
Construction of Johnson-Kendall-Roberts Relations for Adhesive Contact between an Indenter and an Elastic Layer of Arbitrary Thickness

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Abstract

The Johnson-Kendall-Roberts (JKR) theory invariably remains popular among researchers due to its simplicity and mathematical elegance. The theory was originally developed for the contact between two elastic spheres. The recent advances in the JKR formalism, however, led to the creation of a set of formulae suitable for explicit transformation of the non-adhesive force-displacement relations of a contact problem into the respective JKR adhesive ones, which brought an opportunity to construct the JKR relations on the basis of computational methods, e.g. the Finite Element Method (FEM).

Here we present an accurate and robust algorithm that allows conversion of a non-adhesive force-displacement relation obtained from an FEM simulation into the respective JKR force-displacement curve. Broadly speaking, the method can be applied without modification to a wide range of contact problems that involve an axisymmetric convex indenter and an elastic medium such as layers, multi-layered structures, finite size models etc. We discuss possible challenges that arise from the discrete approximate nature of FEM and ways to overcome those challenges. We show how a sequence of auxiliary FEM models can be used to improve overall accuracy and robustness of the process.

The robustness of the present method is demonstrated on a problem of contact between a rigid spherical indenter and a layer of finite thickness. The cases of both compressible and incompressible isotropic material are considered for a wide range of the dimensionless indenter radii (i.e. the results cover problems ranging from an asymptotically thick layer, to the layer of finite thickness, and then to an asymptotically thin layer). These results are in excellent agreement with existing analytical and numerical results published in the literature and the theoretical limiting scenarios.

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