EFFECT OF THE SWIRL ON TOXIC CO & CO_2 GASES IN COMBUSTION CHAMBER

By

Eng. Qasim Abdullah Najm

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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Under Supervision of

Prof. Dr. Essam E. Khalil
Mechanical Power Engineering Department
Faculty of Engineering, Cairo university

Dr. Hatem Omar Haridy
Mechanical Power Engineering Dept.
Faculty of Engineering, Cairo university

Dr. Esmail Mohamed Ali
Mechanical Power Engineering Dept.
Faculty of Engineering, Cairo university

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Approved by the Examining Committee

Prof. Dr. Essam E. Khalil Hassan Khalil (Thesis Advisor and Member)
Mechanical Power Engineering Dept., Faculty of Engineering, Cairo University

Prof. Dr. Abdelhafez Hasanein Abdelhafez (Member)
Mechanical Power Engineering Dept., Faculty of Engineering, Cairo University

Prof. Dr. Hany Ahmed Moneib (Member)
Mechanical Power Engineering Dept., Mataria Faculty of Engineering, Helwan University

FACULTY OF ENGINEERING, CAIRO UNIVERSITY
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Engineer: Qasim Abdullah Najm
Date of Birth: 27 / 11 / 1972
Nationality: Iraqi
E-mail: Qan_72@yahoo.com
Phone:
Address: Anah, Al-Anbar, Iraq

Registration Date: 01 / 03 / 2013
Awarding Date: / /
Degree: Master of Science
Department: Mechanical Power Engineering

Supervisors: Prof. Dr. Essam E. Khalil Hassan Khalil
Dr. Hatem Omer Haridy Kayed
Dr. Esmail Mohamed Ali El-Bialy

Examiners: Prof. Dr. Essam E. Khalil Hassan Khalil
Prof. Dr. Abdelhafez Hasanein Abdelhafez
Prof. Dr. Hany Ahmed Moneib(Prof. in Mataria Faculty of Engineering, Helwan University)

Title of Thesis: EFFECT OF THE SWIRL ON TOXIC CO & CO_2 GASES IN COMBUSTION CHAMBER

Key Words: Turbulence. CFD, Combustion chamber, Swirl Number, Toxic gas

Summary:

This thesis presents a numerical Investigation of flow regimes and turbulent mixing in turbulent reacting swirling 3–D furnace flows. This thesis presents a developed Computational Fluid Dynamics (CFD) program FLUENT (15) to predict the non-premixed air and the fuel (CH4) flame characteristics in a combustion chamber. The swirling numbers 0 , 0.1 , 0.2 , 0.3 , 0.4 , 0.5 and 0.6 were selected to study the effect on the flame characteristics, like Temperature , Velocity, and mass of CH_4 and H_2O focusing on toxic gases CO and CO_2. A different turbulence and reaction models has been studied. It can be concluded that the standard type of $K-\varepsilon$ model of turbulence and flamlet model of combustion gave the best agreement with experimental results. Choosing a different swirl number will show the fluid dynamics behaviour of natural gas diffusion flame and the effective of change the swirl number on most of the above mentioned vectors.It can be noticed that CO_2 increases with increasing the swirl number when the swirl number is less than one. Whereas CO decreases with increasing the swirl number and it reached to maximum value at the first half of the combustor and finally returns to minimum value at near the exit plan.

ACKNOWLEDGEMENT

All thanks are due to the almighty god first and foremost. I hereby would like to express my deep gratitude and thanks to Professors Dr. **Essam E. Khalil**, Dr. **Hatem Haridi** and Dr**. Esmail Mohamed Ali** for their support, continuous encouragement and distinctive supervision throughout the course of this work.

Also, I cannot express, in words, my thanks and gratitude to my family especially my **wife**, my **brothers, sisters** and my **friends** for their great and continuous help and support they provided me to finish this work in a suitable form.

Nevertheless, I cannot forget the support of my colleagues in the Mechanical Power Engineering Department especially Eng. **Saad Ahmad** as well as the support I received from my Professors for their encouragement and guidance throughout the scope of this work.

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NOMENECLATURE

Br	Brinkman number, $Br = \frac{\mu U_e^2}{k\Delta T}$
C	Constant
C_p	Constant pressure specific heat, kJ/kg.K
D_{im}	Diffusion coefficient for species *i* in mixture *m*
D	Fluid Domain
$\vec{F}$	External body forces, (N)
G	Gravitational acceleration, (m/s^2)
G	Filter function
G_b	Generation of turbulent kinetic energy, *k*, due to buoyancy
G_k	Turbulent kinetic energy production
Gr	Grashof number, $Gr_L = \frac{g\beta(T_s - T_\infty)L^3}{v^2}$
H	Enthalpy, (kJ/kg)
h_j^0	Enthalpy of formation of species (*j)*
I	Input mass ratio (secondary to primary mass flow rate)
K	Turbulent Kinetic energy, m^2 / s^2 Thermal conductivity, W/m ^{o}C
K	Dimensionless group describing the turbulent kinetic energy, k.
L_s	Mixing length, (m)
Le	Lewis number, $Le_i = \frac{k}{\rho c_p D_{i,m}}$
M	Mass, (kg)
Nu	Nusselt number, $Nu_L = \frac{hd}{k_f}$
P	Pressure, (Pa)

R	Radius, (m)
Ro	Outer radius of the co–axial burner, (m)
S	Swirl number
U	Mean axial velocity, (m/sec)
U	Fluctuating axial velocity, (m/sec)
V	Fluctuating radial velocity, (m/sec)
W	Fluctuating tangential velocity, (m/sec)
X	Axial distance along center line from burned exit, (m)
Pr	Prandtl Number, $\mathrm{Pr} = \mathrm{C_p}\mu / \mathrm{k}$
Ra	Rayleigh number, $\mathrm{Ra} = \mathrm{Gr} \times \mathrm{Pr}$
Re	Reynolds Number, $\rho \mathrm{U} \mathrm{d} / \mu$
R_i	Net rate of production of species (*i)*
R_j	Volumetric rate of creation of species (*i)*
S	Source term Modulus of the mean rate–of–strain tensor
T	Time, (sec)
R	Radius, (m)
T	Temperature, (K)
r,z,θ	Cylindrical coordinate components

Greek, Letters:

β	Thermal expansion coefficient, (K^{-1})
Δ	Change interval of any property
δ	Elemental interval
ε	Turbulence dissipation, ($m^2/s^{3)}$
ρ	Density, (kg/m^3)
ϕ	Donates Scalar property (i.e. density, energy, ..etc.) Relative humidity, %
τ	Shear Stress, ($kg/m.s^2$)
τ_{ij}	Sub grid–scale stress

∇	Gradient
μ	Molecular viscosity, kg.m/s
ω	Vorticity
K	Von Kármán constant
$-\rho\overline{u'_i u'_j}$	Reynolds stresses term

Superscripts and Subscripts:

–	Mean Property
→	Vector
′	Fluctuating component of any property
*	Guessed property
**	Corrected property
Av	Average
I	Species *i*
In	Inlet
T	Time, (sec)
M	Mass-mixture
Crit	Critical
Ref	Reference
W	Wall / Water vapor
→	Flow direction

Abbreviations

2D	Two dimensional configurations
3D	Three dimensional configurations
CFD	Computational Fluid Dynamics
DNS	Direct Numerical Simulation
LES	Large Eddy Simulation