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SPACE DEBRIS SYMPOSIUM (A6)
Hypervelocity Impacts and Protection (3)

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EFFECT OF DIFFERENT DAMAGE MODELS ON THE SURVIVABILITY ASSESSMENT OF MANNED MODULE FOLLOWING ORBITAL DEBRIS PENETRATION

Abstract

Meteoroid and orbital debris (M/OD) may cause severe damages or even catastrophic failures for a long-term manned spacecraft in orbit due to the hypervelocity impact (HVI) destruction. Herein the catastrophic failures are events that may cause crew loss or system failure following M/OD penetrations. In most cases the catastrophic failure of manned spacecraft is concerned with the penetration events of a pressurized module. Once it was penetrated by M/OD, the module wall would experience perforating, cracking and petaling, which might lead to such typical catastrophic failure modes as crew hypoxia, critical cracking (i.e., the so-called “unzipping”) of manned module. Thus the Burch-Lutz (B/L) model and the Schonberg-Williamsen (S/W) model are developed to quantitatively determine the damage parameters of the effective hole diameter and max crack length.

This paper analyzes the effect of the different damage models on the survivability assessment of manned module following orbital debris penetration. Firstly, such previous hole diameter models as B/L model and S/W model are reviewed. The US Lab Endcone (LEC), the dual-wall system of International Space Station (ISS), is adopted to compare the S/W model and Burch model under different projectile impact parameters. The analysis indicates that the S/W model is only valid for the Whipple shield configurations of International Space Station (ISS) at the projectile velocity of 6.5km/s and 11.3km/s, and that the Burch model, serving as an effective hole diameter model, is not valid when the projectile mass is slightly bigger than the Ballistic Limit Mass (BLM). Secondly, a new hole size empirical model for Whipple shield is proposed based on the B/L model. This model fits well with the S/W model at the projectile velocity of 6.5km/s, and has more widely applicable range than the S/W model. This modified B/L model is further integrated into the catastrophic failure assessment function of Meteoroid Orbital Debris Assessment and Optimization System Tools (MODAOST), the M/OD risk assessment system developed by China Academy of Space Technology. Finally, the S/W model and the modified B/L model are separately utilized for the survivability assessment of the ISS US Lab module following orbital debris penetration. The PCF of crew hypoxia predicted by the modified B/L model is 50% lower than that predicted by the S/W model, and the different PCFs result from the different hole diameters predicted by these two models under different orbital debris impact parameters. This means that the accuracy of all these damage models still need to be improved according to the new HVI tests, especially those at oblique angles and at velocities above 6.5km/s.