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Combustion of Pulverized Coal in Vortex Structures

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Abstract

This second 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, 1994 to March 31, 1994. The construction of the experimental facility for generating two-dimensional shear layers containing vortex structures has been completed. Preliminary shake-down tests of the test facility were conducted for debugging and fine-tuning. A smoke generator was constructed for smoke-visualization of shear layers. Direct photographs of smoke flow patterns of the interfacial region of the mixing layers have been taken. Mean velocity profiles in the direction normal to the tunnel stream direction have been measured with a hot-wire anemometer for different ratios of the initial velocities of the mixing streams. In the next quarter, we plan to conduct schlieren flow visualization of the shear layer, fabricate the particulate feeding system, and measure the velocity field as a function of the particulate concentration in one of the streams.

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I. INTRODUCTION

This second 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) to complete the construction of the shear-layer wind-tunnel facility (ii) to conduct the preliminary shake-down experiments for debugging and fine-tuning the system, (iii) to develop instrumentation for flow visualization, (iv) to obtain pictures of the flow field in the test section for different ratios of the initial velocities of the mixing streams, and (v) to measure mean velocity profiles at the conditions used in (iv).

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. In addition, Mr. Azfar Kamal and Mr. Sudhanshu Astana, also graduate students, were involved in various phases of construction and testing. 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

A substantial part of the effort during this quarter was spent on completing the construction phase of the experimental facility designed in the previous quarter.

Figures 1 and 2 show the schematic diagrams of the experimental facility. Photographs 1 and 2 show the views of the facility at the completed state of fabrication. The test section consists of rectangular channel divided into two parts by a splitter plate. Two dimensional vortex street will be generated in the shear layer of the two gas streams supplied to the upper and lower channels. The details of the air supply systems and the fabrication features of the test section were given in the first quarterly progress report [1]. A flow conditioning system and an exhaust system were added in this quarter.

The first set of experiments consisted of characterizing the mean flow field in the test section. A hot-wire anemometer was used to measure the mean velocity in the streamwise direction. The coordinate system used to denote the velocity vector field is shown in Fig. 3.

Figures 4 to 10 show the profiles of the streamwise mean velocity along Y direction at several distances from the splitter plate (X). In all these experiments the bottom blower inlet was kept fully open which corresponded to a velocity of about 3000 ft/min in the lower stream. The legend in each graph indicates the following velocity in the lower stream which was varied by throttling the inlet of the blower: $U_0 \Rightarrow$ blower was switched off yielding a velocity of zero in the lower stream; $U_A \Rightarrow$ the velocity in the lower stream was about 1000 ft/min; $U_B \Rightarrow$ the velocity in the lower stream was about 2700 ft/min; $U_{max} \Rightarrow$ the blower inlet was fully open yielding a velocity of 3000 ft/min.

Photographs 3 to 6 show the smoke flow pattern of the flow in the test section viewed normally to the mean stream direction at different velocities of the upper stream. The lower stream into which smoke generated by evaporating ethylene glycol solution on an electrically heated aluminum plate was introduced. It is noticed that the lower stream acts like a wall jet attaching to the upper plate in a short distance from the splitter plate when the upper stream velocity was zero (Ph. 3). Also, It is clear as the velocity ratio of the two streams is increased, the vortex structure develops along the interface of the two streams. At the highest velocity ratio it appears that the exposure time of 1/4000 second is barely enough to freeze the motion of the vortex structure in the photographs. It is evident the growth of the shear layer is retarded as the velocity ratio decreases. Further refinement in the flow visualization technique is necessary to resolve the vortex structure.

VI. WORK PLANNED FOR THE NEXT QUARTER

In the third quarter, we plan to pursue the following tasks: (i) refine the smoke visualization technique (ii) install schlieren instrumentation for flow visualization of shear layer, (iii) design and develop particulate feed system, (iv) conduct preliminary tests in homogeneous shear layers, and (v) initiate tests on particulate laden shear layers.

VII. ANTICIPATED PROBLEMS

Although currently we do not expect any major problems in the execution of the project in the next quarter, we expect some difficulties in developing the particulate feed system and obtaining an uniform flow rate.

VIII. CONCLUDING REMARKS

During the second quarter we have completed the tasks as planned. We constructed a new experimental facility for generating two-dimensional shear layers. We have completed the velocity field measurements and currently conducting smoke flow visualization studies. In the next quarter, we expect to refine our flow visualization system and conduct detailed velocity measurements in homogeneous shear layers. We also expect to initiate the studies on particulate-laden shear layers.

IX. REFERENCE

- 1 S. R. Gollahalli, 1994, "Combustion of Pulverized Coal in Vortex Structures," First Quarterly Progress Report, Submitted to Documentation Center, Pittsburgh Energy Technology Center, Pittsburgh, PA.

Figures and Photographs

FIG. 1 Arrangement of the Experimental Facility

FIG. 2 Details of Contraction and Test Sections

Fig 3. Test Section and Coordinate System

Fig. 4 Mean Velocity Profiles in the Streamwise Direction

Fig. 5 Mean Velocity Profiles in the Streamwise Direction

Fig. 6 Mean Velocity Profiles in the Streamwise Direction

Fig. 7 Mean Velocity Profiles in the Streamwise Direction

Fig. 8 Mean Velocity Profiles in the Streamwise Direction

Fig. 9 Mean Velocity Profiles in the Streamwise Direction

Fig 10. Mean Velocity Profiles in the Streamwise Direction

Ph. 1 A View of the Experimental Facility Showing the Test Section and Exhaust System

Ph. 2 A View of the Experimental Facility Showing the Test Section and Air Supply System

Ph. 3 Smoke Flow Pattern in the Test Section (Smoke was introduced into only the bottom stream 1; $U_1 = 3000$ ft/min, $U_2 = 0$ exposure time = $1/2000$ s)

Ph. 4 Smoke Flow Pattern in the Test Section (Smoke was introduced into only the bottom stream 1; $U_1 = 3000$ ft/min, $U_2 = 1000$ ft/min, exposure time $1/2000$ s)

Ph. 5 Smoke Flow Pattern in the Test Section (Smoke was introduced into only the bottom stream 1; $U_1 = 3000$ ft/min, $U_2 = 2700$ ft/min)

Ph. 6 Smoke Flow Pattern in the Test Section (Smoke was introduced into only the bottom stream 1; $U_1 = 3000$ ft/min, $U_2 = 2700$ ft/min, exposure time $1/4000$ s)

In all the above photographs white area represents smoke stream

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