Surface Stress and Microstructural Effects on Elastic Substrate Contact Problems

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Abstract

This work presents an elastic contact model for a half-space indented by a rigid, axisymmetric indenter under frictionless conditions, explicitly accounting for the influence of surface energy and intrinsic material microstructures. The mechanical response of the bulk substrate is characterized using couple stress theory, while surface elasticity theory governs the behavior of the surface layer. The contact pressure distribution is obtained by formulating a governing equation based on force equilibrium and displacement compatibility within the contact region. A combination of finite element discretization, a collocation approach, and the linearity of the governing equations is employed to solve for the unknown pressure profile. The Hankel transform technique is used to analytically derive the fundamental solutions for surface displacement. The contact radius is determined through an iterative bisection algorithm. Comprehensive numerical simulations validate the proposed methodology and highlight the critical impact of both couple stresses and surface effects on the contact response. In particular, the results reveal pronounced size effects when the internal and external length scales are of similar magnitude.

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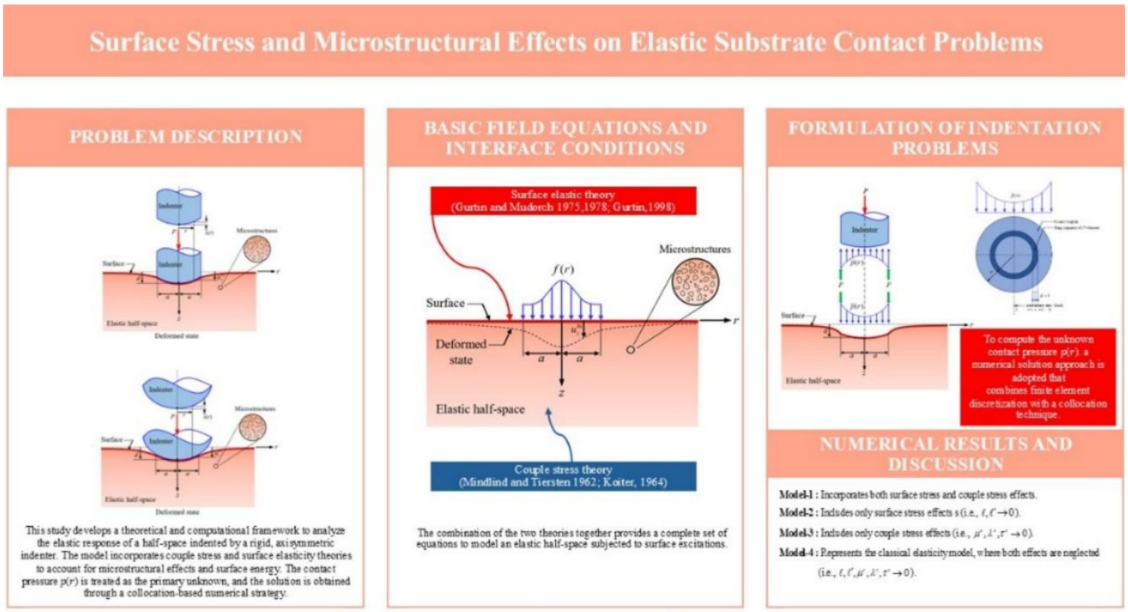

Innovative Description: Forming governing equations via indenter equilibrium and surface-displacement compatibility