Investigation of Mean-Flow Effects on Tubular Combustion Chamber Thermoacoustics Using a Burner Transfer Matrix Approach

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Abstract

The present paper presents a methodology to account for local mean-flow effects on thermoacoustic instabilities to improve typical thermoacoustic calculations generally performed under the zero-Mach number assumption. In some regions of gas turbine and aero-engine combustors, such as the burner region, the Mach number is not negligible and assuming the mean flow at rest may lead to errors in the stability prediction of principal modes [1].

A 3D FEM model of a simplified combustor is solved in COMSOL Multiphysics® with the pressure acoustics interface. The Helmholtz equation is used to model the combustor and the classical n-tau model for the Flame Transfer Function (FTF) is adopted. In order to take into account for local non-zero Mach number effects in the burner region, the burner is replaced with its transfer matrix (BTM) which implicitly takes into account the mentioned effects. In particular, the BTM is computed through the Aeroacoustics interface considering an imposed mean-flow, reproducing numerically the experimental two-source technique.

The obtained matrix is inserted in the FEM thermoacoustic model of the simplified combustor. The BTM ability to represent local mean-flow effects and the impact on the resonant frequencies and their growth rate is then evaluated comparing the results with those provided by an in-house 1D code solving the linearized Navier-Stokes equations in the presence of a mean-flow. Simulations of the burner are performed for different mass-flow rates. Obtained BTM and theoretically derived [2] formulations for the burner transfer matrix are then applied to the combustor model to compare with the zero Mach number case.

Reference

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2. W. Polifke, Combustion instabilities, von Karman Institute Lecture Series, March 2004.