Turbine Aero-Thermal Technologies for 65% Efficiency
DE-FE0031616

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UTSR Project Review Meeting
Daytona Beach, FL
November 5, 2019
This material is based upon work supported by the Department of Energy under Award Number DE-FE0031616

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Overall objective
Develop feasible Conceptual Designs for advanced Aero-Thermal hot gas path front block components, and define a turbine test rig plan for Future programs to validate, and further advance, the technologies.

Technical Approach
Phase I - Discovery
• Generate advanced concepts to address the following technologies:
  • Blade Tip/Shroud Interaction
  • High Blockage Trailing Edge
  • Secondary Flows & Hot Gas Migration
  • Unsteady Aerodynamic Interaction

• Establish technology maturation and test plan to address technology gaps for future execution
Agenda

• Industrial Gas Turbine Terminology
• Major Loss Mechanisms
• Program Objectives – Phase I
• Active Work & Next Steps
• Future Product Validation
CC Plant Efficiency Timeline

- 60% 7HS 2007
- 63.08% 7HA 2018
- 65%

Combine Cycle Plant Efficiency (Percent)

Plant Commercial Operation Date

Industrial Gas Turbine Terminology

Inlet

Flow

Compressor

Combustor

Turbine

Exhaust
Turbine Stages 1 & 2

First two stages have greatest opportunity to impact Gas Turbine efficiency
Blade Tip/Shroud Interaction

- Hot gas leaks over the blade's tip
  - The potential stage work of that flow is mostly lost
  - Thermal loads on the tip, the shroud, and on downstream components increase
  - Over-tip leakage flow forms a vortex that generates additional losses
Blade Tip/Shroud – Tip Leakage, Vortex Loss Studies

- The Phase I program investigated over-tip performance loss mechanisms
- CFD analyses was used to predict the detailed flow physics and quantify performance opportunities
- Component features for Future high-speed rotating rig testing have been identified

Blade Tip Interactions Studies
- Analytical/CFD shroud abradable geometry studies were performed
- Improved system identified

Squealer Tip Studies
- Studies were performed on various concepts
- Performance opportunities exist
- Efficiency benefit is additive with shroud treatment

3-D Aero Tip Analysis
- Evaluated blade design concepts that reduce tip leakage loss
- Performance benefits quantified
- Efficiency benefits are additive with other approaches
High Blockage Trailing Edge Technologies

Objective: Reduce aerodynamic wake loss & trailing edge cooling flow

Approach: Combine airfoil shape, trailing edge cooling/discharge, and fabrication enablers to maximize the performance opportunity

- TBC Thickness increasing causes
  - Excessive airfoil trailing edge thicknesses
  - High aerodynamic blockages
  - High aerodynamic losses
- Analytical/CFD studies performed to identify high-performance TE architectures for future testing

TBC Thickness for previous-generation airfoils

Increased TBC Thickness is ever-increasing to shield against next-generation GT Firing Temperatures

Profile / Trailing Edge Loss
(Shock Loss too!)

Secondary Flows & Hot Gas Migration

- Unsteady CFD was used to predict stage efficiency and aero-thermal fields through the stage.

- Three approaches were targeted to mitigate the secondary/endwall loss and hot gas migration.
  - Use of fluidics
  - Profiling the trench cavity and blade platform
  - Airfoil radial profiling

- A combination of these approaches provides a solution to reduce secondary flow vortex strength and hot gas migration.

- Next steps include testing in a high-speed rotating rig will provide further insight into actual flow physics and performance
Unsteady Aerodynamic Interactions

• Reducing the turbine’s footprint positions airfoils close together, leading to flowfield interactions and loss

• Several fundamentally-different approaches were evaluated to reduce the unsteady loss

• Components and approaches to reduce unsteady interactions have been identified and are candidates for experimental assessment in future rotating rig testing
High Speed Rotating Rig Tests

Highly-Instrumented Turbine Rig Testing Provides Performance & Insight Into Flow Physics

Turbine Rig (From 2009 DOE-funded research) prior to installation in test cell

Turbine Exhaust Scroll

Notre Dame Turbomachinery Facility 5 MW Test Cell Shown

Turbine Cooling Flow Manifold
Product Validation – Follows DOE-Funded Program

GE’s Test Stand 7 Enables Validation Over A Broad Range of Operating Conditions
Summary

- This program’s objective was to develop *mechanically-feasible* emerging *aerodynamic* and *heat transfer* technologies targeting Stages 1 & 2 of the gas turbine to improve the entire turbine system and overall Gas Turbine cycle efficiency.

- In Phase I, GE investigated the following to improve the GT’s efficiency:
  - Blade Tip/Shroud Interactions
  - High Blockage Trailing Edges
  - Secondary Flows & Hot Gas Migration
  - Unsteady Aerodynamic Interactions

- *Advanced tip/shroud, trailing edge, hot gas migration, and unsteady interaction* technologies have been defined with existing tools and following best practices, but critical elements of the proposed components *challenge available empirical data*.

- In the future GEP expects to utilize The Notre Dame Turbomachinery Laboratory facilities for aero-thermal rig testing.
Questions?