ALTERNATIVE FUELS

Ignition Characteristics of Hydrogen and Syngas Fuels

OVERVIEW

Lean premixed combustion technology is widely accepted in gas turbine industry to reduce pollutant emissions. Engines which use this strategy are being installed world-wide. In lean-premix combustors and other types of low-emissions combustors, fuel and air are premixed before combustion. One of the most important concerns is the possibility of autoignition. The pressures and temperatures of air entering the premixer are high enough that the fuel may spontaneously ignite once it is mixed with the air. Autoignition must be avoided at all costs in these systems to protect the combustor components as well as to avoid producing unacceptably high levels of pollutant emissions.

In recent years Hydrogen has garnered interest as a gas turbine fuel because it does not produce the greenhouse gas carbon dioxide when burned. Hydrogen could be used as a pure fuel or as a constituent fuel such in fuels such as syngas or digester gas. Syngas is produced through gasification cycles of organic matter (coal or biomass) and is composed of primarily hydrogen and carbon monoxide. The combustion properties of hydrogen rich fuels can be very different than that of natural gas, so it is very important to understand the ignition delay time characteristics of these new fuels when operating in lean premixed combustion systems.

In this program, ignition delay times are studied for hydrogen and syngas type fuels at conditions matching those in many current gas turbine engines. The effects of temperature, pressure, equivalent ratio, fuel composition and state, and turbulence intensity on ignition delay times are addressed by using experimental and modeling methods. The experimental method is a continuous flow device with a 147-inch-long test section. The device is heavily insulated in order to achieve as close to an adiabatic process as possible. A series of photodiodes, photomultiplier tubes, pressure transducers and thermocouples are used as ignition detectors. The testing pressures vary from one atmosphere to fifteen atmospheres and temperature can go up to 1250 °F. The ignition delay time determined by measuring the period in between fuel injection and autoignition. The exhaust gases are quenched with water after exiting the test section.

An important goal is to establish simple correlations of autoignition delay with fuel composition for easy application for use in gas turbine design. As an example, the following correlation was found for ignition delay of syngas made in a prior study at the UTRC:

$$\tau = 1.29 \times 10^{-7} \exp\left(\frac{3985}{T}\right) [O_2]^{-0.50} [\mathrm{Fuel}]^{-0.25}$$

By simply plugging in the pressure (atm) and temperature (K) of the premixer inlet conditions, a designer can determine the ignition delay time (in seconds) with reasonable accuracy. The goal of this work is to extend this correlation to further operating condition and other types of hydrogen rich fuels.

APPROACH

Experimental Methods: Continuous Flow Reactor. A simplified continuous flow reactor can be found in Figure 2. Figure 3 shows the test rig.

Numerical Tools: CFD, Chemical Kinetics Studies

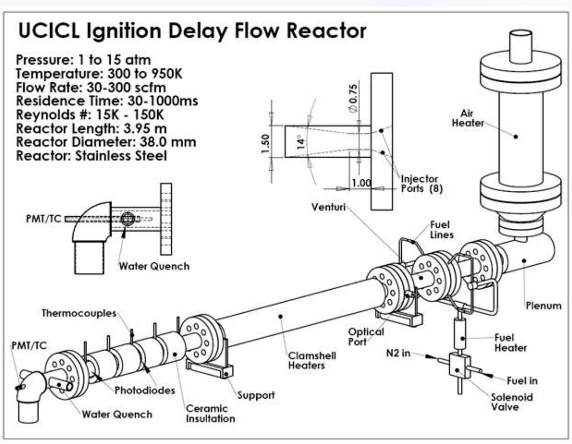

Figure 1. A Continuous Flow Reactor

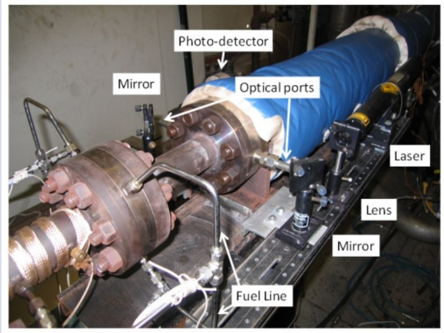

Figure 2. Continuous Reactor Test Rig

GOALS

The goal of this program is to establish the understanding of autoignition in lean premixed combustion systems as a function of fuel composition for various inlet temperature, pressure, turbulence intensities, and fuel concentrations. This research will:

Directly apply to challenges facing advanced gas turbine applications;

Provide insight into the nature of auto-ignition delay in lean, premixed combustion systems by judicious experimental and theoretical analyses;

Provide needed data as an archive for future research.

RESULTS

To date ignition delay times of pure hydrogen have been conducted at pressures and temperatures up to 10 atm and 950K (1250F) respectively. Ignition delay times have been observed to be strongly dependent upon temperature and pressure while only modestly dependent upon the equivalence ratio, and mixture velocity in the flow reactor. Some of the latest results are shown below on an Arrhenius plot below, Figure 4. The results are compared to previous works in both flow reactors and shock tubes.

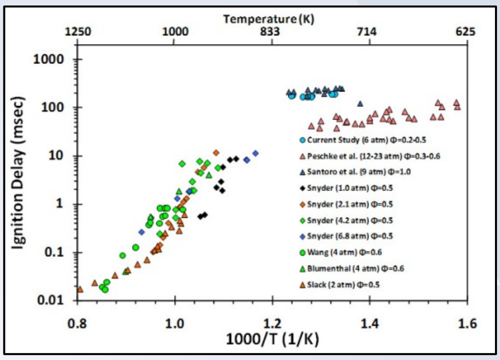

Figure 3. Ignition delay times of hydrogen fuels from current work at UCI and previous studies in both flow reactors and shock tubes.

PUBLICATIONS AND PRESENTATIONS

Autoignition of Hydrogen and Air Inside a Continuous Flow Reactor with Application to Lean Premixed Combustion (2008). Journal of Engineering for Gas Turbines and Power, Vol. 130 051507-1 to 8. September Issue (D.J. Beerer, V.G. McDonell)

Experimental Study of Ignition delay for application to hydrogen and syngas fired lean premixed gas turbine engines (2007). Presented at the 5th US National Meeting of the Combustion Institute, Paper E01, March (D.J. Beerer, V.G. McDonell)

New Syngas/Air Ignition Data at Elevated Pressure and Comparison to Current Kinetics Models (2007). Combustion and Flame, Vol. 149 (1-2), pp. 244-247. (E.L. Petersen, D.M. Kalitan, A. Barrett, S.C. Reehal, J.D. Mertens, D.J. Beerer, R.L. Hack, and V.G. McDonell).

PERSONNEL

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