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DISPERSION ANALYSIS OF DEBRIS CLOUD FROM ALUMINUM AND MAGNESIUM ALLOY PLATES: A COMPARISON BETWEEN EXPERIMENTS AND NUMERICAL SIMULATIONS

Abstract

This study evaluated the dispersion behavior of debris clouds generated during hypervelocity impacts on aluminum and magnesium alloy plates through experiments and numerical analysis. Currently, the number of micro-meteoroids and orbital debris (MMOD) is increasing, posing potential threats to space development's safety and progress. Whipple shields are used in space structures such as the International Space Station (ISS) to address this issue. For a Whipple shield, we propose using a clad material created from aluminum and magnesium alloys through explosive welding and have conducted experiments to evaluate its performance.

To obtain basic data for accurately assessing the protective performance of clad materials, this study examined the dispersion patterns of debris clouds from monolithic plates and investigated their protective capabilities. Specifically, we performed hypervelocity impact experiments using a two-stage light gas gun. In each of these experiments, an aluminum sphere (A2017-T4) was impacted against a 1 mm thick plate of either aluminum or magnesium alloys at a velocity of 7 km/s. During these impacts, we captured the debris clouds with a high-speed camera and analyzed their dispersion patterns, sizes, and shapes. Additionally, we assessed the impact-induced damage on a plate designed to simulate a pressurized wall of spacecraft, evaluating its structural integrity post-impact. The experimental results revealed that magnesium alloys diffuse debris clouds more widely than aluminum alloys, reducing damage per unit area to the pressurized wall. Moreover, numerical simulations using LS-DYNA were carried out to model the dispersion patterns of debris clouds and the dynamics of impacts against pressurized walls. This process considered the physical properties of the materials and the conditions of the impacts to ensure consistency between the experimental and simulation results. To observe both the wave propagation within the material and the dispersion behavior of the debris cloud, the material modeling adopted an adaptive conversion model from Lagrangian elements to Smoothed Particle Hydrodynamics (SPH) particles. The numerical model faithfully reproduces the experimental observations on the dispersion, composition, and density of the debris cloud.

The comparison of experimental data with simulation results yielded an analysis of debris cloud behaviors for elucidating the mechanics of hypervelocity impacts. This research provides fundamental insights to further the development of clad materials made from aluminum and magnesium alloys for use as Whipple shields in space applications.