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Perspective on R&D Needs for Gas Turbine Power Generation in a Carbon Constrained World

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Overview

- Looking at Last 15 Years
  - Requirements for Performance, Durability, Green Operation Substantially Increased
  - Significant Accomplishment in Turbomachinery Technology
- Looking Forward
  - Challenges
    - Requirements Still Present Significant Challenges
    - Currently on Lower Slope of Learning Curve
  - Universities Progress
    - Sophisticated Experimental Instrumentation & Rigs
    - Higher Fidelity Analytical Techniques, e.g. CFD
  - Industry Progress
    - Computer Power
    - Application & Validation of New Technology
    - Lean Operations
  - **To Be Effective University Research Must be Applicable in Industrial Design/Analysis Environment**

Figure 6. Post test images of deposits on C-M1 coupon at various blowing ratios.

UTSR: GT2008-50901

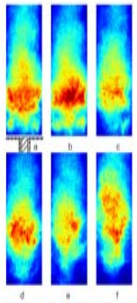
Figure 8: Consecutive images of 80%CH_4 -20% H_2 flame under near blowoff conditions (ϕ =0.42; images separation =2ms)

UTSR: GT2007-27308

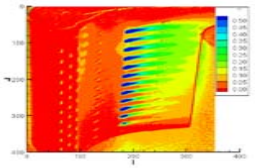
Figure 7. Local Film effectiveness distributions on the pressure surface-PS2 injections: (a) MFR=0.3%, (b) MFR=0.45%, (c) MFR=0.6%.

Industry: GT2007-27546

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Perspective on R&D Needs for Gas Turbine Power Generation in a Carbon Constrained World – **Heat Transfer**

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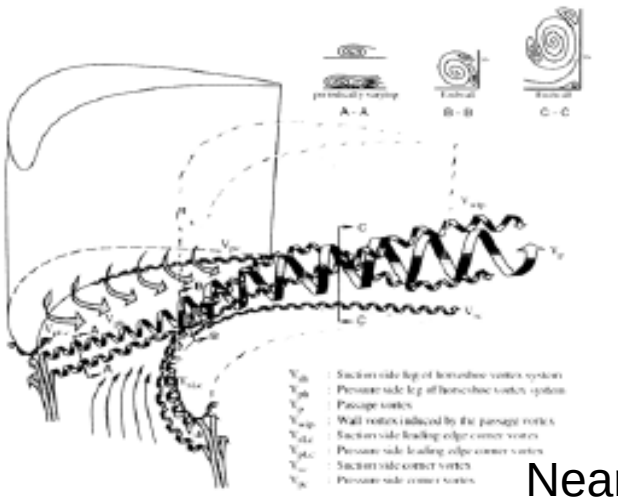
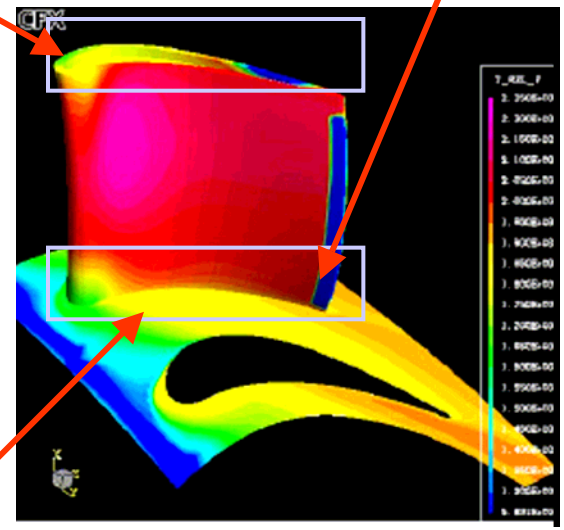
Turbine Blade Heat Transfer

Near Tip (Difficult to Cool Internally)

Often Critical Location

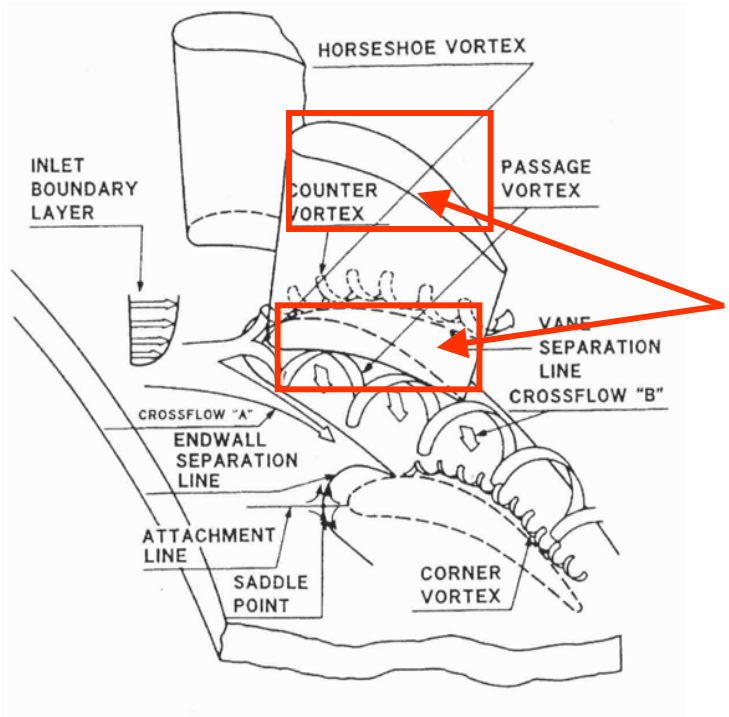




Near Platform & Platform

- Challenge To Predict Both Adiabatic Temperature & Heat Transfer Coefficients – Hot Streak, Phantom Cooling etc.
- Requirements
  - Model to Account for Effects Early in Design Cycle
  - CFD Based Modeling for Detailed Design
  - Experimental Validation

Nozzle Endwall and Near Endwall



Endwall region flow field, [Takeishi, 52].

Near Endwalls

- Challenge To Predict Both Adiabatic Temperature & Heat Transfer Coefficients
- Requirements
  - Model to Account for Effects Early in Design Cycle
  - CFD Based Modeling for Detailed Design
  - Experimental Validation

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Turbine Blade Trailing Edge Heat Transfer

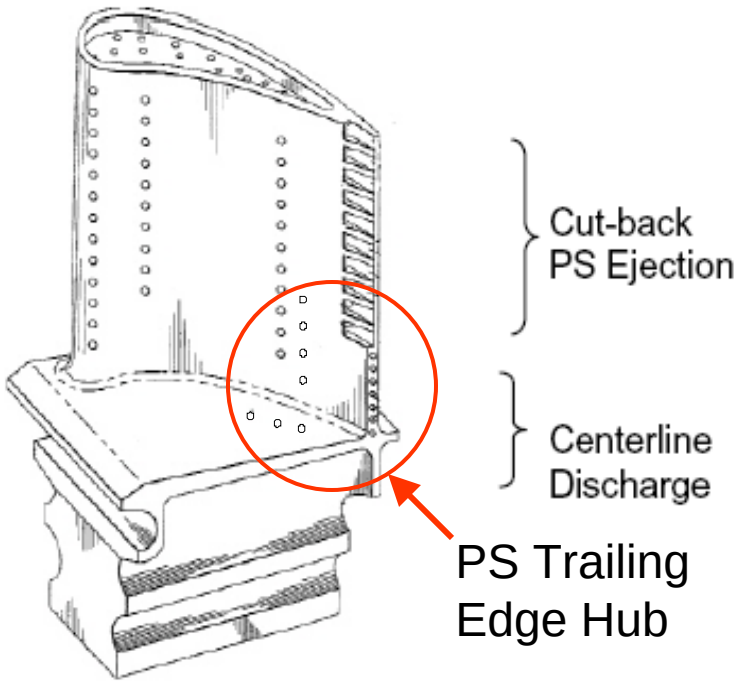


Figure 7. Typical high-pressure turbine blade showing trailing edge cooling openings and pressure side ejection slots, from Lee [11].

- Challenge to Predict Film Effectiveness and Heat Transfer on Pressure Side, Hub, Trailing Edge Region
  - Complex flow
  - Structural Requirement (Local Creep)
  - Flat Combustor Profile
- Requirements
  - CFD Analysis
  - Test Validation

Disk Cavity and Seal Flow

1D Flow Network

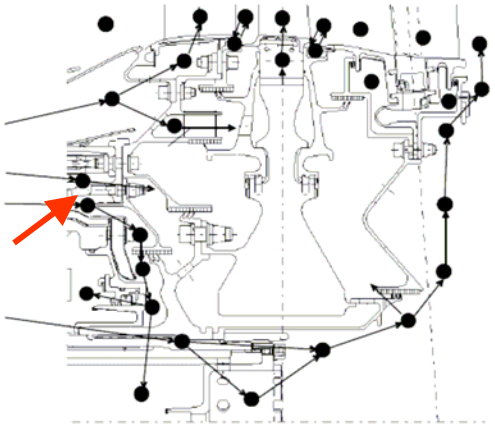
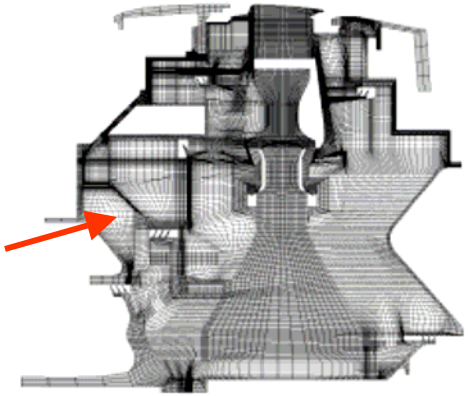


Figure 2 The 'Compact Thermal Model' linked with the main conjugate solution domain

3D CFD



GT2006-90033

Figure 1 Computational grid for conjugate analysis of the turbine rotor-stator system (meridional section)

- Challenge to Predict Heat Transfer HTC & Flow for Internal Secondary Flow
  - Seal Effectiveness for Various Configurations
  - High Swirl
  - Disk Pumping
  - Ingress/Egress
  - Radial Inward Flow (Little Available Data)
- Requirements
  - 1D Modeling
  - CFD Analysis
  - Test Validation

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Combustor gas Side Heat Transfer

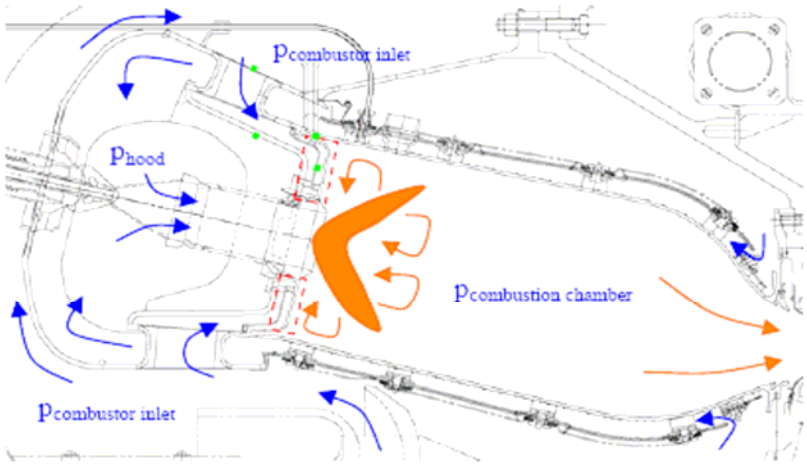

Figure 1: SGT-800 annular combustor: Main flow paths, recirculation zones and soft wall regions.

Figure 3: SGT-800 combustor with soft wall.

GT2009-59313

- Challenge to Predict Gas Side Heat Transfer
  - High Swirl
  - Reattachment at Liner
  - Chemical Reaction
- Requirements
  - CFD Analysis
  - Test Validation

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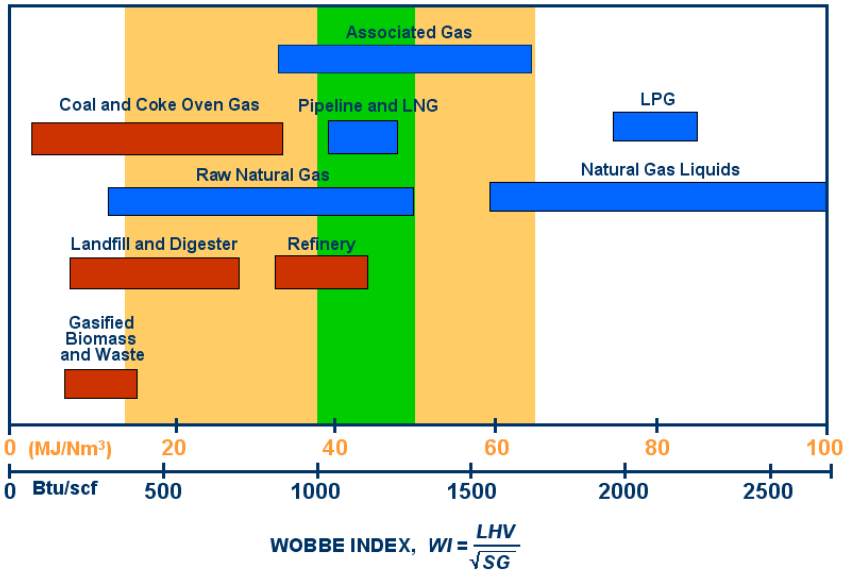
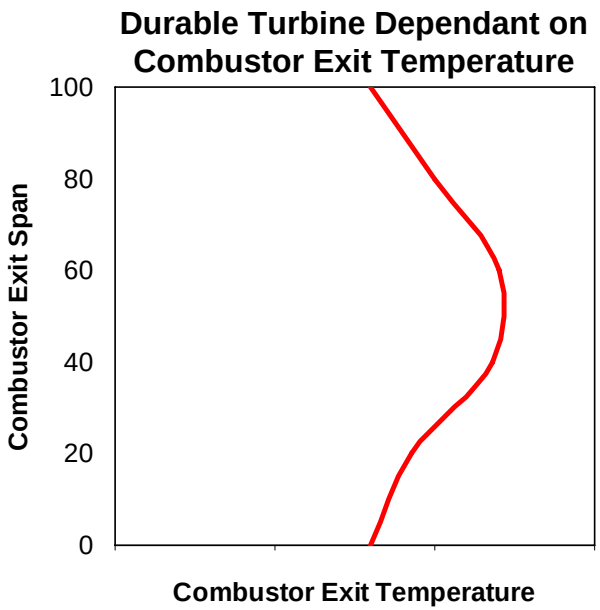
Perspective on R&D Needs for Gas Turbine Power Generation in a Carbon Constrained World – **Combustion**

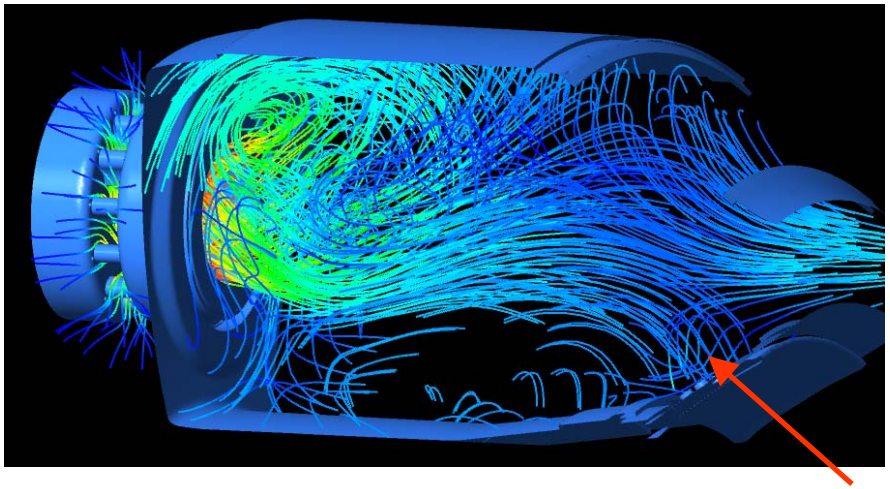
Expanding Gaseous Fuel Range

- Challenge to Operate Lean Premix Systems Over a Wide Range of Wobbe Index
  - Coal Gasification (High Hydrogen)
    - High Flame Speed, Flammability & Diffusion Make Lean Pre-Mix System Difficult
  - Coke Oven Gas
  - Gasified Biomass(Lower Hydrogen)
    - Combustion
    - Chemical Kinetics Modeling
  - Associated Gas (Higher Hydrocarbon)
    - NOx
    - Flashback
    - Combustion Pressure Oscillations
- Requirements
  - Improved Modeling
  - Detailed Kinetics
  - Mixing Technology
  - CFD
  - Test Verification



Combustor Exit Profile





- Challenge to Trim Combustor Exit Profile to Meet Durability Requirements
- Requirement
  - CFD Based Methodology
  - Improved Turbulence Modeling

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Perspective on R&D Needs for Gas Turbine Power Generation in a Carbon Constrained World – **Materials**

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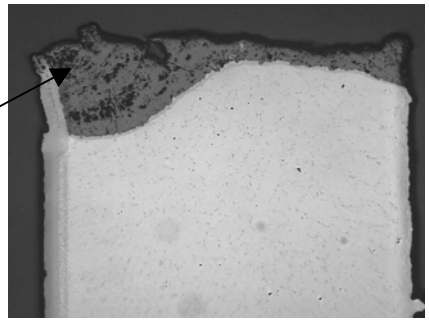
Materials Needs for the Future

- Challenge
  - Material Durability when Exposed to Various Combustion Gas Environments
    - H_2S/H_2/offshore
    - Coke oven gas
  - Degradation Mechanisms including Oxidation, Hot Corrosion, Sulfidation and Thermal Degradation



Turbine blade Tip hot corrosion

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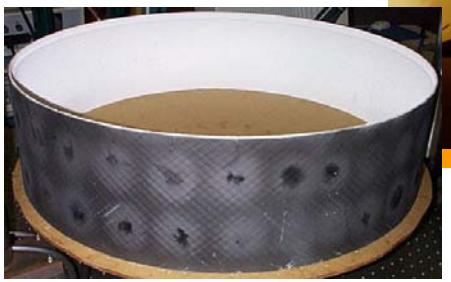
Materials Needs for the Future

- Requirements
  - High Cr Alloys (with Strong Creep Properties)
  - Coatings
    - Environmental
    - Thermal
  - Improved Testing Systems
    - Rig Tests that Demonstrate Engine Environment