1 of 1

Combustion of Pulverized Coal in Vortex Structures

Grant No. DE-FG22-93PC93221

Quarterly Progress Report No. 1

Period Covered: October 1, 1993-December 31, 1993

Prepared by

S. R. Gollahalli
Principal Investigator
Lesch Centennial Professor
School of Aerospace and Mechanical Engineering
The University of Oklahoma
Norman, OK 73019

Submitted to

Document Control Center
U. S. Department of Energy
Pittsburgh Energy Technology Center
P. O. Box 10940, Pittsburgh, PA 15236-0940
Project Officer: Walter Fuchs

The Office of Research Administration
1000 Asp Avenue, Room 314
The University of Oklahoma
Norman, OK 73019

Administrative Contact:
Ms. Cheryl Patton

January 1994

MASTER

Abstract

This first 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". An experimental facility for generating two-dimensional shear layers containing vortex structures has been designed and fabricated. Currently, the test facility is undergoing debugging and fine-tuning. In the next quarter, the test facility will be instrumented and baseline studies will be conducted.

Table of Contents

	Page
ABSTRACT	1
TABLE OF CONTENTS	2
I. INTRODUCTION	3
II. OVERALL OBJECTIVES	3
III. SPECIFIC OBJECTIVES FOR THE REPORTING PERIOD	3
IV. ORGANIZATIONAL DETAILS	3
V. WORK ACCOMPLISHED DURING THE REPORTING PERIOD	3
VI. WORK PLANNED FOR THE NEXT QUARTER	5
VII. ANTICIPATED PROBLEMS	5
VIII. CONCLUDING REMARKS	6
IX. REFERENCES	6
X. FIGURES AND PHOTOGRAPHS	7 to 12

I. INTRODUCTION

This first 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 first quarter were: (i) to update the literature survey, (ii) to design and fabrication of the two-dimensional nozzle, and (iii) to modify the combustion chamber facility already existing in the lab to accommodate the nozzle constructed.

IV. ORGANIZATIONAL DETAILS

Mr. Nelson Butuk, a graduate student in the School of Aerospace and Mechanical Engineering, pursuing his Ph. D. degree program was hired as a research assistant to assist the principal investigator Professor S. R. Gollahalli. Mr. Butuk has a Master's degree from the University of Minnesota. 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

First, a literature search was conducted to update the information base relevant to this project. Some preliminary studies were conducted to determine the feasibility of modifying the existing combustion facility for the experiments of this project. We found that since the existing combustion chamber facility was originally constructed for axisymmetric flames, a substantial amount work would be needed to make it suitable for generating the two-dimensional shear layers required for this project. Hence, in order to save time and to retain the existing facility for other future axisymmetric flame studies, we decided to design and construct a new facility

from scratch for this project. We based our design on the facilities used for some previous studies on two-dimensional shear layers [1,2].

Figures 1-3 show the schematic diagrams of the experimental facility. Photographs 1 to 3 show the views of the facility at the present 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.

Air is supplied by two centrifugal blowers. The large blower supplies air to the lower channel of the shear layer facility. The large blower is a standard centrifugal blower with a 0.35 m (13 1/2") diameter impeller driven by a 5.6 kW (7 1/2 hp) electric motor and capable of delivering air at a flow rate of 0.253- 2.02 m³/s (536 - 4280 cfm). The smaller blower supplies air to the upper channel and is driven by a xxxxx hp motor. This upper channel has provision for locating electric resistance heater elements to heat the air. An arrangement for the introduction of coal particles into this channel will be provided. The rectangular channels are built in modular sections. Each section consists of six aluminum plates 6.25 mm (1/4") thick joined together by aluminum angle pieces of 25 mm x 25 mm x 3 mm (1" x 1" x 1/8") dimensions. A splitter plate also of 6.25 mm (1/4") thick aluminum divides the section into two channels - upper and lower. The 4.4 mm (1 1/64") holes drilled on all the angle pieces and the matching holes on the plates were spaced 25.4 mm (1") apart. To ensure air-tight connections, each section is assembled with the aid of silicon glue and gaskets. The holes of the plate facing the inside of the channel are counter sunk so that the screws joining the plates to the angle pieces are flush with the plates. Figure 4 shows a 3-dimensional sketch of a typical section. The inside cross-sectional area of each channel measures 20 cm x 14 cm (7 7/8" by 5 1/2"). The complete facility consists of four modular sections each of length 15.3 cm (6"), a contraction section, a test section and an exhaust section.

The two gas streams come together at the end of the contraction section in the test section where the splitter plate is machined over 12.5 mm (1/2") length and is beveled at an angle of 4 degrees to make the end as sharp as possible.

The contraction section was designed according to the method introduced by Libby [3]. In this method, potential flow theory is used to derive a profile for walls of a channel to accomplish a monotonically increasing velocity in the flow direction. Two equations for wall profiles interconnecting two channels as shown in Fig. 6 are derived. The two equations relating two channels of height 2α and 2β are:

$$\frac{x_o}{\alpha} = \left[\frac{\beta}{\alpha} / (-\Psi_o + \Pi) \right] \left\{ \ln \Phi + \frac{1}{2} \left[\frac{\alpha}{\beta} - 1 \right] \ln \left(1 + \Phi^2 - 2\Phi \cos \Psi_o \right) \right\}$$

$$\frac{y_o}{\alpha} = \left[\frac{\beta}{\alpha} / (-\Psi_o + \Pi) \right] \left\{ -\Psi_o - \left[\frac{\alpha}{\beta} - 1 \right] \tan^{-1} \left[\frac{-\Phi \sin \Psi_o}{(1 - \Phi \cos \Psi_o)} \right] + \Pi \right\}$$

The variable Ψ_o takes on the value $\Pi/2$ for this particular contraction. The angle Φ is a variable that relates the wall profile coordinates X_o and Y_o . To solve the above two equations for contraction profile, a computer program was written using the secant root finding technique to first search for a value Φ which satisfies the first equation for a given X_o . This value of Φ was then substituted into the second equation and the value of Y_o calculated.

The calculated profile for a contraction ratio of 5 was cut out of 6.25 mm (1/4") thick steel plate for the two side walls of each channel for a total of 4 plates. The profiles decreased from 20 cm (7 7/8") to 3.8 cm (1 15/32") over a length of 60.6 cm (23 7/8") as shown in Figure 5. A thin flexible sheet metal is cut and fixed on top and bottom of the contraction section along the cut profile of the side wall. This sheet was held in place with the aid of aluminum flats connected by screws to the side walls.

The test section is made of quartz glass 8 cm x 16 cm and 42 cm long (3.15" x 6.34" x 16.54") glued together. The flow exits the test section through a rectangular channel connected to an outside duct.

VI. WORK PLANNED FOR THE NEXT QUARTER

In the second quarter, we plan to pursue the following tasks: (i) set up the instrumentation for measuring flow rates of two gas streams, (ii) design and develop particulate feed system, (iii) conduct shake-down tests, (iv) install instrumentation for flow visualization of shear layer, and (v) initiate and conduct preliminary tests in homogeneous 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 delays because of the more than anticipated time required to obtain the test section window material from the vendor. However, we expect that this will not delay the completion of the overall project.

VIII. CONCLUDING REMARKS

During the first quarter we have completed the tasks as planned and the project is on schedule. We constructed a new experimental facility instead of modifying the existing facility. Although some interruptions are expected in the next quarter, we expect that the overall project will be on proposed schedule.

IX. REFERENCES

1. Daily, J. W., Pitz, R. W., Keller, O. J., Ellzey, J. L., and Shepherd, I. G., "The Structure and Dynamics of Two Stream Plane Mixing Layers," Published in Experimental Measurements and Techniques in Turbulent Reactive Flows, ASME, pp. 175-209, 1984
2. Robollo, M. R. "Analytical and Experimental Investigation of a Turbulent Mixing Layer of Different Gases in a Pressure Gradient," Ph. D. Dissertation, Graduate Aeronautical Laboratories, California Institute of Technology, Pasadena, CA, 1973.
3. Libby, P.A. and Reiss, H., "The Design of Two Dimensional Contraction Sections," Quarterly of Applied Mathematics, Vol. 10, pp. 95 -98, 1951.

FIG. 1 Arrangement of the Experimental Facility

FIG. 2 Details of Contraction and Test Sections

FIG. 3 Details of a Gas Flow Module

Ph. 1 A View of the New Test Facility

Ph. 2 Upstream End View of the Test Setup Showing Blowers

Ph. 3 A Close-up View of the Test Section

DATE

FILMED

6 / 10 / 94

END