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INSTABILITY OF CRYOGENIC SWIRL FLOWS UNDER SUPERCRITICAL CONDITIONS

Abstract

Instability characteristics of the flow under supercritical conditions were investigated. Because recent liquid-propellant rocket engines use cryogenic liquid propellant and its combustion chamber works under supercritical condition of the propellants, the study of the propellant injection under supercritical condition is required. And instability characteristics of the flow are related to the response of the flow to the external excitation. Therefore, an experimental study was conducted to investigate the characteristics of a cryogenic swirl flow under subcritical to supercritical conditions.

In the experiment, liquid nitrogen was used as a working fluid to simulate liquid oxygen. A swirl type injector was used to create a hollow cone shape flow. Ambient pressure of the flow was changed up to 5 MPa to create supercritical condition of the injected flow.

First of all, High-speed photography was used to observe the instability characteristics of the flow. Two kinds of the instability mechanism were found from the flow image; precessing vortex core and Kelvin-Helmholtz instability. At first, precessing vortex core in the central toroidal recirculation zone of the flow created helical wave structures on the flow surface. These structures were then rolled up by entrainment of surrounding gas caused by Kelvin-Helmholtz instability. These significant instability phenomena were observed due to the low surface tension and viscosity of the working fluid. Additional analysis of the flow image was conducted using proper orthogonal decomposition method.

The instability frequency of the flow was measured by laser diagnostics using an Ar-Ion laser and a photodetector. The transmission rate of the laser line beam passing through the flow was measured, and the instability frequency was calculated by a spectral analysis. The value of the instability frequency was in order of 10^3 Hz, which is similar to the frequency observed in the liquid rocket engine caused by combustion instability. And the frequency was highly affected by the velocity of the flow.