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

MOTIVATION

The ROL (Rich-Burn, Quick-Mix, Lean-Burn) combustor has been used and studied extensively because it is a key approach for reducing NOₓ emissions while ensuring high combustion stability. Perhaps the most important aspect of the RQL combustor and its NOₓ 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 NOₓ level. This research aims to understand the immediate behavior of NOₓ formation due to air jet interaction with rich crossflow. A single reacting air jet in rich crossflow is chosen to characterize NOₓ 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 NOₓ emission behavior in the wake of single reacting air jet in rich crossflow near the wall, and ultimately determine the origin of NOₓ formation in this Jet-in-Crossflow (JIC) configuration.

APPROACH/EXPERIMENT

Both an experiment and a CFD simulations were carried out
- Collect NOₓ 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 ROL 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 NOₓ 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. NOx flux at different axial locations (F3) were calculated with NOₓ concentration from the experiments and axial velocity values from the CFD results (F3).

RESULTS (cont.)

The NOₓ concentration (not shown) and NOₓ flux both resemble the typical horse-shoe shape cross-section of jet-in-crossflow. The NOₓ flux graph shows two peaks, one on each half of the jet. The axial location of highest NOₓ flux is increasing with increasing distance from the wall. The highest NOₓ 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 NOₓ flux is also increasing with increasing distance from the wall. The highest NOₓ 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 NOₓ locations match the location of the highest temperature regions as they are stretched as moving away from the wall.

SUMMARY

- NOₓ concentration and NOₓ flux follow the horse-shoe shape of jet-in-crossflow with two peaks
- The highest NOₓ mass flux occurs immediately downstream of the high temperature regions on either side of the wake behind the jet
- The spatial extent of high NOₓ 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