Paper ID: 9706
oral
student

SPACE PROPULSION SYMPOSIUM (C4)
Propulsion Technology (3)

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EFFECTIVE STABILITY ANALYSIS OF LIQUID ROCKET COMBUSTION CHAMBERS: EXPERIMENTAL INVESTIGATION OF DAMPED ADMITTANCES

Abstract

Thermo-acoustic instabilities of high frequencies represent a major threat in liquid rocket combustion chambers, potentially leading up to the failure of the propulsion system and the entire mission. While full-scale experiments are rare and expensive, and numerical simulations are still not able to predict high frequency instabilities accurately, analytical models offer a way to rapidly estimate the most important parameters, eigenfrequencies and growth or decay rates. As a presumption for this technique, the properties of acoustic boundary conditions, characterized by their impedance or admittance, have to be known precisely. Especially their behavior in transient situations is important for stability analysis. This can be expressed as a dependence of the admittance on the complex frequency.

A method is described to investigate admittances experimentally with respect to complex frequencies, with an emphasis on higher modes. The set-up consists of a cylindrical domain with superimposed mean flow. The object to be analyzed is placed at the exit of the domain. A pulsed excitation at the eigenfrequency is established at the inlet. Based on an extended multi-microphone technique, the time-dependent, three-dimensional, decaying acoustic field in the domain can be reconstructed from measurements. A separation into different modes, like the first transverse mode, is performed. The instantaneous linear damping rate is extracted from the evolution of the acoustic energy. An evaluation of the field at the exit yields the admittance for the complex frequency.

This method has been applied to a cold sub-scale combustion chamber test rig. A chocked nozzle was investigated as the boundary condition. For the first time results for the complex frequencies were acquired. The data obtained show very good agreement with theoretical predictions. This proves the theory for nozzle admittances for complex frequencies and demonstrates the measurement technique.