Finite Element Based Unloading of an Elastic Plastic Spherical Stick Contact for Varying Tangent Modulus and Hardening Rule

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ABSTRACT

Loading-unloading behavior of a deformable sphere with a rigid flat under full stick contact condition is investigated for varying strain hardening. The study considers various tangent modulus using the finite element software ANSYS. Both the bilinear kinematic hardening and isotropic hardening models are considered. Numerical simulation reveals the qualitative similarity between kinematic and isotropic hardening regarding the variation of interfacial parameters during loading-unloading for various tangent modulus. It is found that the material with kinematic hardening dissipates more energy than the material with isotropic hardening during unloading. However for elastic perfectly plastic material, the loading-unloading behavior is insensitive to hardening model.

Keywords: ANSYS Software, Elastic-Plastic, Loading-Unloading, Sphere Against Flat, Stick Contact, Strain Hardening

INTRODUCTION

Loading-unloading of solid surfaces is inevitable in all the engineering applications to transmit force, motion and power etc. When studied carefully on a very fine scale, all solid surfaces are found to be rough with asperities. For the simplicity of calculation, asperities are assumed spherical at the tip. The study of elastic-plastic contact of a deformable sphere with a rigid flat gives an idea about the happenings when two rough surfaces are in contact. It is possible to predict the elastic response of solids under frictionless contact condition using Hertz (1882) theory. The stress is proportional to the strain within the elastic limit and the deformation is reversible. If the stress exceeds the critical value, the material is plastically deformed and there exists no longer a linear relationship between

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the stress and strain. There occurs permanent change in shape on unloading. The behavior of materials that have been stressed beyond the elastic region is usually described with bilinear hardening using tangent modulus. Kogut and Etsion (2002) (KE Model) considered the elastic-plastic contact of a hemisphere and a rigid flat under frictionless contact condition during loading. They investigated the effect of tangent modulus by varying it up to 0.1E, E being the elastic modulus, and found the difference of resulting contact parameters with that of elastic perfectly plastic material to be less than 20%.

Etsion et al. (2005) found that contact behavior was independent of the physical and geometrical properties of the sphere during unloading of an elastic-plastic loaded spherical contact with a rigid flat under perfect slip contact condition. They choose 2% isotropic linear hardening and observed a marginal variation of results with that of elastic perfectly plastic material. Kadin et al. (2007) studied the multiple loading-unloading of a deformable sphere against a rigid flat under frictionless contact condition. They observed slight additional hardening during the first unloading compared to the first loading. This hardening causes secondary plastic flow. They inferred that the incipient interference to cause secondary plastic flow increases with the increase in strain hardening. Shankar and Mayuram (2008) studied the elastic-plastic transition behavior in a hemisphere in contact with a rigid flat under frictionless contact condition accounting for the effect of realistic material behavior in terms of varying yield strengths and the isotropic strain hardening. They used three tangent modulus, 0.025E, 0.05E, and 0.1E and inferred that with the increase in tangent modulus, the transition from elastic-plastic to fully plastic state occurs in lower dimensionless interference ratio. Sahoo et al. (2010) considered the effect of strain hardening on interfacial parameters of deformable sphere with a rigid flat under frictionless contact condition during loading for a wide range of tangent modulus as high as 0.33E. They inferred that with the increase in strain hardening the resistance to deformation of a material is increased and the material becomes capable of carrying higher amount of load in a smaller contact area. Chatterjee and Sahoo (2010) analyzed the effect of strain hardening during unloading of an elastic plastic loaded sphere against a rigid flat under frictionless contact condition. They observed that higher tangent modulus (strain hardening) results lower residual interference when unloaded from a particular dimensionless interference; which in turn offers less resistance to full recovery of the original shape. Several researchers have considered full stick contact condition as well. Brizmer et al. (2006a) first analyzed the effect of full stick condition on the elasticity terminus of a spherical contact during loading. They found increasing differences in contact parameters with decreasing Poisson’s ratio compared to the perfect slip contact condition. Brizmer et al. (2006b) extended their study for the loading of an elastic plastic spherical contact both under full stick and perfect slip contact condition with 2% isotropic linear hardening and found that the interfacial parameters are insensitive to the contact condition and material properties of the deformable sphere. However they found the contact load and average contact pressure to be slightly affected by Poisson’s ratio for full stick contact condition. Zait et al. (2010a) performed the unloading of an elastic-plastic spherical contact under full stick contact condition with 2% isotropic linear hardening. They found a substantial variation in load-area curve during unloading under full stick contact condition compared to that of perfect slip contact condition.

The effect of strain hardening can be studied by relating the size and shape of the yield surface to plastic strain in some appropriate way (Bower, 2008). Most of the elastic-plastic contact models available in the literature are based either on linear isotropic hardening or with elastic-perfectly plastic materials. Some finite element models have also been proposed to simulate multiple, cyclic loading-unloading using bilinear kinematic hardening. Zait et al. (2010b) used both isotropic and kinematic hardening during the study of multiple normal loading-unloading cycles of a spherical contact.
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