A LGG ARRANGEMENT FOR CUT-OFF OF THE PROJECTILE SABOT

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ABSTRACT/RESUME

Usually, light gas guns (LGG) are used to accelerate projectiles for experimental study of spacecraft shielding performance under impact of space debris. A projectile is placed into polymeric non-split sabot to provide obturation of gas in the LGG barrel. After exit from the barrel, the sabot or its fragments that fly after the projectile, should be separated (cut-off) or deviated from the projectile flight-line. According to a novel approach, a special guard ring mounted at the barrel muzzle is used for fragmentation of a spherical projectile sabot at exit from the LGG barrel, and thin plastic bonded HE placed at the surface of a bush in the guard-plate is used to cut-off the sabot fragments. This approach was tried by numerical simulation and proved by experimental testing.

1. INTRODUCTION

Impact of a projectile of specified shape and mass to a target is necessary to be provided at experimental study of the spacecraft shielding performance under the space debris impact conditions. Other impacts to the target that can disturb the loading should be minimized or excluded. Usually, light gas guns (LGG) are used for experimental study of this kind. A projectile is placed into polymeric non-split sabot to provide obturation of gas in the LGG barrel (see, e.g., [1]). After exit from the barrel, the sabot or its fragments that fly after the projectile, should be separated (cut-off) or deviated from the projectile flight-line.

2. ARRANGENMENTS: PRINCIPLE OF OPERATION

One of possible approach to cut-off the projectile sabot is presented in [2]: the sabot is fragmented while interaction with the special guard ring mounted at the LGG barrel muzzle, and the sabot fragments get radial velocity component. Arrangement of this kind solves the task to cut-off the sabot, if impact of small sabot fragments to the target front surface is permitted by the test conditions; these small sabot fragments loss velocity at flight through the air or helium ballistic channel, so they are unable to induce significant damage to the target. Otherwise, complete cut-off of the sabot fragments is necessary.

To minimise impact of small sabot fragments to the target front surface, use of a thin plastic bonded high-explosive (HE) layer placed at the surface of a bush in the guard-plate was proposed in [3]. Schematic of both arrangements is presented in Fig. 1: sabot is fragmented at interaction with the guard ring; the sabot fragment that arrives first to the HE triggers detonation of it; other sabot fragments loose their velocity in expanding explosion gases; due to variable thickness of the HE layer, these sabot fragments are deviated from the shot-line by explosion gases.

Deceleration of the heavy metallic projectile in rarified atmosphere of the ballistic channel is much less than that of sabot fragments, so the projectile passes the central channel of the bush before the leading sabot fragment arrives to the HE to trigger detonation in it.

Several guard-plates with bushes and HE could be placed along the shot-line to cut-off those sabot fragments that manage to pass the first guard-plate in the wake of the projectile.

3. NUMERICAL SIMULATION

Numerical simulation was used to prove the principle of operation and to select optimal parameters of main parts of both arrangements.

Numerical simulation was performed in 2D axis-symmetrical set-up using DMK code [4-6]; irregular Lagrangian mesh was used for all the numerical regions, automatic local remeshing (splitting and merging of distorted numerical cells) was used; local binary fracture model [7] was used. Mean size of fragments was calculated using Grady model (summary and example of application are presented in [8]) for each numerical cell for values of strain rate and yield at fracture. Calculation of motion of the sabot fragments in exhaust gas (hydrogen), air and explosion gases was performed using PARTICLE module [9]; it was assumed, that all the fragments are spherical and do not affect the state and motion of continuous media carrying them.

In the simulation presented below, the spherical aluminum projectile (diameter 15 mm) is placed into phenylon sabot, the projectile and sabot are accelerated in the LGG barrel (caliber 24 mm) by light gas (hydrogen); pressure at the rear surface of sabot is 40 MPa when projectile leave the barrel; the projectile exit velocity is 6.7 km/s; fragmentation of sabot is

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provided by aluminum guard ring (thickness 1.5 mm); the bush channel is 32 mm diameter; guard-plate is placed at distance of 2 m.

Simulation showed that at impact to the guard ring, sabot is fragmented to particles of mean diameter in the range of 0.001-0.1 mm, the main mass of sabot is fragmented to particles of mean diameter 0.01 mm, velocity of the sabot fragments is in the range of 5-6.5 km/s. Fragmentation of sabot is illustrated by Fig. 2 (*t* is time from impact to the guard ring). A spherical tracer particle (fragment) was extracted from every of 22100 numerical cells of sabot after fracture; the tracer particles of calculated by the Grady model mass and velocity were placed into the centers of donor numerical cells, and further motion of tracer particles was tracked. Flight of projectile and typical sabot fragments is illustrated by Figs. 3-5 (particles are denoted by square markers with dimensions scaled to dimensions of fragments).

Performed simulation showed the following:

- generated by impact to the guard ring shock waves in sabot resulted in full fragmentation of sabot and in deformation of projectile but not in its fracture;
- only small sabot fragments fly along the shot-line in the wake of the projectile, and larger fragments fly at radius >10 mm from the shot-line while moving in the exhaust gas and move to radius of 20-70 mm at arrival to the guard-plate;
- at arrival to the guard-plate the sabot fragments become detached 200 mm from the projectile;
- the sabot fragments are mostly caught in the bush channel by the explosion gases.

4. EXPERIMENTAL TESTING

Experimental testing of the cut-off arrangements was performed using 24 mm caliber LGG LGU-16 [1]. Results of one of the experiments are presented in Figs. 6 and 7; projectile was accelerated to 6.9 km/s. Mounted at the muzzle guard ring fragmented the sabot (see Fig. 6a), and at distance of ~1 m large fragments of sabot moved in radial direction to ~80 mm and fall to ~35 mm behind the projectile. Detonation in the HE was triggered by the leading sabot fragment; practically all the sabot fragments were cut-off by the explosion gases (see Fig. 6b), they impacted the witness plate (placed at the front surface of the guard plate) within radius of ~300 mm from the shot-line (see Fig. 7).

5. CONCLUSIONS

Performed numerical simulations and experimental testing showed working ability of a novel approach to cut-off the non-split projectile sabot:

- use a special guard ring mounted at the barrel muzzle to fragment the sabot at exit from the LGG barrel, and
- use thin plastic bonded HE layer placed at the surface of a bush in the guard-plate to cut-off the sabot fragments.

6. REFERENCES

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7. FIGURES

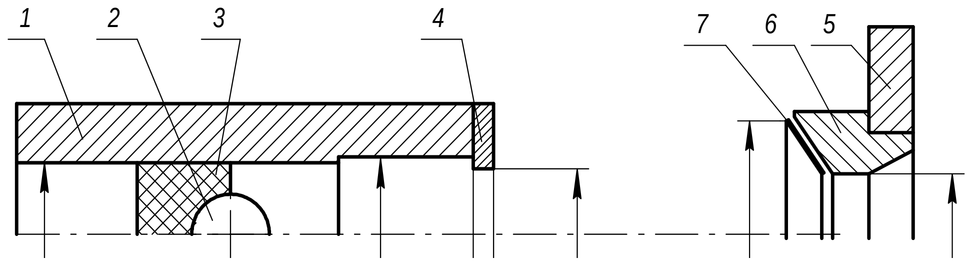

Figure 1. Schematic of arrangement: 1 – LGG barrel, 2 – projectile, 3 – sabot, 4 – guard ring, 5 – guard-plate, 6 – bush, 7 – plastic bonded HE

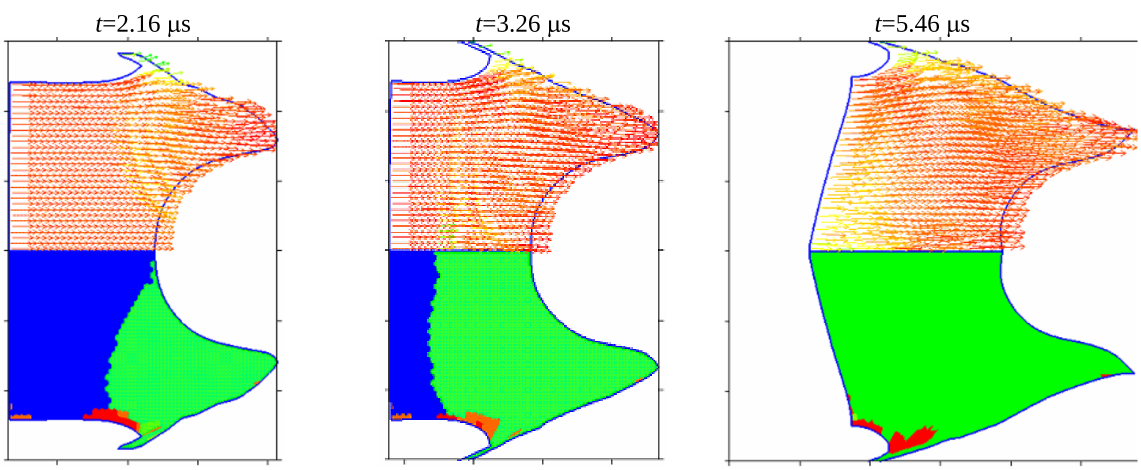

Figure 2. Simulation of the sabot fragmentation: upper half - vector plot of velocity; lower half - plot of state (blue – plastic, green – fractured at shear criterion, red – fractured at spall criterion)

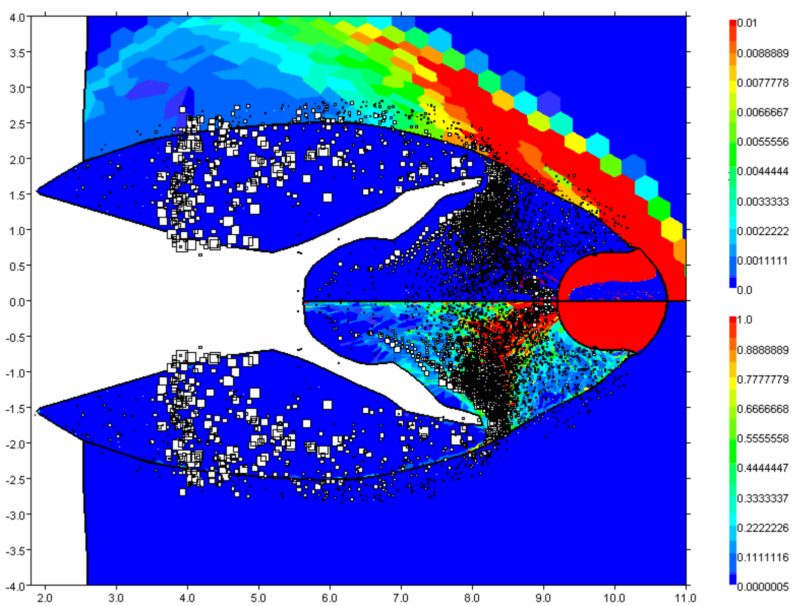

Figure 3. *Simulation of flight of projectile and typical sabot fragments in the barrel exhaust gas (t=11.4 µs): upper half – field of pressure (GPa); lower half – field of density (g/cm^3)*

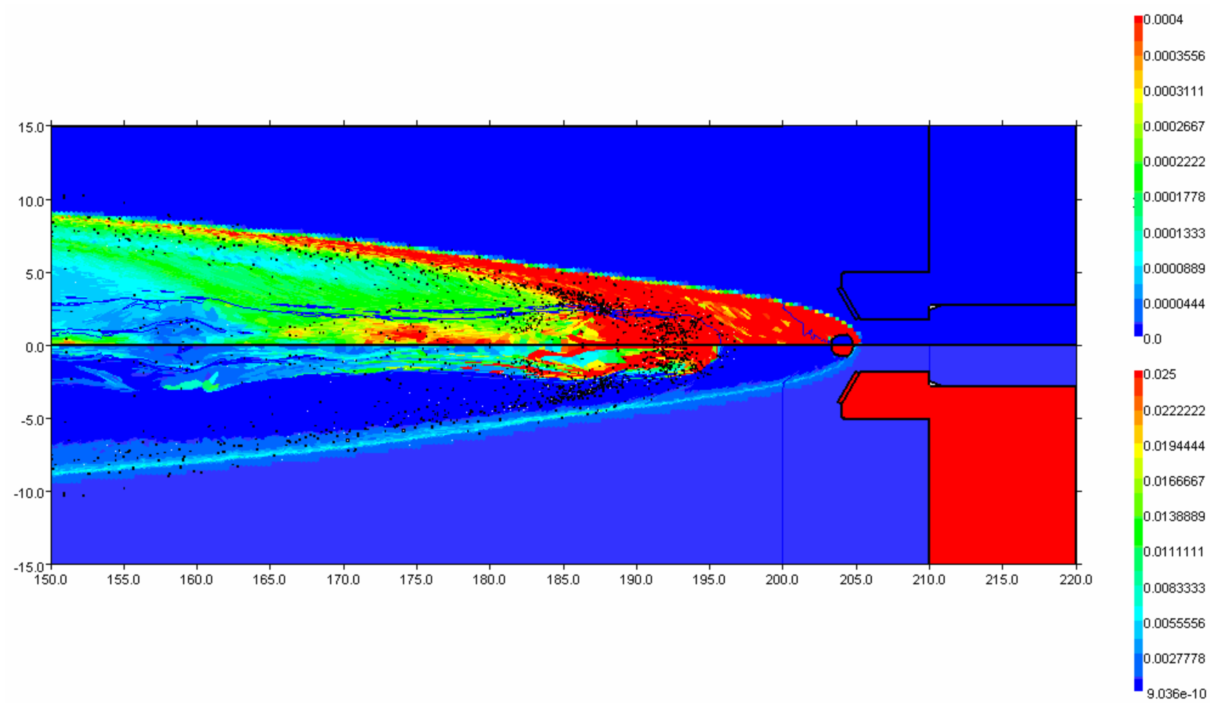

Figure 4. Simulation of flight of projectile and typical sabot fragments in the atmospheric air before arrival to the guard-plate (t=293.4 μs): upper half – field of pressure (GPa); lower half – field of density (g/cm^3)

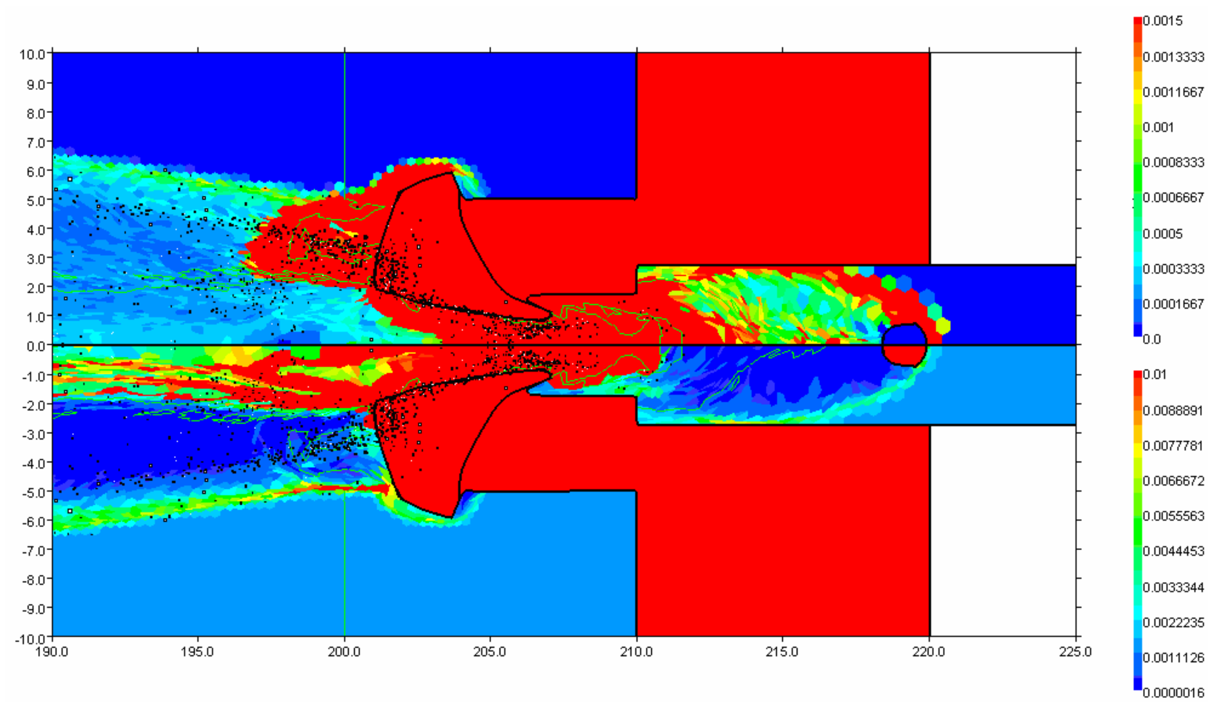

Figure 5. Simulation of flight of projectile through the bush channel and motion of typical sabot fragments in the explosion gases (t=316.4 μs): upper half – field of pressure (GPa); lower half – field of density (g/cm^3)

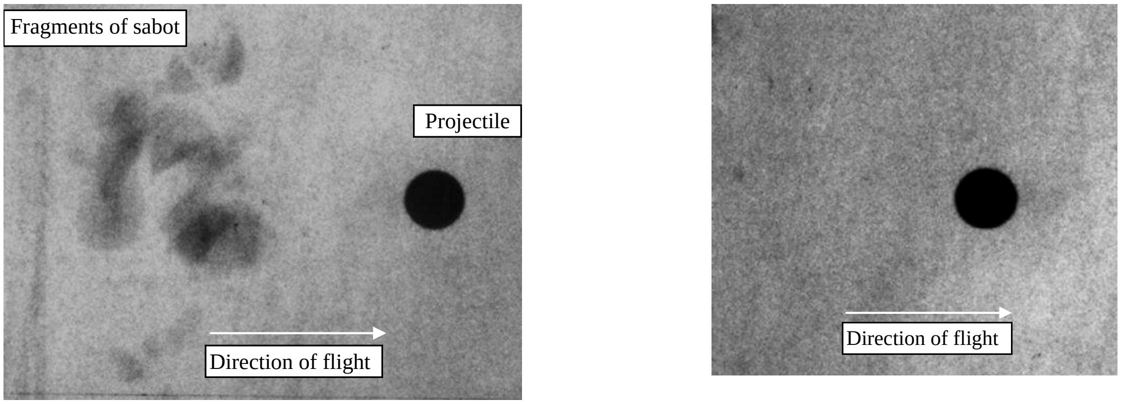

Figure 6. X-ray photos: left - projectile and sabot fragments after fragmentation of sabot by guard-ring; right – projectile after passing through the bush channel (sabot fragments have been cut-off)

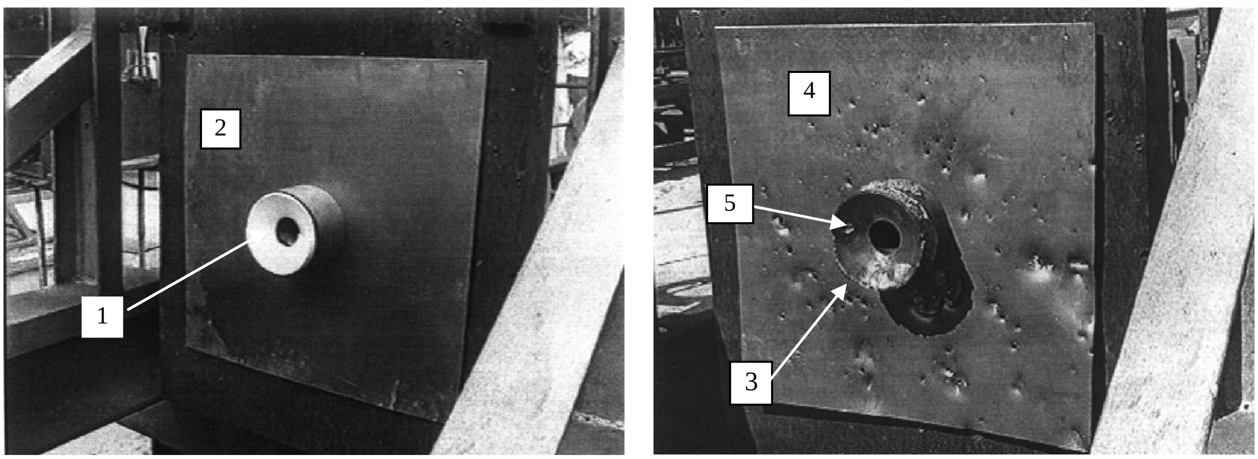

Figure 7. Photos of guard-plate before shot (left) and after shot (right): 1 – bush with plastic bonded HE layer; 2 – witness plate; 3 – bush after explosion of HE; 4 - witness plate after impact of the sabot fragments; 5 – crater at the bush surface produced by impact of the leading sabot fragment