Wave Rotor Performance Evaluation and Unsteady Heat Transfer Study

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**Gas Turbine Topping Combustion Wave Rotor Thermal Performance Analysis**

**Introduction**

Gas turbine engine performance can be significantly improved by implementing constant-volume combustion, particularly using the non-steady wave rotor combustor to replace the conventional steady-flow combustor. The schematic of combustion wave rotor configuration and the combustion wave rotor cycle are shown in figure 1 and figure 2, respectively.

**Method**

A consistent air-standard aero-thermodynamic model for gas turbine engines using wave rotor combination with real-gas caloric behavior and a simple gas-dynamic model.

**Why combustion wave rotor?**

- Constant volume combustion
- Internal wave compression and expansion processes
- Lower entropy production and higher pressure gain

**Discussion 1**

As shown in figure 6, a 25% increase of pressure ratio causes the specific work output increase 24% and specific fuel consumption decrease 19% and the entropy generation decrease 6.7%.

**Discussion 2**

There may have significant quantitative differences in predicted thermal performance between a constant and a temperature-dependent specific heat.

**Unsteady Heat Transfer Study**

**Background**

Quasi-steady heat transfer correlations are widely applied in unsteady flow devices which are often characterized with transient heat transfer process like in the wave rotor. The use of steady-state heat transfer correlations in transient thermal states can cause both magnitude and direction of heat transfer rate to be incorrectly predicted during the transition.

**Objective**

The research is to investigate the transient nature of the thermal response to a sudden change incoming far-field fluid temperature.

**Method**

Boundary layer theory is applied. The governing equations are discretized with Keller-Box implicit finite difference method.

**Discussion**

The transient thermal boundary layer response to a sudden change of far-field fluid temperature for a laminar incompressible flow is studied with initial built-up thermal boundary layer.

**Figure 9** shows a step change of incoming fluid temperature at P=2.0. The fluid-wall temperature difference changes sign. In this case, both magnitude and direction of the heat transfer changes during transition.

**Figure 10** shows the transition of local Nusselt number for incoming fluid temperature step change of R=0.5 and R=2.0, for different Prandtl numbers. For R=2.0, the local Nusselt number is negative initially, and continuously increases over time. For larger Pr, the transition period from initial to final steady sate is longer and occurs later than for smaller Pr, due to the smaller thermal diffusivity.