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A Stochastic Analysis of Plastic Area on Rough Surface Contact in Relation with Transition from Mild to Severe Wear

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1. Introduction

Burwell and Strang [1] considered that the transition from mild to severe wear mode would occur when the total area of plastic regions on a soft surface contacting with a hard surface reaches to the apparent contact area. This paper presents a stochastic analysis of the total area of plastic regions on a flat surface contacting with a rough surface to estimate severity of contact.

2. Analysis

The contact analysis has been made for Greenwood-Williamson's roughness model [2] consisting of a series of spherical caps each with the same radius of curvature, *R*, and having a Gaussian distribution of heights of standard deviation σ^*. Johnson' cavity model [3] has been employed for an indentation of each rigid spherical asperity against a flat surface to estimate the plastic area at each asperity contact, shown in Fig. 1 and Eq. (1).

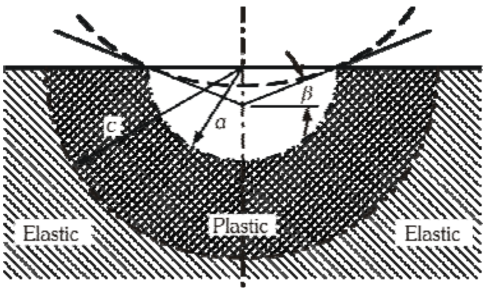

Fig. 1 K. L. Johnson's cavity model [3]

$$\frac{c}{a} = \left(\frac{\frac{E \tan \beta}{Y} + 4(1 - 2\nu)}{6(1 - \nu)} \right)^{1/3} \qquad (1)$$

where c is radius of plastic region, a is radius of contact area, *E* is equivalent Young's modulus, *Y* is yield stress of softer material, n is Poisson's ratio. If the indent depth $\delta << R$, $\tan\beta$ *in* Eq. (1) becomes approximately as

$$\tan\beta = \frac{a}{R-\delta} = \frac{\sqrt{2R\delta - \delta^2}}{R-\delta} \approx \sqrt{\frac{2\delta}{R}}\left(1 + \frac{\delta}{2R}\right)$$

Neglecting the overlap between adjoining plastic regions, the ratio of the total plastic area to the apparent contact area, A_p/A_n, which denotes severity of the contact, can be expressed in terms of the asperity summit height distribution function $\phi(z)$ as

$$A_p / A_n = \frac{2\pi\eta R\sigma^*}{\{6(1-\nu)\}^{2/3}} F_p\left(d^*\right) \qquad (2)$$

where η is the areal density of asperities and

$$F_p\left(d^*\right) = \int_{d_*}^{\infty} (z^* - d^*) \left(\frac{E}{Y}\sqrt{\frac{2(z^*-d^*)}{R^*}}\left(1 + \frac{(z^*-d^*)}{R^*}\right) + 4(1-2\nu) \right)^{2/3} \phi^*(z^*) dz^* \qquad (3)$$

where $z^* = z/\sigma^*$ (*z* is the asperity height measured from the mean of asperity heights)、$d^* = d/\sigma^*$, $\phi^*(z^*)$ is the dimensionless height distribution standardized by σ^*.

The relation between the apparent contact pressure, *p*, and the distance of surfaces, *d*, has been obtained with CEB model [4] which is an elastic-plastic contact model of rough surfaces and the nominal contact pressure can be expressed as.

$$p(d) = \eta E\left\{\frac{3}{4}R^{1/2}\int_d^{d+\delta_c}(z-d)^{3/2}\phi(z)dz\right\} + \pi\eta RH\int_{d+\delta_c}^{\infty}\{2(z-d)-\delta_c\}\phi(z)dz \qquad (4)$$

where δ_c is the critical interference at the inception plastic deformation. For given nominal contact pressure we can obtain the distance of surfaces from Eq. (4) and then we can estimate the severity of the contact from Eqs. (2) and (3).

3. Results and Summary

The product of η, *R* and σ^* in Eq. (2) is approximately constant and the Eq. (3) indicates that the function depends only to $1/R^* = \sigma^*/R$ as for the roughness parameters and thus the ratio of the total plastic area to the nominal contact area, i.e. severity of contact, has good correlation with σ^*/R. In the meantime the plasticity index is written as $\psi = (E/H)(\sigma^*/R)^{1/2}$ [2] and Hirst and Hollander [5] showed that the upper boundary between unsafe and safe surfaces coincides with a line of constant in plasticity index on the criterion map of the transition load. The analysis in this paper supports the experimental results by Hirst and Hollander [5].

4. References

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