Thermo-Acoustic Analysis of an Advanced Lean Injection System in a Tubular Combustor Configuration

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Abstract

In order to reduce pollutant emissions, modern gas turbines are often equipped with lean premixed dry low emission combustion systems, where the engine operates near the lean blow-out limits. One of the most critical issues of lean premixed technology is the onset of combustion instabilities related to a coupling between pressure oscillations and thermal fluctuations excited by the unsteady heat release of the flame. Such instabilities may reduce the life of combustor components, thus, the prediction of the thermoacoustic behavior of a combustion system is a fundamental task during the design of low emission gas turbines. As far as aero-engines are concerned, thermoacoustic issues become much more critical since they are directly related to passenger security. Furthermore the use of liquid fuels makes the physical modeling more difficult. Several numerical methods can be used to predict the thermoacoustic properties of a combustor, ranging from monodimensional network-based tools to fully three-dimensional LES (Large Eddy Simulations) and FEM (Finite Element Method) calculations. In this work an advanced AVIO PERM (Partially Evaporated and Rapid Mixing) Injection System has been been analyzed using the acoustic module of the FEM code COMSOL Multiphysics. The performed analysis is based on the resolution of the eigenvalue problem related to an inhomogeneous wave equation which includes a source term representing heat release fluctuations (the so called Flame Transfer Function, FTF) in the flame region. In the FTF used in this work heat release fluctuations are supposed to be related to velocity fluctuations in the injection plane through a proportionality coefficient and a time delay constant, according to the typical formulation used for premixed combustion. The effect of the mean flow is neglected whereas the effect of temperature variations on pressure waves is included by considering the temperature profile in the combustion chamber obtained from CFD (Computational Fluid Dynamics) computations. Before performing the combustor thermoacoustic analysis, different strategies to model the injection system have been analyzed and compared with each other with the main aim of reducing the geometrical complexity of such system without significantly affecting the acoustic response of the combustor. A criterion to simplify the geometry of the double swirler injector was defined allowing to reduce the number of elements necessary to model this component. The thermoacoustic behavior of the combustor was analyzed both including and not including the FTF. Figure 1 shows the numerical mesh while Figure 2 shows an example of resonant modes obtained in this analysis. Numerical results were compared with both experimental data and results obtained with a monodimensional network-based solver. The acoustic FEM eigenvalue solver has

been successfully applied to predict the thermoacoustic behavior of a tubular combustor in terms of resonant frequencies and acoustic modes. FEM results compare well with results obtained with the monodimensional network-based solver, which uses an equivalent formulation for the FTF, whereas comparisons with available experimental data showed the necessity of an improved FTF, more suitable for liquid fueled gas turbine where the evaporation process could play an important role in the flame heat release fluctuations.

Figures used in the abstract

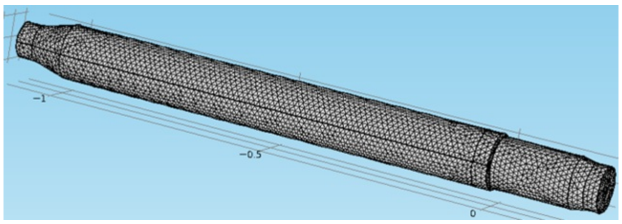

Figure 1: Computational mesh.

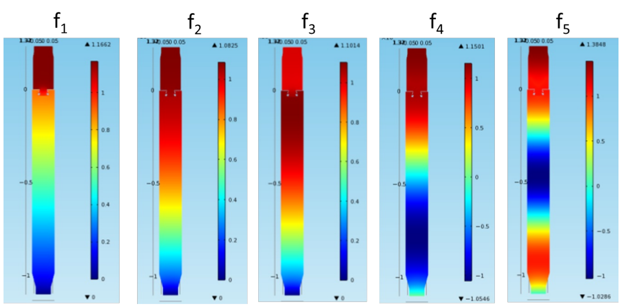

Figure 2: Examples of acoustic modes.