Ain Shams University
Faculty of Engineering
Department of Mechanical Power Engineering

Liquid Fuel Combustion in a Cross-Flow of Multiple Opposing Gaseous Fuel Jets

A Thesis submitted in the Partial Fulfillment for the Requirement of the Degree of Master of Science in Mechanical Power Engineering

By

Ahmed Mounir Abd El-Moneim Hasan Fahim
B.Sc. in Mechanical Power Engineering, 2010

Supervised by

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DISCLAIMER

This thesis is submitted as partial fulfillment of M.Sc. degree in Mechanical Power Engineering, Faculty of Engineering, Ain Shams University.

The work included in this thesis was carried out by the author during the Period from 2015 to 2018, and no part of it has been submitted for a degree or qualification at any other scientific entity.

The candidate confirms that the work submitted is his own and that appropriate credit has been given where reference has been made to the work of others.

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ABSTRACT

Over the past years, levels of exhaust emissions have been increased due to fossil fuels usage continuously with energy demand's growth. An Investigation on the effect of cross flow of multiple opposing gaseous fuel jets on liquid fuel burning was performed that could be retrofit into an existing or future manufactured gas turbine engines to provide an energy solution to problem of growing levels of carbon emissions. The test rig was designed and built with a combustion chamber provided with a dual fuel burner. The developed test rig allowed the burning of liquid fuel in a cross flow of gaseous fuel. While the air was co-axially introduced in a double swirl flow field, the combustion efficiency and flame length were recorded in conjunction with varying the number of opposing jets.

Results verified that the average temperature of the product gases has been generally increased by 21.8 ~ 52.1 % than the original case of burning diesel oil. Local temperature drop, just after entering opposing jets gases, decreased with increasing the number of opposing jets as a result of lower velocity ratio, which in turn affected the shear rates and mixing between hot gases and cold cross flow gaseous fuel. However, overall fuel to air ratio has been increased with same quantity of air, the cross-flow interaction made an improvement in exhaust emissions than without cross flow. The analysis of exhaust emissions attained using cross flow technique generally, has a positive effect on concentration of Carbon Monoxides (CO) by 6.7~ 68.4 % (decreased from 3065 ppm to 968 ppm) and Nitrogen Monoxide (NO) by 15.7 ~ 63.1 % (decreased from 19 ppm to 7 ppm) and percentage of Hydrocarbons (C_xH_y) in the product gases by 26.6 ~ 46.6 % (decreased from 0.15% to 0.08%).

Keywords: -Combustion, opposing jet, cross flow, diffusion flames

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NOMENCLATURE AND ABBREVIATIONS

BP	British Petroleum
CBG	Compressed Biogas
LPG	Liquefied Petroleum Gas
LPM	Liter per Minute
PM	particulate matter
VGV	Variable Guide Vanes
VR	Velocity Ratio (v_{jet}/v_{∞})

Symbols:

A_o	Orifice Area [m]
C	Coefficient of Discharge
C_p	Specific heat at constant pressure [Kcal/Kg.°C]
C_v	Specific heat at constant volume [Kcal/Kg.°C]
D	Combustor Diameter [m]
D_1	Diameter of Reservoir[m]
D_2	Diameter of Sight Glass Tube [m]
$D_{orifice}$ *or d*	Diameter of Orifice [m]
D_{pipe}	Pipe Diameter [m]
g	Gravitational Acceleration [m/s^2]
L	Flame Length [m]
L_{Diesel}	Flame Length for diesel oil combustion only [m]
L_{jet}	Flame Length for diesel oil combustion with a cross flow of opposing gaseous fuel jets [m]
$\dot{m}_a$	Mass flow rate of Air [Kg/s]
$\dot{m}_l$	Mass flow rate of Liquid Fuel [Kg/s]
$Q°_{act}$	Actual Volume Flow Rate [m^3/s]
$Q°_{th}$	Theoretical Volume Flow Rate [m^3/s]

r	Radius [m]
R	Result function
Re	Reynolds Number
t	Time [s]
T_{max}	Maximum local gas temperatures [°C]
T_{min}	Minimum local gas temperatures [°C]
v_{∞}	Mean velocity of hot gases stream in combustor that produced from diesel oil burning
v_{jet}	Gaseous fuel velocity exiting opposing jets
$\dot{V}_l$	Volume flow rate of Liquid Fuel [m^3/s]
w	Uncertainty Value
x	Combustor Axial Distance [m] / Independent Variable

Greek Symbols

β	Orifice Diameter Ratio
Δh	Head difference in manometer [m]
ΔP	Press. Diff. across the orifice plate [Pa]
ΔT_{Jets}	Temperature difference [°C]
Δx	Height Decrease of Liquid Fuel [m]
ρ_a	Air Density [Kg/m^3]
ρ_l	Liquid Fuel Density [Kg/m^3]
ρ_w	Water Density [Kg/m^3]
μ_a	Dynamic Viscosity of air [Pa.s]
μ_w	Dynamic Viscosity of Water [Pa.s]