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SIMULATING IMPACT-INDUCED SATELLITE BREAKUPS WITH A DISCRETE ELEMENT METHOD

Abstract

The Discrete Element Method (DEM) is uniquely suited to modeling the extreme fragmentation typical of impact-induced satellite breakups. Previous work presented at the 2021 IAC showed the suitability of DEM for accurately modeling hypervelocity impacts (HVI) on simple aluminum plates and simplified aluminum CubeSats, both in the hypervelocity and low velocity regimes. In this paper, we extend our DEM material model to include carbon fiber reinforced polymers (CFRP) and apply it to simulate larger, realistically modeled satellites.

We introduce a new orthotropic material model, suitable for modeling CFRP, with the addition of new directional spring elements in our DEM model. Material parameters are derived from macroscopic material properties, with only one parameter per material needing specific calibration. Calibration of the CFRP material model is performed with experimental data, both from literature, as well as from HVI experiments performed at Fraunhofer EMI. A ballistic-limit based calibration procedure allows material parameters to be defined that are suited to both HVI and low velocity impacts.

We apply our aluminum and CFRP DEM models to simulate the breakup of realistic satellites following a HVI. Simulation results are presented as a sequence of images and detailed quantitate fragmentation analysis is also performed. Results are compared to predictions from the NASA standard satellite breakup model. We also perform parameter studies to determine the effect that variations in the impact conditions, such as impact location on the satellite, impactor shape effects, and impact energy, have on the resulting fragment distribution.