A study of AL-bumper thickness effect on damage of Whipple shield by hypervelocity impact of AL-spheres

G. S. Guan, Y. Ha, B. J. Pang, R.Q.Chi

Hypervelocity Impact Research Center, Harbin Institute of Technology,

P. O. Box 3020, Science Park, Harbin Institute of Technology, Harbin, 150080, P. R. China,

(ggsh@hit.edu.cn. / phone: +86-451-86402055)

Hypervelocity impacts on spacecraft in low earth orbit by meteoroids and space debris posed a threat to space missions. All spacecraft in low earth orbit are subject to hypervelocity impacts by meteoroids and space debris. These impacts can damage flight-critical systems, which can in turn lead to catastrophic failure of the spacecraft. Therefore, the design of spacecraft for an earth–orbiting mission must take into account the possibility of such impacts and their effects on spacecraft structure. So, investigation into the impact damage characteristics has become an important problem for spacecraft protection designing.

The Whipple shield was the first configuration developed to protect spacecraft against Meteoroids and Orbital Debris, and it is still extensively adopted. The protection efficiency of Whipple shield made of Al-plate based on thickness of bumper and space between bumper and rear wall is prominence. In particular, the thickness of bumper is an important part effect on impact damage characteristics sizes of the rear wall. Therefore, optimizing thickness of bumper should be considered.

In order to simulate and study the hypervelocity impact of space debris on Al-Whipple shield of spacecrafts, a non-powder two-stage light gas gun was used to launch Al-sphere projectiles. Thickness of the rear wall is 0.3cm, and thickness of witness is 0.17cm. Simultaneity, Thickness of bumper are 0.02cm, 0.05cm, 0.10cm, 0.15cm, 0.20cm, 0.3cm, 0.5cm respectively. Space between bumper and rear wall is 10cm. Space between real wall and witness is also 10 cm. Impact velocities of Al-spheres are 2.33 ± 0.12km/s and 4.36 ± 0.10km/s respectively. Damage mode of bumper and rear wall of Al-Whipple shield were obtained. In this experiment, an Al-plate was used as witness plate, and the maximum depth of fragment craters on the witness plate is taken into account as a protection characteristic of Al-Whipple shields made of different bumper thickness.

The protection efficiency of Al-Whipple shield was evaluated by follow parameter: the penetration hole diameter of bumper, the equivalent penetration hole diameter of the rear wall, the maximum diameter of cratered area on the real wall, the maximum diameter of cratered area on the witness plate, the maximum depth of fragment craters

on the real wall, total number of crater on the real wall, and total number of crater on the witness plate. The aim of the paper is to compare the protection efficiency of the first bumpers made of different thickness Al-plate by impact of spherical aluminum projectile.

In this paper, by experiment results, the law of penetration hole diameter and leading factors effect on penetration hole diameter in bumper from hypervelocity impact, and the law of damage and leading factors effect on damage in rear wall from hypervelocity impact were proposed. As the thickness of bumper increasing, the penetration hole diameter of bumper and the maximum diameter of cratered area on the rear wall increased but there is a limit hole diameter, and the impact damage at center of the rear wall mitigated but diameter of greater cratered area increased. Therefore, there is an optimized thickness for bumper.