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FACULTY OF ENGINEERING

INVESTIGATION OF PLASMA ASSISTED COMBUSTION

By

Abd ElRahman Afify Nour Mokhtar

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**A Thesis Submitted in Accordance with the
Requirements for the Degree of Master of Science**

Under Supervision of

Dr. Mahmoud Mohamed Kamal

Associate Professor at the Mechanical Power
Department

Faculty of Engineering Ain Shams University

Dr. Ahmed Nabil El Sheemy

Assistant Professor at the Mechanical Power Department

Faculty of Engineering

Ain Shams University

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Examiner Committee

Thesis Subject:

Investigation of Plasma Assisted Combustion

Presented by:

Eng. Abd Elrahman Afify Nour Mokhtar

Submitted for partial fulfilment requirements for the Master of
Science (M.Sc.) in Mechanical Power Engineering

Name	Signature
1. Prof. Dr. Mahmoud Abdel Fatah Elkady Mechanical Power Department Faculty of Engineering AL-Azhar University	-----
2. Prof. Dr. Mahmoud Abdel Rasheed Nosier Mechanical Power Department Faculty of Engineering Ain Shams University	-----
3. Dr. Mahmoud Mohamed Kamal Mechanical Power Department Faculty of Engineering Ain Shams University	-----

Statement

This dissertation is submitted to Ain Shams University in fulfilment 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 June 2012 to July 2014 at the Mechanical Power Engineering Department, Ain Shams University.

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

Signature: _____

Name : Abdelrahman Afify Nour Mokhtar

RESERCHER DATA

Name:	Abd Elrahman Afify Nour Mokhtar.
Date of Birth:	06/12/1986.
Place of Birth:	Toukh, Qalubya.
Academic degree:	B.Sc. Mechanical Engineering.
Field of Specialization:	Mechanical Power Engineering.
University issued the degree:	Benha University.
Date of issued degree:	2009

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ABSTRACT

The combustion performance of methane/air triple flames has favorably been affected upon using modulated frequency, pulsed electric discharge via spark plugs. The computations predicted that the density/velocity gradients introduced by the spark pulsating temperature field upstream of the flame base increased the peak local acceleration to 251 m/s^2 . At 40 Hz, a velocity difference as high as 3.5 times the mixture local velocity was provided ahead of the flame lift-off position. At 120 Hz, the normal triple flame stability limit was extended to 14.9 m/s, where 0.011% of the input energy was required for the dielectric breakdown of gases across a 2 mm gap between the two electrodes to involve plasma assisted combustion. Although the peak temperature around the spark increased at least by 1200 K, the correspondingly reduced residence time across the flame zones by 93.3% reduced the NO_x specific emissions by 76%. While the flame tip position was shifted downstream along the first 50% of the combustor length, the HC and CO emissions respectively reached magnitudes as low as 0.09% and 730 ppm. By displacing the high voltage electrode along the combustor centerline, the favorable turbulence effects of the spark discharge pulsating temperature on over-ventilated inverse triple flames were maximized at 120 Hz. As

the mixture fraction gradient was thus reduced to 0.01 cm^{-1} , a flame speed increase of 16.4 m/s provided a maximum firing intensity of 28.6 MW/m^3 ; while the heat flux across the combustor increased with the flame stabilization height. Having the peak rate of radiation heat transfer earlier than the convection one, the efficiency was maintained above 29%. Increasing the mixtures' velocity difference to 3.0 m/s increased the turbulent kinetic energy to a maximum of $9.8 \text{ m}^2/\text{s}^2$ such that enlarging the gap distance to 4 mm increased the stability limit by 21.7%.

Table Of Content

Examiner Committee	i
Statement	ii
Researcher Data	iii
Acknowledgment	iv
Abstract	v
Table of Contents	vii
Abbreviations	ix
Nomenclature	x
List of Figures	xi
List of Tables	xv
Chapter 01 INTRODUCTION	1
1.1 General	1
1.2 Theoretical Background	4
Chapter 02 LITERATURE OF REVIEW	9
2.1 General	9
2.2 Ignition Characteristics	9
2.3 Electric Field Effects on Flames	11
2.4 Plasma Assisted Combustion/Triple Flames	23
2.5 Objective of the Current Research	28

Chapter 03 EXPERIMENTAL TEST RIG AND LAYOUT	29
3.1 General	29
3.2 Operation Principle for Combustion Engine Ignition Circuit ..	29
3.3 Experimental Test Rig Description	30
3.4 Assessment of the Accuracy of the Measured Variables	37
Chapter 04 MATHEMATICAL MODEL	41
4.1 Overview	41
4.2 Governing Equations/Boundary Conditions	41
4.3 Chemical Kinetics/Turbulence-Chemistry Interaction	44
4.4 Mesh Sizing	45
Chapter 05 RESULTS AND DISCUSSION.....	47
5.1 Turbulence/Flame Development due to the Pulsating Plasma Discharge	47
5.2 Combustion Performance of Normal Triple Flames	57
5.3 Combustion Performance of Inverse Triple Flames	74
Chapter 06 CONCLUSION AND RECOMMENDATIONS	86
6.1 Conclusions	86
6.2 Recommendations For Future Works	87
REFERENCES	88

Abbreviations

PAC	Plasma Assisted Combustion
CO ₂	Carbon Dioxide Emissions
CO	Carbon Monoxide Emissions
NO _x	Nitrogen Oxides Emissions
HC	Hydro Carbon Emissions
T.K.E	Turbulent kinetic energy
RANS	Reynolds-Average Navier-stokes
CFD	Computational Fluid Dynamics
RMS	Root Mean Square

Nomenclature

u	Velocity Component in X-Axis
v	Velocity Component in Y-Axis
w	Velocity Component in Z-Axis
ψ	Energy Conversion
Γ_{ϕ_1}	Transport Coefficient
ρ	Density

List of Figures

Figure 3-1: Plasma Generation via electric circuit by internal combustion engine-----	30
Figure 3-2a: Test Rig Assembly commissioned to investigate the effect of electric discharge pulsation on the combustion Performance of triple flames-----	32
Figure 3-2b: Plasma Discharge Layout -----	33
Figure 5-1a: Pulsating Temperature Development in the Spark Region (Before Spark Onset)-----	47
Figure 5-1b: Pulsating Temperature Development in the Spark Region (t=0)-----	48
Figure 5-1c: Pulsating Temperature Development in the Spark Region (t=4)-----	49
Figure 5-1d: Pulsating Temperature Development in the Spark Region (t=8)-----	49
Figure 5-1e: Pulsating Temperature Development in the Spark Region (t=10)-----	50
Figure 5-2a: Effects of Temperature Fluctuations on Turbulence Development(Temperature Variation with time for Different Pulsation Frequencies)-----	50
Figure 5-2b: Effects of Temperature Fluctuations on Turbulence Development(Rate of Velocity Change versus Frequency)-----	52

Figure 5-3a: Spark Discharge-Flame Super-Position (Enhanced Reaction Rate)-----	53
Figure 5-3b: Spark Discharge-Flame Super-Position (Temperature Pattern in the 2-D plane)-----	54
Figure 5-3c: Spark Discharge-Flame Super-Position (Transient Axial Temperature Profile)-----	55
Figure 5-3d: Spark Discharge-Flame Super-Position (Steady-State Axial Temperature Profile)-----	56
Figure 5-4a: Normal Triple Flame with a Downstream Spark Admission (Flame Image)-----	57
Figure 5-4b: Normal Triple Flame with a Downstream Spark Admission (Variation of the Flame Lift-Off Distance with the Electric Power Consumption)-----	58
Figure 5-5a: Flame Images with an Upstream Spark Admission ($v=4\text{m/s}$)-----	60
Figure 5-5b: Flame Images with an Upstream Spark Admission ($v=9\text{m/s}$)-----	60
Figure 5-5d: Flame Images with an Upstream Spark Admission ($v=14\text{m/s}$)-----	60
Figure 5-6a: Computed Structure of the Normal Triple Flame (Reaction Rate Exponential Term)-----	62
Figure 5-6b: Computed Structure of the Normal Triple Flame (Fuel Mass Fraction)-----	62
Figure 5-6c: Computed Structure of the Normal Triple Flame (Temperature Contour)-----	62

Figure 5-6d: Computed Structure of the Normal Triple Flame (Identified Triple Flame Envelope)-----	62
Figure 5-6e: Computed Structure of the Normal Triple Flame (Flame Displacement by Delaying the Spark Admission)-----	62
Figure 5-7: Reaction Rate Exponential Term Development in the Potential Core Region -----	64
Figure 5-8a: Combustion Performance of Normal Triple Flames (Predicted and Measured Flame Stability Limits)-----	66
Figure 5-8b: Combustion Performance of Normal Triple Flames (Variation of the Stability Limit with Frequency and Gap Distance)-	67
Figure 5-8c: Combustion Performance of Normal Triple Flames (Variation of the Stability Limit with the Mixture Velocity Difference)-----	69
Figure 5-8d: Combustion Performance of Normal Triple Flames (Variation of CO, HC and NO _x Emissions with the Stability Limit)-	71
Figure 5-8e: Combustion Performance of Normal Triple Flames (NO _x Formation Time History)-----	72
Figure 5-9a: Computed Structure of Inverse Triple Flame without Outer Air (Reaction Rate Exponential Term)-----	74
Figure 5-9b: Computed Structure of Inverse Triple Flame without Outer Air (Fuel Mass Fraction)-----	74
Figure 5-9c: Computed Structure of Inverse Triple Flame without Outer Air (Temperature Contour)-----	74
Figure 5-10a: Computed Structure of Inverse Triple Flame with an Under-Ventilated Outer Air (Reaction Rate Exponential Term)-----	75

Figure 5-10b: Computed Structure of Inverse Triple Flame with an Under-Ventilated Outer Air (Fuel Mass Fraction)-----	75
Figure 5-10c: Computed Structure of Inverse Triple Flame with an Under-Ventilated Outer Air (Temperature Contour)-----	75
Figure 5-11a: Computed Structure of Inverse Triple Flame with an Over-Ventilated Outer Air (Reaction Rate Exponential Term)-----	76
Figure 5-11b: Computed Structure of Inverse Triple Flame with an Over-Ventilated Outer Air (Fuel Mass Fraction)-----	76
Figure 5-11c: Computed Structure of Inverse Triple Flame with an Over-Ventilated Outer Air (Temperature Contour)-----	76
Figure 5-12: Image of the Inverse Triple Flame ($V=14$ m/s)-----	77
Figure 5-13a: Turbulent Kinetic Energy Development (Axial Profile of the T.K.E.)-----	77
Figure 5-13b: Turbulent Kinetic Energy Development (Variation of T.K.E. with the Mixtures' Velocity Difference and Frequency)---	78
Figure 5-14: Variation of the Heat Transfer Rate with the Stability Limit-----	82
Figure 5-15: Variation of the Primary Current with Time at Different Frequencies -----	82
Figure 5-16: Inverse Triple Flame Stability Limit Variation with the Mixture Fraction Gradient at Different Frequencies -----	85