Modeling of fatigue wear of coatings from viscoelastic materials

Elena Torskaya[1)*] and Fedor Stepanov[1)]

[1)]Laboratory of Tribology, Ishlinsky Institute for Problems in Mechanics RAS, Russia
*Corresponding author: torskaya@mail.ru

New model is developed for studying the kinetics of fatigue wear of a coating made of viscoelastic material, bonded to a rigid substrate. The fatigue mechanism is due to the cyclic interaction of the coating with a rough counter-body, which is modeled by a system of smooth indenters. The model includes quasi static contact problem solution for a slider and viscoelastic coating, the calculation of internal stresses taking into account the mutual effect, and the study of damage accumulation in the material. The interconnected process of decreasing of the coating thickness and changing the contact conditions is analyzed.

Keywords: sliding contact, viscoelasticity, coating, damage, fatigue wear

1. Introduction

Fatigue wear exists due to discreteness of real contact, which causes multiple cyclic loading of surface layers during friction. Damage accumulation caused by stress fluctuations in material at the microlevel; depending on the material the criterion of damage function should contain tensile or principal shear or other stresses. The criterion of reduced stresses, which was confirmed in the experiments described in [1], was used in [2] to model the fatigue wear of elastomers. This paper presents the results of modeling the fatigue wear of viscoelastic coatings.

2. Modeling steps and results

Solution of a quasi-static contact problem for a slider and a viscoelastic layer bonded to a rigid half-space. In conditions of multiple contacts, it is correct to take into account the mutual effect, as it was done in [2], but here an isolated slider is considered. A semi-analytical method for solving this contact problem is described in [3]. Later it was shown that in the case of a compliant viscoelastic coating, the mutual effect is less than for a viscoelastic half-space.

In the next step the internal stresses in the viscoelastic layer are calculated. The method for calculating is given in [3]. At this stage to simulate a discrete contact a periodic system of indenters is considered, where an important parameter is the average pressure over the period p_n. The stresses are determined taking into account the mutual effect by the superposition method.

Following [2] reduced stresses σ_p are taken as a criterion of damage accumulation, usually associated with the amplitude values of stresses. Damage function is calculated at different points in time t:

$$Q(z,N) = \int_0^N g\left(\frac{\Delta\sigma_p(z,t)}{E}\right)^m \Delta t\, dn + Q_0(z) \qquad (1)$$

Here Q_0 is an initial damage of material, g and m are phenomenological constants of material, Δt is one cycle period. Because of sliding the damage function does not depend on the coordinates x and y and is a function of the coordinate z and time only. Average pressure p_n can be considered as time independent constant if the surface of the counter-body is well defined. Another approach is to use p_n randomly distributed in time; it is the simplest way to model damage accumulation in material in the real friction conditions.

Incubation period is finished when (after N* cycles, see Fig.1) damage accumulates up to a critical value Q*. Detachment of damaged material occurs; and further calculations of damage function in time result in determination of linear wear rate. A feature of this study is the continuous change in contact characteristics and stress state with the coating thickness decrease due to wear. In Fig.1,a damage function inside the layer is presented for *N/N**= 1, 1.35, 1.53, 1.63, 1.73, 1.80, 1.85, 1.90 for curves 1-8. Layer – half-space interface is $z=0$. In Fig.1,b the decrease of the layer thickness in time is illustrated for two non-dimensional values of sliding velocity V'=0.0208,0.0625 (curves 1 and 2).

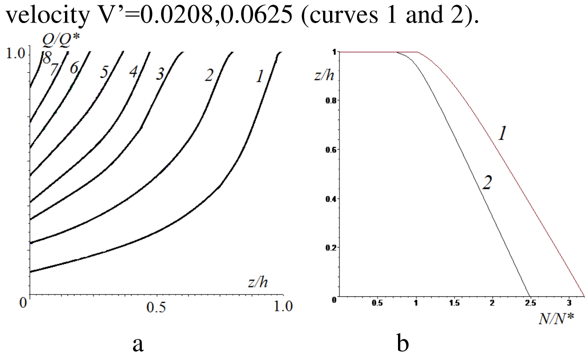

Figure 1: Damage function (a) and wear kinetics (b).

The results presented above are obtained for a constant value of p_n. We also analyzed the influence of the rheological properties of material, the geometry of the system of indenters, the type of function $p_n(t)$ on the accumulation of damage and the rate of linear wear.

Funding: Russian Science Foundation (18-19-00574).

3. References

[1] Kragelsky, I.V., Nepomniachtchi, E.F. "The theory of wear of highly elastic materials", Plastics in sliding bearings, Moscow, Nauka, 1965, 49–56 [in Russian].

[2] Goryacheva, I. G. et al., "Fatigue wear modeling of elastomers", Phys. Mesomech., 22, 1, 2019, 65–72.

[3] Torskaya, E. V., Stepanov, F. I. "Effect of surface layers in sliding contact of viscoelastic solids (3-d model of material)", Frontiers in Mech. Eng., 5, 2019, 26.