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NUMERICAL STUDY OF WHIPPLE SHIELD PROTECTIVE CAPABILITY AT IMPACT VELOCITY ABOVE 7.5KM/S

Abstract

Limited by conventional launch techniques, the projectile velocity executed in the hypervelocity impact(HVI) experiment is seldom above 7.5km/s. The normal ballistic curve of the Whipple shield lacks experimental validation in the high-velocity regime. In order to investigate the protective capability of the Whipple shield in the high-velocity regime, the numerical method plays an important role in the research. However, current numerical methods can't correctly simulate the destruction made by melting debris on the spacecraft hull, because of the shortage of the traditional equation of state(EOS). In this article, a new EOS has been established on the base of the molecular dynamics method and the GRAY three-phase EOS. The new EOS can well deal with the significant material phase transformation happening in the HVI process and has a briefer expression than the GRAY three-phase EOS. The new EOS is adopted in the self-programmed dual domain material point(DDMP) method software to simulate the aluminum HVI problems in the high-velocity regime. The numerical results agree well with the debris clouds from former researchers' cadmium scaling experiment, and the destruction mode of melting debris is correctly simulated. In addition, the combination of the new EOS and the DDMP software is used to predict the ballistic limit of the selected Whipple shield. The numerical result matches well with former researchers' predictions achieved from the artificial neural network and the cadmium scaling experiment, showing that the Whipple shield's protective capability is probably much higher than the estimate of current ballistic limit equations in the high-velocity regime.