Application of a Weakly Non-Linear Analysis to the Analysis of Thermoacoustic Combustion Instabilities

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Abstract

The thermoacoustic combustion instabilities are due to the coupling mechanism between acoustic pressure oscillations and heat release fluctuations. This phenomenon, well known since the beginning of the last century, nowadays gives rise to a greatest interest because it occurs above all in lean premixed combustion chambers fueled by natural gas and used in modern gas turbine for power generation.

Over years has been found that the most suitable approach to study this phenomenon is to solve the inhomogeneous wave equation in the frequency domain considering heat release fluctuations (q') as a pressure source term[1].

In COMSOL Multiphysics® through the Pressure Acoustic interface (acpr) the inhomogeneous Helmholtz equation is solved. A linear Flame Transfer Function (FTF) is usually used to model heat release fluctuations as a delayed function. Solving the eigenvalue problem a linear stability analysis is performed. By means of these methodologies, it is possible to estimate frequency, wave shape and growth rate of the resonant modes [2], but in order to estimate acoustic amplitudes of limit cycles, nonlinear terms must be included into the modeling [3].

In this work, a non-linear Flame Describing Function (FDF) function of the amplitude of acoustic oscillations (r) is considered [4]. A weak non-linear analysis is performed to find the bifurcation diagrams of the acoustic amplitude as function of the intensity index n. For each value of n, the FDF is linearized around a fixed value of amplitude and the eigenvalue analysis is iteratively performed searching for the value of r for which the growth rate is zero, which correspond to a stable limit cycle solution of the system.

Results of the application of this analysis on two shapes of the combustor system, a simple cylindrical configuration and a simple annular one, are reported.

Reference

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