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Title

Multiphase and Multidimensional Effects on Solid Rocket Nozzle Performance

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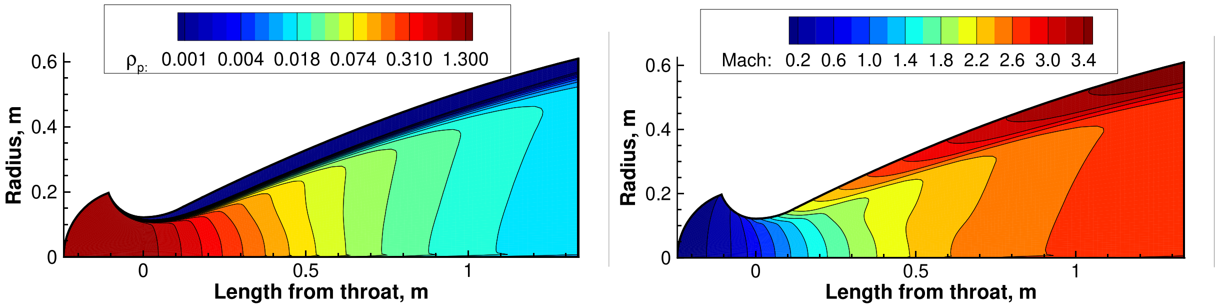
Abstract

The global space transportation system is heavily reliant on solid propellant motors [1]. In Europe, they represent an essential asset, as they are largely employed in the current Vega and Ariane 5 launchers and have been chosen for the next-generation vehicles such as Vega-E and Ariane 6.
The ability to accurately predict the performance of each motor stage has great importance in the overall design of the launcher system, allowing for a more accurate estimate of the payload mass that can be effectively inserted into orbit. In modern solid rocket motors, one of the most important phenomena that contribute to motor losses is related to the two-phase nature of the nozzle flow provided by the presence of condensed species in the combustion products [2]: due to their inertia, the particles, usually formed of aluminum oxide, are characterized by higher temperature and lower velocity with regard to the gaseous phase, providing a reduction of the average exit velocity of the flow. Consequently, the motor performances are deeply influenced by particles own properties such as size and dispersion [3]. The scenario mentioned above is even more complex when it comes to dealing with cutting-edge motors, such as the P120C and the Zefiro family, which are characterized by a three-dimensional aft-finocyl solid grain geometry. Such a feature generates an intrinsic three-dimensional flow close to the nozzle entrance which, affecting the distribution and the properties of the dispersed particles, could provide regions more or less rich of the condensed phase.

In this framework, the present work aims to investigate via a multiphase Eulerian-Eulerian CFD tool the three-dimensional nozzle flow of solid rocket motors, focusing on the description of the physical features of the flow fields and the estimate of the two-phase loss. Particular care will be devoted to the inflow set-up to investigate how a different distribution of the aluminum oxide within the nozzle volume affects the nozzle flow and its performance.

In the following, some preliminary results are provided in order to corroborate the adopted numerical framework. CFD simulations have been performed on the axisymmetric geometry of the Minuteman III stage II with the same tool which will be applied to the three-dimensional configurations envisioned in this work. The figures show the particles density (left) and the Mach number (right) flow fields. As it was expected due to the small size of the droplets (7 microns), the particle density has a regular behavior with a moderately limited particle-free zone. The latter can be clearly visible also in the Mach field. From a quantitative point of view, the present result has been compared with data reported in the scientific literature to validate the estimate of the two-phase and two-dimensional loss. As it is possible to see in the table below, a very good agreement has been achieved.

	Two-phase and two-dimensional losses
Present work	5.06 %
Literature data [4]	5.39 %



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