AIN SHAMS UNIVERSITY

FACULTY OF ENGINEERING

A STUDY OF THE BURNING OF A DUAL PULVERIZED COAL/GAS IN A WATER COOLED COMBUSTION CHAMBER

BY

AMR IBRAHEEM MOHAMED EID

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A Thesis

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Supervised by

Prof. Dr. A. S. GAD EL-MAWLA

Head of Energy and Automotive Engineering Department,

Faculty of Engineering,

Ain Shams University.

Dr. Mohamed Refaat SALEM

Lecturer : Energy and Automotive Engineering Dept.,

Faculty of Engineering,

Ain Shams University.

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بسم الله الرحمن الرحيم

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Examination Committee

Signature

1- Prof. F. M. EL-Mahallawy

Faculty of Engineering, Cairo University.

2- Prof. A. S. ?AD EL-Mawla

Head of Power and Automotive Engineering Department,

Faculty of Engineering, Ain Shams University.

3- Dr. H. A. Moneib

Faculty of Engineering and Technology,

Helwan University.

Date : / / 1990

[illegible] 17/7/1998.

No part of this thesis has been submitted for a degree or a qualification at any other university or institute.

Date :

Signature :

Name : Amr Ibrahim Mohamed [illegible]

ABSTRACT

An experimental study has been performed on a dual pulverized coal/gas flames in a water-cooled combustion chamber to determine the influences of the percentage coal in the fuel on the combustion and heat transfer from the flame. The flames developed in a cylindrical combustion chamber of 20 cm. diameter and operated with a 0%, 15%, 40%, and 47% pulverized coal added to gaseous fuel on a mass basis. The measurements included temperature and CO & CO_2 volumetric concentration values, on dry basis, within the flame, heat transfer to the combustion chamber walls, and the amounts and the carbon content of the residual ashes. The presence of the gaseous fuel in the reactants stream was found to enhance the stabilization tendency of the flame with a resulting overall combustion efficiency of more than 90%. The heat transfer from the flame, near the burner exit, was shown to increase with the increase in the coal percentage in the fuel. The energy contained in the residual ashes and in carbon monoxide at exit from the combustion chamber was estimated to be around 6%.

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CONTENTS

NOMENCLATURE

A	Area.	m^2
C	Gravimetric carbon percent.	%
CO	Carbon monoxide volumetric concentration.	%
CO2	Carbon dioxide volumetric concentration.	%
Cp	Specific heat.	kJ/kg °C
C.V.	Calorific value.	kJ/Kg
D	Combustion chamber internal diameter.	m
d	Jet diameter.	m
daf	Coal or residuals analysis based on dry ash free.	%
dp	Particle diameter.	µm
EL	Energy loss	kJ
h	Ash percent by mass.	%
m	Mass flow rate.	kg/sec
mp	Mass flow rate of primary stream.	kg/sec
ms	Mass flow rate of secondary stream.	kg/sec
O2	Oxygen volumetric concentration.	%
Q	Quantity of heat.	kJ
q	Heat flux.	kW/m
R	Combustion chamber radius.	m
r	Radial distance.	m
T	Gas temperature.	°C
Ti	Input temperature.	°C
To	Outlet temperature.	°C
t	Time.	sec
U	Velocity.	m/sec

U_g	Gas phase velocity	m/sec
U_s	Solid phase velocity.	m/sec
U'	Velocity fluctuation.	m/sec
V	Volatile matters percent.	%
X	Axial distance from the burner exit.	m
α	Coal loading ratio.	%
γ	Coal energy ratio.	%
Φ	Mass ratio.	%
θ	Swirl degree.	%

Subscripts

c	Coal.
C.L	Centre line.
h	Ash.
L	losses.
p	Primary.
s	Secondary.
1	Single phase flow.
2	Two phase flow.

CHAPTER (1)

INTRODUCTION

The renewed interest in the use of pulverized coal as a substitute fuel for power generation and industrial heating has motivated research work to optimize the current burning methods [1], [2]. It is known that the major problems associated with pulverized coal burning are the difficulty of achieving a stable flame [3], the deterioration of heat transfer surfaces due to ash deposition [3], and the requirement of a high particle residence time to ensure complete burning [3].

Pulverized coal particles injected into a combustion space are first heated up and subsequently, decompose with a resulting evolution of volatiles, [1]. This is followed by the mixing and reaction of the volatiles with surrounding gases. Finally, surface reaction of the remaining char occurs as reactants diffuse into the particle surface, [1]. Flame stability is mainly dependent on the heating up, decomposition and mixing processes while the ash properties and the required residence time are determined by the char burning rate. Previous studies, [1-3], indicated that the processes influencing stability are dependent, in turn, on coal type, particle size, excess air, burner design and the rate of particle heating. The latter is determined by the temperature of surrounding gas and the temperature of enclosing combustor walls.

A possible way of ensuring pulverized coal flame stability with a reduced influence of the preceeding factors ... to burn coal in a stream of a gaseous fuel. The more rapid and intense chemical reactions of the gaseous fuel would provide sufficient energy to cause rapid heating up and decomposition of coal particles and, hence, enhance flame stabilization.

In the present work a mixture of gaseous fuel and pulverized coal was burned in a cylindrical water-cooled combustor. The main objective of the study was to determine and quantify the influences of the percentage coal in the fuel on the combustion and heat transfer characteristics of the flame. These are determined from detailed local measurements of temperature and CO & CO2 percentages and from heat flux measurements to the combustion walls. The measurements also include the amounts and the carbon content of the flying and deposited ash.

The present results have strong implications to the heat transfer problem of gaseous fuels. The addition of coal to the gaseous fuel could be expected to enhance the comparatively poor heat transfer characteristics of the gaseous flames.

The thesis contains five chapters and one appendix:

Chapter (1) introduction

Chapter (2) reviews previous related work.

Chapter (3) provides a detailed description of the experimental set-up, the measuring techniques, and the experimental programme.

Chapter (4) is concerned with the presentation and discussion of the experimental results.

Chapter (5) present the conclusion of the present work and the suggested recommendations for future work.

Appendix (1) contains the calibration curves of the orifices of the primary air, the secondary air, and the gaseous fuel.

CHAPTER(2)

LITERATURE SURVEY

This chapter provides a review of the previous work on different topics related to the present work. The review starts by considering the aerodynamics of co-axial jets and, then, the burning characteristics of pulverized coal flames.

2.1 Aerodynamics of co-axial jet

2.1.1 Single phase jet

El-MAHALLAWY and HABIB [4], performed an experimental work on the mixing of an annular jet and a central swirling jet in a cold model furnace. The parameters investigated were the effect of swirling one or both of the two jets and the direction of swirl of each of them relative to the other on the aerodynamic mixing pattern. The results showed that swirling the two streams at the same time will give better mixing than swirling one stream only, (figure 2.1), and that the opposite direction of swirl represents the best condition of mixing as compared to all other cases (figure 2.2).

2.1.2 Two phase jet

Laser doppler velocimeter (LDV) measurement of a two-phase axisymmetric turbulent jet was carried out by MODARRESS and WUERE [5]. The data for the mean velocity components, turbulence intensity and turbulent shear stress