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PARAMETRIC STUDY AND SENSITIVITY ANALYSIS OF HYBRID ROCKET MOTORS WITH DOUBLE-TUBE CONFIGURATION

Abstract

The practical implementation of hybrid rocket motors has historically been hampered by the slow regression rate of the solid fuel. In recent years, the research on advanced injector designs has achieved notable results in the enhancement of the regression rate and combustion efficiency of hybrid rockets. Following this path, this work studies a new configuration called double-tube characterized by injecting the gaseous oxidizer through a head end injector and an inner tube with injector holes distributed along the motor longitudinal axis. This design has demonstrated a significant potential for improving the performance of hybrid rockets by means of a better mixing of the species achieved through a customized injection of the oxidizer. Indeed, the CFD analysis of the double-tube configuration has revealed that this design may increase the regression rate over 50% with respect to the same motor with a conventional axial showerhead injector. However, in order to fully exploit the advantages of the double-tube concept, it is necessary to acquire a deeper understanding of the influence of the different design parameters in the overall performance. In this way, a parametric study is carried out taking into account the variation of the oxidizer mass flux rate, the ratio of oxidizer mass flow rate injected through the inner tube to the total oxidizer mass flow rate, injection angle, number of injector holes and their diameter. The data for the analysis have been gathered from a large series of three-dimensional numerical simulations that considered the changes in the design parameters. The propellant combination adopted consists of gaseous oxygen as oxidizer and high-density polyethylene as solid fuel. Furthermore, the numerical model comprises Navier-Stokes equations, k-ε turbulence model, eddy-dissipation combustion model and solid-fuel pyrolysis, which is computed through user-defined functions. This numerical model was previously validated by analyzing the computational and experimental results obtained for conventional hybrid rocket designs. In addition, a sensitivity analysis is conducted in order to evaluate the influence in the performance provoked by the possible growth of the diameter of the inner fuel grain holes during the motor operation. The latter phenomenon is known as burn through holes. Finally, after a statistical analysis of the data, a regression rate expression as a function of the design parameters is obtained.