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FRICTIONAL CHARACTERISTICS OF RANDOMLY ROUGH HERTZIAN CONTACTS IN PARTIAL SLIP

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ABSTRACT

Although the dissipation of energy is, in some ways, a phenomenon to be avoided, because it leads to surface damage, it is, at the same time, useful in a range of circumstances where absorption of mechanical energy is desirable, such as a frictional energy damper. Oscillating frictional contacts will be object of the present investigation.
Topographically smooth Hertzian contacts dissipate energy by frictional hysteresis when they are subjected to a constant normal load and oscillatory tangential shear. The details of the mechanism underlying this phenomenon have been known for over sixty years, since the pioneering solution of Cattaneo [1] and Mindlin [2]. It has proved extremely helpful in understanding the performance of many problems undergoing the so-called ‘partial slip’ regime, which is encountered in a number of applications where fretting damage plays a significant role [3]. An important generalisation of the Cattaneo-Mindlin procedure was recently developed independently by Jäger [4] and by Ciavarella [5], who show that, in any single or multiply-connected plane contact the Cattaneo procedure for scaling the corrective shear traction will apply and the technique may be applied with only limited error to a three-dimensional problem.

The design of frictional dampers is currently of considerable interest, particularly in the gas turbine industry, and the limitations of the classical solution are becoming more apparent in various ways. For example, it is not clear that a classical friction law will continue to apply at very small contact dimensions and another problem, addressed here, is the effect of surface roughness. There are many ways in which roughness can be tackled in contact problems, and the approach taken is a very idealised one, intended (a) to expose the general nature of the behaviour of partial slip contacts in the presence of imperfections, (b) to give some idea of the different distribution of dissipation present in a rough contact compared with a smooth one, and (c) to reveal the tangential compliance of the contact, together with its hysteresis loop.

In [6] we have tackled the geometrically very simple problem of an axi-symmetric sphere, of radius R, is pressed normally, by a force P, onto a surface consisting of an array of spherical asperities, of radius ρ, regularly spaced on a grid composed of equilateral triangles. All the asperities were assumed to have the same height in this very simplified model.

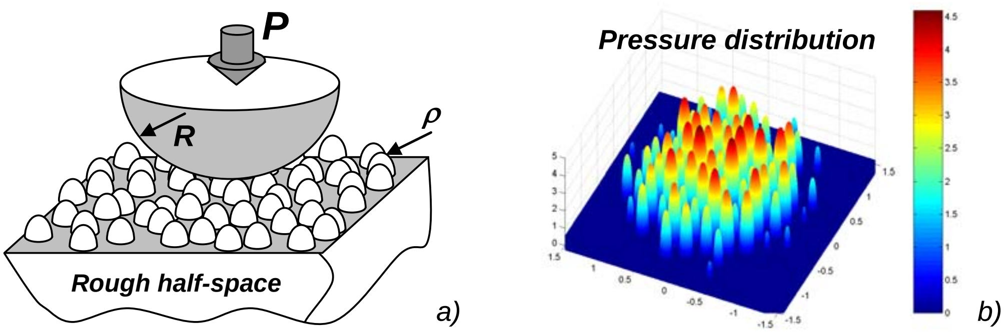

Figure 1. (a) Schematic of the idealised problem under investigation and (b) Pressure distribution induced by the application of normal load.

Here we extend the problem by allowing the asperities heights (and tip radii) to vary (Fig. 1(a)). The first step in the calculation is to determine the number of asperities in contact for a given applied load, the load each individual asperity carries, and the resultant contact pressure distribution (Fig. 1(b)). The solution of the contact problem obtained for various *rms* roughnesses, shows how small deviations in asperity structure lead to large changes in local maximum pressure (Fig. 2(a)).

The partial slip contact problem is subsequently investigated. In the rough form of the contact, we expect those asperities lying in the macroscopic stick region to be in partial slip, and those in the macroscopic slip region to be in sliding. The frictional loops corresponding to local asperities are therefore considered (Fig. 2(b)).

Extensions of the proposed technique to real 3D contacts are also discussed.

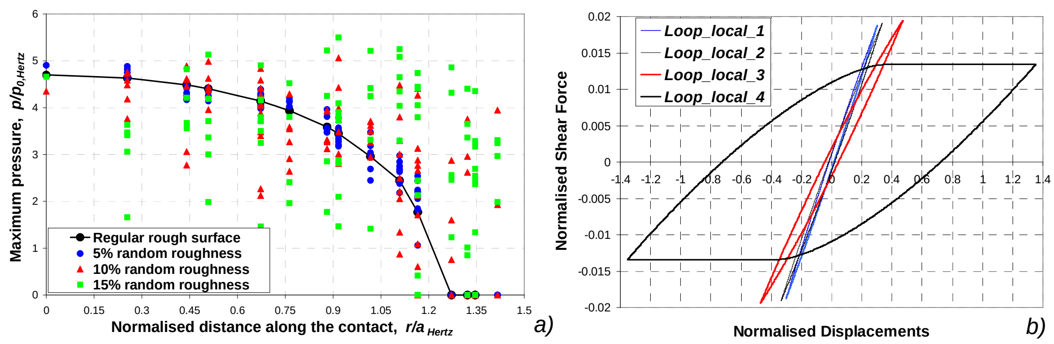

Figure 2. (a) Peak pressure variation at asperity level as a function of the rms roughness and (b) frictional hysteretic loops at asperity level.

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