

**CFD INVESTIGATION OF JET FAN SYSTEMS
FOR POLLUTION CONTROL AND SMOKE
CLEARANCE IN UNDERGROUND CAR PARKS**

By

Eng. Sherif Mohamed Gomaa El Sayed

**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

**FACULTY OF ENGINEERING, CAIRO UNIVERSITY
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GIZA, EGYPT
2014**

ACKNOWLEDGMENT

Foremost, all praises to Allah Almighty for the strength and blessings used to complete this thesis.

I would like to express my sincere gratitude to my advisors, Prof. Dr. Essam E. Khalil, Prof. Dr. Mahmoud A. Fouad, and Prof. Dr. Ahmed A. Medhat for the continuous support of my MSc study and research, for their patience, motivation, enthusiasm, and immense knowledge. Their guidance helped me in all aspects of researching and writing this thesis. I could not have imagined having better advisors and mentors.

My sincere thanks also goes to Eng. Maged Fouad for his immense support and motivation which helped me in completing this work, and my closest friend Eng. Shady Mohamed for his stimulating discussions and valuable suggestions. I am also deeply thankful to my informants and friends for their help.

Last but not least, I thank my family who encouraged me and prayed for me throughout the time of my research. This thesis is heartily dedicated to my mother, the soul of my father, my wife, and my brothers.

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NOMENCLATURE

Symbol	Quantity
a_λ	Spectral absorption coefficient
C	Linear-anisotropic phase function coefficient
C_e	Constant = 0.21
C_p	Constant pressure specific heat
E	Total energy of a fluid particle, J
\vec{F}	External body force, N
g	Gravitational acceleration, m/s^2
G	Incident radiation
G_b	Generation of turbulent kinetic energy, K, due to buoyancy
G_k	Turbulent kinetic energy production
G_λ	Spectral incident radiation
H	Ceiling height above the fire, m
h	Enthalpy, J/Kg
h_j°	Enthalpy of formation of species j, J/Kg
I	Unit tensor
J_j°	Diffusion flux of species j
K	{ Turbulent kinetic energy, m^2/s^2 Thermal conductivity coefficient, W/mK
L_c	Characteristic length, m
M_t	Turbulent Mach number
m°	Mass flow rate, Kg/s
n	Refractive index of the medium
P	{ Pressure, Pa Perimeter, m
Pr	Prandtl number
Pr_t	Turbulent Prandtl number
q°	Wall heat flux, W
q_r	Radiation flux
Q_s	Heat Release Rate, KW
r	Radial position, m
R_i	Net rate of production of species i
Re	Reynolds Number
S	{ Area Source term Modulus of the mean rate-of-strain tensor Rate of creation

S_G	User-defined radiation source
$S_{\theta k}$	Diffusion coefficient
t	Time, s
T	Temperature, K
u	Instantaneous velocity component in x direction, m/s
U	Bulk velocity, m/s
U^*, U_τ	Friction velocity
\vec{v}	Velocity vector
v	{ Velocity magnitude, m/s
	{ Instantaneous velocity component in y direction, m/s
w	Instantaneous velocity component in z direction, m/s
Y	Smoke rising past height
Y_j	Mass fraction of species j
Y_M	{ Contribution of the fluctuating dilatation in compressible
	{ turbulence to overall dissipation rate
y_v	Physical viscous sub-layer thickness
y^*	Dimensionless distance from the wall
x, y, z	Cardinal coordinate components

Greek Letters

δ_{ij}	Kronecker delta, = 1 for $i = j$ and = 0 for $i \neq j$
ε	Turbulence dissipation rate m^2/s^3
μ	Dynamic viscosity, $kg/(s.m)$
μ_t	Turbulent viscosity, $kg/(s.m)$
ν	Kinematic Viscosity, m^2/s
ρ	Density, kg/m^3
τ	Shear Stress, Pa
τ_{ij}	Subgrid-scale stress, Pa
$\bar{\tau}$	Stress tensor
Φ	Scalar property
∇	Gradient
ω	Specific dissipation
σ	Stefan-Boltzmann constant, $W m^{-2} K^{-4}$
λ	Wavelength, m
π	A mathematical constant = 3.1415
Γ	Diffusion coefficient, m^2/s
θ	Temperature of smoke above ambient, $^{\circ}C$

Superscripts and Subscripts

—	Mean Property
→	Vector
`	Fluctuating component of any property
=	Tensor
T	Transpose
crit	Critical
eff	Effective property
h	Heat
<i>i, j</i>	Counter
<i>i, j, k</i>	Donates Cartesian coordinate direction takes the value of the axes X,Y,Z
m	{ Mass Mainstream
<i>P</i>	Point P
ref	Reference
t	Turbulent quantity
w	Wall
r	Radiation
G	Incident radiation
b	Black body
∞	Ambient property
s	{ Smoke Scattering

Abbreviations

ACH	Air Change per Hour
BS	British Standards
CFD	Computational Fluid Dynamics
CPU	Central Processing Unit
DNS	Direct Numerical Simulation
DO	Discrete Ordinates radiation model
DTRM	Discrete Transfer Radiation Model
FDS	Fire Dynamics Simulator
EWT	Enhanced Wall Treatment functions
HRR	Heat Release Rate
LES	Large Eddy Simulation
LMA	Local Mean Age of air
LNEC	Laboratório Nacional de Engenharia Civil
PM	Post Meridiem
PPM	Parts Per Million
RAM	Random Access Memory
RANS	Reynolds Averaged Navier- Stokes equations
RNG	Renormalization group
RSM	Reynolds Stress Model
RST	Reynolds Stress Turbulence
RTE	Radiation Transport Equation
SIMPLE	Semi-Implicit Method for Pressure-Linked Equations
S2S	Surface-to-Surface radiation model
UDF	User Defined Function
JF	Jet Fan Height
HH	Human Height

ABSTRACT

Land in urban areas has traditionally been used for housing and entertainment purposes. Due to the limited availability of usable land in such areas, most car parks have typically been built vertically underground. Recently, ventilation in underground car parks using the jet fan system is becoming more common as well as more challenging in design.

In the present study, a jet fan model was developed and validated with experimental measurements along with a comparison between CFD results and analytical correlations for the fire modeling. An underground car park was chosen for this investigation with a net area of 5290 m² and 3.7 m height. Two ventilation modes were considered; normal pollution ventilation and smoke clearance. Four parameters were examined to study the ventilation efficiency in the car park; the effect of the jet fan numbers and configurations, the consideration of the smoke clearance, the consideration of the ventilation zones, and the consideration of the fire location with a fire source of 4 MW. The ANSYS FLUENT 14.0 software was used for all numerical results obtained.

This study shows the importance of using the concept of the Local Mean Age of air (LMA) in the design of such systems. Velocity contours at 1.7 m, the average adult human height, within the car park were maintained within an accepted range. The desired ACH was achieved. Results showed that dividing the car park into zones is highly recommended and should be taken in the design of the jet fan system, providing that each zone has a sufficient source of fresh air. When the fire location was considered, the temperature is limited in the zone, where the fire is detected, and it is within an accepted range. The CO₂ mass fraction was presented and showed how the jet fans contribute in reducing the concentration of contaminants.