An experimental and numerical coordinated approach for the improvement of hybrid rockets performance

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Combined experimental and numerical research activities can improve the knowledge of different phenomena occurring during the combustion processes in hybrid rocket engines, such as complex interactions among fluid dynamics, solid fuel pyrolysis, oxidizer atomization and vaporization (in case of liquid oxidizer), mixing and combustion in the gas phase, particle formation, and radiative characteristics of gas and flame. Also the ablation process of the nozzle thermal protection, and multidisciplinary approaches identifying the most promising solutions, evaluating expected performance and optimal design parameters, can further benefit from an experimental and numerical combined approach.

The paper presents the research project aiming to build a scientific Italian community focused on the study, experimental activities development and creation of numerical codes in the field of hybrid propulsion for the space access and exploration. The project is two-years lasting and is characterized by the commitment for a resource optimization and for a cost containment. It involves a network of four Italian Universities; each of them being responsible for a specific topic.

The task of Politecnico di Milano is the experimental activity concerning the study, development, manufacturing and characterization of advanced hybrid solid fuels characterized by a high regression rate, measured at lab-scale in a two-dimensional slab chamber, useful to investigate the boundary layer, the flame structure, and the general development of the combustion process.

University of Naples is responsible for experimental activities focused on the characterization at rocket motor scale of the solid fuels developed and characterized at laboratory scale by Politecnico di Milano. The University of Naples research unit is involved in firing tests carried out at several chamber pressures and oxidizer mass fluxes, and different fuel compositions. Test will be performed using GOx or NOx as oxidizer in order to compare also the influence of the kind of oxidizer on the fuel behavior. In all the tests average regression rate, motor thrust, chamber pressure, oxidizer mass flow rate, characteristic velocity c*, efficiency, and fuel consumption spatial distribution are measured or calculated to compare the experimental data with the theoretical models, in order to evaluate the fuel composition influence on regression rate, combustion efficiency and stability.

The University of Rome, besides to the expertise on the modeling of gas-surface thermochemistry, developed in the studies on ablative thermal protections, has experience in the field of numerical simulation of reacting flows, particularly in the presence of partially catalytic wall, and in the field of internal ballistics of solid rocket motors. The University of Rome has been studying the combustion chamber and nozzle of the hybrid rocket, defined in the coordinated program by advanced physical-mathematical models and numerical methodologies.

Politecnico di Torino has been working on a multidisciplinary optimization code for optimal design of hybrid rocket motors, strongly related to the mission to be performed. The developed procedure will be a tool for the scientific community for hybrid rockets design, but also a tool to be used to highlight the propellant characteristics which must be chosen for future developments.

The overall research project aims to increase the scientific knowledge of the combustion processes in hybrid rockets, using a strongly linked experimental-numerical approach. Methodologies and obtained results will be applied to implement a potential upgrade for the current generation of hybrid rocket motors.

This paper presents the overall strategy, the organization, and the experimental and numerical results of this joined effort to contribute to the development of improved hybrid propulsion systems.