EFFECT OF BURNER QUARL GEOMETRY ON FLAME BEHAVIOR IN AXISYMMETRIC FURNACES

by

Eng. Ebram Boshra Hanna Tadrous

A Thesis Submitted to the

Faculty of Engineering at Cairo University

in Partial Fulfillment of the

Requirements for the Degree of

MASTER OF SCIENCE

in

MECHANICAL POWER ENGINEERING

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Title of Thesis:

Effect of Burner Quarl Geometry on Flame Behavior in Axisymmetric Furnaces

Key Words: CFD, Recirculation Zone, Pollutants, Velocity Vectors

Summary: Combustion engines design mainly depends on achieving high combustion efficiency, taking into account pollutants concentrations resulting from combustion process. Researchers always try new ways to design efficient combustion chambers by studying the effects of changing different variables like burner position, direction, design, the quality of fuel used, and its impact on the performance of combustion systems. Many researches dealt with studying these flames either practically or theoretically and came to understanding the prevalence of these flames. The thesis contains a numerical study to simulate the combustion process in non-premixed flame of natural gas burner of 300 kW gas turbine, using computational fluid dynamics program (Ansys Fluent 14).The combustion chamber of the gas turbine is a cylinder of diameter 1.07 m, and a length of 1.6 m ending with conical shape until you reach cylinder diameter of 0.3 m, with a length of 0.7 m, where the exit of combustion products. The model was divided into a mesh of about 1.7 million cells. The numerical simulations were performed by solving the governing equations in a three-dimensional model using realizable K-Ɛ equations to express the turbulence. To ensure high accuracy, the results were compared to the experimental ones. The study contains the effect of four variables on the efficiency of the combustion process. It was found that there are two zones of recirculation. The primary one is at the center of the furnace and the position of the secondary one varies by changing the quarl angle of the burner. It was found that the increase in temperature in the secondary recirculation zone increases by increasing the swirl number of the inlet air stream. Also it was found that recirculating part of the combustion products back to the combustion zone decreases pollutants formation specially nitrogen monoxide. And we did not find a clear effect of any variable on the stability of the flame due to the perpendicular direction of fuel and air entry.

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Nomenclature

Symbols and Quantities

A	Sonic speed, m/s
C	Constant
c_p	Constant pressure specific heat, KJ/ (Kg·K)
D	Diffusion coefficient
E	Total Energy of fluid particle, N
G	Acceleration of gravity, m/s^2
$\sigma_{s\lambda}$	Spectral scattering coefficient
G_λ	Spectral incident radiation
H	Enthalpy, KJ/Kg
$\vec{J}_i$	Diffusion flux of species i
n	Refractive index of the medium
M	Mach number
Mw	Molecular Weight
P	Pressure, Pa
Pr	Prandtl number
σ	Stefan-Boltzmann constant
R_i	Rate of production of species i
S	Source term
Sc	Schmidt number
T	Temperature, K
u_j	Velocity magnitude in direction of x_j, m/s
$\vec{v}$	Velocity vector
Y_i	Mass fraction of species i
x, y, z	Cartesian co-ordinate components
K	Thermal conductivity, W/ (m·K)

Greek Letters

Δ	Boundary Layer thickness
$\bar{\bar{\tau}}$	Stress tensor
σ	Turbulent Prandtl number
μ	Dynamic viscosity, N.s/m2
ρ	Density,Kg/m^3
∇	Gradient
β	Thermal expansion coefficient

Superscripts and Subscripts

$-$	Mean property
$'$	Fluctuating component of any property
B	Buoyancy
I	Counter
Ij	Indicates two different Cartesian coordinates
K	Turbulent kinetic energy
M	Mass, Kg
P	Point node property
T	Turbulent quantity
W	Wall property
μ	Dynamic viscosity