MODELING THE IMPACT OF MICROPOLAR BODIES

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To improve the survivability of a material subjected to high stress rates associated with impact, it is necessary to understand the mechanisms responsible for a material's behavior and to develop predictive models capable of describing such behavior. Various experiments have been developed to characterize material properties by subjecting test specimens to uniaxial impact loads and measuring resulting deformations and propagating stress waves. Simplified, one-dimensional models, which may be solved analytically [1], have the following uses: (1) such models give insight into the behavior of materials subjected to impact, (2) they suggest desirable constitutive properties [2] or design parameters, and (3) they allow for the determination of constitutive properties from experimental results. Micropolar theories are often used in the study of polycrystalline and granular media due to their ability to capture behavior not described using classical continuum approaches [3]. These models possess additional degrees of freedom, which are often associated with rotation and described with an additional vector field when compared with classical continuum mechanics. For this work, a one-dimensional model is proposed to model the impact of a micropolar body kinematically described with two displacement fields: one field associated with longitudinal displacement and one associated with rotation. Note that the rotation is in the same direction as longitudinal displacement, leading to a material referred to as a noncentrosymmetric one-dimensional micropolar medium [4]. (This type of model is actually related to models used in the analysis of rope, helical springs, and wood fibers.)

Two second-order partial differential equations result from the application of the balance of momentum and the balance of angular momentum, yielding a mixed initial-boundary value problem consisting of initial conditions, matching conditions at the interface of the projectile and target, and boundary conditions on the free surfaces of the projectile and target. The resulting initial-boundary value problem is solved using Laplace transforms. It should also be noted that impact produces a transient loading, such that the harmonic solutions typically assumed for micropolar wave propagation problems may not be employed.

The results of this analysis show two different waves propagating at two different wave speeds for both the longitudinal and rotational displacements; the displacements may be used to obtain stress and couple stress waves traveling through projectile and target. By choosing the constitutive properties properly, the elastic solution may be recovered and the amount of coupling between longitudinal and rotational deformation may be controlled. It is hoped that this research will provide a first step in the development of models better suited to granular materials, in particular, the post-failure comminution behavior of armor-grade ceramics [5]. Results from this preliminary work also suggest that features associated with micropolar media may be studied using traditional plate impact tests.

References

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