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Analysis of High-Velocity Impact of Honeycomb Sandwich Structure with Material Point Method

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Honeycomb material has been widely used in engineering fields such as aerospace engineering, aeronautics engineering, and vehicle engineering for its outstanding material properties. Many shielding structures are made of the honeycomb material, since the honeycomb material can be an excellent energy absorber when it is compressed.

The high-velocity impact of aluminium honeycomb sandwich structure is focused in this paper. Shielding high-velocity impact is an important issue in aerospace and some other engineering fields. The spacecraft, for example, will face the threat from space debris and the impact velocity of the debris can be in the order of km/s.

High-velocity impact will lead to extremely large deformation of the material, dynamic fracture and fragmentation, phase changes, and even melting or vaporization[1]. Traditional Lagrangian mesh-based methods will encounter mesh distortion, which deteriorates the accuracy and ceases the computation abnormally. Eulerian mesh-based methods, on the other hand, still need careful treatment of material interface tracking and history variables recording.

The material point method (MPM), which is a Lagrangian meshfree particle method, combines the key ideas of Lagrangian description and Eulerian description and inherits their advantages[2]. A group of material points are adopted to discretize the material domain, and they deform with the material and carry all the history variables. A set of uniform background mesh is also used in MPM, and it serves to calculate the spatial derivatives and to solve the momentum equations. MPM does not suffer from mesh distortion, and it can easily track the material interfaces and the history variables. MPM is very efficient especially for large deformation. The non-penetration condition between different objects can be automatically satisfied, so MPM is very suitable for simulating the high-velocity impact process[3] of the honeycomb sandwich structure, which contains many contacts between the impactor and the structure as well as between the walls of the microstructures of the honeycomb material.

The dynamic responses and the failure of the aluminium honeycomb sandwich structure subject to high-velocity impact of millimetre-sized debris are simulated and investigated with material point method. The micro-structure model of the honeycomb is built and directly used in the simulation. Discretization refinement is adopted in the impact region to capture the deformation and failure details. The influences of the size of the debris and the impact velocity are thoroughly investigated after the MPM model is validated. The results show that the size of the hole on the front panel is much influenced by the size of the debris, while the size of the hole on the back panel is mainly determined by the impact energy. The failure region of the sandwich structure is truncated-cone shaped when the impact velocity is higher, which implies dispersing and absorbing the original impact energy. For lower impact velocity, the tunnelling effect is obvious, which means that only the honeycomb cells in the immediately contacted region and the cells very close to that region are destroyed during the impact.

Future work may include investigations on much higher impact velocity which can simulate more realistic orbital environment. MPM are also ready for structures made of other complicated materials such as foam material or textile material.

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