NUMERICAL INVESTIGATION FOR CONTROL OF SMOKE IN CAR SERVICE CENTER

by

Eng. Ahmed Saber Ahmed Mohamed

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: NUMERICAL INVESTIGATION FOR CONTROL OF SMOKE IN CAR SERVICE CENTER

Key Words: Car service center, impulse ventilation, smoke control, Jet fan, Fire Dynamics Simulator.

Summary:

This study present numerical investigation for designing impulse ventilation system to manage smoke produced due to car on fire in underground workshop at car service center. By studying effect of changing different variables on visibility, temperature and velocity at human level to insure not to exceed limits stated by NFPA to apply evacuation plane. The study is performed using FDS to simulate 13 case studies in workshop its dimension is 50m×25m×4.5m.The workshop contain random distribution of cars, paint furnace and paint store.

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Table of Contents

Nomenclature

Symbol Quantity

c_p	Constant pressure specific heat
c_s	Solid material specific heat
Kg	Grad factor
V Critical	Critical Velocity
Q	Heat Release Rate
H_D	Hydraulic height
T_∞	Ambient temperature
D	Diffusion coefficient, Dilution parameter
f_b	External force vector
g	Acceleration of gravity
h	Enthalpy; heat transfer coefficient
h_α	Enthalpy of species α
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 mth 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

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
$\overline{W}$	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_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

Superscripts and Subscripts

−	Mean property
″	Quantity per unit area
‴	Quantity per unit volume
Δ	Change interval of any property
∞	Ambient property
b	Property for evaporating droplets or particles
cj	Ceiling jet property

F	Fuel property
flow	Flow property
g	Gas property
i	Counter
ij	Indicates two different Cartesian coordinates
n	Spectral band counter
r	Radiant quantity
s	Soot property
T	Transpose
t	Turbulent quantity
w	Wall property
α	Property for species α

Abbreviations

AFFF	Aqueous Film Forming Foam
ACH	Air Changes per Hour
CFD	Computational Fluid Dynamics
CPU	Central Processing Unit
DNS	Direct Numerical Simulation
DVS	Ducted Ventilation System
FDS	Fire Dynamics Simulator
HRR	Heat Release Rate
HRRPUA	Heat Released Rate Per Unit Area
HRRPUV	Heat Released Rate Per Unit Volume
IVS	Impulse Ventilation System
LES	Large Eddy Simulation
MW	Megawatt
KW	Kilowatt
NFPA	National Fire Protection Association
MPI	Message Passing Interface

Abstract

Smoke is considered one of the most dangers factors in car service center in case of fire. As it causes reduce in visibility and deaths due to high temperature or toxicity also prevents applying evacuation plan for workers and cars.

This study present numerical investigation for designing impulse ventilation system to manage smoke produced due to car on fire in underground workshop at car service center. By studying effect of changing supply rate, extraction rate, the number of jet fans, operating speed of jet fans, the direction of the smoke extraction and the use of smoke barriers on the visibility, temperature and air velocity at human level to insure not to exceed limits stated by NFPA to apply evacuation plane for workers and cars.

The study is performed using Fire dynamic simulator to simulate 13 case studies in underground workshop its dimension is 50 m long ×25 m width × 4.5 m height. The workshop contain random distribution of cars, paint furnace and paint store.

The results show that using jet fans and smoke barriers instead of the traditional system of duct ventilation system gives good results in controlling the smoke and allows increasing work space inside the workshop by increasing the maximum height permitted to lift cars. It also shows that Increasing smoke extraction rate than fresh air supply rate make the entrance act as supply point decreasing smoke concentration at entrance which is highly recommended for evacuation.

Chapter 1 Introduction

1.1 Background

Car parks and service areas pose a range of fire risks, from flammable liquids to high tech equipment, plus a potentially combustible mix of dust, swarf and lubricants. If a fire breaks out, a lot of smoke is produced with high temperature producing poor leakage ability and difficulties in evacuation. When the height of the Workshop is restricted such as our case study after a few minutes, the workshop will probably be full of smoke over the whole height, which makes it very hard for staff to apply evacuation plane or locate the fire extinguishers. Because of this, it is very important provide the workshop with a smoke ventilation system to let staff to eliminate fire at its initial phase in a smokeless environment.

1.1.1 Class A fires

Class A fires involve fabrics and plastics, which pretty much describes the interiors of most makes of vehicle these days. The contents of office area are also highly combustible, including paperwork, files, chairs and desks. A foam fire extinguisher is suitable for use on Class A fires. [1]

1.1.2 Class B fires

Depending on the level of repairs carried out, workshop might include a variety of flammable liquids including Fuel, waxes, thinners, solvents, paints and oils. Fires involving these substances are Class B fires. AFFF foam fire extinguisher is suitable for use on Class B fires. [1]

1.1.3 Class C fires

For electrical equipment, such as testing machines, computers and even printers.CO_2 fire extinguisher is suitable for use on Class B fires. [1]