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Plastic and slipping zones at the adhered complete contact edge of elastically dissimilar materials

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Slipping at a sharp contact edge is studied. An eigenvalue problem of a complete contact between elastically dissimilar materials is considered. A slipping is thought to take place in the region where the ratio of the shear to normal stresses is greater than the coefficient of friction (COF) on the contact. Whereas, the contacting bodies will yield at the sharp edge owing to the inevitably occurring high stress values at the edge. The size of the slipping and plastic zones is compared to consider the propensity to either a tribological failure or a fatigue one.

Keywords: complete contact, edge slipping, plastic zone, elastically dissimilar, failure

1. Introduction

In an adhered complete contact problem, an interface slipping is supposed to take place in the region, $\sigma_{r\theta}/\sigma_{\theta\theta} \geq f$ where $\sigma_{r\theta}$, $\sigma_{\theta\theta}$ and f are the shear, normal surface tractions and the coefficient of friction (COF), respectively. The leading edge slip in the vicinity of the sharp contact edge is of primary concern because it is the location of stress intensification where the asymptote is considered. Simultaneously, a plastic zone can also be concerned in that location owing to the intensification. It is interesting to compare the size of the slip and plastic regions on the interface (x_s and x_p, respectively) in the vicinity of the edge because either a tribological failure or a fatigue failure is brought into focus corresponding to $x_s > x_p$ or $x_p > x_s$. The condition of $x_s = x_p$ is investigated here incorporating the material dissimilarity of the contacting bodies.

2. Analysis

First, we proposed a contact between a quarter plane (indenter, body 2) and a half plane (substrate, body 1) whose elastic properties are different. An asymptotic analysis has been carried out, and the eigen-solutions of the stress components together with the order of singularities were obtained, whose asymptotic forms are expressed as follows [1].

$$\frac{\sigma_{ij}}{G_o} = \left(\frac{r}{d_o}\right)^{\lambda_I-1} f_{ij}^{I}(\theta) + \left(\frac{r}{d_o}\right)^{\lambda_{II}-1} f_{ij}^{II}(\theta)\,, (i,j) = (r,\theta)\ ;$$

$$G_o = (K_I)^{\frac{\lambda_{II}-1}{\lambda_{II}-\lambda_I}} \cdot (K_{II})^{\frac{\lambda_I-1}{\lambda_I-\lambda_{II}}} \text{ and } d_o = (K_{II}/K_I)^{\frac{1}{\lambda_I-\lambda_{II}}} \quad (1)$$

where λ_I, λ_{II} are the eigenvalues, which provide the order of stress singularities (λ_I-1, λ_{II}-1). $f_{ij}^{I}(\theta)$, $f_{ij}^{II}(\theta)$ are the angular functions, which show the spatial variation of the stresses. K_I and K_{II} are the generalized stress intensity factors at the contact edge.

The slip zone size, x_s, was obtained from $\sigma_{r\theta}/\sigma_{\theta\theta}=f$. Then, the following equation was derived.

$$\frac{x_s}{d_o} = \left[\frac{f_{r\theta}^{II}(0) - f\cdot f_{\theta\theta}^{II}(0)}{f_{r\theta}^{I}(0) - f\cdot f_{\theta\theta}^{I}(0)}\right]^{\frac{1}{\lambda_I-\lambda_{II}}}. \quad (2)$$

In turn, the plastic zone size, x_p, can be obtained by letting $J_2 = 3k_i^2$ (i = 1 or 2, the body number) where J_2 and k_i are the second invariant of the deviatoric stress tensor and the shear strength in pure shear of the materials in contact, respectively. Finally, G_o/k_i (i = 1,2) for $x_s = x_p$ is evaluated by substituting Eq. (1) into J_2, and letting $r = x_s$ and $\sigma_{zz} = \nu(\sigma_{rr} + \sigma_{\theta\theta})$ for a plane strain condition.

3. Results and Discussion

Figure 1 shows $\sigma_{r\theta}/\sigma_{\theta\theta}$ at λ_I (here, $\lambda_I < \lambda_{II}$), and the results of G_o/k_1, G_o/k_2 for $x_s = x_p$ and $f = 0.3$, as an example, plotted in the domain of the Dundurs parallelogram, (α,β). As anticipated, a leading edge slip does not occur in the region of $\sigma_{r\theta}/\sigma_{\theta\theta} < 0.3$. It is found that G_o/k_i needs to be increased as the indenter tends to be incompressible and the substrate rigid for $x_s = x_p$. The influence of the material dissimilarity and COF on x_s will be discussed in detail.

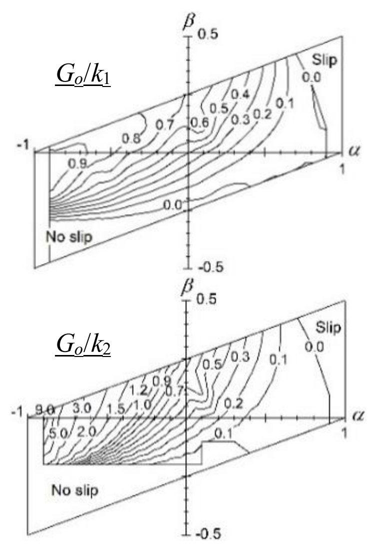

Figure 1: Plots of G_o/k_1 and G_o/k_2 for $x_s = x_p$ and f = 0.3.

4. References

[1] Kim H.-K. et al., "Asymptotic analysis of an adhered complete contact between elastically dissimilar materials," J. Strain Analy., 49, 2014, 607-617.