

**EFFECT OF THE SWIRL ON TOXIC CO & CO₂
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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Title of Thesis: EFFECT OF THE SWIRL ON TOXIC CO & CO₂ 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 CH₄ and H₂O focusing on toxic gases CO and CO₂. A different turbulence and reaction models has been studied. It can be concluded that the standard type of K-ε model of turbulence and flamellet 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 CO₂ 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.

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NOMENECCLATURE

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, $Gr_L = \frac{g\beta(T_s - T_\infty)L^3}{\nu^2}$
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 °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, $Pr = C_p \mu / k$
Ra	Rayleigh number, $Ra = Gr \times Pr$
Re	Reynolds Number, $\rho U d / \mu$
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
$-\overline{\rho u'_i u'_j}$	Reynolds stresses term

Superscripts and Subscripts:

–	Mean Property
$\vec{\quad}$	Vector
'	Fluctuating component of any property
*	Guessed property
**	Corrected property
A_v	Average
I	Species i
In	Inlet
T	Time, (sec)
M	Mass-mixture
$Crit$	Critical
Ref	Reference
W	Wall / Water vapor
\rightarrow	Flow direction

Abbreviations

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