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PARAMETRIC STUDY OF COMBUSTION INSTABILITY IN A MULTI-INJECTOR ROCKET COMBUSTOR USING 2D PLANAR DETACHED EDDY SIMULATIONS

Abstract

Accurate modeling of combustion dynamics in liquid rocket engines remains a formidable challenge. The prediction of combustion instability is extremely complex due to the interaction of physical phenomena at different time and spatial scales such as acoustics, turbulence, hydrodynamics, species diffusion, chemical reactions and heat transfer. Within the U.S. Air Force Center of Excellence on Multi-Fidelity Modeling of Combustion Dynamics framework, Purdue University, MIT, University of Michigan, and University of Wisconsin-Madison are collaborating to develop reduced order models (ROMs) and data-driven techniques to efficiently simulate and predict combustion instabilities in liquid engines. The project aims to integrate ROMs into a multi-fidelity model that can predict the stability characteristics of a full-scale LRE containing multiple injector elements and provide a tool for designers to efficiently characterize the combustion dynamics of the liquid engines in shorter times and lower computational cost.

This paper presents the development of high-fidelity computational fluid dynamic simulations used for the training datasets for ROMs to predict the combustion instability behavior of multi-injector rocket combustors. 2D planar Detached Eddy Simulations are used to evaluate the performance, combustion dynamics, and stability of each configuration as well as met the requirements to create the ROMs. The combustor uses gas-centered shear coaxial injectors with warm gaseous oxygen and gas methane as propellants. Flow conditions are varied in the study including oxidizer and fuel inlet temperature, equivalence ratio, and presence of external heat sources for flame anchoring. Different distributions of oxidizer posts length, fuel collar thickness, fuel annulus gap, number of injectors, flat face vs. beveled injector geometry, chamber length, and presence of manifold are also analyzed. The high-fidelity simulations have been performed with Purdue's in-house CFD code GEMS (General Equation and Mesh Solver), which has been validated against experimental data from Purdues experimental rigs such as the Continuously Variable Resonance Combustor (CVRC) or Transverse Instability Combustor (TIC). A parametric study is presented along with a detailed physics analysis of the effects of each parameter in the stability behavior of the multi-injector rocket combustor.