CALIBRATION OF THE FRENCH CEG HYPERVELOCITY LAUNCHER

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ABSTRACT

Within the Inter Agencies Debris Committee third working group framework, CNES has started a calibration campaign of the French C.E.G. (Centre d'Etude de Gramat) hypervelocity launcher. The same calibration test series has already been conducted by NASA JSC, NASDA, ESA and RKA.

By completing those tests with the CEG Light-Gas Gun (LGG), CNES has two purposes :

- to be able to compare the French test facilities with existing and calibrated ones,
- to get ready with high velocity testing on space structures.

This second aim is related to the general pattern of the CNES debris's policy : to be able to shield spacecraft again space debris and to limit space debris production.

All the test hardwares were prepared by NASA and shipped to CNES with projectiles and test instructions. The delivered targets consist of 4 multi-layer shields composed of bumpers (2 or 3 plates), one rear wall and one witness plate. Bumper and rear wall materials are Al6061T6, witness plates are 0.16 cm thick Al2024T3 mounted 15 cm behind rear wall. All projectiles are Al2019T4 spheres (0.79 or 1 cm in diameter).

The paper presents the CEG LGG, the test conditions (mass and size of the projectile, dimension of the target, impact incidence) and the test results : X-ray registration, post test study of the damage (craters, holes, etc..).
It will also present the numerical calculations that have been done by CEG with his OURANOS code.

1. INTRODUCTION

Within the Inter Agencies Debris Committee third working group framework, CNES has started a calibration campaign of the French C.E.G. (Centre d'Etude de Gramat) hypervelocity launcher. The same calibration test series has already been conducted by NASA JSC, NASDA, ESA and RKA.

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- to be able to compare the French test facilities with existing and calibrated ones,
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2. PERSEPHONE LIGHT GAS GUN

2.1 Launcher description

The first stage of the launcher is mainly derived from a single-stage powder version. He is made up of three main parts.
The first one is the powder breech, 15 l in volume for a maximum powder mass of 6 kg.
The second is the 8m long, 98 mm calibre pump tube which provides a high compression ratio for light gas.
The third is the piston which consists of a polyamide part for extrusion in the convergent and a polyacetal part for controlling start pressure.

The intermediate part of the launcher is the high pressure section which is a bore bound with a ring, designed to withstand 1.2 GPa maximum pressure. This section is attached to the pump and the launch tube by means of 2x16 M42 bolts.

The second stage or launch tube of the launcher consists of three 2.5 m long sections, which are fit together

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thanks to cylindrical jointings. After each shot this tube has to be honed on site.

2.2 Launcher performances

Available measurements are :

- muzzle projectile velocity (Flash X-Ray)
- projectile velocity along the entire launch tube : (velocity interferometer)
- Pressure variations pattern in powder breech & in high pressure section (piezoelectric transducers)
- tensile loads bolts (strain gages)

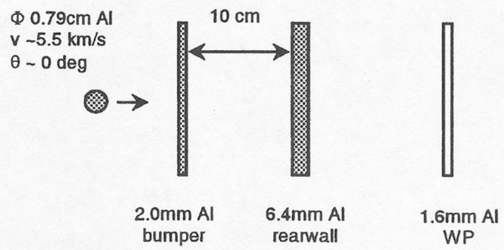
The maximum calculated velocity (6.9 km/s) is obtained with 760g powder mass and 3.5 bar hydrogen pressure. This calculation has been confirmed by the following experiment :

Shot parameters :
800g powder mass, 7.7 g projectile mass,
4.5 bar hydrogen pressure.

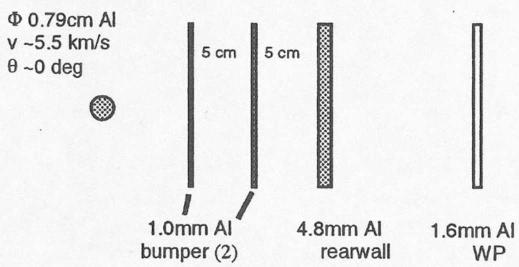
Measurements :
Peak hydrogen pressure : 1.1 Gpa,
projectile muzzle velocity : 7 km/s.

3. TEST CONDITIONS

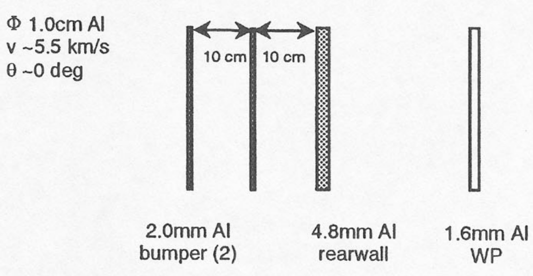
3.1 Test 1



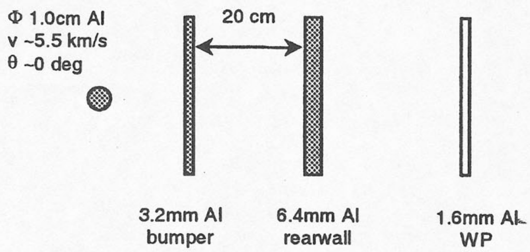
3.2 Test 2



3.3 Test 3



3.4 Test 4



4. TEST RESULTS

The results for the fourth test will be only available in april 2001.

4.1 Test 1

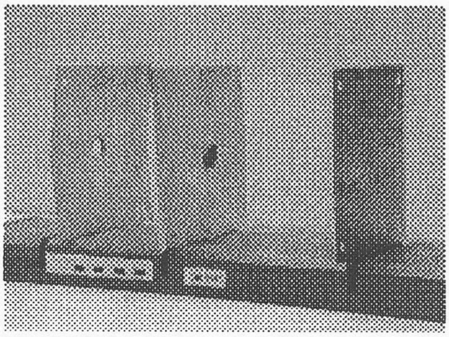


Fig 1. Test 1

Damage description :

Plate 1 : 17 mm Hole with front and rear surface lips
Plate 2 : Circular pattern of multiple craters <3.5 mm
Detached spall on back measuring 25*20 mm
Witness Plate : No Damage

4.2 Test 2

Fig 2. Test 2

Damage description

Plate 1 : 13 mm Hole with front and rear surface lips
Plate 2 : 37*40 mm Hole surrounded by multiple smaller holes < 2 mm
Plate 3 : Multiple craters forming a 85 mm area
Witness Plate : No Damage

4.3 Test 3

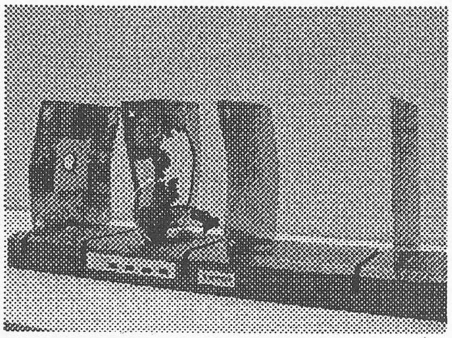


Fig 3. Test 3

Damage description

Plate 1 : 19 mm Hole with front and rear surface lips
Plate 2 : 80*75 mm Hole surrounded by multiple smaller craters < 3 mm
Plate 3 : Multiple craters (Φ 6 mm)
Witness Plate : No Damage

5. NUMERICAL CALCULATIONS

5.1 OURANOS description

Studies in the field of projectiles efficiency and target protection have been expanding at CEG over the last ten years. These studies are led by the constant search for synergy between experimentation and numerical simulation.

The Ouranos hydrocode was developed by the Commissariat à l'Energie Atomique. The software includes a Lagrangian component and an Eulerian one closely linked to each other through space and time coupling.

The material behaviour is simulated by the use of two main models : an equation of state that expresses the value of hydrostatic pressure as a function of density and internal energy, and a constitutive relation between the deviatoric strain and stress.

5.2 Test #3 simulation

This are preliminary results. At this time results for test#3 only are available.

Fig 4. presents the OURANOS calculation for the first plate perforation. The calculated hole diameter is ~23 mm (experience 19 mm)

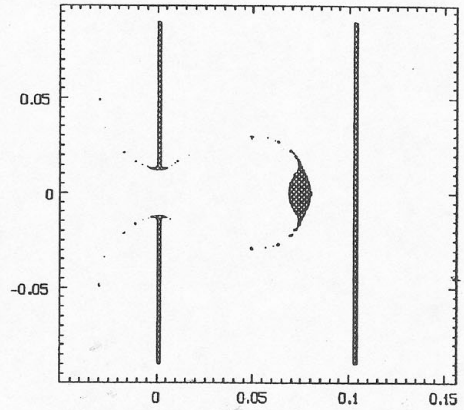


Fig 4. Plate 1 peforation

Figure 5. presents a simulated "X-Ray" photograph obtained thanks to fig 4. This photographs can be compared with fig 5, which is the real experiment X-Ray.

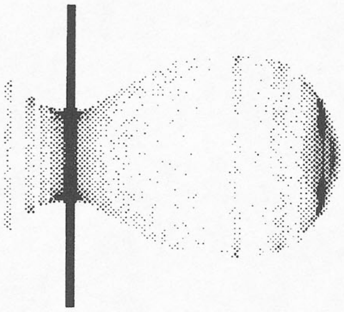


Fig 5. Perforation Plate 1 "X-Ray" from calculation

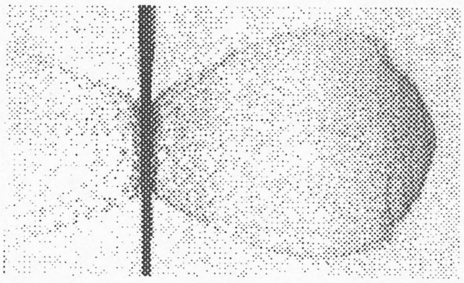


Fig 6. Perforation Plate 1 "X-Ray" from experiment

The same calculations have been done with the second plate perforation.

The calculated hole diameter is ~80 mm (experience 75 mm). Fig.7 & 8 presents the OURANOS calculation and the simulated X-Ray photograph.

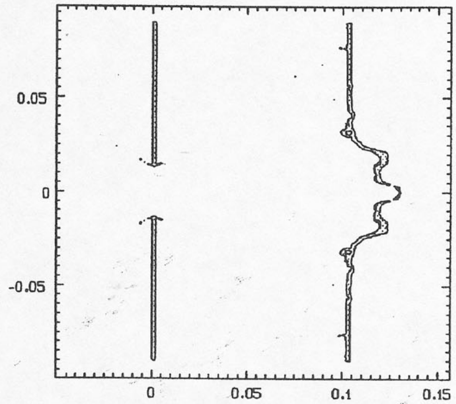


Fig 7. Plate 2 peforation

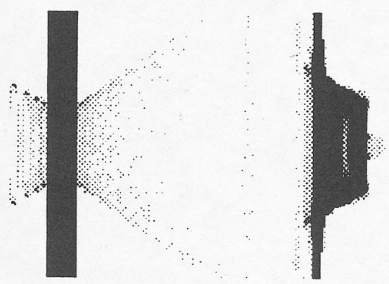


Fig 8. Perforation Plate 1 "X-Ray" from calculation

6. CONCLUSION

This calibration campaign allowed CNES to calibrate the CEG Light Gas Gun Persephone. The tests that have been already done have shown that the launcher is reliable, and that CEG and NASA JSC test results are matching.

CNES also decided to perform shock measurements during test #2. This tests allowed us to built a shock results data base that will be available for future shock propagation calculations.

At last, OURANOS preliminary results are comparable with experiment, what gives proof that OURANOS calculations are compatible with long projectile flight path.

7. REFERENCES

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Aerobalistic Range Association. 45th annual meeting, 10-14 october 1994.

[2] « *OURANOS : The DGA's hydrocode for impact dynamics study*» - Sibeaud JM. DGA/DCE/CEG European Forum on the Ballistics of projectiles. St LOUIS 10-14 April 2000.