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MEETING THE CHALLENGES OF HYPERVELOCITY IMPCT TESTING AT 10 km/s

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1. INTRODUCTION

The ability to evaluate the ballistic response of spacecraft hardware to the impacts of projectiles with known properties at velocities of interest, e.g., 9 to 11 km/s, has been an elusive goal of the hypervelocity impact community. This velocity range is greater than the capability of two-stage, light-gas guns traditionally used to test spacecraft shields, structures, and thermal protection systems. To meet the need for test capabilities at these higher velocities, the university of Dayton research institute (UDRI) developed a three-stage, light-gas gun capable of launching nylon, aluminum, aluminum oxide, and stainless steel spheres to velocities up to 10 km/s. The paper will describe, in detail, our efforts to meet the challenges we faced in order to successfully perform hypervelocity impact tests at these higher velocities

2. HYPERVELOCITY IMPACT TESTING

There are three requirements for the successful performance of most hypervelocity impact tests. The first is for a launcher that can accelerate relevant projectiles to the desired velocity. The second is for sabots that are capable of (1) supporting a projectile subjected to extreme launch-acceleration loads and (2) easily releasing the projectile, without disturbing its flight, after it exits the launch tube. Finally, a means must be provided for cleanly capturing the discarded sabots without affecting the flight of the projectiles or damaging the targets.

The Space Research Institute at McGill University constructed a three-stage, light-gas gun [1] during the 1960's and used it to launch 12.7-mm-diameter Lexan disks with masses of 1.5 grams (9.6 mm thick) and 1.1 grams (6.4 mm thick) to velocities of 9.6 and 10.5 km/s, respectively. Our three-stage, light-gas gun is similar to McGill's with one exception. McGill's gun had a short second-stage launch tube. We use our 75/30-mm, two-stage, light-gas gun in its normal configuration with a full-length launch tube. A small high-pressure section and a 7.62-mm-diameter launch tube are attached to the muzzle of the 30-mm launch tube to form the third stage. The 75/30-mm, light-gas gun was loaded normally except for the placement of the second-stage "projectile" or driver which was loaded near the muzzle of the 30-mm launch tube. In operation, the three-stage-gun firing cycle uses a strong shock, generated in the 30-mm launch tube by the rupture of the second-stage burst disk, to accelerate the driver and compress a second charge of hydrogen to accelerate the projectile in the 7.62-mm launch tube. Our first successful test firing of the UDRI three-stage, light-gas gun was in August 2008. In this test, a 2.38-mm-diameter aluminum sphere cleanly impacted a scaled Whipple shield at a velocity of 9.07 km/s.

The maximum stress in a sabot varies with the launch package mass and the set of loading conditions used to accelerate the projectile to the desired velocity. Peak accelerations in a two-stage, light-gas gun vary from several hundred thousand gees to about 1.6 million gees. The moderate launch loads that result from these accelerations permit the use of axially-split, aerodynamically-separating sabots. Because the accelerations and loads imposed on the sabots by the three-stage gun can be extreme (~15 to 16 million gees), split, aerodynamically-separating sabots could not be used to launch projectiles with the three-stage gun. A simple, "one-piece" sabot design and a means for discarding and capturing it were required. Nylon sabot bodies with imbedded aluminum or titanium pushers were used to support Nylon, aluminum, aluminum oxide, and stainless steel spheres during their launch. Release of compressive loads in the projectile and the pusher at the end of the launch cycle caused them to separate and move apart during their travel downrange. Adequate separation of the sabot and projectile allowed the projectile to pass through a deflector placed 215 cm downrange of the muzzle of the 7.62-mm launch tube without disturbing its flight. The sabot body and imbedded pusher were deflected away from the shot line by a slight ramp at the end of the deflector and captured when they crashed into a thick steel plate about 90 cm down range of the deflector. The projectile passed through a hole in the steel plate, before the arrival of the discarded sabot, and impacted the target.

The following table lists the various projectile materials, diameters, and maximum velocity achieved with each material to date. A figure showing the launch velocities achieved with different launch package weights is presented below the table.

Sphere Material	Diameter Range, mm	Maximum Velocity
Nylon	1.44 to 3.18	1.59 mm to 10.13 km/s
2017-T4 Al	1.01 to 3.18	1.40 mm to 10.03 km/s
Aluminum Oxide	1.00 to 1.90	1.00 mm to 9.56 km/s
440C Stainless Steel	0.60 to 1.60	0.89 mm to 9.71 km/s

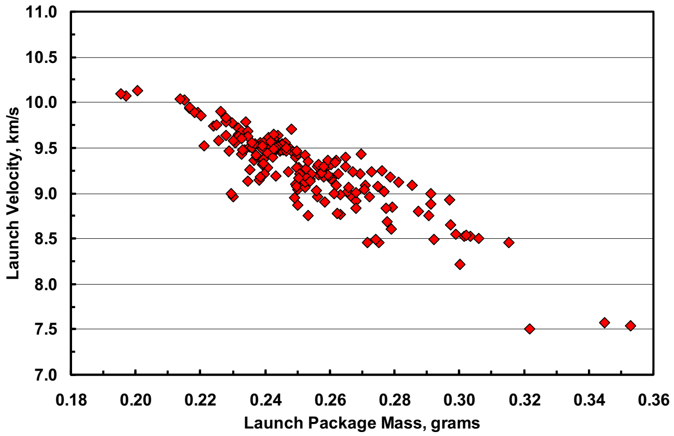

FIGURE 1: PERFORMANCE OF THE UDRI 75/30/7.62-MM, THREE-STAGE, LIGHT-GAS GUN

REFERENCES

[1] Friend, W.H., C.L. Murphy, and I. Shanfield, “Review of Meteoroid-Bumper Interaction Studies at McGill University,” NASA-CR-54857, August 1966.