Correlation of Ignition Delay with Natural Gas and IGCC Type Fuels: 03-01-SR112

FACT SHEET

I. PROJECT PARTICIPANTS

A. Prime Participant: University of California, Irvine

B. Sub-Award Participants: None

II. PROJECT DESCRIPTION

A. Objectives

This project aims to establish easy to use ignition delay correlations for Natural Gas (NG) and synthetic gases ("syngas") associated with the Integrated Gasification Combined Cycle (IGCC) application based on experimental and numerical data to support the efforts in advancing low-emission technology and the use of alternative fuels. The effect of fuel composition on ignition delay is emphasized.

B. Background/Relevancy

Background.

Lean premixed combustion is a proven strategy to reduce emissions. However, the reactive mixture in the premixed combustion system can spontaneously ignite without any external ignition sources under the right conditions. This phenomenon, often called autoignition, is a critical safety and reliability issue for advanced low-emission gas turbines that rely upon premixing of fuel and air to achieve emission goals. This issue is exacerbated by the increasing need to consider the use of fuels other than natural gas in order to facilitate the production of clean energy and relieving the concentrated dependency on petroleum fuels.

Relevancy.

In order to avoid autoignition, lean premixed combustion systems must be designed based on understanding of the ignition delay characteristics. This project studies autoignition of near and longer term alternative fuels, specifically liquefied natural gas (LNG) and liquefied petroleum gas (LPG) and Integrated Gasification Combined Cycle (IGCC) syngas, emphasizing the effect of variation found in the specific fuel compositions. Because alternative fuels typically have wide ranges of compositions depending upon their genesis, design tools that can describe how this variation in fuel composition impacts ignition delay will by beneficial to developing reliable, low emission fuel flexible gas turbines.

C. Period of Performance

07/01/2003 – 06/30/2004

D. Project Summary

This project is studying autoignition phenomena of fuel related or derived from natural gas including LPG and LNG and fuel containing H_2/CO such as those produced by gasification of biomass or coal. An existing high-pressure flow reactor at the University of California, Irvine Combustion Laboratory (UCICL) is serving as the experimental test bed. The emphasis of the project is on fuel compositions found in IGCC applications. Numerical analyses are being conducted throughout the project to provide guidance to the experiments and to support development of correlations. Tasks involved in this project include: i) upgrading the existing facility to simulate various fuel compositions at a wider range of operating conditions than previously possible, ii) reviewing current available mechanisms for IGCC type fuels and conducting experiments and numerical analysis, iii) analyzing the results of the experiments and numerical analysis and obtaining empirical expressions relating ignition delay to operating conditions and fuel compositions, and finally iv) verifying and refining the obtained empirical correlations by an iterative approach.

III. PROJECT COSTS

$181,763

IV. MAJOR ACCOMPLISHMENTS SINCE BEGINNING OF PROJECT

Experiment

Facility preparation has been completed including the fabrication of the re-designed air heating system, insulation blankets, modification of pressure system, and re-evaluation of the fuel composition control system. The maximum operating temperature and pressure have been increased from 1125F to 1400F and from 8atm to 18atm, respectively. This expanded capability will facilitate the experiments at the conditions complementing the range achieved by typical flow reactors and shock tubes.

Numerical Analyses

Reaction mechanisms for H_2/CO containing fuels (IGCC type fuels) have been collected, and are being systematically reviewed and applied as illustrated in Figure 1. This example result shows interesting features in the ignition delay characteristics that will be experimentally investigated. Temperature sensitivity analyses were also performed to identify key reactions. Chemistry change involving HO_2 and H_2O_2 appears to be responsible to the autoignition characteristics observed (Figure 1). In addition, the range of the IGCC syngas composition studied was proposed coinciding with the specific interest in coal gasification and hydrogen production in the U.S. Preliminary numerical analyses suggest that the presence of CO can reduce the ignition delay time by as much as 50% relative to pure H_2 at some conditions, however, at typical gas turbine inlet conditions, the presence of CO has little affect on the ignition delay time.

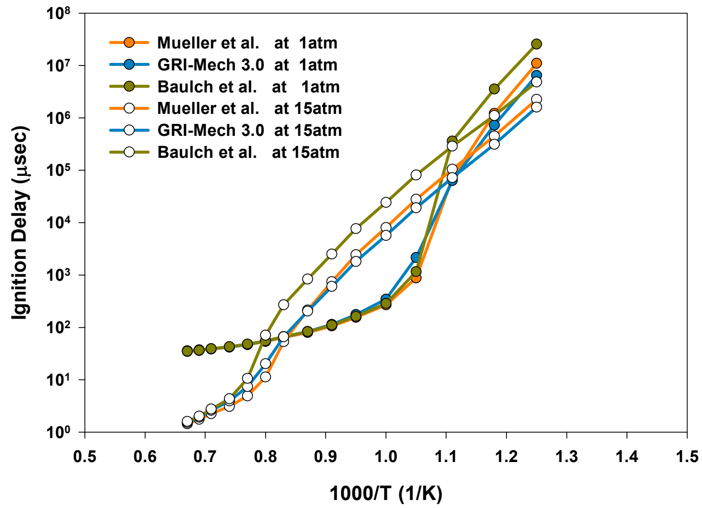

Figure 1: Calculated Ignition Delay for IGCC-type Fuel (50% H_2, 50% CO) – Air, using Three Mechanisms

V. MAJOR ACTIVITIES PLANNED DURING THE NEXT 6 MONTHS

Experiments.
The upgraded heater system is being integrated into the flow reactor. Upon completion of the integration and other setup/preparations, experiments will be conducted using NG. In the mean time, preparations for IGCC type fuels will be continued including the evaluation of mass flow controllers/meters and review/modifications to the range of compositions and fuel control methods, if necessary.

Numerical Analyses.
Reaction mechanisms for H_2/CO containing fuels will be continuously collected and added to the evaluation. Sensitivity analyses for an extended temperature range, especially at lower temperatures where CHEMKIN simulations currently have convergence issue, and more various fuel compositions will be performed for further observations and more comprehensive analyses of ignition delay profiles obtained from the mixture modeling.

VI. MAJOR ACCOMPLISHMENTS PLANNED IN OUTMONTHS (6-18 MONTHS)

Following accomplishments are expected:

- Experiments will be conducted using NG and IGCC syngas.
- Observations made based on numerical analyses will be verified in the experimental studies.
- Empirical/analytical correlations for ignition delay will be obtained.
- Additional sensitivity analyses will provide further kinetics explanations to the autoignition characteristics.

VII. ISSUES

Experiments.

Because ignition delay times of H_2 are significantly shorter relative to NG at higher temperatures, experimental observations establishing the effect of components such as CO or diluents will be challenging and may be limited to lower temperatures (which are really more in the range of typical gas turbine compressor discharge temperatures and/or syngas temperatures produced by hot gas clean up strategies). In addition, large flow rate turndown of IGCC syngas constituents may require further modifications to the fuel composition control method and/or limit the range of conditions studied.

Numerical Analyses.

Autoignition simulations using CHEMKIN (AURORA) are experiencing a convergence problem, particularly at lower temperatures (below 1000 K), making numerical analyses at typical gas turbine conditions challenging. CANTERA is being evaluated as an alternative kinetics calculation code.

VIII. ATTACHMENTS – None.