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Title

Estimation of Hard Start Mechanism by Visualization Test of Hypergolic Bipropellant Thruster

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Abstract

Bipropellant thrusters are important components for spacecraft orbit and attitude control by injecting hot combustion gas at high velocity through a nozzle. The oxidizer/fuel is often a combination of nitrogen tetroxide (NTO)/hydrazine (N2H4), which is hypergolic propellants. The ignition process is extremely complex because it is a multi-component gas-liquid multiphase flow and involves condensed phase reactions [1]. In recent years, it has become clear that an oxidizer with high vapor pressure becomes a gas-liquid multiphase injection when the chamber pressure is close to a vacuum, such as at the start of propellant injection. In addition, a hard start is likely to occur when such a condition occurs [2]. Hard start has the potential to destroy the combustion chamber by causing a rapid increase in chamber pressure. However, the exact mechanism is not understood.

The objective of this study is to estimate the hard start mechanism of a hypergolic bipropellant thruster from visualization tests and numerical calculations. Using a visualization chamber, high-speed photography and chamber pressure measurements were performed in a vacuum environment to observe the hard start process. In addition, spray tests were performed using simulated fluid with injector backpressure control to observe propellant injection and impact conditions up to the pre-ignition pressure. In the simultaneous oxidizer/fuel injection test, when the injector backpressure was close to vacuum before the hard start occurred, the oxidizer was in flash boiling injection and the propellants collided differently than nominal. Therefore, a large amount of oxidizer impacted the combustion chamber wall surface. Subsequently, the oxidizer on the wall and the fuel for film cooling reacted and vaporized in a liquid-liquid reaction. Calculation of flame propagation velocity from the visualized images at the time of the hard start suggested that the hard start was an ignition with detonation. Based on these results, a hard start scenario was developed by comparing numerical calculations and test results considering detonation.

References

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