A Study of Transient Dynamics with Frictional Contact: Oblique Elastic Impact of Spheres

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Abstract: *Oblique elastic impact of spheres and the related case for cylinders have been studied cases for many years in simulations of systems with loose supports, such as heat exchanger tube-support interaction, as well as granular flows and robotic task modeling. The problem is a relative simple one in the class of transient frictional contact problems in that the stresses away from the contact zone are typically neglected. The available continuum model solutions from literature show some very interesting features. For near normal angles of incidence, these solutions combine a Hertzian contact stress solution in the normal direction with a partial-slip shear stress distribution in the tangential direction, in which a central portion of the contact zone is sticking while the coincident points of the outer annulus slide relative to one another. Both stress distributions change rapidly over the impact duration. The partial-slip shear stress distribution is caused by the simultaneous inclusion of tangential compliance and friction effects, and gives rise to tangential force reversal prior to the loss of contact. Initial investigations using the penalty contact formulation in Abaqus/Explicit™ v. 6.7 show some very interesting results. Both the normal and shear stress results show smooth distributions, however the shear stress distributions show an unexpected antisymmetry. Nevertheless, the Abaqus/Explicit™ solution is able to capture the essential features of tangential force oscillation predicted by continuum models.*

Keywords: *Oblique elastic impact, friction, explicit dynamics, penalty contact.*

1. Introduction

Engineers commonly turn to finite element analysis to handle contact problems due to the difficulty of determining the interactions within the contact zone of the contacting bodies. This difficulty is caused by lack of available analytical solutions, particularly in the presence of friction, and the possibility of changes to the geometric configuration of the bodies in response to the contact forces, particularly in the transient dynamic solution of vibration dominated systems.

The formulation approach taken in finite element contact analysis is quite different than the analytical formulation of these problems (Laursen, 2002). Therefore, finite element formulations can lead to solutions that are independent of the assumptions common to continuum-based analytical solutions. Again, the lack of analytical solutions makes it difficult to evaluate the correctness of the finite element results in some cases. This fact accepted, however, it is not unreasonable to expect finite element solutions of relatively simple problems, even with complex interactions such as those introduced by friction, to match continuum based solutions.