NUMERICAL INVESTIGATION FOR SMOKE SPREAD IN AN UNDERGROUND SUBWAY STATION

By

Eng. Mahmoud Amer Ahmed Abdel Fattah

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 the Supervision of

Prof. Dr. Essam E. Khalil Hassan Khalil

Prof. Dr. Mahmoud Ahmed Fouad

Dr. Esmail Mohamed Ali El-Bialy

Mechanical Power Engineering Department

Faculty of Engineering

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Approved by the Examining Committee

Prof. Dr. Osama Ezzat Abdel-Latif	**Member**
Prof. Dr. Samy Morad Morcos	**Member**
Prof. Dr. Essam E. Khalil Hassan Khalil	**Thesis Advisor and Member**
Prof. Dr. Mahmoud Ahmed Fouad	**Thesis Advisor and Member**

FACULTY OF ENGINEERING, CAIRO UNIVERSITY

GIZA – EGYPT

2014

Engineer: Mahmoud Amer Ahmed Abdel Fattah
Date of Birth: 05 / 12 / 1988
Nationality: Egyptian
E-mail: Mahmoud_Amer@eng.cu.edu.eg
Phone: 01060886120
Address: Gizeret El Warak, El Warak, Giza, Egypt
Registration Date: 01 / 10 / 2011
Awarding Date: / /
Degree: Master of Science
Department: Mechanical Power Engineering

Supervisors: Prof. Dr. Essam E. Khalil Hassan Khalil
Prof. Dr. Mahmoud Ahmed Fouad
Dr. Esmail Mohamed Ali El-Bialy

Examiners: Prof. Dr. Osama Ezzat Abdel-Latif
Prof. Dr. Samy Morad Morcos
Prof. Dr. Essam E. Khalil Hassan Khalil
Prof. Dr. Mahmoud Ahmed Fouad

Title of Thesis: **NUMERICAL INVESTIGATION FOR SMOKE SPREAD IN AN UNDERGROUND SUBWAY STATION**

Key Words: Subway Train Fire, Plug-holing, Visibility, FDS

Summary:

Smoke is the most fatal factor in the event of subway fire because smoke spreads in direction coincide with passenger's evacuation path. It reduces visibility and can cause fatalities by asphyxiation. This research presents a numerical study of smoke spread in underground subway station. This research investigates the effect of exhausting smoke by single point extraction and exhausting smoke by multi-point extraction on smoke spread inside the station, plug-holing phenomenon and passengers' life safety. Also, effect of adding smoke barriers at stairs entrance on smoke spread inside the station, plug-holing phenomenon and passengers' life safety is studied. Evacuation time is predicted for different combustion model and different number of people. Fire Dynamics Simulator (FDS) software version 5.5.3 is utilized to simulate 9 case studies in 150 m long, 20 m wide and 13 m height domain with a subway car fire source simulated as a fire with a unsteady heat release rate of 35 MW resulted from burning Heptane as a fuel. Results show that exhausting smoke by multipoint extraction system in underground subway station gives better performance than single point extraction system. By increasing the distance between vents in multipoint extraction system, plugholing phenomenon is reduced, smoke spread is reduced and tenable conditions improves at human level. Smoke barrier addition to ventilation system has a great effect on the efficiency of smoke extraction, plugholing reduction and tenable conditions improvement at human level.

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NOMENCLATURE

Symbol	Quantity
C	Constant
C_s	Smagorinsky constant (LES)
c_p	Constant pressure specific heat
c_s	Solid material specific heat
T_0	Ambient temperature
D	Diffusion coefficient, Dilution parameter
F	Froude number
f_b	External force vector
g	Acceleration of gravity
h	Enthalpy; heat transfer coefficient
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
$\dot{m}'''_{\alpha}$	Mass production rate of species a per unit volume
p	Pressure
$\bar{p}_m$	Background pressure of mth pressure zone
Pr	Prandtl number
$\dot{Q}$	Total heat release rate
$\dot{q}''$	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
t	Time
U	(u,v,w) Velocity vector, Integrated radiant intensity
$\bar{W}$	Molecular weight of the gas mixture
W_α	Molecular weight of gas species α
$\mathbf{x}$	(x, y, z) Position vector
X_α	Volume fraction of species α
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 $i \neq j$
σ_s	Scattering coefficient
τ_{ij}	Viscous stress tensor
χ_r	Radiative loss fraction
∇	Gradient
ε	Dissipation rate
κ	Absorption coefficient