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PERSEUS (Projet Etudiant de Recherche Spatiale Européen Universitaire et Scientifique)

Composite Nozzle Realization

The 7th European Conference for Aeronautics and Space Sciences

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Abstract

Launched at the 2005 Paris Air Show, the PERSEUS (Projet Etudiant de Recherche Spatiale Européen Universitaire et Scientifique) initiative was conceived by the French Space Agency (CNES). As part of the forward-planning efforts of its Launch Vehicles Directorate, this project is looking to spur innovative technical solutions in all areas related to launchers, aimed chiefly at students in higher education.

To achieve this objective, Perseus is pursuing an original approach in which students, lecturers/researchers, postgraduate students and university space club members are coordinating their efforts to build technology demonstrators. The long-term goal is to develop a launcher for 10-kilogram nanosatellites in Low-Earth orbit. A step-by-step approach is the best way of getting there, with the kind of oversight and procedures widely used in the aerospace industry.

1. Introduction

Every year, new objectives are defined, with the aim that the students bring innovations to the work carried out by their predecessors. Feedback is an essential part of this project. This year, IMA's objectives were to design and manufacture two nozzles with different manufacturing methods.

The first one is composed by a carbon / phenolic body manufactured by filament winding while the other, also made of carbon / phenolic, is manufactured by pressurized polymerization (Compound method).

These two nozzles will, or not, have a graphite neck that will allow a lower ablation.

For the past ten years, IMA has been participating in the nozzle project with the aim of innovating and enriching the results achieved year after year. This year, IMA will also carry on the assembly of all the modules created by the PEGASE project (ENSAM, ENSCBP, Ecole des Mines, IUT de Bordeaux, IMA).

2. Compound method

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This method consist to cure preimpregnated strip in a mould, placed in a hot press, which can be programmed to cook the product homogeneously and allowing optimum degassing.

The peculiarity of this method is that we can consider the material "homogeneous" and pseudo-isotropic since the strips of preimpregnated intermingle in all directions.

We have developed nozzles with and without a graphite collar.

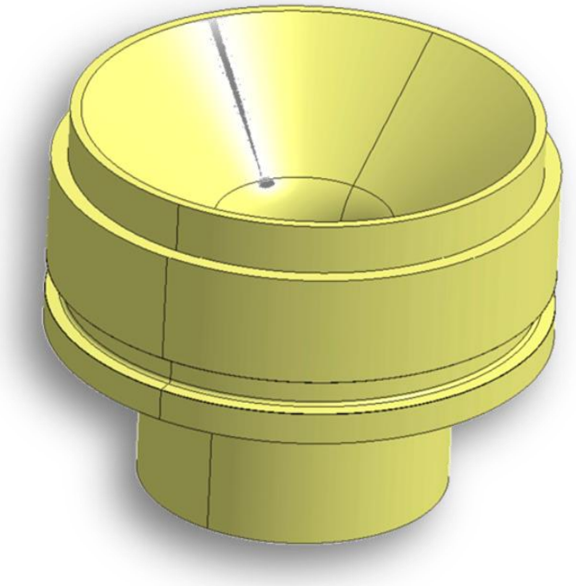

Figure 1 – Nozzle 3D view

3. Manufacturing

a) Design a mold composed by high thermal conductivity steel, which can resist to 10 tonnes, which can fit on a hydraulic press.
b) Cut 1kg of pre-impregnated carbon phenolic in strips (300*5mm).
c) Insert the strips in a cold preform.
d) Install the mold on the hydraulic press.
e) Extract the mix from the preform and insert it in the mold.
f) Cure during 4 hours at 185°C with increasing compression cycle.
g) Machine the compound product.

⚠ Several sequence of degassing is necessary to avoid porosity in the material.

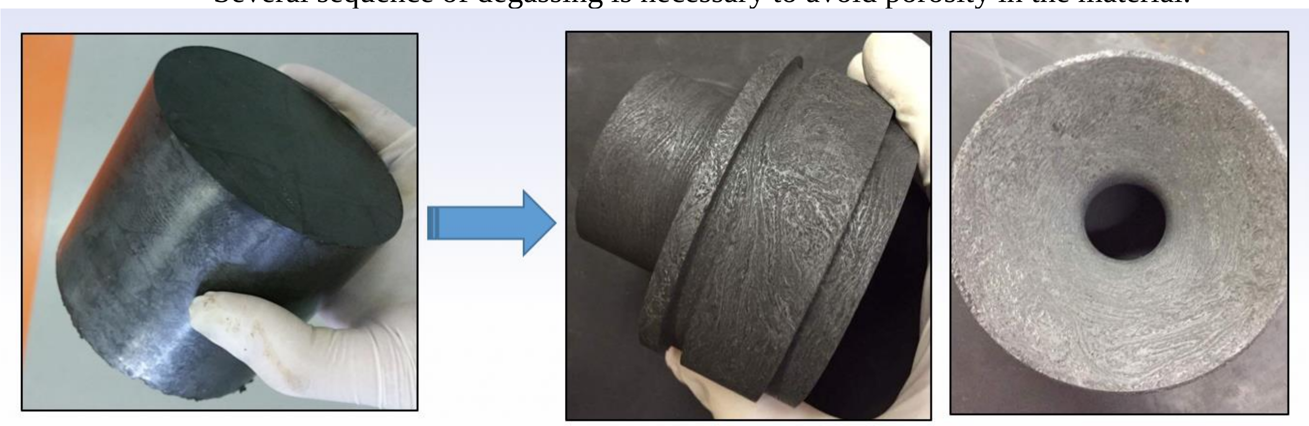

Figure 2 - Manufacturing process

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4. Tests of the compound

Following the manufacturing of our first compound nozzle, we wanted to know the mechanical characteristics of this material, This is why we launched a series of mechanical and thermal tests, described below:

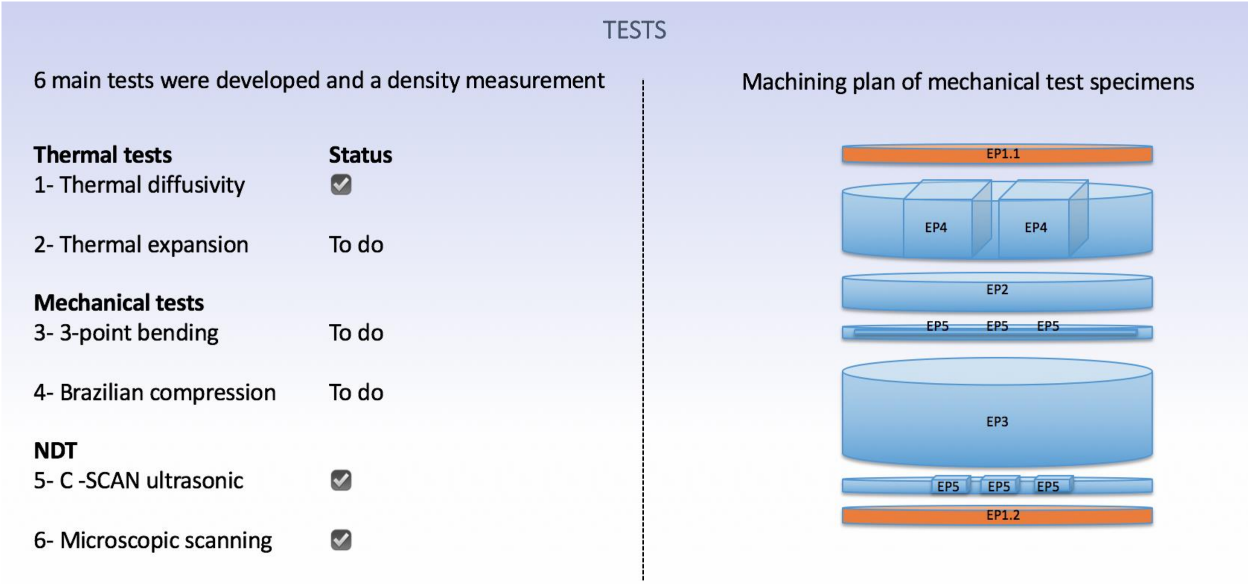

Figure 3 – Test specimens

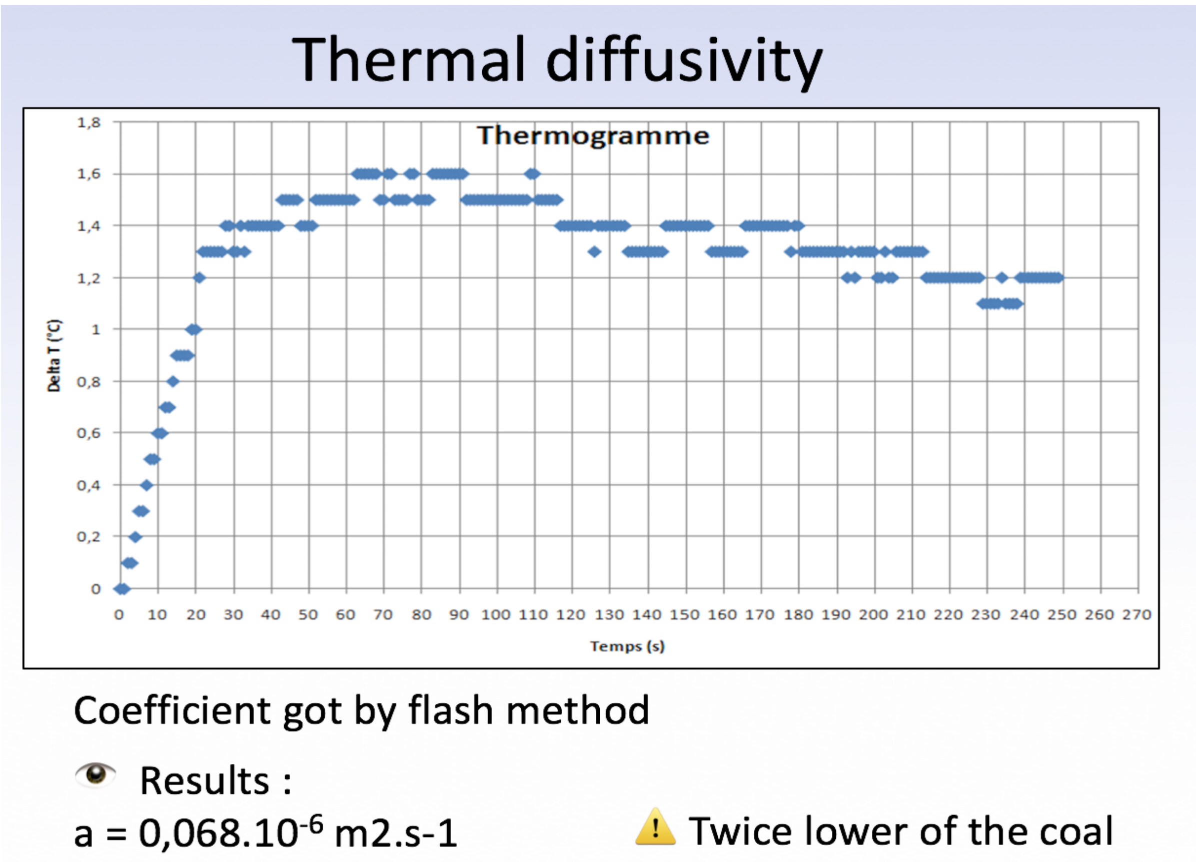

Figure 4 – Thermal diffusivity of the compound test

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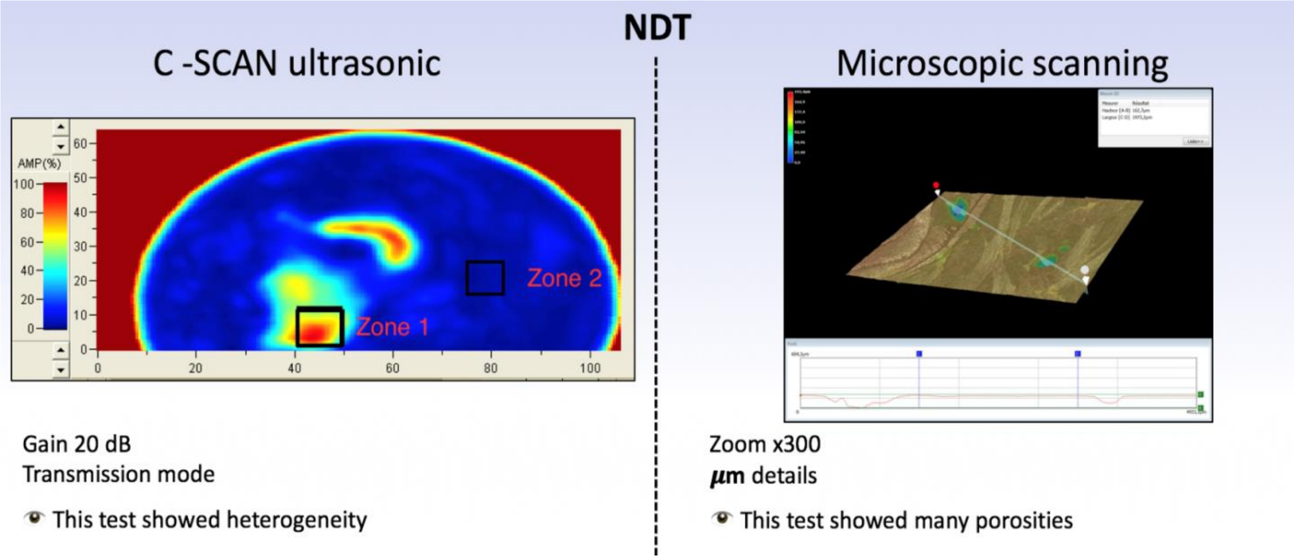

Figure 5 – NDT test

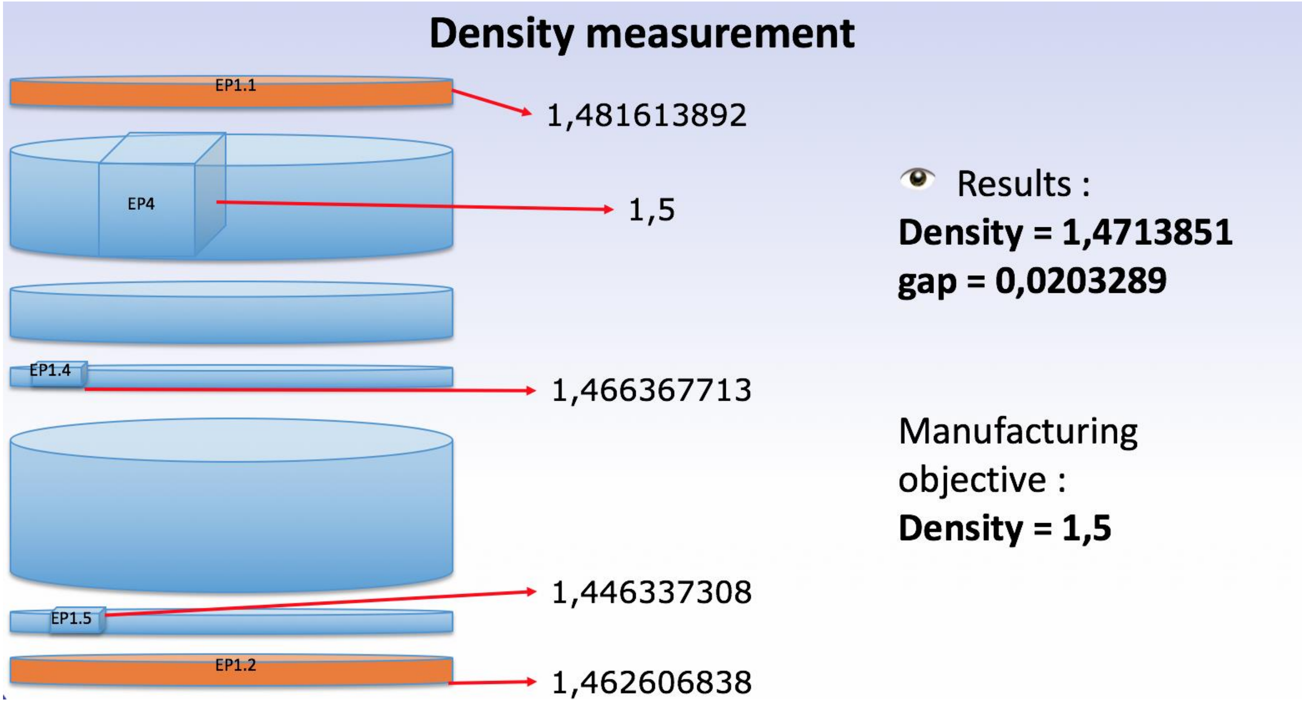

Figure 6 – Density Measurement of the compound

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5. Launch on a test bench (ONERA)

We were fortunate to be able to make a shot of our nozzle in ONERA facilities (Toulouse)
This launch took place on a bench with "green" powder from the Cesaronni Pro 98 engine.
This trials allowed us to measure the neck nozzle ablation without a graphite collar.
The results have exceeded our expectations, the ablation of the neck is less important than on the commercial Cesaronni Pro 98 nozzle, therefore the thrust of our homemde nozzle trials is 10% more important than the commercial nozzle.

Figure 7 – Launch on a test bench (ONERA)

	Before	After
Ø neck nozzle	23,9 mm	24,04 mm
Weight	360 g	334 g
Recolted debris	-	19 g

Figure 8 - 19 grams of $Al^{2}O3$ has been recolted on the nozzle after the trials

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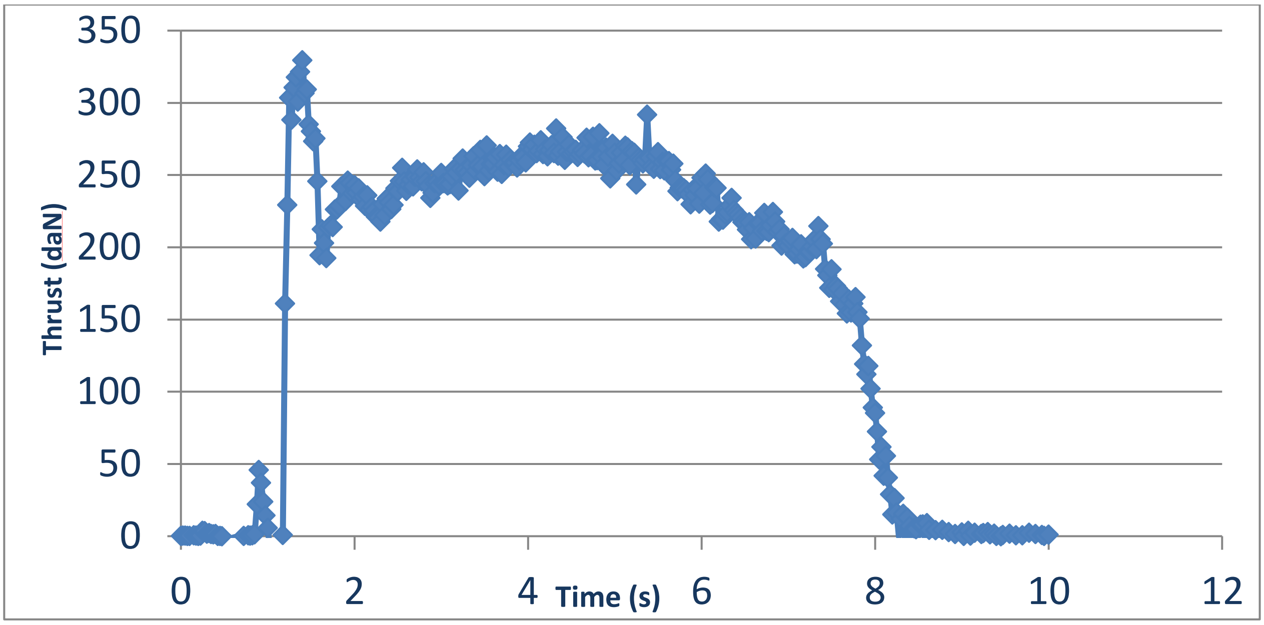

Figure 9 - Thrust curve

6. Conclusion

Each member of the team was deeply invested in this project. Despite the planned slots, we often took on our personal time. This project allowed us to confront the current industrial challenges for which research, innovation, testing and project management are the key words.

After the successful launch on a test bench, IMA school has been chosen to manufacture 3 composite nozzle for the PERSEUS rocket launch in 2018.