A shaft with a mass moment of inertia of unit rod length I has a disk whose mass moment of inertia is I_0. The shaft rotates with a constant angular velocity φ_0 and is suddenly clamped at the left end. Calculate the dynamic bending moment.

The boundary condition on the right end of the shaft requires the equality of the torque of the external forces M_x(l) = M_x(0)cosrl of the moment of inertia of the disk mass

$$M_u = -I_0\ddot{\varphi}(l) = I_0\omega^2\varphi(l) = I_0 r^2 \frac{GI_p}{I}\cdot\frac{M_x(0)}{rGI_p}\sin rl = \xi\lambda\sin\lambda,$$

were $\xi = I_o/Il$, $\lambda = rl$.

From this equality comes frequency control

$$tg\,\lambda = \frac{1}{\xi\lambda}.$$

Knowing your own functions

$$X(x) = sinrx,\ \ X'(x) = rcosrx,\ \ X'(l) = \xi lr^2 X(l).$$

Based on the dependence, we get:

$$(r_n^2 - r_m^2)\int_0^l X_m(x)X_n(x)dx =$$

$$= X_n(l)X_m^{'}(l) - X_m(l)X_n^{'}(l) = -(r_n^2 - r_m^2)\xi lX_n(l)X_m(l).$$

This shows that the eigenfunctions are orthogonal to the weight and are defined as

$$p(x) = 1 + \xi l\delta(x - l).$$

Now consider the initial condition $\varphi(x,0) = \varphi 0(1 - e(-x))$, which means that the initial speed of rotation of the shaft is constant everywhere, except for the section x = l.

$$2r\int_0^l X^2(x)dx = rl(X^2(l) + (X'(l))^2) - X(l)X'(l) = rl(1 + \xi^2\lambda^2 - \xi)X^2(l),$$

$$\int_0^l X^2(x)dx = \frac{l}{2}(1 + \xi^2\lambda^2 - \xi)X^2(l).$$

The initial condition takes the form

$$\sum_{n=1}^{\infty} C_n\omega_n X_n = \varphi_0(1 - e(-x)).$$

We multiply this equality by the eigenfunction $X_{m(x)}$, weight $p(x)$ and integrate along the length of the shaft

$$C_n\omega_n\int_0^l (1 + \xi l\delta(x - l))X_n(x\cdot X_m(x)dx = \varphi 0\int_0^l (1 - e(-x))(1 + \xi l\delta(x - l))X_n(x)dx,$$

$$C_n\omega_n\left[\int_0^l X_n^2(x)dx + \xi lX_n^2(l)\right] = \varphi_0 = \left(\xi l\sin\lambda_n - \frac{\cos\lambda_n - 1}{r_n}\right).$$

Using the partial equation, from where cosλ = ξrlsinλ, and the integral, we get

$$\int_0^l X^2(x)dx,$$

the dependence from which we find constant integrations

$$C_n\omega_n\square_n^2 = \varphi_0\frac{l}{\lambda_n},$$

$$C_n = \varphi_0\frac{2}{\omega_n\lambda_n}\frac{1}{(1 + \xi^2\lambda^2 + \xi)\sin^2\lambda_n} = 2\frac{\varphi_0 l}{c\lambda_n^2}\frac{1}{1 + \xi\sin^2\lambda_n},$$

$$c = \sqrt{GI_p/I}.$$

This is how we get the equation for the angles of rotation of the shaft

$$\varphi(x,t) = 2\frac{\varphi_0 l}{c}\sum_{n=1}^{\infty}\frac{\sin r_n x\cdot\sin\omega_n t}{\lambda_n^2(1 + \xi\sin^2\lambda_n)}.$$

Hence, by differentiation, we find the torque equation

$$M_x(x,t) = GI_p\varphi'(x,t) = 2\varphi_0\sqrt{IGI_p}\cdot\sum_{n=1}^{\infty}\frac{\cos r_n x\cdot\sin\omega_n t}{\lambda_n(1+\xi\sin^2\lambda_n)}.$$

Presentation of the main material

For medium-carbon ferritic-pearlite steels, the carbon content or the amount of pearlite in the structure is the main factor in the change in strength and plasticity. An increase in the carbon content reduces the impact viscosity and increases the temperature of the visco-brittle state. The most attractive properties are medium-carbon and medium-alloy steels (0.3—0.5 % C; σ 0.2 = 700...850 MPa, σv = 900—1100 MPa) [5]. These steels are characterized by increased strength properties, low sensitivity to stress concentrators, high durability and sufficient viscosity. High-strength medium-alloyed steels with a C content of 0.4 % provide σv = 2100 MPa [6—8]. Indicators of physical and mechanical properties have their own dimensions and are characterized by the corresponding physical processes. There was a need to bring indicators to a single measurement and evaluation base (Fig. 2). A universal indicator for evaluating multidimensional indicators is a percentage ratio. Thus, measurements of, for example, boron coatings, microhardness on the surface of the hardened part to the core, will vary from the maximum to the nominal value that can be taken, respectively — Nmax — 100 %, Ncer — 80 %, Nmin — 60 %, under the actual measurement condition — Nmax = 16000 MPa; Nser = 12000 MPa; Nmin = 8000 MPa. We also use similar assumptions for other indicators (E (MPa), Kp, σv (MPa), σt (MPa), CSU (J/cm2), δ (%), Ψ(%).

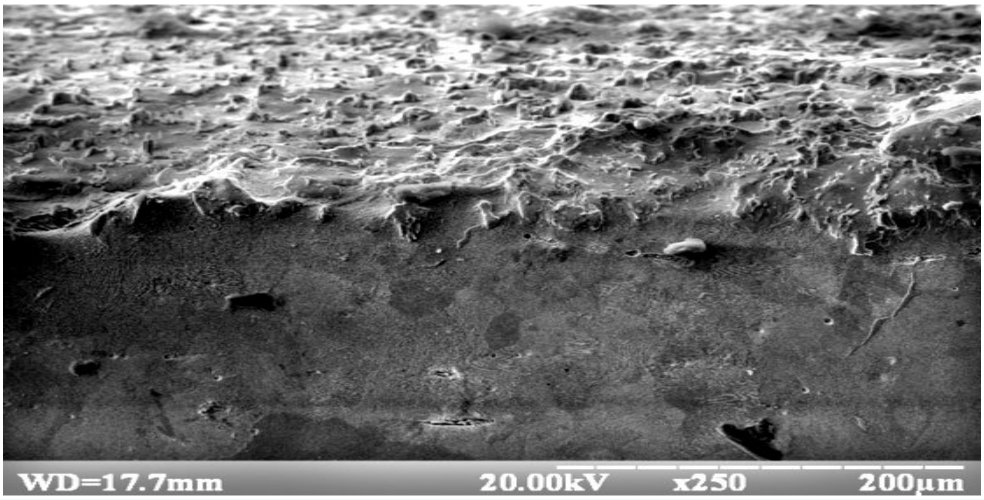

Fig. 2. Microstructure of the surface layer of steel 45 after hardening treatment technology

Summarizing the differences in percentage size allows you to build a generalized model of the composition of physical and mechanical properties for each method of strengthening parts and highlight the optimal balance of component characteristics (Fig. 3) [8—9].

An analysis of the existing technological methods of strengthening the surface layer of the part was carried out. The dynamics of the transformation of the microstructure during the implementation of a number of technological methods of strengthening have been studied. A graphical model of the dependence of the hardness of the surface layer of steel 45 on the technology of strengthening treatment was developed.

Conclusions

A mathematical model of the load of the crankshaft was obtained, which allows to take into account the complex of real loads with high accuracy, to determine the optimal method and processing technology to increase wear resistance, as well as the graphical dependence of the complex of physical and mechanical properties of materials based on strengthening methods.

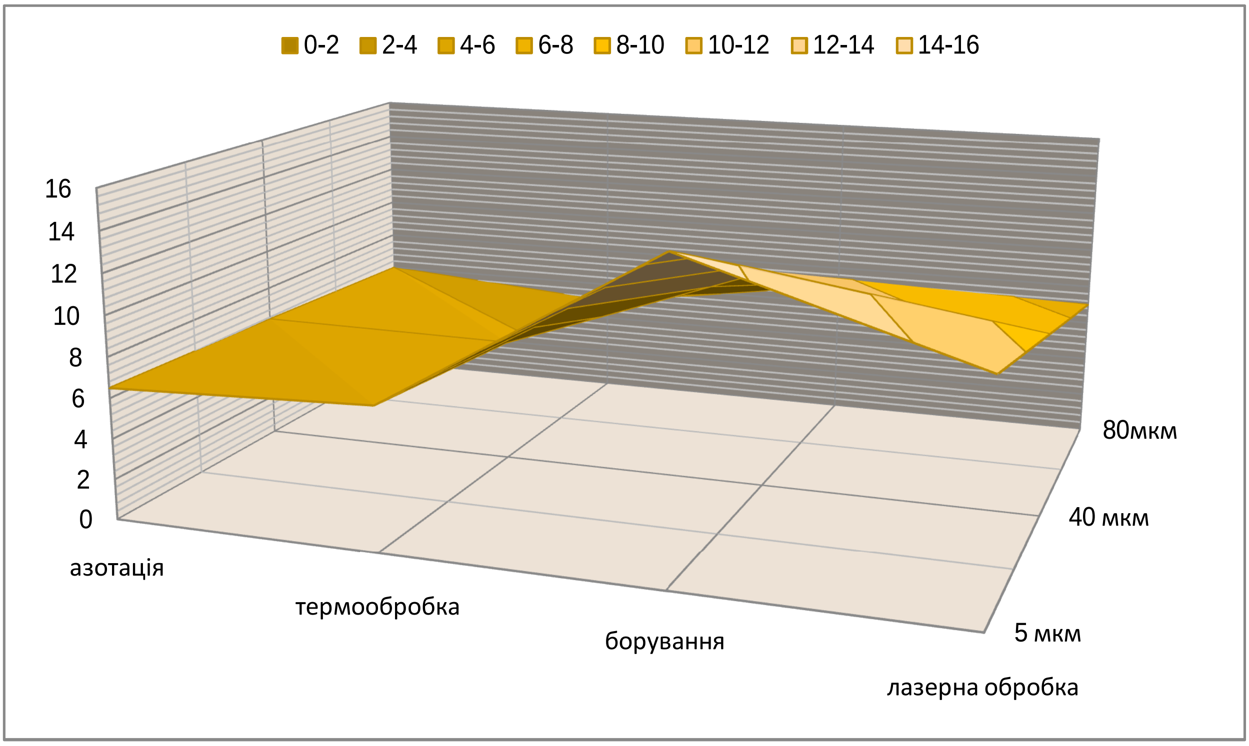

Fig. 3. Graphical dependence of the complex of physical and mechanical properties of the material on the methods of hardening

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