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DYNAMIC MODELING AND SIMULATION OF A HYDROGEN PEROXIDE MONOPROPELLANT THRUSTER

Abstract

In this article, a dynamic model was developed using a 1-D heterogeneous packed bed reactor with a two-phase flow assumption. Properties within the catalytic reactor are axis-symmetric and vary with axial location and time. Mass and heat transfer between a liquid-gas mixture and solid catalyst were considered as well as thermal and catalytic decomposition processes. The model was numerically solved using MacCormack's finite difference method and generated in a MATLAB environment for computer simulation. A 100 N-scale monopropellant thruster was developed and tested using a highly concentrated Hydrogen Peroxide. MnO2/PbO/Al2O3 catalyst was fabricated and mounted inside the catalyst bed for the experiment. Firing tests in a steady-state mode were conducted in various operating conditions and the results were compared with the results from the simulation for the model validation. During this process, key parameters including mass and heat transfer coefficients were selected to fit the experimental data through a Design Space Exploration approach with the Gaussian Processes Regression method. With the established modeling tool, it was possible to run a numerical simulation to predict the transient behavior of the hydrogen peroxide monopropellant propulsion system. The results show that a transient behavior of the hydrogen peroxide monopropellant propulsion system can be adequately predicted by a newly developed dynamic model. A parametric study was also conducted to emulate the low-frequency instability of the monopropellant propulsion system. The feed line of the propulsion system was actively perturbated to stimulate the chugging instability within the catalytic reactor. The aspect ratio of the reactor and injection momentum of the propellant were varied for the simulation. The results revealed that the phase shift between the oscillatory mass flow rate measured at the inlet and outlet of the reactor, which indicates the residence time within the system, plays a key role in predicting the possibility of the occurrence of the low-frequency instability. As a result, the dynamic model developed in this research proved to effectively simulate the transient behavior of the Hydrogen Peroxide monopropellant thruster. The model was also possible to predict the low-frequency combustion instability of the monopropellant thruster.