

AN INVESTIGATION OF NONLINEAR TIP-SAMPLE FORCE MODELS FOR NANOINDENTATION

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ABSTRACT

Current physical models of tip-sample interactions in nanoindentation and atomic force microscopy are exclusively based on either the Johnson-Kendall-Roberts (JKR) or Derjaguin-Muller-Toporov (DMT) models of adhesive contact respectively. Analytical and numerical models bridging the transition regime between the two models have been demonstrated but their use has been limited due to the difficulty in obtaining a force relation in terms of displacement from them. The current thesis examines various transition models with aim of selecting a model from which a transitional force-displacement relation can be derived.

For this purpose, firstly a general equivalence between the newer Schwarz and the more established Maugis-Dugdale model is demonstrated through the comparison of critical forces from both the models. Since the Maugis-Dugdale model does not provide an expression for critical force, an analytical expression is derived and demonstrated to be valid. This conclusion allows us to derive a force expression from the Schwarz transitional model in terms of displacement. A new reformulation of the JKR and Schwarz models, in terms of a nondimensional parameter is also presented. The derived force expression is then expressed as a third-order polynomial through a series expansion. Since indentation models typically use linearized force expressions, it is demonstrated that a nonlinear third-order expression results in an economically viable accuracy. Finally a method of material parameter identification is outlined which coupled with existing nonlinear models of nanoindentation should result in greater accuracy in characterization.