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# ASSESSMENT OF COMBUSTION INSTABILITY MECHANISMS BASED ON AN ENERGY BALANCE ANALYSIS

**Abstract**

Combustion instabilities represent a formidable challenge and risk in the development and operation of liquid rocket engines. The coupling of unsteady heat release with the acoustic field present in the combustion chamber may provoke high-amplitude pressure oscillations that can damage and even destroy the engine. 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. In this way, the availability of high-fidelity CFD simulations has opened the door to accurately compute the energy balance of the combustion processes, thereby providing a better understanding and assessment of the effects and coupling mechanisms that drive the stability of combustors.

The energy balance analysis consists of the local and global integration of the terms in the Navier-Stokes energy equation as well as the fluctuation energy. The former equation provides the energy budget time evolution whereas the integration of the latter equation allows to compute the growth rates of the fluctuation energy terms. Both equations are integrated locally in small control volume subdomains, and globally, accounting for the full combustor domain. The result is the quantification of the relative contribution of each term in both energy equations towards assessing their coupling mechanisms and effects in combustion instability. The energy balance analysis is computed by post-processing the output data of high-fidelity CFD simulations performed with Purdue's in-house CFD code GEMS. This code is a finite-volume solver that is second order accurate in both space and time and solves the conservation equations in a coupled form. GEMS uses a hybrid LES-RANS approach called Detached Eddy Simulation (DES) to model turbulence.

This paper presents the application of the energy balance analysis methodology to unit problems that represent simplified cases of common scenarios present in practical combustors extensively studied at Purdue University. This approach allows for a clear isolation of effects and breakdown of physical phenomena while gaining insight into the combustion instability coupling effects and driving mechanisms.