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

2011 UTSR Gas Turbine Industrial Fellowship

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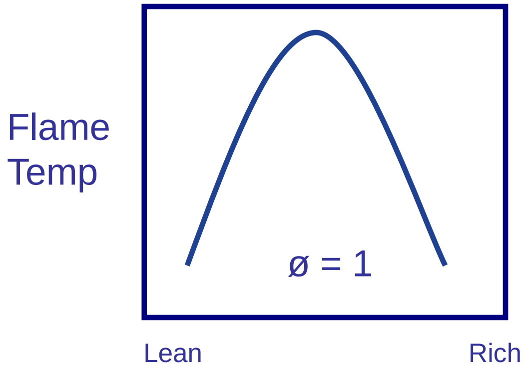
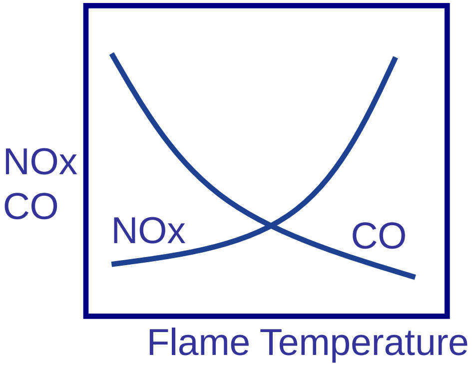
Background

- 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



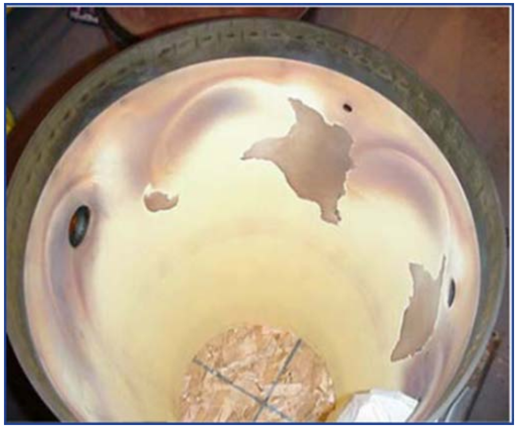


Background

- 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



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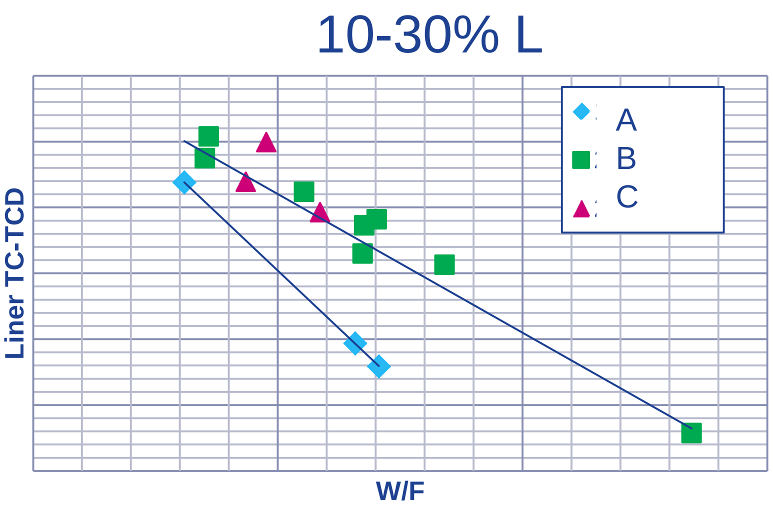
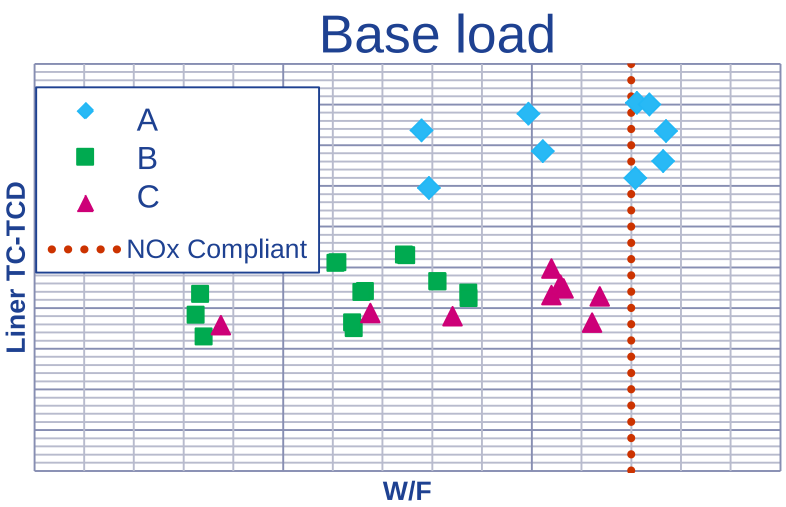
Assumptions & Analysis

- 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





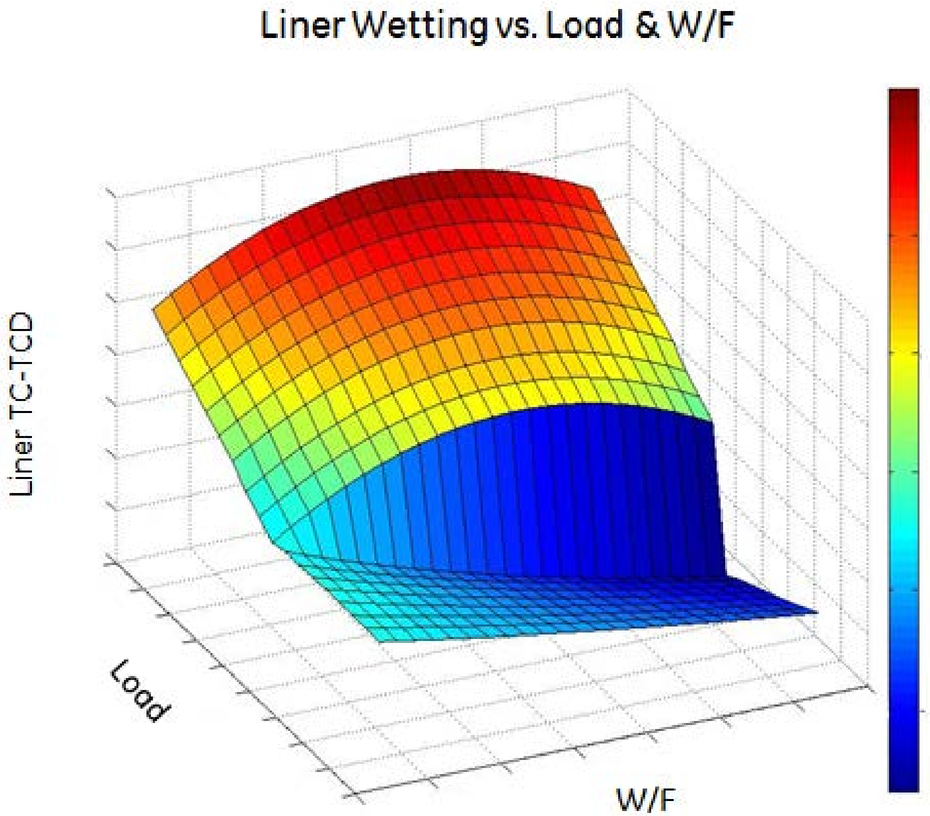
Transfer Function

- 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

Acknowledgments

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imagination at work