Support of Combustion Dynamics Simulation and Characterization at General Electric

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This report is intended to provide a summary of work completed under the University Turbine Systems Research (UTSR) program at General Electric Power Systems in Greenville, South Carolina. While general details of the work completed under this internship are provided in the following summary, specific information pertaining to design, simulation, and analysis performed is not given due to proprietary concerns.

The privilege of working with General Electric's professional engineering staff has greatly improved my understanding of combustion dynamics and of related flow physics. I want to specifically thank Dr. Kwanwoo Kim for spending a great deal of time mentoring me over the course of the semester. He has reinforced my decision to pursue a career path in combustion. I want to thank Dr. Shiva Srinivasan and Mr. John Intile for selecting me through the UTSR program, providing me the opportunity to work with GE. I have been greatly impressed by their understanding and confidence in the work they carry out. I also want to thank the staff at the South Carolina Institute for Energy Studies (SCIES) and the Department of Energy for managing and funding the UTSR program.

INTRODUCTION

The work outlined in this summary was directed toward gas turbine needs established by General Electric and more generally industry and government institutions whose goal was and is to improve the efficiency, reliability, and associated costs associated with such systems. Specifically, the work outlined in the following section addressed four major needs: (1) improve the dynamic stability of combustion systems under lean operation, (2) improve upon computational methods which predict the acoustic response of combustors, (3) increase the understanding of the interaction of heat release, pressure fluctuation, fuel/air distribution, and associated boundary conditions, and (4) reduce emissions, improve efficiency, and expand operability.

There were two industry objectives set prior to beginning the work performed over the course of the semester. These objectives were geared towards (1) application of GE's CDA tool to simulate acoustic response of various combustor geometries and (2) determine the role and influence that physical and chemical various mechanisms, modeled mathematically, have on the final computational results. There were also three student objectives related to this work: (1) enhance understanding of combustion systems, (2) gain exposure to design methodologies, and (3) assist with other areas related to gas turbine systems. To achieve these objectives, three approaches were implemented. First, multiple simulation cases were performed to characterize the combustor response trends for a range of boundary conditions. Second, these results were compared with experimental test rig results to aid in improvement of algorithm accuracy. Finally, by working with GE combustion experts and using the simulation results, discussion of future algorithm development could proceed.

SUMMARY

SIMULATION - CDA

The primary focus of the internship was to apply a Matlab-based software package developed by GE that predicts the dynamic behavior of a combustor. The dynamic behavior of combustion systems is of great importance because of the effects such unsteady behavior can have on operational performance, structural integrity, and cost. Over the course of the internship, I have applied CDA to simulate several operation conditions. This section outlines what operational conditions were simulated.

Comparison with Experimental Data

Based upon data obtained in combustor rig tests, CDA was used to simulate such conditions for comparison purposes to validate the results of the algorithm set.

Varying Geometry

Several combustor geometry designs were simulated in CDA to determine the effect of such geometry variations on the combustion dynamics.

Variations in Gas Properties

The gas properties (such as temperature and pressure) were varied to determine how the thermo-acoustic properties changed.

Time Variable Variation

The temporal characteristics (related to the fuel supply) were varied to determine the consequent dynamic properties.

Iteration Algorithm

A separate set of algorithms was developed to automatically run the CDA tool so that the user would not need to manually enter simulation conditions. The program reads data contained in Excel files that specify the appropriate boundary conditions and iterates through each condition.

SIMULATION - CFD

A commercial computation fluid dynamic (CFD) software package was used to simulate various boundary conditions for several combustor designs. One aspect that was of particular interest was the incoming equivalence ratio and the resulting flow characteristics when the ratio was varied.

ANALYSIS - SIGNAL PROCESSING

Several sensors are currently being considered for implementation into GE gas turbine combustors to monitor combustion characteristics. To aid in processing the large amount of data obtained from testing of these sensors, several algorithms were developed to simplify the analysis procedure. This set of algorithms made use of Matlab's graphical user interface capabilities for reading data and setting specific parameters which are used to determine analysis sensitivity (such as windowing used for FFT analysis).