FUEL INJECTION AND MIXING

Ignition Characteristics of Natural Gas Type 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. So, it is very important to understand the ignition delay time is determined by measuring the period between fuel injection and autoignition.

In this program, ignition delay times are studied for natural gas 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 is 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 high purity methane between 800 to 950K and elevated pressures:

$$\tau = 1.06 \times 10^{-4} \exp\left(\frac{90960}{T_{mix}}\right) P^{-1.0}$$

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. Current work in the flow reactor is determining the effect of ethane and propane addition on the ignition delay of natural gas.

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

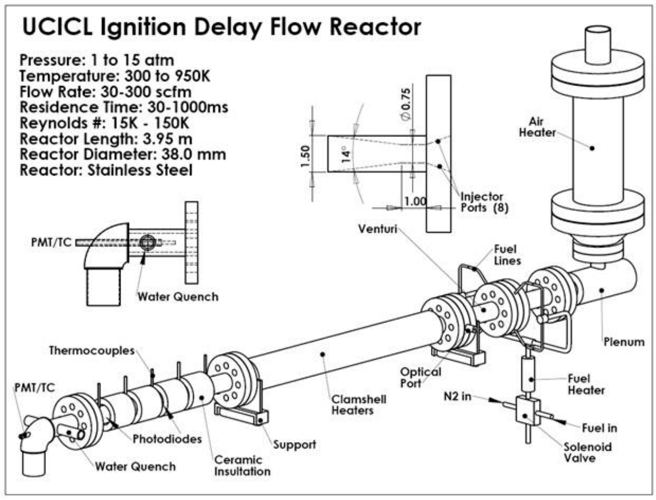

Figure 1. A Continuous Flow Reactor

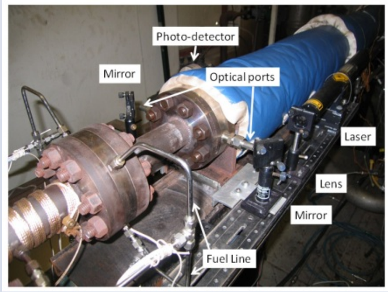

Figure 2. Continuous Reactor Test Rig

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 fuels (methane, ethane and propane) 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 in Figure 4. Plotting the data in this format results in straight lines whose slope is proportional to the overall reactions activation energy.

Methane has been observed to have the longest ignition delay time while ethane and propane possess shorter delay times. This suggests that as natural gas mixtures become richer (possessing higher fractions of higher hydrocarbons) they will have shorter delay times.

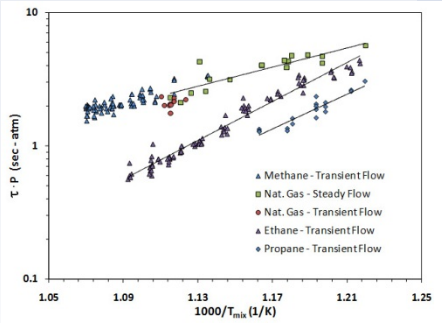

Figure 3. Comparison of ignition delay times for pure fuels: methane, ethane and propane in addition to Irvine natural gas. The higher molecular weight hydrocarbons tend to have shorter ignition delay times.

RECENT PRESENTATIONS

AUTOIGNITION OF METHANE, ETHANE AND PROPANE IN TURBULENT HIGH PRESSURE AND INTERMEDIATE TEMPERATURE FLOWS (2010). Presented at the 6th US National Meeting of the Combustion Institute, Paper 22C1, May (D.J. Beerer, V.G. McDonell, and G.S. Samuelsen, L. Angello)

INTERPRETATION OF FLOW REACTOR BASED IGNITION DELAY MEASUREMENTS (2010). Presented at the ASME Gas Turbo Expo, Paper GT2010-60269, June (D.J. Beerer, V.G. McDonell, and G.S. Samuelsen, L. Angello)

PERSONNEL

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