NUMERICAL INVESTIGATION FOR SMOKE SPREAD IN UNDERGROUND TUNNELS

By

Eng. Ahmad Emad El-din Mohamed Hamdy

A Thesis Submitted to the
Faculty of Engineering at Cairo University
in Partial Fulfilment of the Requirements for the Degree of

MASTER OF SCIENCE
In
MECHANICAL POWER ENGINEERING

FACULTY OF ENGINEERING, CAIRO UNIVERSITY
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Title of Thesis: **NUMERICAL INVESTIGATION FOR SMOKE SPREAD IN UNDERGROUND TUNNELS**

Key Words: (Smoke Control-Jet fans- Underground Tunnels -FDS)

Summary:

The present work is a numerical simulation for smoke control in underground tunnels, simulation cases investigation aims to study the Smoke propagation, Toxic gases, Temperature and Visibility For these purposes, various simulations were performed in Al-Azhar road tunnel having: 2.4 km length; curved cross section with a width of 8 m and height of 6.5 m; two lanes (each of them used only for one traffic direction);. The tunnel investigated was equipped with a longitudinal ventilation system .

Three different burning vehicles (Single car, Four Cars, and a bus), placed in the center of the driving lane. Peaks of the heat release rate were assumed to be: 5, 20 and 30 MW for the Single car, Four Cars, and a bus, respectively, simulated as a fire with an unsteady heat release rate resulted from burning Heptane as a fuel at jet fan velocity of 22, 26 m/sec. In this investigation, Fire Dynamics Simulator (FDS) software version 5.5.3 is utilized to simulate six case studies in 80 m long, 8 m wide and 6.5 m height domain with a different fire source (single passenger car, four cars and Bus)

Disclaimer

I hereby declare that thesis is my own original work and that no part of it has been submitted for a degree qualification at any other university or institute.

I further declare that I have appropriately acknowledged all sources used and have cited them in the references section.

Name: Ahmed Emad el-din Mohamed Hamdy Date:

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LIST OF SYMBOLS AND ABBREVIATIONS

Symbol	Quantity
At_v	Ceiling jet velocity decrement factor
c_p	Constant pressure specific heat
C_s	Smagorinsky constant
c_s	Solid material specific heat
D	Diffusion coefficient, Dilution parameter
f_b	External force vector (excluding gravity)
g	Acceleration of gravity
h	Enthalpy; heat transfer coefficient
h_α	Enthalpy of species α
H	Plume height ,m
ΔH	Heat of combustion
I	Radiation intensity
I_b	Radiation blackbody intensity
I_n	Radiation intensity integrated over the band n
$I_{b,n}$	Radiation intensity of black body integrated over the band n
k	Thermal conductivity; suppression decay factor
K	Light extinction coefficient
K_m	Mass extinction coefficient
L	Length scale
$\dot{m}'''_{b,\alpha}$	Mass production rate of species a by evaporating droplets/particles
$\dot{m}''_F$	Fuel mass flux
$\dot{m}'''_\alpha$	Mass production rate of species a per unit volume
p	Pressure
$\bar{p}_m$	Background pressure of m^{th} pressure zone
Pr	Prandtl number
$\dot{Q}$	Total heat release rate
Q^*	Characteristic fire size
$\dot{q}''$	Heat flux vector
$\dot{q}'''$	Heat release rate per unit volume
$\dot{q}''_c$	Convective flux to a solid surface

$\dot{q}_r''$	Radiative flux to a solid surface
R	Universal gas constant
r	Radial distance from the impinging point of the plume into the ceiling
Re	Reynolds number
s	Unit vector in direction of radiation intensity
S	Visibility, m
Sc	Schmidt number
S_{ij}	Symmetric rate of strain tensor
T	Temperature, C
t	Time, Sec
U	(u,v,w) Velocity vector, m/s
u^+	Non-dimensional stream-wise velocity
u^*	Friction velocity
$\overline{W}$	Molecular weight of the gas mixture
W_α	Molecular weight of gas species α
x	(x,y,z) Position vector
X_α	Volume fraction of species α
$Y_{O_2}^\infty$	Mass fraction of oxygen in the ambient
Y_F^1	Mass fraction of fuel in the fuel stream
Y_α	Mass fraction of species α
y_s	Soot yield
Z	Mixture fraction
Z_f	Stoichiometric value of the mixture fraction

Greek Letters

δ_{ij}	Kronecker delta, = 1 for i = j and = 0 for i ≠ j
ν_s	Yield of solid residue in solid phase reaction
ν_α	Stoichiometric coefficient, species α
σ_s	Scattering coefficient
τ_{ij}	Viscous stress tensor
χ_r	Radiative loss fraction
∇	Gradient
ε	Dissipation rate
θ	Azimuth angle (cylindrical coordinates)
κ	Absorption coefficient
λ	Wave length
μ	Dynamic viscosity
ρ	Density
σ	Stefan-Boltzmann constant

Abbreviations

ASHRAE	American Society of Heating, Refrigeration, and Air-Conditioning Engineers
AGGIH	American Conference of Governmental Industrial Hygienists
BS	British Standards
CFD	Computational Fluid Dynamics
CPU	Central Processing Unit
DNS	Direct Numerical Simulation
FDS	Fire Dynamics Simulator
FVM	Finite Volume Method
FHRR	Fire Heat Release Rate
HGV	Heavy Goods vehicle
HRR	Heat Release Rate
IVS	Impulse Ventilation Systems
IDLH	Immediately Dangerous to Life or Health
LES	Large Eddy Simulation
MPI	Message Passing Interface
NFPA	National Fire Protection Association
NIOSH	National Institute for Occupational Safety and Health
OSHA	Occupational Safety & Health Administration
PEL	Permissible Exposure Limit
PIARC	Permanent International Association of Road Congresses
RTE	Radiation Transport Equation
REL	Recommended Exposure Limits
SHE	Smoke and Heat Extraction
SHEVS	Smoke and Heat Exhaust Ventilation Systems
TLV	Threshold Limit Value
WW	Werner Wengle
WEL	Work Exposure Limits