Combustion of Pulverized Coal in Vortex Structures

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Abstract

This sixth quarterly report describes the activities and accomplishments of the research team at the University of Oklahoma, Norman, Oklahoma, related to the project entitled "Combustion of Pulverized Coal in Vortex Structures" during the period January 1, 1995 to March 31, 1995. The work performed in this quarter consisted of the following four tasks: (i) design and fabrication of a computer-driven traversing mechanism for traversing LDV transmitter and receiving optics, (ii) color schlieren photography, (iii) presenting a report in the panel-review meeting in Pittsburgh, (iv) installation of additional safety devices in response to the letter of Dr. Sean Plasynski, and (v) streamwise velocity measurement in the isothermal heterogeneous shear layer with nonreacting particles using LDV. In the next quarter, we plan to continue this work with heated shear layers in which particles undergo pyrolysis. Flow visualization and mean velocity field measurement instrumentation will continue as the major experimental techniques.

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I. INTRODUCTION

This sixth quarterly progress report covers the overall objectives, the specific objectives for the reporting period, the organizational details, the work that has been accomplished during the reporting period, the work planned for the next quarter, and an assessment of the anticipated problems.

II. OVERALL OBJECTIVES

The overall objectives of the project are: (i) to investigate the changes in the characteristics of large scale vortex structures in the shear layer caused by the introduction of inert solid particles in one of the feed streams; (ii) to understand the effects of pyrolyzing solids on the shear layer behavior; (iii) to study the effect of combustion of the pyrolysis products on the shear layer structure, heat release rate, and pollutant emission characteristics; and (iv) to study the effect of modifying the shear layer characteristics on the ensuing flame behavior.

III. SPECIFIC OBJECTIVES FOR THE REPORTING PERIOD

The specific objectives for the reporting period were: (i) design and fabrication of a computer driven traversing mechanism for traversing LDV transmitter and receiving optics, (ii) conduct color schlieren photography, and (iii) to conduct streamwise velocity measurement in the isothermal heterogeneous shear layer with nonreacting particles using LDV.

IV. ORGANIZATIONAL DETAILS

Mr. Nelson Butuk, a graduate student in the School of Aerospace and Mechanical Engineering, pursuing his Ph. D. degree program continued to work as a research assistant assisting the principal investigator, Professor S. R. Gollahalli. An undergraduate student in Mechanical Engineering, Mr. Benny Foreman and another graduate student Mr. Michael Babb helped Mr. Butuk. The mechanical engineering technician of the School, Mr. Bill

Hill, and the machinist, Mr. Steve Dean helped the research team during the reporting period.

V. WORK ACCOMPLISHED DURING THE REPORTING PERIOD

VA Design and Fabrication of Computer Driven Traversing Tables

The laser velocity meter has to be traversed along a vertical plane at several streamwise directions. For this purpose, a three-dimensional traverse was designed and constructed. This task consumed a great deal of time during this quarter. The traverses in two directions x and y (streamwise and horizontal direction perpendicular to it) are manually controlled. The traverse in the vertical z direction is computer-driven. The software using Strawberry systems Workbench program has been adopted. Figure 1 shows the schematic of the LDV traversing arrangement.

The LDV is based on a helium-neon laser and grating-controlled detector system. The system is operated in forward scatter-mode. For measuring continuous phase velocity, magnesium oxide particles of mean diameter $2\text{ }\mu\text{m}$ are injected with a fluidized bed feeder. The dispersed phase velocities are measured using injected particles.

VB Pulverization of Coal

We need pulverized coal of known size, preferably containing monosized particles. However, coal particles are not spherical and are not commercially available with monosize range. We explored the possibilities of using monosized particles of other materials. The cost of such particulate material, when commercially available, was prohibitively high. Since particles cannot be retrieved and recycled in the present set up, the available budgetary precluded this approach. Hence, we decided to grind and sieve coal ourselves to obtain particles of a narrow size range. We bought several US standard sieves and reactivated an existing pulverizing mill and shaker system. We are using Illinois-No. 6 bituminous coal for this study. Since coals have different moisture content they had to be conditioned by preheating them for 4 hours at 150 F before each test. For this purpose an electrical oven was installed.

VC Development of Color Schlieren System

The experiments with the continuous light source and using 35 mm camera with as low as 1/8000 second exposure on a 3600 ASA film showed, the time scale was not short enough to resolve the individual vortex structure. Hence, a xenon arc flash light source was obtained. This light source produces white light flashes at duration as short as 1.5 μ s. A schlieren system was assembled using 75 mm diameter achromatic lenses of 250 mm focal length. The horizontal knife edge described in the previous report was replaced by a color schlieren filter in the focal plane. Some photographs were obtained by using these systems.

VD Presentation in the Panel Review

The principal investigator traveled to Pittsburgh, PA on January 25 to present a report to the panel reviewing the program. There, he met the program manager Dr. Walter Fuchs, who attended his presentation.

Following the review, the PI received a letter from Dr. Sean Placynski about some safety concern of the panel. Subsequently, a letter was sent to Dr. Placynski describing the safety features already in place and the additional features that will be used before combustion tests will be conducted.

VE Experiments Performed

Color schlieren pictures taken with 1.5 ms duration strobe flash show that there are nonuniformities in the spanwise distribution of the flow field and corroborate the findings of the velocity field measurements.

The velocity field in shear layers with one stream heated and the other stream cold were measured. The data were analyzed and the shear layer growth rate parameter d was calculated.

VI. WORK PLANNED FOR THE NEXT QUARTER

In the next quarter, we plan to pursue the following: (i) continue the mean velocity field probing in nonisothermal shear layers with cold and pyrolyzing particles, (ii) continue our effort to improve schlieren visualization system to resolve vortical structures, and (iii) obtain the rms values of fluctuating velocity and its distribution at several locations of the shear layer.

VII. ENCOUNTERED and ANTICIPATED PROBLEMS

In this quarter we experienced several problems in the operation of particulate feeding and obtaining narrow-size range distribution of coal particles. Also, the construction of debugging of the computer driven traverse system consumed much more time than we had anticipated. Hence, we are somewhat behind schedule.

In this quarter, we do expect some delays because of the installation of additional redundant safety features. Although , we expect to catch up on some of these during summer, when the academic demands are lower, we may have to request a no-cost extension. We will know about it in early summer.

VIII. CONCLUDING REMARKS

During the sixth quarter we encountered problems in the operation of particulate feeding system and in the construction of traversing system for the laser velocimeter. We have conducted experiments to obtain color schlieren systems. We have determined the effects of heating on the growth rate of shear layers. This effort will continue in the next quarter with heated streams and pyrolyzing particles.

Figure 1. Computer-controlled LDV Traversing System