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PREDICTION OF THERMOACOUSTIC INSTABILITIES BY THE LINEARIZED NAVIER-STOKES EQUATIONS INCORPORATED WITH THE NONLINEAR N-TAU MODEL

Abstract

Combustion instabilities are frequently encountered in liquid rocket engines (LREs) and gas turbines, due to the coupling between unsteady heat release and pressure fluctuations in the combustor. Acoustic models based on Helmholtz equations equipped with specific heat release models are commonly adopted because of the low computational costs. However, the application of the method in LREs may lead to large errors as the mean flow is no longer negligible. In this paper, the stability analysis is constructed for the model based on the linearized Navier-Stokes equation equipped with a nonlinear n-tau model for unsteady heat release. Linearized Navier-Stokes equations are solved in the frequency domain by using eigenfrequency analysis in COMSOL with Arnoldi algorithm, which enables the treatment of the combustion system with complex geometry. The thermoacoustic instabilities of a Rijke tube with mean flow effects are investigated by the proposed method, in comparison with the analysis with classical acoustic method. The proposed method is then applied in a model LRE with radial and tangential instabilities. The results show the equivalency of the present method with the classical acoustic method for low speed cases. The effects of mean velocity field, as well as the nonlinearity in heat release model, are thoroughly investigated, ranging from frequency shift, eigenmodes, etc. in frequency domain to limit cycle amplitudes in time domain. The stability boundaries, including the abstract stability and conditional stability, are also obtained with the help from the bifurcation analysis. The proposed method is capable to deal with the thermoacoustic systems with complex geometry and nonlinear unsteady heat release like LREs.