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INVESTIGATION OF COMBUSTION UTILIZING NON-CIRCULAR PORTS

By

Osama Ahmed Metwally Hassan Kashkousha

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Under Supervision of

Prof. Dr. Mahmoud Abd El-Rasheed Nosir

Professor at the Mechanical Power Department

Faculty of Engineering

Ain Shams University

Dr. Abd El-Aziz Morgan Abd El-Aziz

Associate Professor at the Mechanical Power
Department

Faculty of Engineering

Ain Shams University

Dr. Mahmoud Mohamed Kamal

Associate Professor at the Mechanical Power
Department

Faculty of Engineering

Ain Shams University

Cairo

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Examiner Committee



The undersigned certify that they have read and recommended to the faculty of engineering , Ain Shams University for acceptance a thesis entitled by **“Investigation of Combustion Utilizing Non – circular Ports”**, submitted by Osama Ahmed Metwally Hassan Kashkousha, in partial fulfillment of the requirements for the degree of Master of Science in Mechanical Power Engineering.

Name	Signature
1. Prof. Dr. Hendawy Salem Mohamed Mechanical Power Department Faculty of Engineering Cairo University	
2. Prof. Dr. Adel Abd El Malek El Ahwany Mechanical Power Department Faculty of Engineering Ain Shams University	
3. Prof. Dr. Mahmoud Abd El-Rasheed Mechanical Power Department Faculty of Engineering Ain Shams University	
4. Dr. Mahmoud Mohamed Kamal Mechanical Power Department Faculty of Engineering Ain Shams University	

Statement

This dissertation is submitted to Ain Shams University in fulfillment of the requirements for the degree of Master of Science in Mechanical Engineering.

The work included in this thesis was made by the author during the period from October 2009 to January 2012 at the Mechanical Power Engineering Department, Ain Shams University.

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

Date	:	4-11-2012
Signature	:	O. A. Kashkousha
Name	:	Osama Ahmed Metwally Hassan Kashkousha

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ABSTRACT

Combustion Control using Elliptic jets issued from elliptic nozzles has gained a lot of interest during the last four decades due to the obtained favorable aerodynamic features and enhanced mixing characteristics of two flowing streams of fluids than two dimensional jets issued from circular nozzles. These efforts were done in response to the increased demands for higher efficiency burners for various industrial applications.

Burner nozzle element was designed and equipped to the combustor rig to carry out the proposed investigation experimentally of the characteristics of diffusion flames for three elliptic burner nozzles of different aspect ratios; 1.6, 2, 3.3 respectively. Flame Temperature, turbulence Characteristics as well as emissions [CO , NO_x , UHC...] were measured and compared to those of diffusion flames issued from circular nozzles of equivalent cross section area.

Four burner nozzle configurations were investigated; single elliptic burner nozzle in circular co – flow, applied cross flow admissions on diffusion flames issued from elliptic burner nozzle, two concentric nozzles configurations using biased injection element [this configuration was applied for normal diffusion flames and for inversed diffusion flames].

Numerical simulations were performed for the four configurations to predict and estimate the expected experimental flame properties and predicting the optimized firing conditions when using burners equipped with elliptic nozzles.

It was found that a single elliptic burner nozzle of aspect ratio 3.3 produced the lowest carbon monoxide concentration level indicating more oxidation of carbon monoxide to carbon dioxide as a result of the enhanced air entrainment into the jet core. This occurred due to the effect of further increase of nozzle aspect ratio.

Retarding the cross flow reduced the CO concentrations as the premixing effect increased the rate of oxidation of CO into CO_2 . The reduction of NO_x concentrations was recorded due to the increased level of homogeneity and reduced local peak flame temperatures. These effects reduced the formation of NO_x according to the Zeldovich Mechanism.

Favorable interaction zones resulted due to varying the modulating angle between the inner and outer nozzles in two concentric nozzles configuration.

Inversed diffusion flames issuing from elliptic nozzles had reduced CO concentrations due to the enhanced mixing and combustion rates upon increasing the number of active points in the unburned regions.

The peak turbulent kinetic energy was maximized at the major axis tips to pronounce increased jet entrainment by 478% in comparison to concentric circular jets. Increasing the aspect ratio from 1.6 to 3.3 nearly duplicated the peak turbulent kinetic energy and resulted in 9% increase in the combustion efficiency with 25% UHC reduction. As dominated by the peak turbulent energy merging, the optimum angular positioning of the two jets was 35° for higher inner jet velocity. For lower inner jet velocity, the best angular positioning was 45° and 30° for higher and lower inner aspect ratio, respectively. By introducing radially opposing air jets, the optimum angular positioning decreased to 25° as the flame was shortened by about 43%. The multi-stage air cross-flow revealed more aerodynamic features. Using less number of stages and increasing the cross-flow admission distance to 20 cm at increased cross-flow percent to 70% minimized the average UHC and No_x emissions. The optimum performance was thus found when lifted flame premixing features were coupled with the impinging cross-flow stabilizing effects

Table of Contents

Examiner Committee	I
Statement	II
Acknowledgment	III
Abstract	IV
Table of Contents	VI
Nomenclature.....	X
Greek Letters	XI
Subscripts and Superscripts.....	XII
Abbreviations.....	XIII
List of Figures.....	XIV
List of Tables	XX
 CHAPTER 1: INTRODUCTION	 1
1.1 General	1
1.2 Thesis Layout.....	4
 CHAPTER 2: PHYSICAL INSIGHT	 6
2.1 Introduction to free jets	6
2.2 Dynamics of Three Dimensional Jets.....	6
2.2.1 Self Induction Mechanism	7
2.2.2 Axis Switching Phenomenon.....	7
2.2.3 Vortex Ring Bifurcation	8
2.2.4 Flow Patterns.....	9
2.2.5 Velocity Field.....	10
2.2.6 Entrainment characteristics.....	11
2.3 Relevant Combustion Topics.....	13
2.4 Combustion Flow Types.....	14
2.4.1 Annular Flow	14
2.4.2 Coaxial Jets	14

2.4.3 Cross-Flow Jets	17
2.5 Combustion Control	18
2.6 Small Scale Mixing	19
 CHAPTER 3: LITERATURE SURVEY	 21
3.1 Introduction	21
3.2 Review of Previous Works	22
3.2.1 Characterizing the cold flow features of elliptical jet configurations	22
3.2.2 Characterizing the cold flow features of elliptical jets with the active control via pulsation.....	24
3.2.3 Highlighting the combustion features of single and concentric elliptical jets..	27
3.2.4 Highlighting the Aerodynamics and Combustion Features of elliptical jets with the active control via cross - flow	31
3.3 Discussion of previous work and scope of the present work	34
 CHAPTER 4: EXPERIMENTAL TEST RIG AND MEASURING TECHNIQUES.....	 36
4.1 Introduction	36
4.2 Test Rig Layout and Configurations	37
4.3 Components of Test Rig	48
4.4 Measuring Instruments	53
4.5 Experimental Procedure.....	61
4.6 Error Analysis	63
 CHAPTER 5: EXPERIMENTAL RESULTS	 67
5.1 Introduction	67
5.2 Biased Injection Configuration	67
5.3 The Currently Proposed Testing Experiments & Testing Procedure	67
5.4 Proposed Measurements	69
Experiments	70
1. Investigating the diffusion flames issuing from burners fitted with single elliptical nozzles in circular co – flow air stream	70
2. Investigating the effect of Cross – Flow air on diffusion flames issuing from burners with single elliptic nozzles in a circular air co - flow	79

3. Investigating the Diffusion Flames issuing from burners fitted with two concentric elliptic air/fuel nozzles using the Biased Injection Configuration.....	89
4. Investigating the Inversed Diffusion Flames Issuing from Burners fitted with two concentric elliptic air/fuel nozzles using the Biased Injection Configuration	105
Conclusions.....	114
 CHAPTER 6: COMBUSTION MODELING AND SIMULATION	115
6.1 Conservation Equations and the Physical Model	115
6.2 Conservation Equations	115
6.2.1 Mass Conservation	116
6.2.2 Momentum Conservation	117
6.2.3 Energy Conservation	120
6.3 Introduction to Combustion Modeling and CFD	121
6.3.1 Transport Equations	122
6.3.2 The Damkohler Number	123
6.3.3 Conservation Laws	124
6.3.4 Three Turbulent – Flame Interaction Regimes	125
6.4 Mathematical Solution Method	127
6.4.1 Discretization Method	127
6.4.2 Convection Discretization.....	128
6.4.3 Diffusion Discretization.....	129
6.4.4 Source Term Linearization	130
6.4.5 Finite Difference Equation.....	130
6.5 Solution Algorithm and Combustion Modeling.....	131
6.5.1 Selection of appropriate Combustion Model	133
6.5.2 Eddy Dissipation Model Coefficients.....	134
6.5.3 The PDF for NO modeling	134
6.6 Investigated Cases	136
Case (A): Single Elliptic Burner (Fuel Nozzle) in a Circular Co-flow.....	137
Case (B): Biased Injection Configuration	145
Case (C): Single Elliptic Fuel Nozzle In A Cross-Flow Configuration.....	159
Case (D): Inversed Diffusion Flames Issued From Biased Injection Configuration.....	171

CHAPTER 7: CONCLUSIONS AND RECOMMONDATIONS FOR FUTURE WORKS..
..... 182

REFERENCES. 184

APPENDICES.

Appendix A..... 188

Appendix B..... 189

Nomenclature

A	Cross section Area [m^2]
A_j	Junction Surface Cross section area [m^2]
C_d	Coefficient of Discharge.
D	Equivalent Diameter [mm]
D_a	Damköhler number,
E	Activation Energy [W]
ΔH	Pressure Head [m]
l_k	Kolomogrov' s length scale
l_d	Diffusive Layers length
m^o	Mass Flow rate [kg/sec]
ΔP	Pressure Difference [bar]
Q	Mass Flux at particular location [$kg/m^2.s$]
Q_o	Mass Flux at nozzle exit with equivalent diameter [$kg/m^2.s$]
T_a	Activation Temperature [K]
T_f	Flame Temperature [K]
T_j	Junction Temperature [K]
T_w	Wall Temperature [K]
U	Mean Axial Velocity at a particular location [m/s]
U/U_o	Normalized Axial Velocity
U_{Conv}	Convection Heat Transfer Coefficient [Watt/ $m^2.K$]
U_o	Mean Exit Velocity at a particular location [m/s]
x/D	Axial distance to Jet Diameter Ratio