Paper ID: 90023
oral
student

IAF SPACE PROPULSION SYMPOSIUM (C4)
Interactive Presentations - IAF SPACE PROPULSION SYMPOSIUM (IPB)

Author: Mr. Gianluca Cocirla
Sapienza University of Rome, Italy, gianluca.cocirla@uniroma1.it

Dr. Marco Grossi
Sapienza University of Rome, Italy, marco.grossi@uniroma1.it
Prof. Daniele Bianchi
Sapienza University of Rome, Italy, daniele.bianchi@uniroma1.it
Prof. Bernardo Favini
Sapienza University of Rome, Italy, bernardo.favini@uniroma1.it
Dr. Ferruccio Serraglia
European Space Agency (ESA), Italy, ferruccio.serraglia@esa.int
Mr. Dario Scoccimarro
European Space Agency (ESA), France, dario.scoccimarro@esa.int
Dr. Nicola Ierardo
European Space Agency (ESA/ESRIN), Italy, nicola.ierardo@esa.int
Mr. Claudio Milana
AVIO S.p.A., Italy, claudio.milana@avio.com

THREE DIMENSIONAL AND MULTIPHASE SIMULATIONS OF AFT-FINOCYL SOLID ROCKET MOTORS

Abstract

Current space transportation systems heavily rely on solid propellant rocket motors (SRM), which are crucial components for their high thrust, relatively low cost, easier scalability, and long-term storage capabilities. These attributes make SRMs essential to improve the flexibility of prominent launchers currently employed worldwide. To enhance SRM performance, contemporary designs incorporate complex aft-finocyl geometries and solid grain propellants containing up to 20% aluminum particles by mass. The inclusion of aluminum serves to release significant heat as the particles burn, forming aluminum oxides. However, the addition of metal particles introduces challenges and potential risks such as slag accumulation, nozzle scouring, and mechanical erosion.

Understanding the three-dimensional, two-phase flow dynamics in these propulsive systems is crucial for addressing the thermal and mechanical loads to which the motor and especially the nozzle materials are subject. However, experimental studies face great challenges due to the harsh internal operating conditions of SRMs, making numerical simulations a necessary tool to better understand the underlying physics and efficiently support the design and development phase. Within this context, the present study employs numerical modeling to scrutinize the impact of three-dimensional multiphase internal flows, typical of modern aft-finocyl solid rocket motors. The primary focus is on providing a good estimate of the expected thermal loads inherent to such systems, with a specific emphasis on the wall heat flux within the nozzle assembly. Indeed, as numerical simulations and experimental activities have shown, the nozzle component is subject to a very challenging environment in which three-dimensional effects, arising from the complex propellant grain geometry, play a primary role in generating a strong variation of the heat flux in the azimuthal direction. This behavior is further exacerbated by the alumina particles presence that, concentrating in specific regions of the motor, may provide an enhancement of the erosion of the protection

material due to their potential impacts on the nozzle walls. Aiming to relate the described phenomena to the motor design, the forthcoming full paper will outline an extensive parametric study encompassing motor grain geometry, with particular attention to fins design. Numerical simulations will be performed employing an in-house Reynolds-averaged Navier-Stokes solver featuring second order in space and third order for time accuracy. Turbulence closure is achieved with the Spalart-Allmaras one-equation model, while the dynamics of the aluminum oxide particle will be addressed with different approaches, ranging from heavy-gas to Eulerian-Eulerian up to Eulerian-Lagrangian coupling.