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HIGH-FIDELITY MODELING OF DEBRIS AND MICROMETEOROIDS IMPACTS ON EXTERNAL SANDWICH STRUCTURES OF SPACECRAFT

Abstract

To ensure mission success goals, spacecraft must be analysed for their ability to survive hypervelocity impacts (HVI) by space debris and micrometeoroids, as collision of a functional spacecraft with even a millimetre-sized object can be detrimental. Consequences may include loss-of-spacecraft failures owing to damage of components vital for its functioning (e.g., electronics units or connecting cables), as well as the bursting of pressurized containers, such as propellant tanks. In turn, this can cause multibillion-dollar financial losses for spacecraft owners.

To avoid such scenarios, micrometeoroids and debris impact survivability must be carefully analysed during the early stages of spacecraft development. In such analyses, special attention has to be paid to the most commonly used external elements of spacecraft structures – sandwich panels that enclose and provide attachment points for spacecraft subsystems. Perforation of a structural sandwich panel sends high-speed debris into the spacecraft and can be considered as a failure criterion for most otherwise unprotected components (e.g., circuit boards, cables, propellant tanks etc.)

Correspondingly, this study is focused on the development and verification of high-fidelity numerical models of honeycomb- and foam-core sandwich panels for HVI simulations that can be used to access spacecraft vulnerability to collisions with sub-centimetre debris and meteoroids. Combined use of FEM and meshless solvers enabled efficient representation of fragmentation and large deformations experienced by the materials during HVI. In particular, hybrid Lagrangian FE/meshless SPH elements have been used, allowing finite elements to convert into SPH particles at high deformation levels, when traditional FE method becomes inefficient. Major feature of the developed models is the explicit meso-scale representation of the core materials – honeycomb and open-cell aluminium foam. This enabled properly capturing in simulations such experimentally observed phenomena as the "channelling effect" of honeycomb and the "multishock effect" of open-cell foam – both resulting from interactions of the core materials with hypervelocity fragments propagating through them. The developed computational models have been verified against available experimental data.