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EXPERIMENTAL INVESTIGATION OF SELF-EXCITED COMBUSTION INSTABILITIES WITH INJECTION COUPLING IN A CRYOGENIC ROCKET COMBUSTOR

Abstract

High-frequency combustion instabilities present a serious risk for the operation of liquid propellant rocket engines. Due to high energy release densities in the combustion chamber, those thermoacoustic oscillations can rapidly grow to high amplitudes which may result in the destruction of the engine. Even though combustion instabilities have been under investigation since the 1950s, the underlying coupling mechanisms are still not completely understood.

For this reason combustion instabilities are investigated at the DLR Institute of Space Propulsion. The combustion chamber D (BKD) shows self-excited high-frequency combustion instabilities of the first tangential resonance mode for certain operating conditions. This cylindrical combustor has a diameter of 80 mm and the cryogenic propellants H2-LOx are injected by 42 shear-coaxial elements. At the maximum chamber pressure of 80 bar a thrust of 24 kN can be achieved. Due to the representative conditions, BKD offers a potential platform to study the coupling mechanisms and to gain a better understanding of the phenomena.

Two different types of self-excited high frequency combustion instabilities have been detected by operating BKD. The first type of instability with medium amplitudes has already been investigated in more detail. In a previous study the corresponding mechanism was identified: heat release fluctuations with resonance frequencies of the LOx post drive the first tangential resonance mode of the chamber volume. The second type of instability was observed for different operating conditions and is characterized by higher amplitudes, more than 75 % of the static chamber pressure. Analysis of the pressure data showed that amplitude and frequency of the acoustic field vary strongly over time, which complicates interpretation of the coupling mechanism. However, by using highly resolved information of the acoustic field in the time domain, both from the combustion chamber and the injector volumes, and acoustic modelling of the injector elements, insights into the mechanisms could be gained. For regions of lower amplitudes the pressure oscillations are driven by LOx mass flow fluctuations, similar to the first type of instability. With increasing amplitudes also the frequency of the unstable mode increases and shifts into a region, where interaction with the hydrogen injector 1L mode is very likely.

Within the framework of the current study it can be shown, that for the coupling mechanisms of two different types of self-excited combustion instabilities under representative conditions in BKD, injection coupling plays a significant role.