FLASHBACK CHARACTERISTICS OF SYNGAS-TYPE FUELS UNDER STEADY AND PULSATING CONDITIONS

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1. OBJECTIVE

The objective of this project is to improve the state of the art in understanding and modeling of flashback, which is known to be a significant issue in low emissions combustors containing high levels of hydrogen. While particular attention is given to coal-derived gaseous fuels, consideration has also been given to other candidate fuels, such as process gas or other fuels containing hydrogen or higher hydrocarbons.

The proposed project consists of three main thrusts. First, we performed a systematic design of experiments that formed the test matrix for the experiments performed under this project. Because of the significant number of independent parameters under examination (e.g., fuel composition, pressure, pre-mixer design), a systematic effort was needed so that the resulting parameter studies were of sufficient breadth and detail, yet still realistic in scope. The second and third research thrusts investigate the flashback characteristics of synthetic gas fueled combustors under steady and pulsating conditions, respectively. We are currently performing an extensive series of tests that characterize the dependence of flashback characteristics upon fuel composition, pressure, inlet temperature, and pre-mixer configuration. Parallel efforts are focusing on developing a computational methodology for correlating these results and predicting flashback behavior under steady and oscillatory conditions.

2. ACCOMPLISHMENTS TO DATE

Over this year, many new undertakings occurred for this project. First of all, we started a new test matrix with the goal of more traditional "fast" flashback occurrences. Our conditions for this matrix were 7.1 atm, 500K, and nozzle velocity of 21 m/s. For each fuel composition, the equivalence ratio was increased 0.3~0.5 until "rapid flashback" occurred. We noted for these cases that each had a point where the centerbody temperature would increase almost discontinuously with a slight equivalence ratio increase ($\Delta T>150F$). Also, noted was that pure H_2 and 80/20 H_2/CO fuels would not stabilize; the flame would either flashback or blowoff. Importantly, flashback was no longer occurring at a nearly constant T_{ad} as the slow flashback mechanism (Combustion Induced Vortex Breakdown) did.

To better characterize these differences, an optically accessible premixer was fabricated for high speed imaging. This premixer (nozzle) allowed for imaging upstream of the combustion region.

Thus, as equivalence ratio was increased to flashback, the flame would then propagate upstream from the large combustion region quartz tube to the small nozzle quartz tube and end at the swirler. The image sequences showed that, for this particular nozzle configuration, the flame propagated upstream in the vortex tube. Moreover, propagation speed was estimated by plotting flame position by time going frame by frame (note that the capture rate was 2000fps). From these plots it was evident that for H_2 cases less than ~80%, the flame would move a small distance, dwell for a time, then move some more. This along with the fact that the flame stayed in the vortex tube supported CIVB for the flashback mode. For the high H_2 cases, it was unclear if this phenomenon was occurring or not, because the frame rate needs to be increased (i.e., the flame flashed back in ~4 frames.

3. FUTURE WORK

We will be continuing our flashback characterizations under non-oscillatory flow conditions. Tests will consist of going to higher combustor pressures and preheat temperatures for the optically accessible premixer. We will also be using several different swirler angles to study the effect of geometry on flashback. Additionally, focus will start to be directed towards oscillating conditions, which is scheduled for the third quarter of 2007. We will continue to look for trends in flashback as our database enlarges so that we can better understand flashback occurrences with syngas fuels. We will continue to communicate with industrial partners to obtain valuable input for testing and data analysis.

4. PAPERS PUBLISHED/COMPLETED PRESENATIONS/STUDENTS SUPPORTED UNDER THIS GRANT

Noble, D., Zhang, Q., and Lieuwen, T., "Syngas Fuel Composition Sensitivities of Combustor Flashback and Blowout," *23rd Annual International Pittsburgh Coal Conference*, Pittsburgh, Pa, September 25-28, 2006.

Zhang, Q., Noble, D., And Lieuwen, T., "Hydrogen Effects Upon Flashback And Blowout With Syngas Fuels," *7th International Colloquium on Environmentally Preferred Advanced Power Generation (ICEPAG)*, Newport Beach, CA, September 5-8, 2006. [Presentation Only]

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