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Author: Mr. Sukmin Choi
Korea Advanced Institute of Science and Technology (KAIST), Korea, Republic of

Mr. Sangwoo Jung
Korea Advanced Institute of Science and Technology (KAIST), Korea, Republic of
Prof. Sejin Kwon
Korea Advanced Institute of Science and Technology (KAIST), Korea, Republic of

LOW-ORDER DYNAMIC MODEL OF HYDROGEN PEROXIDE CATALYTIC REACTOR FOR TRANSIENT BEHAVIOR PREDICTION

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 distance and time. Mass and heat transfer between a liquid-gas mixture and solid catalyst were considered as well as thermal and catalytic decomposition. 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 and the results were compared with the results from the simulation for the model validation. During this process, key variables such as reaction rate constants were calibrated to fit the steady-state test results. Using this data, it was possible to run numerical simulation using a dynamic model to predict the transient behavior of the HTP monopropellant propulsion system.

The results show that a transient behavior of the HTP monopropellant propulsion system can be adequately predicted by a newly developed dynamic model. A comparison between the simulation and test results shows that the model is capable of predicting pressure and temperature changes across the catalyst reactor at a given time.

Parametric study was also conducted to emulate the low-frequency instability of the monopropellant propulsion system. The feeding line was simulated using method of characteristics method and added to the existing code. Aspect ratio of the catalyst reactor and injection momentum of the propellant were varied for the simulation. Pressure instability was witnessed both in the test and simulation results at the initial phase of the start-up sequence in high aspect ratio and low momentum conditions.

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.