Inelastic response of ceramics under impact: brittle damage, plasticity and comminution.

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ABSTRACT

A mechanism-based constitutive law has been developed for the inelastic deformation of ceramics under impact. Initially, the material is elastic with no inelastic deformation, but damage commences at a critical stress state that nucleates the growth of wing cracks. These are assumed to grow in compression starting from Mode II pre-existing flaws, with the rate of growth of the cracks given by a power-law in terms of their Mode I stress intensity factor. When cracks from neighboring pre-existing flaws meet each other, they cause the ceramic to turn into a granular material composed of many particles. From then on a viscoplastic Drucker-Prager model is used to predict the deformation of the ceramic, with maintenance of a high hydrostatic compression playing an important role in the strength of the material. If the hydrostatic compression is extreme, compressive crack growth and Drucker-Prager deformation are both suppressed, and inelastic straining can occur by lattice plasticity associated with dislocations and twinning. This constitutive law has been incorporated into finite element codes and simulations carried out for long W rods penetrating SiC, and for spheres and cylinders impacting trilayers of steel and ceramic. These calculations predict the regimes of interface defeat, dwell and penetration in the case of long rod impact, and can predict ballistic limits in the case of the trilayers. They also provide insights into the nature of the inelastic strain fields, stress and pressure in the ceramic under compressive dynamic loading, and suggest concepts for what controls the transitions from interface defeat to penetration.