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Title

Sensitivity study on a low order model for the analysis of transverse combustion instability

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Abstract

In the framework of liquid rocket engines (LREs), high-frequency combustion instability is one of the main threats to deal with. It manifests as self-sustained pressure oscillations with a well-defined spectrum, resulting from a complex feedback coupling of hydrodynamics, acoustics and unsteady heat release. The effort in its comprehension and prediction combines experiments and numerical models, spanning from high-fidelity simulations to low order tools. Low order modeling is characterized by low computational costs achieved through a simplified physics, requiring then a proper thermoacoustic coupling through a response function (RF).
In the context of low order modeling of combustion instability, the RF presented in [1] has provided good results [1,2]. While a common practice in response function modeling is to link directly pressure and heat release rate fluctuations, the present RF modulates the injected fuel mass flow rate as a function of pressure oscillations in the injectors. In this way it mimics the sustaining mechanism discussed in [3], characterized by the disruption of the fuel flow and the cyclic accumulation and release of fuel pockets from the injectors, whose unsteady combustion closes the feedback loop. Such RF is embedded in a multispecies Eulerian solver in which reactants burn through a simplified reaction mechanism.
This formulation includes several parameters, whose calibration has shown to be crucial to predict longitudinal instability in a quasi-1D framework [2]. The present work aims to extend the RF sensitivity analysis to a more complex scenario, with the goal of reproducing experimental data from unstable LREs. Indeed, it addresses the effects of each parameter on the RF behavior and, therefore, on the field and its stability in a multi-injector engine afflicted by tangential instability. In particular, the 82-injector oxygen-methane engine taken from [4] is used as reference test case.
Having assessed the role of the RF parameters on the system's dynamics, a key aspect concerns the capability of the model to capture the effect of damping devices. Specifically, the focus is on baffles, analyzing in detail different configurations and the subsequent modifications in the engine stability features.
In the final paper, a thorough sensitivity analysis on the RF main parameters will be shown, as well as the effect of baffles on the flowfield.

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