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NUMERICAL COMPUTATIONS OF NOZZLE PERFORMANCE LOSSES IN SOLID ROCKET MOTORS

Abstract

The objective of this paper is to comprehensively reconstruct nozzle performance losses in solid rocket motors (SRMs) utilizing a high-fidelity computational fluid dynamics (CFD) approach. Traditionally, reduced models like the Solid Performance Program (SPP) have been employed for SRM performance predictions. However, advancements in computing power now enable the use of more sophisticated tools. In contrast to the SPP, which relies on independent efficiency models for loss contributions, CFD simulations offer two significant advantages. Firstly, motor performances are directly derived from numerical computations without relying on initial theoretical estimates. Secondly, the CFD approach considers the interactions among various phenomena affecting motor performance, giving the possibility to highlight how each contribution works with the others.

The employed mathematical and numerical model is designed to account for all physical phenomena contributing to performance reduction. Consequently, the CFD model solves compressible Navier-Stokes equations for multiphase and reacting flows. For particles dynamics, crucial in modern composite propellants with metal powders, a polydispersed Eulerian approach is chosen. Additionally, a finite-rate chemistry model is employed to handle recombination reactions in the divergent nozzle section.

To display the robustness and versatility of the CFD approach, extensive numerical simulations are conducted on a diverse range of solid rocket motors (e.g., Space Shuttle RSRM, Vega Zefiro family). These motors represent various operational scenarios spanning the extensive history and current roles of solid rocket motors. As it will be presented in the final manuscript, an excellent agreement is found between computed results and experimental data, especially for the newer motor design, showing how the CFD approach represents a valid and viable solution to evaluate solid rocket performances.