FUEL INJECTION AND MIXING

PREMIXER DEVELOPMENT

OVERVIEW

Premixed-catalytic combustion is demonstrating significant advancement for low emission gas turbine technology. In the catalytic combustion process, the time and temperature to initiate and complete the combustion reaction are reduced. The reduction in both parameters inhibits the formation of thermal NOx is avoided resulting in an overall reduction in NOx emissions.

Catalytic combustion requires a well mixed, uniform fuel-air stream entering the catalyst bed. Non-uniformities in both fuel-air mixture and flow velocity can result in thermal stress “hot spots” and poor fuel utilization as well as emissions of HC, CO and soot. Conversely, improvements in premixing uniformity while minimizing pressure drop penalities will enable the broader utilization of catalytic combustion in both new gas turbine engine designs as well retrofits in existing gas turbine designs with concomitant improvements in efficiency and reductions in pollutant emissions.

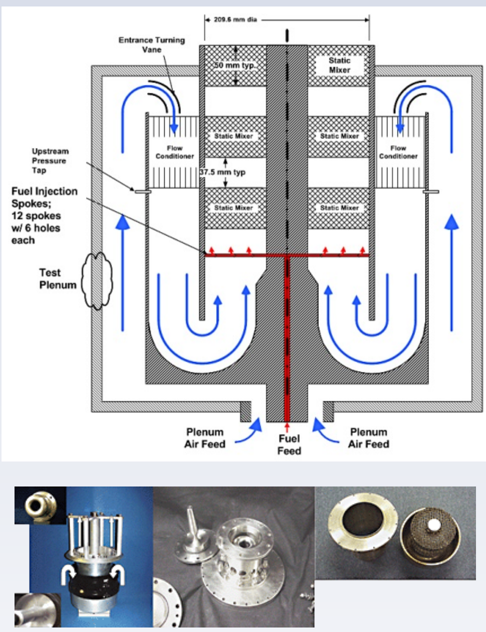

Figure 1. Premixer Concept, Baseline, Gen 1, Gen 2

GOALS

Improving fuel-air Premixer for catalytic combustion will be accomplished with the following design parameters: Consideration of gas turbine geometric constraints, minimizing volume requirements.

- Velocity uniformity +/- 10% of mean;
- Fuel-air uniformity +/- 3% of mean
- Minimize pressure drop across premixer (goal < 4%)
- Incorporate technology and design considerations to result in an economically viable retrofit to existing stationary power generation gas turbines.

For the specific project design consideration retrofitting to an existing gas turbine engine, the premixer design needed to reverse the direction of flow. The premixer design incorporated an involute curve (i.e. a nautilus shell) around the flow reversal as well as a throat to promote highly turbulent kinetic mixing.

RESULTS

Test and analysis of the baseline premixer suggested that significant improvements were possible. Maintaining the physical constraints of the target engine as the primary design boundary, the strategies incorporated to enhance baseline state of mixing were;

1. Utilize involute curve for flow reversal to accelerate the flow minimize recirculation zone formation,
2. Incorporate a “throat” for highly turbulent kinetic mixing,
3. Deceleration of flow after throat with an involute curve,
4. Use of alternate (wall) fuel injection locations.

CFD Modeling was utilized to iterate and refine the design. The Generation 1 premixer included wall injection (rather than “spokes”) for fuel further upstream to increase mixing time. Modeling suggested no recirculation zone that could result in auto-ignition.

Subsequent physical testing of both mixture and velocity uniformity agreed well with the model predictions.

Design and development of Gen-2 premixer incorporated lessons learned from Gen-1 by use of wall fuel injection from only one curve surface (greatly improving fabrication and ultimately reduce cost).). The Gen-2 mixer also tested the scalability of the design (the Gen-2 design was 1/8th the size of Gen-1). Subsequent physical testing once again validated the CFD model design for the Gen-2 system.

The smaller size of the Gen-2 permitted testing in a reacting engine test bed. The mixture, velocity, and pressure drop goals were met. Emission measurements were encouraging but inconclusive.

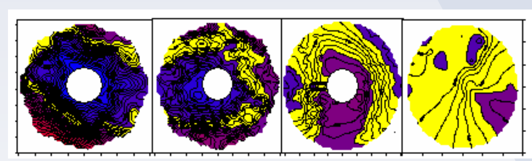

Figure 2. Fuel/Air Concentration for:
a) Baseline, b) Baseline-Mod, c) Gen 1, d) Gen 2 Design

Parameter	Target	Baseline Mixer idle	Baseline Mixer full power	Gen 1 Mixer (8b) idle	Gen 1 Mixer (8b) full power	Gen 2 Mixer idle	Gen 2 Mixer full power
% Pressure Loss	<4.00%	1.10%	2.10%	1.80%	3.20%	2.00%	3.40%
Fuel Concentration							
PF	0.03	0.29	NT	0.08	0.07	0.05	0.03
MPF	0.06	0.48	NT	0.15	0.10	0.09	0.05
Velocity							
PF	0.1	0.27	NT	0.36	0.25	0.15	NT
MPF	0.2	0.89	NT	0.80	0.59	0.17	NT

Figure 3. Premixer’s performance versus target

RECENT PUBLICATIONS/PAPERS

DESIGN AND TESTING OF A UNIQUE, COMPACT GAS TURBINE CATALYTIC COMBUSTOR PREMIXER (2003). ASME Paper GT2003-38778, presented at the 48th ASME International Gas Turbine and Aeroengine Congress and Exposition, Atlanta. R.L. Hack, V.G. McDonell, G.S. Samuelsen, J. Blust, P. Dutta, K.O. Smith, and D.K. Yee.

PERSONNEL

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