Atomization of Oil-in-Water Unsteady Emulsion at Gas Turbine Conditions

2011 UTSR Gas Turbine Industrial Fellowship

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Background

- Liquid fuel is burned in the combustors through a diffusion flame, creating a high temperature and high NOx combustion.
- Water is injected to cool flame and decrease NOx emissions
- A water-in-oil emulsion system is located in liquid fuel line upstream from combustor and injected as mixture
Background

- Eliminated Atomizing Air (AA) system-accessory cost & water consumption savings
- “AA passage” is now fed with CD shroud air
- TBC spallation at risk – Predictive methods needed
  Previous issues resolved by reducing rate of water injection
- “Liner wetting” Transfer function development
- Emissions requirements
- Define acceptable liner “wetting” limits
- Validation of transfer function
Assumptions & Analysis

- Analyzed fired test data- test configurations A, B, & C. Each had similar geometries
- Evaluated the air blast temp and flow effects
- Water injection rate and magnitude effects
- Regression analysis for transfer function fit
  Application of transfer function to load cycle data
Test Data & Results

- **10-30% Load**
  - minor wetting issues- large W/F lead to wetting

- **50% Load**
  - problem area--no clear trends

- **Base Load**
  - No Liner wetting issues- NOx emissions easily reached
Transfer Function

• Two functions derived
  10-50%L \[ Y = f(X_0, X_1, X_2) \]
  50-BL \[ Y = f(X_3, X_3) \]

• Applied at GT load cycle
  • Up to 50% Load- increased W/F value will approach liner wetting
  • NOx compliant at 50%L range may see liner wetting
  • Past 50% liner wetting is not an issue
Discussion

• At Base load it is expected that temperature will increase until a W/F limit is reached- this limit appears to be outside current emissions requirements and is negligible to our current scope.

• As W/F ratio approaches 1.0, the consistency of the emulsion changes from a mixture of water droplets suspended in fuel to a semi-stable mixture having a texture of a heavy cream. At 50% L the mixture approaches this ratio, this could play a role in the strange behavior around this point.

• At 50% L the temperatures and pressures may be approaching a critical point for this breakup and a transition into heating and vaporization may be driving the atomization.
Conclusion

• Initial approach to Liner Wetting transfer function Developed
• Base Load conditions able to meet emissions without threat of liner wetting
• Limit W/F rate at low Loads to prevent liner wetting

Future

• Definition for acceptable “liner wetting” limits
• Defining a requirement for W/F vs. Load
• High Air Blast Temp expected to assist in the jet breakup-new hardware configuration tests
• More test points needed in the mid-load range to characterize behavior
• Further Development of transfer function model with new test data
Fellowship Summary

• Joined Aerothermal Design team working on development projects and various support role.

• Great Experience, gained valuable knowledge of Gas turbine Combustion fundamentals and its application through GE Combustion Design.
  • Attended weekly training sessions
  • Worked with highly knowledgeable and trained engineers
  • Data reduction and analysis
  • Predictive models based on theory and data
  • Roles in development and experimental testing
  • Verification of theory and design through experimental tests

• Overall great pleasurable experience working with General Electric
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