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A LINEAR STABILITY ANALYSIS OF UNIQUE LOW FREQUENCY MODE ON UNI-DIRECTIONAL VORTEX INJECTION HYBRID ROCKET ENGINES

Abstract

On uni-directional vortex injection (head-end swirling injection) hybrid rocket engines (UVIHREs), it is not certain that there is unstable combustion oscillation mode unique to hybrid rocket engines. Axial hybrid rockets have a linear low frequency instability unique to hybrids that is amplified by the couple of the time lag from the disturbance of fuel vaporization to the heat convection of the turbulent boundary layer combustion and the one of heat conduction and fuel vaporization of solid fuels. In fact, low frequency combustion oscillations that seemed to be due to this mechanism have occurred in many experiments. However, in UVIHREs, such low frequency oscillation has never been observed and there was no research investigating whether this mode is unstable or not in UVIHREs. In this paper, linear stability analysis for the system of the whole combustion chamber of UVIHREs that include the hybrid unique mode is conducted. This research extends the linear stability analysis for axial hybrids by Karabeyoglu et al [1]. In this research, the phenomena occurring in the combustion chamber is separated into roughly three parts. The first phenomenon is the set of turbulent boundary layer combustion and heat conduction to the solid fuel. The second one is the set of solid fuel heat conduction and fuel vaporization. The third one is the gas dynamics of main flow in the combustion chamber. About these separated phenomena, the linear transient functions are derived. The first and third phenomena that are related to the fluid dynamics are newly derived. The stability analyses are conducted on the local system of unique mode to hybrids and the whole chamber. The local system consists of the couple of first and second response functions because in the whole chamber system this pair represents the unique mode of hybrids. The result of the linear stability analysis on the local system shows the unique mode is also unstable as axial cases if there is no disturbance of vortex intensity. Next, the transfer function of the couple of the all models is derived. This function shows the disturbance propagation from the oxidizer mass fraction and vortex intensity to the density at the injector. The stability analysis for the whole transfer function shows that on the whole chamber system of UVIHREs, the couple of the hybrid unique mode is the only unstable mode and the chamber bulk mode and acoustic modes are stable.

[1] Katabeyoglu et al., AIAA 2003-4463.