Study of Fuel Composition Effects on Flashback Using a Confined Jet Flame Burner

OVERVIEW

Flashback is the main operability problem associated with converting lean, premixed combustion systems from operation on natural gas to operation on high hydrogen content fuels. In the present work, a jet burner configuration is used to develop systematic data evaluating the effect of wide range of fuel compositions (H2, CO, and CH_4) on jet flame flashback propensity. The fuels are premixed with air at equivalence ratios corresponding to constant adiabatic flame temperatures. Schlieren and intensified OH* imaging system with a high speed camera are used to capture the highly dynamic process of flashback. The analysis of variance of the results leads to correlations between fuel composition and flame temperature with (1) critical flashback velocity gradient and (2) burner tip temperature.

OBJECTIVES

- Enhance fundamental understanding on fuel composition effects on flashback
- Develop and verify the models predicting the boundary layer flashback

RESULTS

- The burner consisted of a 1inch burner tube confined by a larger quartz tube. The use of quartz allowed visualization of the flashback processes occurring. Figure1 shows the schematic of the axi-symmetric single injector rig set up. The confinement holder is designed with potential to investigate various diameters of enclosures.

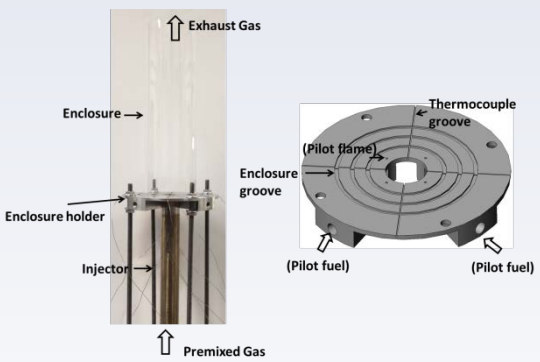
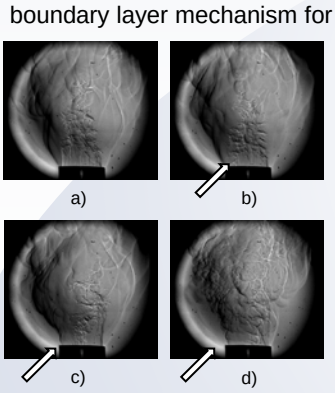


Figure 1 Schematic of the axi-symmetric single injector rig and the enclosure holder

- From the Schlieren and intensified OH* images, a main observation is that flashback is occurring through the boundary layer mechanism for these attached flames.



The Schlieren images cannot be taken with the confinement in place since the confinement interferes with the light whereas the intensified OH* images can be captured with the confinement in place.

Figure 2 Schlieren images of flashback for fuel composition of 100% H2 (no confinement)

RESULTS (CONTINUED)

The sequences of selected images in Figure 2 and Figure 3 correspond to

a) Prior to flashback
b) Initiation of flashback
c) Flame continues to regress into the injector
d) Flame is fully regressed within the injector.

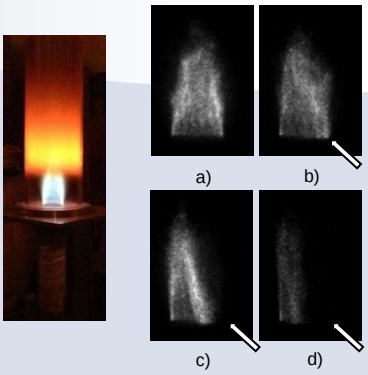
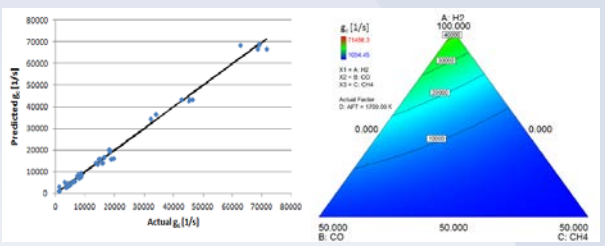


Figure 3 Intensified OH* images of flashback for fuel composition of 100% H2 (with confinement

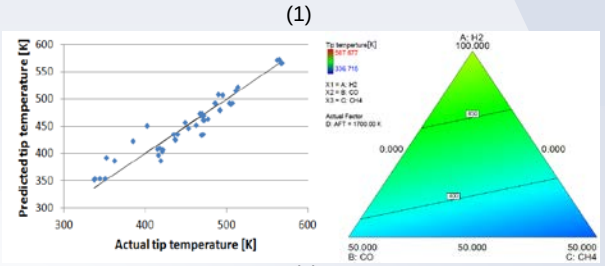
- Analysis of Variance (ANOVA) yields correlations between the fuel composition and reaction AFT parameter and (1) the flashback velocity gradient (g_c) and (2) injector tip temperature(T). This relationship can provide guidance for how fuel composition impacts flashback propensity at the engineering level.

$$g_c = (2.401 \cdot H_2 + 5.381 \cdot CO - 1.632 \cdot CH_4 - 0.264 \cdot AFT + 0.604 \cdot H_2 \cdot CH_4 + 0.00264 \cdot CH_4 \cdot AFT)^2$$

$$T = -1.58 \cdot H_2 - 3.63 \cdot CO - 4.28 \cdot CH4 + 0.38 \cdot AFT$$



(1)



(2)

Figure 4 ANOVA of (1) critical velocity gradient (2) tip temperature

- Higher hydrogen content and higher AFT lead to higher flashback propensity. Adding methane or carbon monoxide inhibited flashback to a different extent. 50/50 blends (by volume) of H2 and CO produce reactions with much higher flashback propensity than similar H2/CH4 blends.
- Higher hydrogen content and higher AFT lead to higher burner tip temperature at flashback.
- Using the burner tip temperature as the unburned gas temperature in laminar flame speed calculations allows further collapsing of critical velocity gradient data plotted vs. laminar flame speed.

RECENT PUBLICATIONS/PAPERS

Brendan Shaffer, Zhixuan Duan and Vincent McDonell, *Study of Fuel Composition Effects on Flashback Using a Confined Jet Flame Burner,* Accepted by Journal of Engineering for Gas Turbines and Power 2012

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