CHARACTERIZING NO_X EMISSION BEHAVIOR IN THE WAKE OF SINGLE REACTING JET IN RICH CROSSFLOW NEAR THE WALL

MOTIVATION

The RQL (Rich-Burn, Quick-Mix, Lean-Burn) combustor has been used and studied extensively because it is a key approach for reducing NO_x emissions while ensuring high combustion stability. Perhaps the most important aspect of the RQL combustor and its NO_x formation is the Quick-Mix section ,where multiple fresh air "Jets" enter perpendicularly into the rich combustion product "Crossflow." However, all of past studies were exclusively focused on overall mixing and *final* NO_x level. This research aims to understand the immediate behavior of NO_x formation due to air jet interaction with rich crossflow. A single reacting air jet in rich crossflow is chosen to characterize NO_x emission behavior in the wake (immediate downstream) and near the wall (before jet-to-jet interaction).

GOAL

The current research aims to understand and characterize the NO_x emission behavior in the wake of single reacting air jet in rich crossflow near the wall, and ultimately determine the origin of NO_x formation in this Jet-in-Crossflow (JIC) configuration.

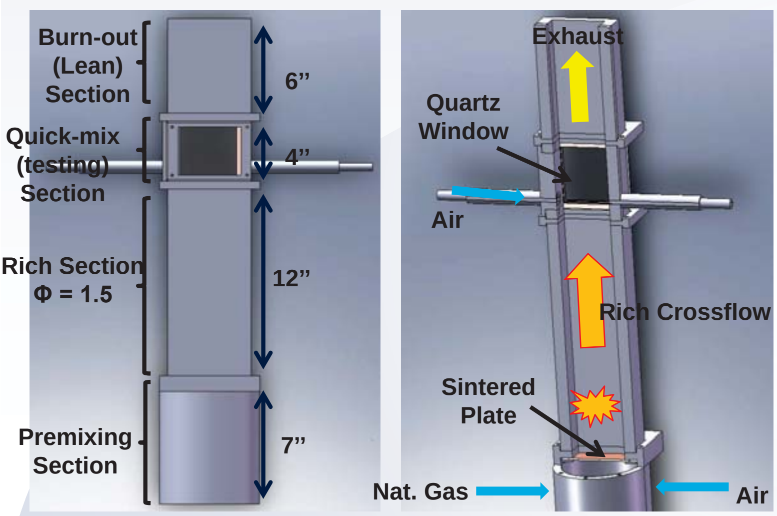
APPROACH/EXPERIMENT

Both an experiment and a CFD simulations were carried out

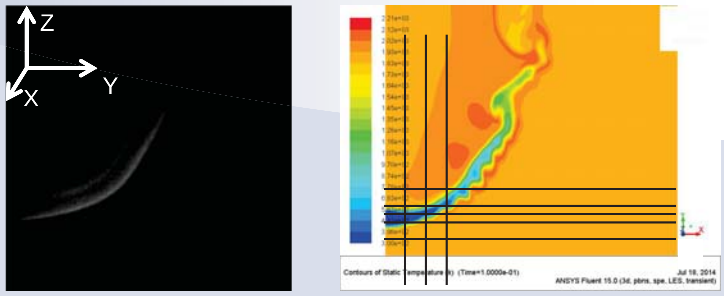
- Collect NO_x sample using a sampling probe at various locations
- Conduct CFD (ANSYS FLUENT) simulations of the Quick-Mix section at a reacting condition

RESULTS

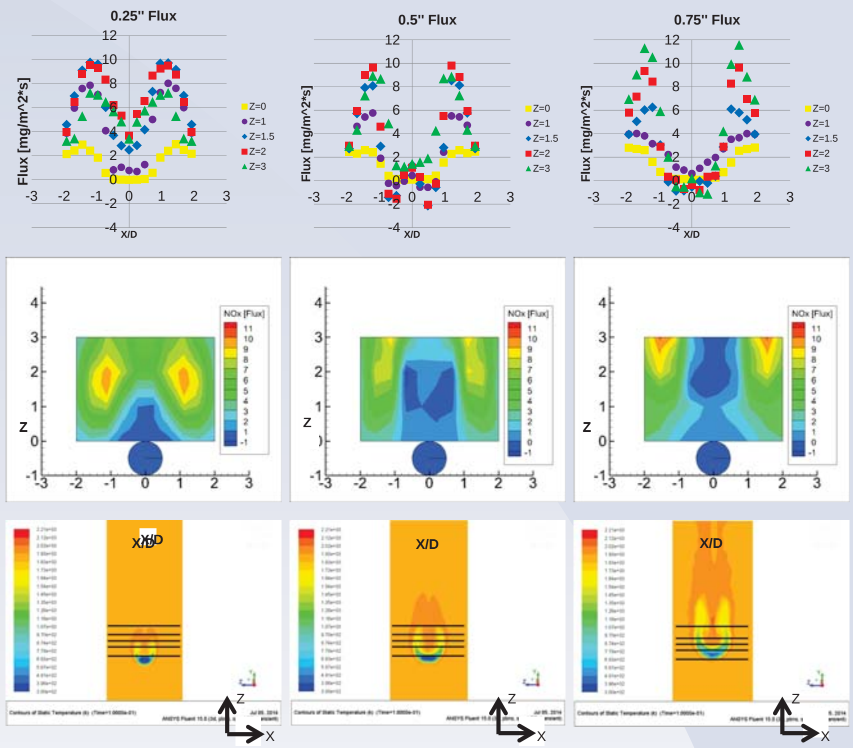
The experimental rig (F1) is essentially a small scale RQL combustor with a single air jet in Quick-mix section. The testing section results in classic JIC problem with rich crossflow created by natural gas and air burning at equiv. ratio of 1.5 (F2). The NO_x concentration level was measured at 5 different axial locations (Z=0, 1, 1.5, 2 and 3) spaced by one jet diameter (0.26'') (F3 top). The velocity and temperature profile of the test section was calculated by CFD simulation (ANSYS FLUENT). The LES method was used to simulate but flow was stable well before 0.1s. NO_x flux at different axial locations (F3) were calculated with NO_x concentration from the experiments and axial velocity values from the CFD results (F3).



F1. Experimental Rig (Left: Overall View, Right: Cut-away View)



F2. Reacting Jet in Test Section (Left: OH Image, Right: CFD Image)



F3. Left Col: 0.25'', Center Col: 0.5'', Right Col: 0.75'' away from the wall

Top Row: NO_x Flux, Middle Row: Contour of NO_x Flux, Bottom Row: Jet Temperature Profile

RESULTS (cont.)

The NO_x concentration (not shown) and NO_x flux both resemble the typical horse-shoe shape cross-section of jet-in-crossflow. The NO_x flux graph shows two peaks, one on each half of the jet.

The axial location of highest NO_x flux is increasing with increasing distance from the wall. The highest NO_x flux occurs at Z=1.5, Z=2, and Z=3, respectively for 0.25'', 0.5'' and 0.75'' away from the wall.

The radial location of highest NO_x flux is also increasing with increasing distance from the wall. The highest NO_x flux occurs at X/D=1, X/D=1.5, X/D=2, respectively for 0.25'', 0.5'' and 0.75'' away from the wall. The highest NO_x locations match the location of the highest temperature regions as they are stretched as moving away from the wall.

SUMMARY

- NO_x concentration and NO_x flux follow the horse-shoe shape of jet-in-crossflow with two peaks
- The highest NO_x mass flux occurs immediately downstream of the high temperature regions on either side of the wake behind the jet
- The spatial extent of high NO_x flux regions increases with increasing distance from the wall because the jet cross-section and the highest temperature regions are stretched (both axial and radial) as moving away from the wall

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