Fuel Flexible Boiler with Active Control to Optimize Performance

OVERVIEW

A strategy to reduce the carbon signature of combustion systems is to use renewable fuels such as those derived from waste processes. Anaerobic digestion of waste water and organic waste is one example in which mixtures of carbon dioxide and methane are generated. In addition, due to concerns over NO_X emissions, industrial combustion system manufacturers have turned to lean premixed combustion technology. Although these techniques have proven to lower NO_X emissions by reducing peak flame temperature, they are not without their limitations, especially relative to stability. Combined with variability in fuel composition and ambient conditions, instabilities can be significant. One potential solution is using passive controls for air staging. The low swirl injector can exploit the aerodynamic properties of propagating turbulent premixed flames and can also readily adapt to any existing burner configuration.

GOAL

Investigate the performance of a low swirl injector operated on biogas in 0.4 MMBTU/hr boiler simulator

1. Lower emissions
2. Ensure safe operation of the burner based on different fuel compositions (flame stability and lean blowoff prevention)
3. Maintain and/or increase thermal efficiency

BURNER GEOMETRY AND TEST FACILITY

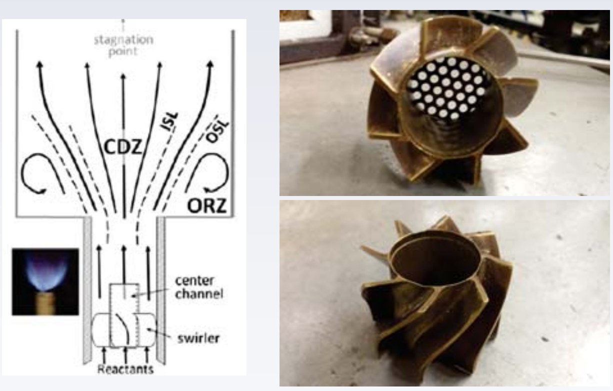

Figure 1: Low Swirl Injector

The Main component of the Low Swirl Injector is a swirler consisting of # curved vanes attached to the outer surface. The center channel allows a portion of reactants to bypass the swirler. A perforated screen is fitted at the entrance of this center-channel to control the ratio of mass flows between the unswirled center-channel and the swirled section.
The heart of the LSI swirler lies in the open center-channel which helps prevents a vortex breakdown and promotes a flow divergence. This is a key aerodynamic feature that allows the flame to stabilize.
The base fuel used is natural gas with up to %50 volume of carbon dioxide added to simulate biogas. The total fuel flow changes based on the higher heating value (HHV) of the fuel. Fuel flow is controlled by use of sonic orifices and regulators.

SYSTEM FLOW CHART

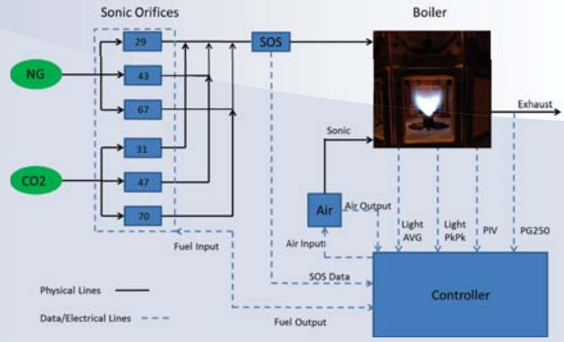

Figure 2: System diagram with feedback control from sensors

SENSORS & DIAGNOSTICS

There are three main sensor categories:

1) Flame Stability
   - *Flame Luminosity:* Fiber optic probe attached to a photomultiplier tube measures the intensity and oscillations of the heat release from the flame.

2) Emissions
   - *Horiba PG250:* Analyzer capable of measuring NOx, CO, CO2, and O2.

3) Flow Field Evolution
   - PIV (Particle Image Velocimetry)
     - Fluid with entrained particles is illuminated so that particles are visible. Motion of particles is used to calculate speed and direction(velocity field) of flow.
     - Helps deduce how flame couples and responds to turbulent flow field

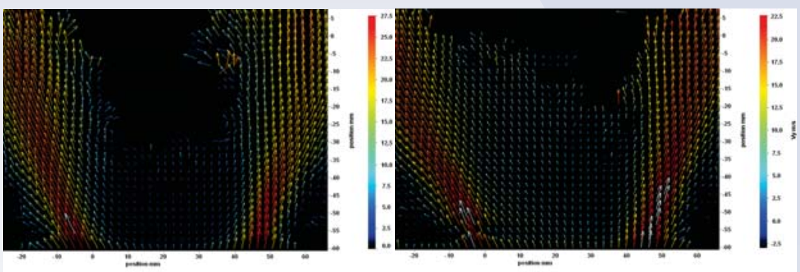

Figure 3: PIV Images 80% CH4/20% CO2 Equivalence Ratio=0.8 Left Image: .357 Blockage Right Image: .457 Blockage

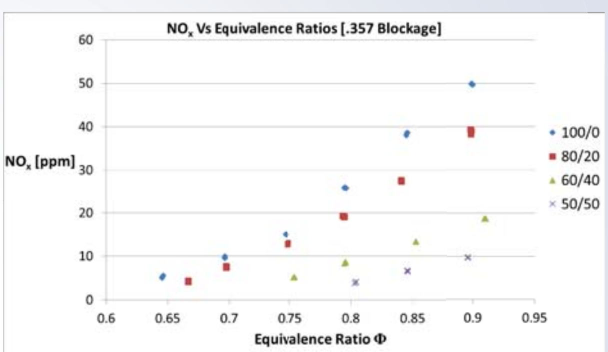

Figure 4. NO_x versus Equivalence Ratio for a .357 blockage for different Biogas Blends (see legend)

FUTURE WORK

Integration of a fuel composition sensor will be investigated. Burners are usually coupled to a certain composition of fuel and at leaner conditions fuel variability can influence the dynamics of the burner. A gas composition sensor would detect the gas composition and adjust accordingly to avoid instabilities.

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PERSONNEL

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