Modeling and Simulation of Fracture and Failure in Hypervelocity Impact

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Abstract

Numerical simulations of hypervelocity impact (HVI) phenomena are an important part of hypervelocity research, but also face challenges due to the large deformations and shock wave discontinuities involved. The most common methods currently used for such simulations are meshless particle-based methods, such as Smoothed Particle Hydrodynamics (SPH), which can handle the large deformations and creation of new free surfaces cause by fragmentation and spallation. Other techniques include hybrid methods which combine particle methods with mesh based finite element formulations. All of these numerical methods have been shown to perform and represent HVI phenomena relatively well, but they are based on continuum theory which is not ideally suited for representing the discontinuities in shock waves responsible for many HVI phenomena. In this paper we present a completely different approach to simulating HVI by using a discrete method. We focus our numerical investigations on the dynamics of the material fragmentation upon impact with the goal of demonstrating the feasibility of using a discrete approach for simulating HVI phenomena.

The simulation model we present in this paper is loosely based on the Discrete Element Method (DEM). For modeling the solids, we use discrete spherical particles interacting with each other via potentials. The particles are linked together via spring element to form a solid. Fracture and fragmentation is handled by removing the spring elements connecting individual particles. The parameters for the model were chosen by direct comparison to HVI experiments perfumed at our institute.

The focus of our numerical simulations is on HVI of thin plates and we compare our results with experimental results published in literature at a variety of impact velocities and target thickness to impactor diameter ratios. We find that our simulations correspond very well to experimental data when the impact conditions create shock pressures in the target and impactor many times greater than the material strength, but deviate when shock pressures are low. Using our proposed model, we investigate the feasibility of using DEM for HVI by performing a series of parameter studies with impactors of different shape ratios and angles and analyzing the post-impact debris cloud. In conclusion, we examine the feasibility of using a completely discrete approach to simulate HVI phenomena. We have found that using a discrete element approach leads to very stable, energy-conserving simulations of HVI that correspond to experiments.

Keywords: Computer Simulation, Discrete Element Method, Failure, Hypervelocity Impact.