AIN SHAMS UNIVERSITY

FACULTY OF ENGINEERING

# INVESTIGATION OF PLASMA ASSISTED COMBUSTION

*By*

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B.Sc. Mechanical Power Engineering Department, 2009

**A Thesis Submitted in Accordance with the**

**Requirements for the Degree of Master of Science**

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# 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.

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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 NOx 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 $m^2/s^2$ such that enlarging the gap distance to 4 mm increased the stability limit by 21.7%.

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# 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 |
| $\psi$ | Energy Conversion |
| $\Gamma_{\phi_1}$ | Transport Coefficient |
| $\rho$ | Density |

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