Computational Investigations of Boundary Effects on CFD Simulations of Thermoacoustic Instabilities

by

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Abstract:

The increasing awareness of environmental issues has been challenging gas turbine designers since early 90s. Lean premixed combustion is one of the strategies to achieve low NOx emission, and has been widely applied in gas turbines. However, near the lean-combustion limit, the gas turbines are more susceptible to thermoacoustic instabilities, which may cause loud noise, violent vibration, structural destruction, and time and economic cost. Thus, it is desirable and essential to predict and control the occurrence of thermoacoustic instabilities. Many studies have been focusing on the Computational Fluid Dynamics (CFD) simulations to explore this phenomenon, but they either made simplifications and ignore some complex but important mechanisms, or required impractically long time for computations. In this talk, I will first present the key issues in simulating the coupling process of heat release rate and pressure fluctuations involved in thermoacoustic instability phenomenon. Then I will talk about the potential sensitivity analysis approaches that are applicable to investigations of boundary condition effects on thermoacoustic instabilities. The focus is on the formulation of Continuous Sensitivity Equation (CSE) method applied to the Direct Numerical Simulation (DNS) of thermoacoustic instability problems. This proposed sensitivity analysis approach only requires a single run of the CFD simulation. Moreover, the sensitivities of field variables, pressure, velocity and temperature to boundary-condition parameters are directly obtained from the solution to sensitivity equations. Thermoacoustic instability is predicted by the Rayleigh criterion and indicated by Rayleigh index. The sensitivity of Rayleigh index is computed utilizing the sensitivities of field variables. This approach is validated through the 1-D thermally induced acoustics problem.

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