

IGNITION RATE MEASUREMENT OF LASER-IGNITED COALS

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Authors: John C. Chen
Vinayak Kabadi

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North Carolina A&T State University
Department of Mechanical Engineering
1601 East Market Street
Greensboro, NC 27411

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Abstract

We are proposing to establish a novel experiment to study the ignition of pulverized coals under conditions relevant to utility boiler. Specifically, our aims are to determine the ignition mechanism, which is either homogeneous or heterogeneous, of pulverized coal particles under various conditions of particle size, coal type, freestream oxygen concentration, and heating rate. Furthermore, we will measure the ignition rate constants of various coals by direct measurement of the particle temperature at ignition, and incorporating this measurement into a mathematical model for the ignition process.

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Executive Summary

During the past reporting period, we recruited a new graduate student for work on this project. Mr. Maurice Richardson will be responsible for the design, construction, and testing of the two-wavelength pyrometer for particle-temperature measurement. The pyrometer is expected to be completed during this summer, when this project ends. At that time, Mr. Richardson will use the pyrometry system in another coal-ignition study to complete his MS degree.

Also during this reporting period, we took delivery of the data-acquisition system, as well as the optical components needed for the pyrometry system. This completes the equipment and supplies purchases for this project.

We are continuing work on the manuscript be prepared for submission to *Energy and Fuels* for review.

Introduction

Over the last several decades many experiments have been conceived to study the ignition of pulverized coal and other solid fuels. We are constructing a laser-based apparatus which offers several advantages over those currently in favor. Sieve-sized particles are dropped batch-wise into a laminar, upward-flow wind tunnel which is constructed with a quartz test section. The gas stream is not preheated. A single pulse from a Nd:YAG laser is focused through the tunnel and ignites several particles. The transparent test section and cool walls allow for application of two-color pyrometry to measure the particles' temperature history during ignition and combustion. Coals ranging in rank from lignites to low-volatile bituminous, and chars derived from these coals, will be studied in this project. For each fuel type, measurements of the ignition temperature under various experimental conditions (particle size and free-stream oxygen concentration), combined with a detailed analysis of the ignition process, will permit the determination of kinetic rate constants of ignition.

This technique offers many advantages over conventional drop-tube furnace experiments. One is the ability to directly measure ignition temperature rather than inferring it from measurements of the minimum *gas temperature* needed to induce ignition. Another advantage is the high heating rates achievable — on the order of 10^6 K/s. This is a significant improvement over experiments which rely on convective heating from a hot gas, which typically achieves heating rates of 10^4 K/s. The higher heating rate more closely simulates conditions in conventional coal combustors used for power generation.

It should be noted that single-particle behavior governs the conditions of this experiment; i.e., the particle suspension is dilute enough that particle-to-particle effects (other than radiative heat transfer) are not important. In actual combustors, particle loading, especially near the injector, is high enough that such “cooperative effects” dominate. Our approach is to gain a clear

understanding of single-particle behavior with this experiment, before facing the more difficult problem encountered with cloud suspensions.

Objectives

Our objectives for this project are:

1. Construction of the laser-ignition experiment, including:
 - 1.1. gas delivery and regulation system;
 - 1.2. wind tunnel;
 - 1.3. exhaust system;
 - 1.4. laser system and beam-guiding optics;
 - 1.5. optical detection system; and
 - 1.6. data acquisition and processing;
2. Shakedown testing of the various components;
3. Ignition of coals of various rank, from lignites to low-volatile bituminous;
4. Measurement of the ignition temperatures of these fuels under various experimental conditions (particle size and free-stream oxygen concentration);
5. Extraction of ignition rate constants from temperature measurements by application of an appropriate heterogeneous-ignition analysis.

Results from This Reporting Period and Discussion

Personnel

Mr. Maurice Richardson, currently a graduating senior in the Department of Mechanical Engineering, has been recruited to work on this project as part of his MS degree. He will begin working this summer, and will continue into the fall, when he officially begins his MS program. Mr. Richardson will be responsible for the design, construction, and testing of the two-wavelength pyrometer for particle-temperature measurement. The pyrometer is expected to be completed during this summer, when this project ends. At that time, Mr. Richardson will use the pyrometry system in another coal-ignition study to complete his MS degree.

Experiment

During the past reporting period, we took delivery of the data-acquisition system, as well as the optical components needed for the pyrometry system. This completes the equipment and supplies purchases for this project.

We are continuing work on the manuscript be prepared for submission to *Energy and Fuels* for review.

Goals for Next Quarter

During the next reporting period, we will complete the two-color pyrometry and begin its testing. In addition, we will complete the manuscript for submission to *Energy and Fuels*.