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NUMERICAL STUDY OF WHIPPLE SHIELD'S SPALLATION FAILURE CAUSED BY HYPERVELOCITY IMPACT AT 8KM/S

Abstract

The spallation is a common phenomenon happening during the hypervelocity impact(HVI), especially in the high-velocity regime of the Whipple shield, Although the limitation of conventional launch techniques makes the HVI experiment of high-velocity regime very expensive, fortunately, in recent years a series of experiments with impact velocity at 8km/s has been conducted, providing a reference of great value for the improvement of the numerical simulation method. As pulverization and spread of the projectile's debris plays an important role in the formation of spallation, the size of particles used in the numerical simulation of the destruction of the Whipple shield needs to be sufficiently small, resulting in the huge amount of calculation. For axisymmetric problems, the discretization method under the cylindrical coordinate system can be used to reduce the amount of calculation significantly, however, the calculation error will come out in the area near the symmetric axis, resulting in the wrong simulation of Whipple shield's failure mode.

In this article, a new discretization method has been developed on the base of the staggered grid material point(SGMP) method. To overcome the calculation error in the nearby area of the symmetric axis, the shape function and the boundary condition are improved for the cylindrical coordinate system. Through the new discretization method coupled with the multi-phase equation of state(EOS), the spallation of the Whipple shield's back wall is clearly simulated, and agrees well with the recently conducted experiment. In addition, the failure mode of the Whipple shield in the high-velocity regime and the forming condition of back wall's spallation failure have been analyzed via the numerical simulation, offering references for the design of the spacecraft's protection structure.