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RESEARCH TITLE: MECHANISMS AND OPTIMIZATION OF COAL COMBUSTION

PRINCIPAL INVESTIGATOR: KYRIACOS ZYGOURAKIS

STUDENTS AND THE DEGREE FOR WHICH THEY ARE REGISTERED:
D. Sam Perkins, Ph.D., Y. W. Cai, Ph.D.

INSTITUTION/ORGANIZATION: Dept. of Chemical Engineering, MS 362
Rice University
Houston, Texas 77005-1892
(713) 527-8101 Ext. 3509

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I. ABSTRACT

OBJECTIVE: The main objectives of this project are to:

(1) elucidate the fundamental pyrolysis and combustion mechanisms and quantify the effect of several important process conditions on the combustion behavior of chars;
(2) measure some key structural parameters of coals and chars needed for the optimal design of coal combustors;
(3) develop and test models that can predict particle ignitions and calculate the burn-off times of coal and char particles; and
(4) propose process modifications that will improve combustion efficiency and lower the emission levels of atmospheric pollutants.

WORK DONE AND CONCLUSIONS:

A new technique combining video microscopy, image processing and thermogravimetry was developed to detect ignitions of char and coal particles. Chars were prepared at heating rates ranging from 0.1 ˚C/s to 1,000 ˚C/s using two reactor systems. The first system used was a TGA/VMI reactor that is built around a thermogravimetric analyzer and is equipped with a sophisticated video microscopy system. Heating rates up to 20 ˚C/s could be achieved with this reactor. A captive sample reactor was used to produce chars at high pyrolysis heating rates. This reactor was also equipped with a video microscopy system and could achieve heating rates as high as 1,000 ˚C/s with good reproducibility.

Chars produced from Illinois #6 and Pocahontas coals were then reacted with oxygen at ambient temperatures ranging from 400 to 750 ˚C. The multiple-particle combustion experiments were recorded and the video tapes were processed with the help of a digital image analysis system to obtain time-resolved light intensity traces for *each* of the reacting char particles. By analyzing the light intensity traces and the simultaneously collected thermogravimetric data, we were able to accurately detect thermal particle ignitions. While isolated ignitions could be detected by either thermogravimetry or video microscopy alone, multiple ignitions occurring over a short period of time could only be detected through video

microscopy. This is because the reactivity peaks caused by the sudden increase in the combustion rates of ignited particles overlapped when these ignitions occurred within a short time interval, leading to a broad maximum in the reactivity pattern. On the other hand, thermogravimetric data allowed us to detect faint ignitions where the rise in the char particle temperature was not high enough to produce bright light emissions.

Our video microscopy setup also enabled us to observe that some char particles ignited multiple times in the same combustion run. These secondary ignitions commonly occurred at high combustion temperatures and high oxygen concentrations. Secondary ignitions could produce a separate reactivity peak, if there was a sufficiently long delay between the primary and secondary ignitions. In many cases, however, the secondary ignitions occurred very soon after the primary ignitions and video microscopy was the only means of detection.

SIGNIFICANCE TO THE FOSSIL ENERGY PROGRAM: The macropore structure of chars is a major factor in determining their reactivity during the gasification stage. Our studies aim at quantifying through *direct measurements* (a) the effect of pyrolysis conditions of the macropore structure of chars, and (b) the effect of the macropore structure on the char reactivity pattern observed during gasification at high temperatures where intraparticle diffusional limitations are rate-controlling. These studies will provide essential parameters for the optimal design of coal combustion processes.

PLANS FOR THE COMING YEAR: Our plans include studies of the ignition of coal particles that are rapidly heated in an oxygen-containing atmosphere. The mechanism of coal ignition will be investigated using video microscopy and thermogravimetry. We will also conduct experiments to determine the effect of process conditions on the ignition and reactivity behavior of coals and chars. The heating rates, particle sizes, combustion temperatures and oxygen concentrations will be among the process conditions investigated.

II. HIGHLIGHT ACCOMPLISHMENTS

The combination of video microscopy with digital image processing gave us a powerful tool for detecting ignitions occurring in ensembles of reacting char particles. By allowing us to characterize in detail the ignition behavior of *individual particles* in an ensemble, the new technique provided us with information that previously could be obtained only with single particle experiments. Thus, we expect that the new ignition detection technique will be particularly useful for studying particle interactions, which play an important role in coal combustion. Video microscopy was also very useful in identifying the ignition mechanism of reacting char particles. Our results showed that the ignition of char particles typically occurs heterogeneously. Other transient phenomena (such as multiple ignitions of a single particle) were also detected.

III. ARTICLES AND PRESENTATIONS

[1] D. S. Perkins and K. Zygourakis, "Ignition and Reactivity of Coal and Char Particles," presented at the 1996 Annual AIChE Meeting, Chicago, IL, November 10-15, 1996.

[2] D. S. Perkins and K. Zygourakis, "Ignition of Coal and Char Particles: Role of Pore Structure and Process Conditions," to be presented at the 1997 Annual AIChE Meeting, Los Angeles, CA, November 1997.

[3] D. S. Perkins and K. Zygourakis, "Detection of Coal and Char Particle Ignitions," *to be submitted* (1997).