Operative Research Project on Hybrid Engine in Europe (ORPHEE)

Executive summary (from final report of the project)

Hybrid technology appears as an innovative, high performance and promising propulsion technique in number of space missions. By combining characteristics taken from both solid and liquid propulsions, this technology is expected to provide mainly high performance with throttleability and stop - restart capabilities. However, the current state of the art outlines that the standard fuels (mainly based on a hydrocarbonic polymer) suffer a low regression rate which induces complex grain shapes and low loading ratio. In order to achieve advanced fuels and to acquire a better knowledge, the Operative Research Project on Hybrid Engine in Europe (ORPHEE) was conducted from 2009 to end 2011, on the cooperation of nine partners (SME, Astrium SAS and Astrium GmbH, Avio, Onera, DLR, Politecnico di Milano, University of Naples, University Polytechnic of Bucharest, Thyia), and supported by funding from the European Commission's Seventh Framework Programme (FP7/2007-2013). The overall logic of this project was devoted to increase the readiness of advanced fuels from a TRL1 to TRL2-3 and propose a coherent approach dealing with promising applications identification, mathematical models building, demonstrators and test bench designs, and technological roadmap definition.

A first study aimed to select potential interesting fuels by characterising the fuel composition and its combustion at small scale. A specific task was devoted to the scaling up of these compositions in order to reach a formulated grain mass of 7kg. One focused on the process of metallic powders addition and the verification of the grains integrity and homogeneity. The obtained fuel grains were fired by using gaseous oxygen. Accurate study of test results allowed describing the regression rate evolution in function of global mass flux and geometric shape of the grain and gave experimental data for numerical tools validation. More specifically, these tests provided information on the aptitude of metallic powders to increase the regression rate at large scale. It is observed that their effect is much less important than it was demonstrated at small scale.

Based on these results, two preliminary road-maps have been built by the ORPHEE partners. They address suitable hybrid propulsion demonstrators that are dedicated to space applications (selected through a market survey and system analysis). Technological needs in term of development and associated time periods are presented a TRL of 6 for the two demonstrators have been identified.

UPB- Contribution

Activities conducted under the project ORPHEE, have helped to create a knowledge database, fully used in educational activities in the UPB. The project, also helped to develop an experimental basis for hybrid rocket engine testing , necessare to complete the model used to evaluate the scalability and controllability of the rocket engine. At the same time, the tests performed was used as the basis for the development of LES turbulence model,one of the objective of WP 430 . The project was attended by experienced teachers , young researchers, and even students. Project results were materialized by creating a test engine, and a real engine, which will be used for a sounding rocket. After completion of the project, research results will be used in specialized courses presented students from Faculty of Aerospace Engineering from the University POLITEHNICA of Bucharest.
The research results were the subject of four publications and a patent proposal.

Papers:

Chelaru T.V. Mingireanu F. *Hybrid rocket engine, theoretical model and experiment*, Acta Astronautica 68 (2011) , AA4027, ISSN 0094-5765,Volume/issue 68/11-12, pp.1891-1902.

Chelaru T.V., Mingireanu F.,Enache V., Neagu I., *Mathematical model and experimental results for hybrid rocket engine, types of injectors, scratches design, thrust control*, Proceedings of 62nd International Astronautical Congress (CD), ISSN: 1995-6258 Cape Town, SA. 03-08 Oct. 2011.

Chelaru T.V. , Mingireanu F., Enache V., Neagu I., *Scalability and dynamic stability of hybrid rocket engines*, Proceedings of the 5th International Conference on Recent Advances in Space Technologies-RAST2011, pp.723-728, ISBN:978-1-4244-9615-0, Istambul, Turkey, 09-11 Jun. 2011.

Chelaru T.V**.** Mingireanu F.*, Hybrid rocket engine, theoretical model and experiment*, 60th International Astronautical Congress, ISSN 1995-6258, Daejeon, Republic of Korea, 12-16 October 2009

Patent proposal:

Suborbital launcher with hybrid jet control system (based on hybrid rocket engine). OSIM registration no. A/01225-24.11.2011.


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