Effect of the Gap Conditions in Sliding Contact of the Periodic Punch on the Viscoelastic Foundation

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Surface microgeometry has the significant effect in sliding contact of viscoelastic bodies. The cyclic deformation of the contacting bodies in sliding causes the hysteretic losses in the material and leads to the friction force. The classical approach to study the friction of viscoelastic rough bodies is based on calculating hysteresis losses and adhesion for each asperity or a system of separate asperities with given shape of tips. In the present study, friction is modeled taking into account the whole surface geometry - both tips of asperities and valleys between them. The various conditions inside the valleys are considered: the molecular adhesion between the contacting surfaces, no adhesion, or existence of an incompressible fluid in the gap. Both analytical and numerical methods are used to solve the periodic contact problems and to analyze the effect of the gap conditions on the contact pressure, real contact area, and friction force for various loading, velocity and microgeometry parameters.

The model suggested is based on the solution of the contact problem for a 3D wavy surface sliding with the constant velocity v along the *x*-axis on the boundary of a viscoelastic foundation taking into account the molecular attraction in the gap between the bodies. The shape of the wavy surface is described by the periodic function. (Fig. 1).

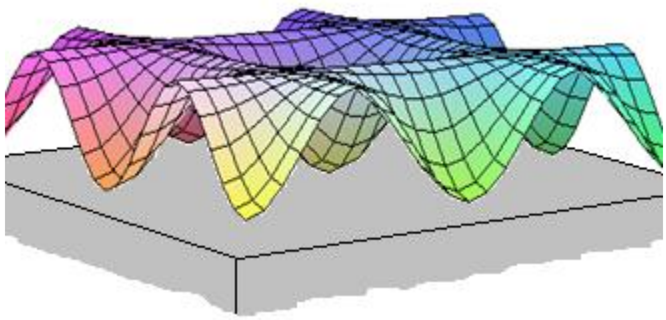
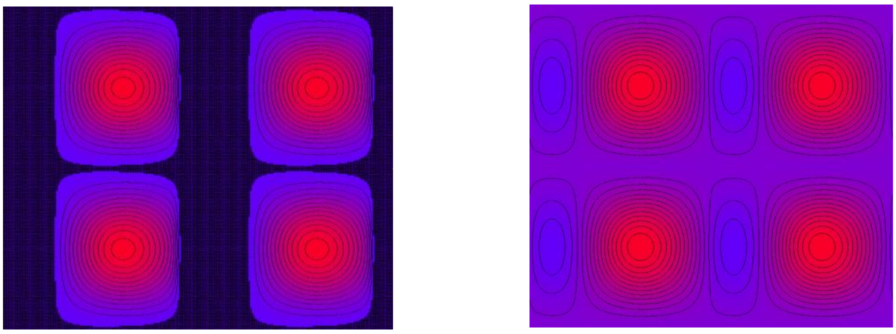


Fig. 1. Scheme of contact between a rigid wavy surface and a viscoelastic foundation.

The mechanical properties of the viscoelastic foundation are described by the linear 1-D model. To take into account the adhesive (molecular) attraction between the surfaces, the negative adhesive stress $p = -p_a(\delta)$ acting on the boundary of the viscoelastic foundation is considered, where δ is the value of gap between the surfaces. The Lennard-Jones function and its Maugis-Dugdale approximation are used to describe the dependence of the adhesive stress on the gap between the surfaces.

The 3D contact problem is solved by dividing the zone of interaction into strips (Kalker, 1990). In each strip a 2D contact problem is solved. The boundary conditions for the contact pressures and displacements in each strip are formulated with taking into account various regimes of the gap filling: saturated contact, discrete contact with saturated adhesive interaction, discrete contact with zones of adhesive interaction and zones of free boundary, and the existence of the incompressible fluid of the given volume inside the valleys which can support the load.



a b

Fig.2 Contact spots calculated by neglecting adhesion (a) and taking into account adhesion effect (b) for the same load applied to each period and the same velocity.

Results of calculations are used for analysis of the combined effect of surface roughness and adhesion, or surface roughness and fluid inside the valleys on friction force in sliding contact of viscoelastic bodies.

The results indicate that due to adhesion

- a significant increase in the real contact area and hysteretic friction force arises,
- the contact saturation occurs at lower loads (see Fig.2),
- a contact between surfaces exists even for negative (tensile) loads.

The results also indicate that the real contact area and the friction force decrease due to existence of the incompressible fluid inside the valleys.

The results obtained can be used for evaluation of the friction force at various scale levels of roughness under different contact conditions. In particular, it was shown that the adhesive friction plays the important role for micro- and nano-scale levels for which the size of the gap is close in order of magnitude to the radius of adhesive forces action.

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