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SPACE PROPULSION SYMPOSIUM (C4)
Propulsion System (2) (2)

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A COMPUTATIONAL MODEL FOR STABILITY AND SENSITIVITY ANALYSIS OF A CLASSIC TYPE HYBRID ROCKET MOTOR

Abstract

The hybrid rocket motors (HRM) use a two-phase propellant system that offers some remarkable advantages but also arises some difficulties like the neutralization of their combustion instabilities. Much of the research in the field of hybrid propulsion is focused on the understanding and control of the non-acoustic and acoustic type combustion instabilities. In this work we first present a simplified 1-D mathematical model for HRM based on the coupling of the hybrid combustion process with the complete unsteady flow and with the heat transfer inside the solid propellant. The flow model is the unsteady 1-D Euler system of gas dynamics, which include source terms representing geometrical and physicochemical effects (friction, kinetic heating due to friction, heat loss to the wall through convection and radiation). The HRM system including the flow equations, the thermal conduction equation inside the solid propellant and the fuel's regression rate law is solved numerically in a coupled manner. The platform of the numerical simulations is a high order cell-centred finite volume method. The time-advancement is done using an implicit second-order scheme combined with a dual-time explicit relaxation. This mathematical and computational 1-D model has already been tested with good results. The HRM model includes a number of uncertain parameters whose actual values are known only approximately or can vary around some reference values. We only enumerate here the parameters included in the source-like terms and those related to the fuel's regression rate. The objective of the sensitivity analysis is to determine quantitatively the behavior of the responses of the HRM model locally around a chosen point of the trajectory in the phase-space of parameters and dependent variables. In this work, the response considered is the pressure in the combustion chamber and/or the thrust. The sensitivities are useful for design and for optimization purposes. The HRM mathematical model is first linearized around a base-case state. The linear model is used for the development of the local adjoint sensitivity and stability analysis tools. The computational and stability analysis model developed in this work are simple, computationally efficient and offer the advantage of taking into account a large number of functional and constructive parameters used in the HRM design. The results include a sensitivity and a numerical stability analysis, done by examining the pressure in the combustion chamber of a HRM model.