Wave propagation in damaged ceramics

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Ceramics are used as a light-shielding material. When a projectile penetrates a ceramics target very complex phenomena (such as fragmentation, and pulverization) take place. One of the still misunderstood steps remains the behavior of ceramics just after fragmentation, i.e., the interaction between the projectile and the micro-cracked target and the wave propagation in damaged ceramics.

Two different types of mechanical models to describe damage in ceramics are considered. The first one is a micro-mechanics based damage model [1] where damage is introduced through a physical parameter. During the damage process the mechanical model loses its isotropy and its homogeneity but the geometric homogeneity is preserved. In the second one damage is introduced by the presence of microcracks in an isotropic and homogeneous elastic solid [2]. This geometric heterogeneity induces a loss of isotropy and of homogeneity. Both models take into account the physical reality, where geometric and material heterogeneities are present.

For both models we have used a discontinuous Galerkin (DG) numerical scheme, which ensures an efficient parallelization, with a leapfrog scheme for the time discretization and a Godunov-type choice of the flux. In the second model the main focus lies on the contact conditions at crack surfaces (including crack opening and closure and stick-and-slip with Coulomb friction). Here the interfacial numerical Godunov type flux is obtained by solving a non-linear and non-smooth system associated to the boundary conditions.

We have done some specific numerical simulations on wave propagation in a damaged ceramics using both models. The geometry and the boundary conditions of the numerical simulations were chosen to correspond to some experimental settings (see [3, 4]). The first one corresponds to a loading-unloading shock experiment using a gas launcher while the second corresponds to a two-step experiment: the pre-fragmentation of the ceramics using an electrical generator of intense pressure followed by a simple shock experiment on the same gas launcher. The idea of this second test is to create cracks inside the material, without destroying the studied sample. Thus, the ceramic can be recovered for another test (as a plate impact test on a gas launcher). The two models are compared against available experimental data.

Concerning the cracks distribution, we have considered two cases, also inspired from the experimental design. The first one concerns a plane wave acting on region with a circular micro-crack distribution while the second one includes a circular wave acting to a region with parallel micro-cracks. Finally, some other numerical experiments concern architected meta-materials, designed to blast energy dissipation, with a hexagonal distribution of the micro-cracks.

References

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