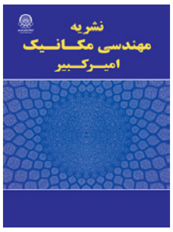

Amirkabir Journal of Mechanical Engineering

Amirkabir J. Mech. Eng., 53(7) (2021) ***-3
DOI: 10.22060/mej.2020.18513.6832

Numerical simulation simultaneous use of longitudinal ventilation and smoke extraction from the ceiling in fires inside tunnels

S. O. Haghani, E. Barati*

Mechanical Engineering, Khayyam University, Mashhad, Iran

ABSTRACT: Ventilation is essential to provide a smoke-free path for safe passenger evacuation and effective rescue services in case of a tunnel fire, because the closure tunnels increase consequences of accidents significantly. In the present study, the simultaneous use of longitudinal ventilation and smoke extraction from the ceiling in fires inside tunnels and physical phenomena has been investigated. Fire dynamics simulator will be used as a CFD tool. This simulation was performed to investigate the effect of the longitudinal distance of the smoke extraction system from the fire source on the smoke back-layering length and the maximum temperature in the two operating conditions used by this system downstream and upstream the fire source. In the present work, the smoke extraction system is located on the ceiling of the tunnel. The results show that using a smoke extraction system upstream of the fire source will increase the maximum temperature, but using the same system downstream will reduce the temperature throughout the tunnel and prevent smoke back-layering. However, attention to the smoke extraction velocity prevents the plug-holding phenomenon. The results also show that the simultaneous use of two smoke extraction systems at the upstream or downstream of the fire source will have a better result and The maximum temperature is reduced by 10%.

Review History:

Received: 2020-05-30
Revised: 2020-11-21
Accepted: 2020-12-24
Available Online: 2020-12-26

Keywords:

Tunnel
fire
Maximum temperature
Smoke back-layering
Smoke extraction system

1. INTRODUCTION

Designing an efficient emergency ventilation system is one of the main approaches to prevent the perilous fire in tunnel phenomenon. For this purpose, firstly, fire behavior and its heat release rate should be investigated. Knowing about temperature distribution and smoke movement is the second step.

The issue of fire safety in tunnels is very essential because the closure tunnels increase consequences of accidents significantly. Therefore, it is necessary to control fire development and smoke propagation with appropriate measures when fire occurs. The ventilation system is used to control smoke propagation and the suppression system is used to prevent fire spread in tunnel. Ventilation is essential to provide a smoke-free path for safe passenger evacuation and effective rescue services in case of a tunnel fire.

Research has been conducted in recent years to reduce the risk of fire in tunnels. Heidarinejad et al. [1] studied fire in the tunnel with operating ventilation and suppression systems. The results showed that increase in water flow rate leads to increase in cooling effect of suppression system. Haghani and Barati [2] studied the effect of blower location on the maximum temperature and spread of smoke in case of fire inside tunnels. The results showed that the blower location has a significant effect on critical velocity and volumetric flux and it can reduce critical volumetric flux by at least 11 percent. Kong et al. [3] studied smoke back-layering length with different longitudinal fire locations in inclined tunnels under natural ventilation. The results showed that smoke back-layering length drops progressively with increasing downstream length.

In the present study, the simultaneous use of longitudinal ventilation and smoke extraction from the ceiling in fires inside tunnels and physical phenomena has been investigated.

2. PROBLEM STATEMENT AND PHYSICAL DESCRIPTION

The numerical modeling is performed in a tunnel model with dimensions of 0.25× 0.25× 12 m. There is a fire occurring in a tunnel, a burner is used as the fire source. The squared gas burner with dimensions of 0.1 m is employed as fire source to supply continuous heat release rates. The burner is placed on the center of the tunnel; ambient temperature is considered 20 °C. Fig. 1 shows the geometrical representation of tunnel.

3. NUMERICAL MODEL

The numerical model is constructed by Fire Dynamic Simulator (FDS). The fire dynamics simulator has been developed at NIST to explore fire behavior and to analyze the efficiency of fire protection systems. Simulation of fire-driven flow can be conducted in FDS by employing LES turbulence

*Corresponding author's email: E.Barati@Khayyam.ac.ir

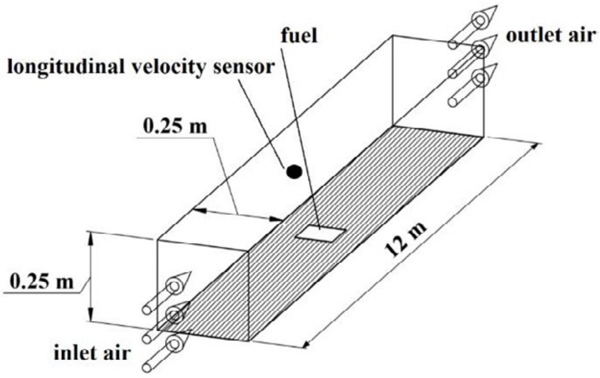

Fig.1. A geometrical representation of tunnel

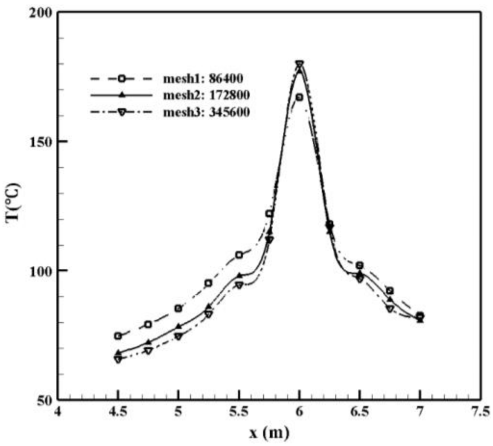

Fig. 2. Distribution of temperature in various computational mesh

model. FDS has been extensively utilized in research of smoke behavior and its validity has been broadly verified. Governing equations are solved numerically in FDS. The physical equations include Navier-Stokes equations for flow analysis, energy conservation equations for temperature distribution and other scalar equations for smoke and particulates transport.

To have a better calculation accuracy, mesh refining is performed. The FDS user guide proposes a non-dimensional expression of $D^* = (\frac{\dot{Q}}{\rho_\infty T_\infty c_p \sqrt{g}})^{0.4}$ for assessing a mesh resolution with D^*. The recommended value of $\frac{D^*}{\delta x}$ is in the range of 4-16 [4]. Fire grid numbers are studied to confirm that the results are grid-independent. Along with the numerical simulations described in the next section, other simulations are conducted with the precise target of verifying the model validity, by examining the agreement between experimental results and model predictions. Fig. 2 shows distribution of temperature in various computational mesh and Fig. 3 illustrates the variation of critical velocity with heat release rate (HRR) and a remarkable agreement is observed and the simulation is compared with Wu and Bakar [5] and Li et al. [6].

4. RESULTS AND DISCUSSION

Fig. 4 shows ceiling temperature distribution through the tunnel with use of two smoke extraction systems upstream

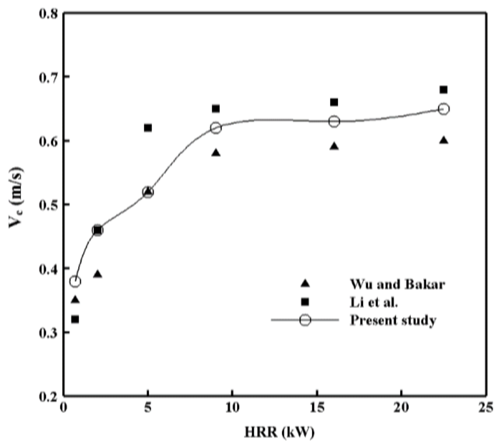

Fig. 3 variation of critical velocity with HRR

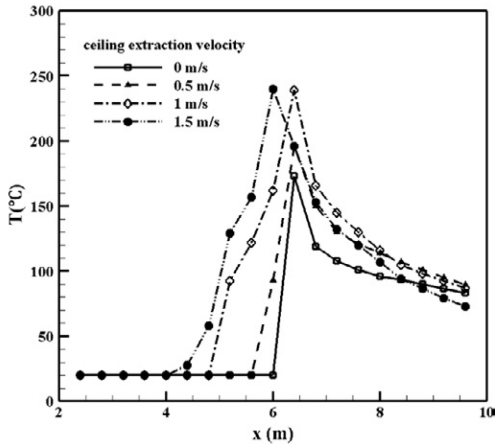

Fig. 4. ceiling temperature distribution through the tunnel with use of two smoke extraction systems upstream of fire source (V_L=0.53 m/s)

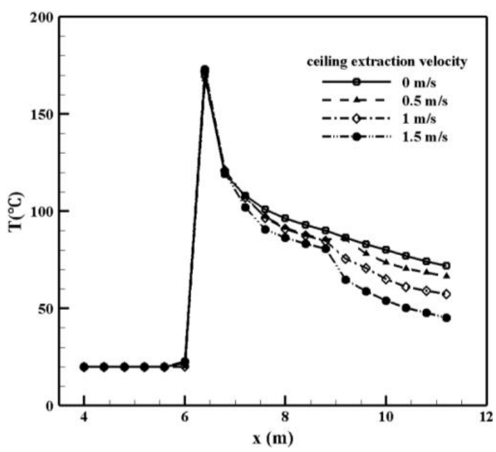

Fig. 5. ceiling temperature distribution through the tunnel with use of two smoke extraction systems downstream of fire source (V_L=0.53 m/s)

of fire source. The results show that using a smoke extraction system upstream the fire source will increase the maximum temperature.

Fig. 5 shows ceiling temperature distribution through the tunnel with use of two smoke extraction systems downstream of fire source.

The results show that using a smoke extraction system downstream the fire source will reduce the temperature throughout the tunnel and prevent smoke back-layering.

5. CONCLUSIONS

In this study, Numerical simulation Simultaneous use of longitudinal ventilation and smoke extraction from the ceiling in fires inside tunnels was investigated. The results showed that using a smoke extraction system upstream of the fire source will increase the maximum temperature, but using the same system downstream will reduce the temperature throughout the tunnel and prevent smoke back-layering. However, attention to the smoke extraction velocity prevents the plug-holding phenomenon.

6. REFERENCES

[1] G. Heidarinejad, R. Vasheghani Farahani, Numerical Simulation of Fire in Tunnel with Ventilation and Suppression Systems, Modares Mechanical Engineering, 18(8) (2018) 209-220(In Persian).

[2] S.O. Haghani, E. Barati, Numerical study on the effect of blower location on the maximum temperature and spread of smoke in case of fire inside tunnels, Amirkabir Journal of Mechanical Engineering, 52(11) (2019) 171-180 (In Persian).

[3] J. Kong, Z. Xu, W. You, B. Wang, Y. Liang, T. Chen, Study of smoke back-layering length with different longitudinal fire locations in inclined tunnels under natural ventilation, Tunnelling and Underground Space Technology, 107 (2021) 103663.

[4] K. McGrattan, S. Hostikka, J. Floyd, H. Baum, R. Rehm, W. Mell, R. McDermott, Fire dynamics simulator technical reference guide, National Institute of standards and technology, (2010).

[5] Y. Wu, M.A. Bakar, Control of smoke flow in tunnel fires using longitudinal ventilation systems–a study of the critical velocity, Fire Safety Journal, 35(4) (2000) 363-390.

[6] Y.Z. Li, B. Lei, H. Ingason, Study of critical velocity and backlayering length in longitudinally ventilated tunnel fires, Fire safety journal, 45(6-8) (2010) 361-370.

HOW TO CITE THIS ARTICLE

*S.O. Haghani, E. Barati , Numerical simulation simultaneous use of longitudinal ventilation and smoke extraction from the ceiling in fires inside tunnels, Amirkabir J. Mech Eng., 53(7) (2021): ***-3.*

DOI: 10.22060/mej.2020.18513.6832