SPACE PROPULSION SYMPOSIUM (C4)
Poster Session (P)

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NUMERICAL SIMULATION OF A SINGLE HYDRAZINE DROPLET BURNING WITH A DETAILED KINETIC MECHANISM

Abstract

A single hydrazine (N2H4) droplet model has been developed, and combustion simulations of the droplet in a di-nitrogen tetroxide (NTO: N2O4) atmosphere have been performed. The model and results describe the hydrazine combustion process and its flame structure in detail that can reveal phenomena inside thruster chambers.

Hydrazine is now a popular rocket fuel, but the exact mechanism of hydrazine combustion is still uncertain. The accident of AKATSUKI propulsion system may still be fresh in our memory. As one of the factors of uncertainty, there is no decisive numerical combustion model for hydrazine, nor has a hydrazine/NTO chemical kinetic model been correlated with experimental data. Also, combustion occurring in the thruster chamber is complex, and evaluation of the model that describes the fuel's combustion in a simple system, not the thruster system, is needed.

In our present study, we modelled hydrazine liquid droplet combustion as the simplified system of the thruster combustion. The hydrazine droplet was burned in an NTO atmosphere at steady state. The model includes a detailed kinetic reaction model. We first verified the hydrazine and NTO detailed kinetic reaction model through comparison with experimental data then we performed parametric simulations.

The droplet model includes liquid-gas phase change, vaporization, gas compositional change, and heat release. We developed the code into a two-phase liquid-gas system in spherical coordinates, added an optically-thin radiation model, and incorporated the improved hydrazine-NTO detailed mechanism. The physical phenomena are governed by the mass conservation equation, the energy conservation equation, and species balance equations. This nonlinear two-point boundary value problem is solved by Newton's method with adaptive gridding techniques.

The burning rate is computed as an eigenvalue, which removes the uncertainty associated with employing evaporation and condensation rate laws in its evaluation. From a physical viewpoint, the burning rate controls ignition delay and heat release, and it depends on the droplet diameter and conditions of the surrounding gas. Depending on the environmental conditions, combustion products and dominant reactions that govern the system are different. The hydrazine and NTO detailed kinetic mechanisms can explain such differences and flame structure in detail. Also the simple burning simulation of the hydrazine droplet will give the key to problems that occur in the thruster chamber. We will discuss the products and the process of the combustion related with the environmental conditions and the burning rate.