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SPACE DEBRIS SYMPOSIUM (A6)
Hypervelocity Impacts and Protection (3)

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HYPERVELOCITY IMPACT TESTING OF ADVANCED MATERIALS AND STRUCTURES FOR MICROMETEOROID AND ORBITAL DEBRIS SHIELDING

Abstract

Due to the increasing population of orbital debris in near Earth environments, the requirements for micrometeoroid and orbital debris (MMOD) protection continue to increase. For future orbital laboratories or crewed transfer vehicles, improvements in protective capability of MMOD shields are required while weight and space budgets can be expected to decrease. Towards this goal, a series of 117 hypervelocity impact experiments have been performed on candidate configurations incorporating new materials and structures considered promising for MMOD shielding. Single-, double-, and triple bumper shields have been tested, with varying total standoff and areal density. Aluminum, titanium, copper, stainless steel, nickel, nickel/chromium, reticulated vitreous carbon, silver, ceramic, aramid, ceramic glass, and carbon fiber materials have all been utilized in the test program, in the form of monolithic plates, open-cell foam, flexible fabrics, or rigid meshes. A procedure to classify and rank the performance of the various configurations was developed, applying a figure of merit for non-perforated results based on two primary failure modes: cratering and impulsive loading. The top performing configuration was found to be a double-bumper configuration with copper foam bumper plates and a monolithic aluminum rear wall. Of the top ten performing shields, the common characteristics were a monolithic aluminum outer bumper, with foam and/or Kevlar fabric inner bumper plates. In addition to the figure of merit based ranking, the ballistic limit of aluminum equivalent structures was calculated, and the ratio between test projectile diameter and critical projectile diameter of the equivalent structure was determined. This procedure gave additional insight into target performance, and the magnitude of enhancement gained through the application of advanced materials and structures. Preliminary ranking of the various foam materials was made, with copper found to provide the best protection against hypervelocity impact of aluminum spheres. Additional uprange witness plates were applied during impact testing to classify ejecta constitution and lethality. Although solid, damaging fragments were noted for impacts on monolithic aluminum outer bumper plates, for meshes, foams, and fabrics the ejecta was found to be effectively non-damaging. As such, shielding configurations incorporating this type of outer structure would reduce the threat of secondary impacts, in addition to mitigating the generation of new debris.