Serbian Tribology Society

SERBIATRIB '13

13th International Conference on Tribology

Faculty of Engineering in Kragujevac

Kragujevac, Serbia, 15 – 17 May 2013

EQUILIBRIUM STATE FORMATION FEATURES OF SURFACE LAYERS OF MACHINE PARTS

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Abstract: *The article describes the problem of forming the equilibrium state of surface layer of friction units. The possibility of taking into account the parameters of the lubricant in the mathematical model of the relationship of the wear rate with the equilibrium parameters of surface layer of parts is considered. Possibility of technological support equilibrium parameters of surface layer of machine parts is discussed.*

Keywords: *friction, wear rate, surface layer, machining, quality parameters, equilibrium state.*

1. INTRODUCTION

Practice of exploitation of machines and mechanisms shows that one of the major causes of failures of various kinds of equipment is the destruction of its parts or wear. Destruction and wear usually begins with working surfaces, so the state of the last often becomes the dominant factor in determining the reliability and durability of manufactured equipment.

Study the wear of machine parts friction units indicate that the transition to the normal process of wear most of them are directed to change their initial geometry.

During the break-in such quality parameters of machine parts undergo significant changes as profile deviation, waviness, roughness of their surfaces, as well as the physical and mechanical characteristics of the surface layer. If time and the wear are large enough, the stable steady state is reached tribosystem when the geometry of parts surfaces becomes conformal.

2. THE STUDIED PHYSICAL MODEL

Research the wear can provide a theoretical justification of the possibility of existence of stable reproducing geometric shapes of surfaces and their physical and mechanical properties in wear process in the given conditions of relative motion and loading.

This rationale is based on the fundamental principles of thermodynamics of dissipative systems, which tribosystem are.

Such systems can exchange with other systems and the environment energy and mass (eg, mass worn out particles), so stationary states characterized by a constant gradient of entropy can occur

$$\Delta S = S^{\circ} - S = \text{const}, \quad (1)$$

where S°– entropy of the equilibrium state of the system; S – instantaneous entropy of the system.

In the steady state, all the processes of heat and mass transfer are independent of time, as determined by the configuration of the system only in general terms and conditions on its borders.

Tribosystem exhibit properties of self-organization consist of to consistently reproduce the macroscopic space-time structures that can exist only through the exchange of flows of energy (matter).

Under self-limitation created by nature, as tribosystem located on the border of artificial devices and natural systems, and the self-organization can arise from a chaotic state, that is, the initial conditions do not matter, and the running-in period, of course, increases and decreases life of the friction units.

The equilibrium state of the surface is determined by the minimum of its free energy, which may differ from the minimum of surface, which is responsible for one of the reasons for the deviation of the real surface of the crystal from the initially smooth and the emergence of so-called natural roughness [3]. Such modifications of surface geometry are sub roughness, which significantly exceeds the atomic scale roughness arising at vibrations of the atoms or molecules due to thermal fluctuations.

The most appropriate criterion for selecting materials for the parts of tribosystems can be taken minimum value of frictional work [4].

Friction work calculated by the formula [5]

$$W_{fr} = fFS_{fr}, \quad (2)$$

where F – normal force of friction pair elements interaction; f – a friction coefficient; S_{fr} – friction track.

Tribosystem are open thermodynamic systems that exchange energy and matter with the environment. Friction is the process of converting the external mechanical energy into internal energy in the form of vibration and wave motion of particles of tribosystem followed by thermal, thermionic, acoustic, and other phenomena. Most of this energy is converted into heat and is given to the environment, the other - is to change the physical and chemical state of the surface layers of the material. Dissipation of energy corresponds to an increase of entropy ($dS > 0$).

Energy balance of tribosystem according to the first law of thermodynamics describes by the equation.

$$W_{fr} = q + \Delta W . \quad (3)$$

where q – energy of heat exchange with the environment, ΔW – change of internal energy is the sum of the energy used to change the structure of the material and energy of heating.

At the same time, the work of the friction force is the sum of the work of plastic deformation, hysteresis loss and the elastic deformation of the dispersion, that is, the work expended in the formation of new surfaces and associated with the surface energy of solids [6, 7].

The basis of the thermodynamic approach to fracture and wear of solids is energy mechanical analogy (deformation) and thermal (melting and sublimation) of failure.

The energy spent on the deformation and fracture of solid bodies, compared with one of the thermodynamic characteristics of the material (heat of sublimation enthalpy of the solid and liquid state, latent heat of fusion). In this case, it is assumed that thermodynamic properties are independent of the structure of the material. The body is treated as a continuous, homogeneous, isotropic medium with a statistically uniformly distributed structural elements.

Plastic deformation is considered as a combination of a large number of acts of microscopic atomic-molecular rearrangements associated with the generation of sources of deformation (dislocations).

Plastic deformation of the surface temperature below the recrystallization temperature leads to work hardening of the surface layer and its strengthening. At widely differing hardness structural components of the material and repeated exposure of loading occurs initially high wear of soft base; specific pressures acting on the solid component thereby increasing, solid components are pressed into a soft base, some of them are broken up and moved further under the forces of friction. As a result of such selective wear surface enriched solid structural components and gets stitch structure that during wear of babbit, for example, according to research of M. M. Khrushchov and A. L. Kuritsyna [8].

As a result of the interaction of the interfaced parts new surfaces are formed, which is followed by the energy release, γ_{ef}, consumed for its forming [6]:

$$\gamma_{ef} = f(F, Rz, HV), \quad (4)$$

where F – the normal force of friction pair elements interaction; Rz – ten point height of irregularities [9].

Rough surface can be considered as a set of irregularities randomly located on a perfect surface and having a random size, in other words, as the realization of the random field. This approach makes it possible to represent the surface as a scalar random function [10]

$$z = z(t, \omega), \quad (5)$$

where the parameter t runs through the set of values of T, defined by the spatial arrangement of the rough surface; ω – elementary event of a probability space Ω.

To determine the surface characteristics required for calculations in tribology, often enough knowledge only first two derivatives of the function $z(t, \omega)$. Thus there is a need to calculate the density of the joint distribution of several random variables.

Quantify the contact of rough surfaces is an important step in the development of physical models of frictional interaction. It requires consideration of both the characteristics of the roughness, and the specific properties of the contacting bodies, depending on their internal structure, loading time and environmental conditions.

Most of the friction units of products used in engineering works in conditions of oiling This requires a comprehensive study of processes in the area of friction as lubricant in some way facilitates extraction of heat from the friction contact zone, the removal of the zone of wear and corrosion protection, and the protection of the friction surfaces and other structures from the effects of the environment and also seal gaps, etc.

Taking into consideration that expression, V_W / S_{fr} (V_W – the volume of the worn material, S_{fr} – the friction track) represents the value of the wear rate J_V [11], and 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 [12]

$$\Delta W = f\left(HV, HV_0, \alpha_0, G\right), \tag{6}$$

where G – a displacement module of an examined material; α_0 – a 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; based on energy-based approach to the problem of defining the relationship of the wear rate of work surfaces of machine parts with quality parameters of the surface layer the wear rate functional relationship with geometrical (roughness) and physico-mechanical (degree of work hardening) parameters of surface layer of machine parts during normal operation can be represented a

$$J_V = \frac{0{,}55FG(0{,}9 f\pi S_{fr} Rz_{bal}\sigma_{0,2} + 4F)\exp(200/T)}{\pi S_{fr} Rz_{bal} N_{bal}^2 HV_0^2 \sigma_{0,2}} \tag{7}$$

where J_V – the wear rate [m^3/m]; F – the normal force of friction pair elements interaction [N]; f – a friction coefficient; S_{fr} – the friction track [m]; Rz_{bal} – the balanced roughness of the interfaced surfaces of the components [m]; $\sigma_{0,2}$ – the yield strength conditional with the tolerance of 0,2% for the value of the plastic deformation at stressing [Pa]; T – the temperature in friction area [K]; N_{bal} – the balanced degree of hardening; HV_0 – a microhardness of a undeformed material [Pa].

3. CONCLUSION

On the basis of [13] can be defined relationship equilibrium parameters of surface layer parts with machining process parameters.

The analysis of the experimental research results of the wear rate of contacted surfaces after machining has shown that the received mathematical model of the correlation between the wear rate and the technological requirements of machining allows for calculating the wear rate of the interfaced machine components after the running-in period.

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