SHOCK15-2015-000167
Abstract for an Invited Paper
for the SHOCK15 Meeting of
the American Physical Society

High Speed Dynamics in Brittle Materials

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Brittle Materials under High Speed and Shock loading provide a continuous challenge in experimental physics, analysis and numerical modelling, and consequently for engineering design. The dependence of damage and fracture processes on material-inherent length and time scales, the influence of defects, rate-dependent material properties and inertia effects on different scales make their understanding a true multi-scale problem. In addition, it is not uncommon that materials show a transition from ductile to brittle behavior when the loading rate is increased. A particular case is spallation, a brittle tensile failure induced by the interaction of stress waves leading to a sudden change from compressive to tensile loading states that can be invoked in various materials. This contribution highlights typical phenomena occurring when brittle materials are exposed to high loading rates in applications such as blast and impact on protective structures, or meteorite impact on geological materials. A short review on experimental methods that are used for dynamic characterization of brittle materials will be given. A close interaction of experimental analysis and numerical simulation has turned out to be very helpful in analyzing experimental results. For this purpose, adequate numerical methods are required. Cohesive zone models are one possible method for the analysis of brittle failure as long as some degree of tension is present. Their recent successful application for meso-mechanical simulations of concrete in Hopkinson-type spallation tests provides new insight into the dynamic failure process. Failure under compressive loading is a particular challenge for numerical simulations as it involves crushing of material which in turn influences stress states in other parts of a structure. On a continuum scale, it can be modeled using more or less complex plasticity models combined with failure surfaces, as will be demonstrated for ceramics. Models which take microstructural cracking directly into account may provide a more physics-based approach for compressive failure in the future.