Discrete Particle Methods for Simulating Hypervelocity Impact Phenomena, Failure and Fragmentation

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ABSTRACT

In this paper we introduce a mesh–free computational model for the simulation of high-speed impact phenomena. Within the framework of particle dynamics simulations we model a macroscopic solid ceramic tile as a network of overlapping discrete particles of microscopic size. In this context, Particle-based methods are often referred to as the Discrete Element Method (DEM). Using potentials of the Lennard-Jones type we integrate the classical Newtonian equations of motion and perform uni-axial, quasi-static load simulations to customize our three model parameters to the typical tensile strength, Young’s modulus and the compressive strength of a ceramic. Subsequently we perform shock load simulations in a standard experimental set-up, the edge-on impact (EOI) configuration. Our obtained results concerning crack initiation and propagation through the material agree well with corresponding high-speed EOI experiments with Aluminum Oxinitride (AlON), Aluminum Oxide (Al₂O₃) and Silicon Carbide (SiC), performed at the Fraunhofer Ernst-Mach-Institute (EMI). Additionally, we present initial simulation results where we use our particle–based model to simulate a second type of impact experiments where an accelerated sphere strikes a thin aluminum plate at hypervelocity speed. To our knowledge, these simulations constitute the first application of DEM to the hypervelocity regime. Corresponding hypervelocity experiments are done at our institute to investigate the debris clouds arising from such impacts, which constitute a miniature model version of a generic satellite structure that is hit by space debris in the earth’s orbit. Our findings are that a discrete particle based method leads to very stable, energy-conserving simulations of hypervelocity impact scenarios. Our chosen interaction model seems to work particularly well in the velocity range where the local stresses caused by impact shock waves markedly exceed the ultimate material strength.

REFERENCES