Abstract:
The presented work describes the experimental investigation of nitrogen oxide (NOx) emissions from reacting jets in a vitiated crossflow (RJICF). It is motivated by interest in axial staging of combustion as an approach to reduce undesirable NOx emissions from gas turbine combustors operating at high flame temperatures (>1900K). In lean-premixed combustion, NOx levels are exponential functions of temperature and linear functions of residence time. Consequently, NOx production rates are high at such temperatures, and conventional combustor architectures are unable to simultaneously deliver low NOx and part-load operability. A RJICF is a natural means of implementing axial staging. Therefore, a fuller understanding of the governing processes and parameters regarding pollutant formation within this complex flow field is critical to the next generation of gas turbine technology advancement.

It is clear that RJICF NOx production is a highly coupled process. A key challenge was decoupling the interdependent jet parameters in order to observe fundamental NOx production sensitivities. Data is presented for premixed jets injected into a vitiated crossflow of lean combustion products. The jets varied in: fuel selection (methane or ethane or a combination), equivalence ratio ($0.8 \leq \phi_{jet} \leq 9.0$), momentum flux ratio ($2 \leq J \leq 40$), and exit geometry (pipe or nozzle). The crossflow temperatures ranged from 1350K – 1810K, and the reacting jets induced a bulk averaged temperature rise on the flow ($\Delta T$) ranging from 75K – 350K. In addition, several data series were replicated with varied ethane/methane ratios at constant $\phi_{jet}$ to influence flame lifting independent of other parameters. Similarly, the jet exit geometry was varied to influence shear layer vortex growth rates. Overall, these data indicate that NOx emissions are largely determined by $\Delta T$. However, significant variation was observed at constant $\Delta T$ levels. The data is consistent with the idea that this variation is controlled by the stoichiometry at which combustion actually occurs, referred to as $\phi_{Flame}$. $\phi_{Flame}$ is influenced by $\phi_{jet}$ and pre-flame mixing of the jet and crossflow that, in turn, is a function of flame lift-off distance (LO), nozzle geometry, and crossflow temperature.

The data highlights the importance of flame lifting as well as the potential importance of post-flame mixing effects. Both are complex problems and are not directly addressed in this work. Further work in these areas would significantly deepen understanding of the relevant phenomena in RJICF NOx production.

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