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

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DE-FG26-04NT42176
Oct. 1, 2004- Sept. 30, 2007

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. Measurements and analysis are performed under steady and oscillatory flow conditions. While particular attention is given to coal-derived gaseous fuels, consideration is also 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, the recipient shall perform a systematic design of experiments that shall form the test matrix for the experiments performed under this project. Because of the significant number of independent parameters that need to be examined (e.g., fuel composition, pressure, pre-mixer design), a systematic effort is needed so that the resulting parameter studies are of sufficient breadth and detail, yet still realistic in scope. The second and third research thrusts shall investigate the flashback characteristics of synthetic gas fueled combustors under steady and pulsating conditions, respectively. The recipient shall perform an extensive series of tests that characterize the dependence of flashback characteristics upon fuel composition, pressure, inlet temperature, and pre-mixer configuration. Because flashback is often found to be strongly influenced by combustor oscillations, great effort shall be taken to characterize the effects of oscillations. Work shall be performed under conditions where the combustor is as “quiet” as possible and where external oscillations of varying amplitude and frequency are imposed. Parallel efforts shall focus on developing a computational methodology for correlating these results and predicting flashback behavior under steady and oscillatory conditions.

2. ACCOMPLISHMENTS TO DATE

Over the past year, our efforts were focused upon performing flashback testing under non-oscillatory conditions. These tests were performed at pressures up to 4.5 atm and inlet temperatures up to 460 K. For each of these tests, the unburned velocity in the combustor was held constant, with a nozzle velocity varying between 20-60 m/s. We used 21 evenly spaced fuel combinations of $H_2/CO/CH_4$ for our tests, in order to simulate various syngas fuels co-fired with natural gas. Flashback was initially detected by thermocouples on the outer wall of the premixer along with visual confirmation via a video camera. We have since added a thermocouple to the outer surface of the centerbody, approximately 1.7 cm from the tip to aid in flashback detection.

These data show two different mechanisms of flashback, which we refer to as “fast” and “slow” flashback. In the latter case, this data showed that flashback was not as strong of a function of H_2, except at higher percentages of hydrogen (above 60 to 80%). We also noted that traditional flashback, the former mechanism, occurred only for these high H_2 cases, i.e., equivalence ratio was increased until the flame “flashed back” all the way through the premixer. For the other cases, we noticed a different flashback mode, very similar to the observations at T.U. Munich, which they refer to as “Combustion Induced Vortex Breakdown” (CIVB). This was where the flame caused a flow expansion upstream, which caused the vortex breakdown point to move upstream. This allowed for the stabilization point to move upstream bringing the flame with it causing the flashback. We have been extensively studying the parameters that led to CIVB versus traditional flashback, because it is not well documented. We have also developed a simple physics based model to predict the propensity of the fuel nozzle to this flashback which, which is principally a function of flame angle with respect to the flow and temperature ratio across the flame. Moreover, from these experiments, we determined that for CIVB flashback was not strongly related to flame speed; it was flame temperature that dominated the flashback mode – a result that agrees well with our model. This latter point was experimentally demonstrated through tests utilizing the centerbody thermocouple and correlating flame location in the nozzle with flame temperature and flame speed.

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 some of our cases, we will lower our unburned velocity, allowing for more “traditional” flashback occurrences. Additionally, focus will start to be directed towards oscillating conditions, which is scheduled to begin the first quarter of 2007. We will continue to look for trends in flashback as our database enlarges so that we can more accurately predict and understand flashback occurrences.

4. PAPERS PUBLISHED/STUDENTS SUPPORTED UNDER THIS GRANT

Noble, D.R., Zhang, Q., Shareef, A., Tootle, J., Meyers, A., and Lieuwen, T., “Syngas Mixture Composition Effects Upon Flashback and Blowout,” ASME Turbo Expo 2006, May 8-11, 2006, Barcelona, Spain, GT2006-90470.

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