Considerations of oblique impacts of non-spherical, graphite-epoxy projectiles

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ABSTRACT

The DebriSat hypervelocity impact experiment, performed at the Arnold Engineering Development Center, is intended to update the catastrophic break-up models for modern satellites including many modern materials like structural panels of carbon-fiber, reinforced polymer (CFRP). Subsequent to the experiment, fragments of the DebriSat have been extracted from porous, catcher panels, and thus far, one of the key observations from the collected fragments is that CFRP represents a large fraction of the fragments and that these fragments tend to be thin, flake-like structures or long, needle-like structures pointing to the need to consider non-spherical orbital debris.

Previous work examined the case of an arbitrarily oriented cylindrical projectile impacting normal to the surface of a simple double-wall, Whipple shield, with a thermal blanket on the outer surface [1]. This work extends that development using numerical simulations to oblique impacts at a representative orbital speed of 7 km/s and addresses the complexities associated with that addition.

A sample of the progress that has been made on understanding the complexities of oblique impacts is shown in Fig. 1. Simulations have been performed for obliquities of 0°, 22.5°, 45° and 67.5°. In addition to the multiple impact obliquities, the cylindrical projectiles have been considered rotated with respect to the velocity vector. In Fig. 1a, the projectile’s central axis is aligned with the velocity vector, and in Fig. 1b, the projectile’s central axis is rotated orthogonal to the velocity vector. In each of these impact scenarios, the length of the cylinder as a function of the cylinder diameter is shown. The length of the cylinder that does not perforate the shield is shown open, and the length that fails the shield is shown closed. The midpoint at each cylinder diameter represents the ballistic limit of the shield. This paper discusses the collection of simulation data and the development of the empirical, ballistic limit model that is shown with the simulation data.

Fig. 1 Representative results of critical cylinder length against a Whipple shield as a function of cylinder diameter, obliquity and orientation. The orientation in a) is cylinder aligned with the velocity vector and b) is cylinder orthogonal to the velocity vector.