Modern Applied Science; Vol. 11, No. 2; 2017
ISSN 1913-1844 E-ISSN 1913-1852
Published by Canadian Center of Science and Education

Numerical Simulation of Critical Velocity in Ventilation

Jabar Kesadian[1] & Armen Adamian[2]

[1] MS in Mechanical engineering (energy conversion), Niayesh technical engineering faculty, central Tehran, Iran

[2] Assistant professor of mechanic department, Islamic Azad University of Central Tehran Branch, Faculty of Engineering, Iran

Correspondence: Jabar Kesadian, S in Mechanical engineering (energy conversion), Niayesh technical engineering faculty, central Tehran, Iran. E-mail: jkasadian@yahoo.com

Received: September 2, 2016 Accepted: September 16, 2016 Online Published: October 17, 2016

doi:10.5539/mas.v11n2p19 URL: http://dx.doi.org/10.5539/mas.v11n2p19

Abstract

Given the importance of the safety and health of passenger's in underground tunnels, analysis and simulation of fires in tunnels is to design a ventilation system. Longitudinal ventilation systems are widely used in tunnel ventilation and are one of the most important parameters for fire safety in this type of critical velocity system. Critical velocity of ventilation is minimum longitudinal velocity flow of air that prevents the smoke from the fire to the upstream flow.

In this study, the effects of the distance between the fire source of the tunnel, obstacle before and after the fire, several sources of fire in the tunnel and ventilation shaft tunnels will be discussed on the critical velocity. Each effect parameter according to a correlation analysis of numerical results obtained using the solver FLUENT software Airpak and then the relationship between dimensionless critical velocity and dimensionless heat release are stated.

Keywords: critical velocity, governing equations, ventilation

1. Introduction

Due to increasing population growth and urban and inter-urban roads need to use the tunnels to reduce traffic and shortening the path. There are 1,500 kilometers of tunnels used in Europe. (Haack, 2002) Although the issue of tunnel safety is always an important issue in the design of tunnels. There will always be a risk that the issue of fires that because of lack of oxygen may cause serious consequences in case of fire (Nfpa, 2003; Rahmanian et al., 2014)

This phenomenon is causing hazards to life and property in many years. Events such as this can be a fire in the Baku and Daegu underground tunnels South Korea that resulted in 289 deaths and 189 people. (Carvel et al., 2005) Hence safety of the tunnel at the time of the fire and smoke from a fire flow control is very important.

Fire a complex distribution of energy as light and heat that field position is examined in two models. By starting a fire in the tunnel, a column of smoke due to the buoyant force moves towards the roof of the tunnel and then expands symmetrically on both sides of the tunnel. (Hurley et al., 2015; Moghaddam et al., 2016) This includes non-linear interaction phenomena of turbulence, chemical reactions, heat and light in the area of fire. (Hanson et al., 2000; Shayesteh, 2015)

Fire in a closed area is advanced form of multiple types and amounts of fuel, and the amount depends on the level of emissions. Fire in closed environment factors influencing the growth can be mainly two parameters, environmental characteristics and fuel parameters. Stages of fire is divided., according to fire the combustion curve, area growth, fully developed fire and the collapse of the course (Karlsson & Quintiere, 1999)

The worst conditions in terms of safety and complexity, is the fire fully developed. At this point the heat release rate is the maximum rate of smoke production and thus the highest content of its own and to prevent back flow smoke ventilation rate is needed. So if the ventilation rate is determined based on the maximum heat release rate, another heat release rates also flowing back. So this scenario for a fire in the tunnel was considered in this study.

In longitudinal ventilation, smoke exit strategy creates a flow of air in the tunnel is long, so that smoke and hot gases forced to move in the direction of the tunnel and is blown in the direction of flow. Thus upstream from the pollutant source of fire and hot gases and toxic secure and safe way for passengers departing and arriving officers caused the fire source. So determining the capacity of the system is important, because if system capacity is low smoke and polluted air in the opposite direction of the air flow created by the ventilation system and fire source moves towards upstream.

This phenomenon is called smoke streaming minimum ventilation flow rate is called critical velocity, so that the smoke flowing back upstream toward the source of fire prevention. Ventilation critical velocity the rate of heat release from the fire source, intake air temperature, intake air density, heat capacity of air depends on the geometry of the tunnel and tunnel slope. (Li, Lei & Ingason, 2010; Elahinia, 2016)

In recent years, several studies have been done in the field of numerical simulation and experimental modeling of fire. Fire phenomena tunnel with mass transfer is a disturbing phenomenon. Physically combustion phenomena due to the complexity of modeling is not very full, for this reason, different research methods have been proposed to test this complex phenomenon, in general, three categories of full-scale, small-scale numerical simulation is divided.

Heat release rate can be associated with a third critical velocity based on the Froude number is expressed as an empirical relationship. (Thomas, 1968) Following the large heat release rate in terms of critical velocity which leads to the correct empirical relationship was examined. (Oka & Atkinson,1995) Tilt impact on critical velocity was investigated and finally a corrective relationship was provided for critical velocity. (Atkinson & Wu, 1996; Moghaddam et al., 2016)

The study was conducted due to the geometry of the tunnel on critical velocity that finally critical velocity of the hydraulic diameter as the characteristic length between the known ventilation and the relationship was critical velocity in the tunnel with the effect of different geometry. (Wu & Bakar, 2000) Also, ambient occlusion index closed the tunnel using a small tunnel models and numerical models to calculate critical velocity was investigated. (Kang, 2010) The impact of smoke spread in a tunnel blockage and experimental results on a small scale was reported. Results showed that the presence of obstruction, obstruction tunnel almost as much critical velocity is reduced. (Lee & Tsai, 2012)

The results of the study during the critical velocity and the smoke and ventilation shows that length of the tunnel is directly proportional to the size of the fire and ventilation speed and altitude varies inversely tunnel. (Hu, Huo & Chow, 2008) Effect of the fire source was investigated on critical velocity ventilation, so that the results showed that the critical velocity to stretch the fire (gas burner) along the length of the tunnel first increased and then reduced and also the maximum speed fire-square crisis does not happen. (Li & Chow, 2008)

The effect of aspect ratio on the temperature distribution of smoke from fire on an experimental basis in the tunnel with a scale of 1 to 20 reviews and also FDS fire tunnel is simulated. (Lee & Ryou, 2005) Studies show that the effects of ventilation rate on the rate of burning of these two parameters are directly related to each other. (Roh et al., 2008; Raad, Moghaddam & Elahinia, 2016) Also, the effect of the fire source was investigated on critical velocity in the tunnel near the critical velocity is increased, (Hu, Peng & Huo, 2008) and near the outlet tunnel decreases rapidly. (Tsai, Lee & Lee, 2011)

Also, if a fire occurs by two separate fires source, critical velocity decreases with increasing distance between them. (Tsai, Chen & Lee, 2010) Temperature distribution under the roof of the tunnel by twelve test (Hu et al., 2007) and was just a simulation. (Hu et al., 2006) (using the code FDS) so that the results show that temperature changes exponentially over and under the roof of the tunnel is reduced. The results of the fire simulation with experimental data comparing the accuracy of the FDS code in this case are measured.

Smoke from a fire in floor height of the house and a fire in the tunnel looked was critical velocity, shows good agreement between the simulation results with experimental data. (Tilley, Rauwoens & Merci, 2011) Then, the temperature distribution in a road tunnel ventilation and determine critical velocity FDS codes were examined. (Niknam, Madani & Salarirad, 2012) The effect of the slope and lateral position on the source of the fire in the tunnel under the roof of the tunnel was investigated how the temperature distribution. (Fan et al., 2013; Hu et al., 2013)

In a study, fire plume is devoted as a source of input current to this area. Low control volume, is input source. Due to the small number of areas in the computing equation modeling (heat and mass transfer) assuming a uniform and ideal gas is used for each region. (Novozhilov, 2001) Optimum ventilation system in case of fire by computational fluid dynamics simulation performance was evaluated. (Yuan & You, 2007) Fluent in simulation accuracy Commercial Code longitudinal ventilation compared with experiments performed in a road tunnel were approved. (Vega et al., 2008)

Numerical simulations of two road tunnels with a central route for escape in case of fire were studied. (Modic,

2003) The rate of heat generation in a fire in the tunnel New York was studied using numerical calculations. (Willemann & Sanchez, 2002) Comparison of one-dimensional model for areas where the developed, to assess critical velocity air flow ventilation was provided. In this model one-dimensional method is developed for areas where heat flow is used and in other three-dimensional fluid flow equations solved in detail. (Colella et al., 2009)

Critical velocity air conditioning and heat release rate of two parameters on the distribution of smoke were investigated. This study shows that contrary to the critical velocity, the heat release rate has very little effect on the distribution of smoke. (Kunsch, 1998) In reviewing that factors slope and it was in tunnel area is shown, how to spot the source of the fire cannot correctly predict the spread of smoke. Hence fire was considered as areas for the location of the fire were distinguished in different cars. (Chen et al., 2003)

In a study on the efficiency of the ventilation system in fire, found when the fire exits in smoke at the top of the fire should be opened, Smoke outlets and opening fire on both sides of the output of fresh air in the bottom of the fire and ventilated system performance. (Ballesteros et al., 2006)

Researchers provide a way to slow down the critical velocity of ventilation, smoke extraction points around the tunnel was built that these points of smoke extraction in the truth as an intermediate shaft tunnels that makes smoke come out of the shafts embedded in the roof of the tunnel. Finally, using numerical methods to reduce the amount of critical velocity depends on the number of points and their distance to the source of the fire. [42] The dynamic effect of floating in a tunnel with longitudinal ventilation in order to study the effect of the fire source was investigated on critical velocity ventilation.

Results in such a way that non-dimension critical velocity has any clear dependence on the diameter of the fire source, the current density Buoyant and not ambient air. (Le et al., 2014) Driven flow profile of the output of longitudinal ventilation in tunnel roof to improve the performance of the fire was investigated. The numerical results of this study suggest that the use of exit points in roof of the tunnel efficiently reduce air pollution through the tunnel. (Harish & Venkatasubbaiah, 2014)

The use of hybrid ventilation to create a safe environment in the upstream and downstream of the fire in the tunnel tested experimentally. If the proper distance and shafts in the ceiling there is a fire place, there will be conditions downstream of the press. As a result of smoke in the tunnel height even with the use of different shafts in roof of the tunnel remains constant.

Hence experimental value for predicting the amount of smoke in conditions of high heat release rate was presented. (Tanaka et al., 2015) The critical velocity and Back flow by one-tenth-scale analysis of results and solving computational fluid dynamics were studied. Hydraulic diameter parameter as a variable was chosen to identify different tunnels. (Chen et al., 2015)

In this study, the effect parameters, away from the fire source of the tunnel, obstacle before and after the fire, existence are several sources of fire in the tunnel and ventilation shaft between tunnels will discuss on the critical velocity. Each effect parameter according to a correlation analysis of the numerical results and the relationship between dimensionless critical velocity and dimensionless heat release stated. It is worth noting that in this study only investigated the effects of fire and combustion phenomena phenomenon is not modeling.

2. The Governing Equations

Due to costly real-scale studies are usually performed in very special cases. That's why researchers emergency ventilation system design, use of numerical simulation. Field models as models Computational Fluid Dynamics (CFD), also known as computers with high computing capacity they need.

In this models, first the modeling area to be determined. Then boundary conditions are applied to restrict the solution. Governing equations, the equations of conservation of mass, momentum, energy and species that are solved together in pairs. Thus, time averaging is done on equations (RANS) or location (LES).

Depending on which of the above two approaches used in discrete equations, algebraic equations of the form is changed. In the first approach in the entire range of computing and in computational cells of equations of mass, momentum, energy and species distribution modeling solution and are including Reynolds stresses. In the second approach, conservation equations in the computational domain larger than the size of the filter cells directly solved and in smaller the size of the filter cells, Reynolds stresses are modeled.

Governing equations using time averaging in k-ε turbulence model are as follows. In this study was to investigate the phenomenon of fires in tunnels and the use of computational fluid dynamics Conservation equations (momentum, energy and mass) using FLUENT solver Airpak is done in software.

Conservation of mass equation:

$$\frac{\partial \rho}{\partial t}+\frac{\partial}{\partial x_i}(\rho u_i)=0 \tag{1-3}$$

Momentum conservation equation:

$$\frac{\partial}{\partial t}(\rho u_i)+\frac{\partial}{\partial x_j}(\rho u_i u_j)=-\frac{\partial p}{\partial x_i}+\frac{\partial}{\partial x_j}\left(\mu\left[\frac{\partial u_i}{\partial x_j}+\frac{\partial u_j}{\partial x_i}-\frac{2}{3}\delta_{ij}\frac{\partial u_i}{\partial x_i}\right]\right)+\frac{\partial}{\partial x_j}(-\rho\overline{u_i' u_j'}) \tag{2-3}$$

In the above equation, such as the Reynolds stresses are calculated according to the following equation using the approximate Bouzinsk:

$$-\rho\overline{u_i' u_j'}=\mu_t\left(\frac{\partial u_i}{\partial x_j}+\frac{\partial u_j}{\partial x_i}\right)-\frac{2}{3}\left(\rho k+\mu_t\frac{\partial u_k}{\partial x_k}\right)\delta_{ij} \tag{3-3}$$

In this equation, k represents the kinetic energy of turmoil and turbulence kinetic energy and ε represents the dissolution rate are defined in accordance with the following formula:

$$k=\frac{1}{2}\overline{u_i' u_i'}\ ,\ \varepsilon=\left(\frac{\mu}{\rho}\right)\overline{\frac{\partial u_i'}{\partial x_j}\frac{\partial u_i'}{\partial x_j}} \tag{4-3}$$

Also in the model (k-ε) $\mu_t = \rho C_\mu \frac{k_\mu}{\varepsilon}$ turbulence viscosity and equation expresses the conservation of energy as:

$$\frac{\partial}{\partial t}(\rho \mathrm{E})+\frac{\partial}{\partial x_i}\left[u_i\left(\rho \mathrm{E}+p\right)\right]=\frac{\partial}{\partial x_j}\left[\left(K+\frac{c_p\mu_t}{\mathrm{Pr}_t}\right)\frac{\partial T}{\partial x_j}+u_i\left(\tau_{ij}\right)_{eff}\right] \tag{5-3}$$

In the above equation *(Tij) eff* represents the effective stress tensor is expressed according to the following equation:

$$\left(\tau_{ij}\right)_{eff}=\mu_{eff}\left(\frac{\partial u_i}{\partial x_j}+\frac{\partial u_j}{\partial x_i}\right)-\frac{2}{3}\mu_{eff}\frac{\partial u_k}{\partial x_k}\delta_{ij} \tag{6-3}$$

K is coefficient of thermal conductivity and $\mathrm{Pr_t}$ isturbulence Prandtl number and amount is 0.85. As well as $E = u + \frac{v^2}{2}$ represents the total energy per unit mass in which the internal energy per unit mass u and v is velocity. Also effective viscosity expressed as $\mu_{eff} = \mu + \mu_t$. Turbulent kinetic energy equation and its demise rate is expressed as follows.

$$\frac{\partial}{\partial t}(\rho k)+\frac{\partial}{\partial x_i}(\rho k u_i)=\frac{\partial}{\partial x_j}\left(\left[\mu+\frac{\mu_t}{\sigma_k}\right]\frac{\partial k}{\partial x_j}\right)+G_k-\rho\varepsilon$$

$$\frac{\partial}{\partial t}(\rho\varepsilon)+\frac{\partial}{\partial x_i}(\rho\varepsilon u_i)=\frac{\partial}{\partial x_j}\left(\left[\mu+\frac{\mu_t}{\sigma_\varepsilon}\right]\frac{\partial \varepsilon}{\partial x_j}\right)+C_{1\varepsilon}\frac{\varepsilon}{k}\left(G_k+C_{3\varepsilon}G_b\right)-C_{2\varepsilon}\rho\frac{\varepsilon^2}{k} \tag{7-3}$$

In this equation, $G_k = -\rho\overline{\acute{u_\iota}\acute{u_J}}\frac{\partial u_j}{\partial u_i}$ is the kinetic energy produced and constants in the equation just $C_{1s} = 1.44$ ، $C_{2s} =$ ،$C_\mu = 0.09$ ،$\sigma_k = 1$ و $\sigma_s = 1.3$ are expressed. Such contamination is the transfer equation as follows.

$$\frac{\partial}{\partial t}(\rho C_i)+\frac{\partial}{\partial x_j}(\rho C_i u_j)=\rho\frac{\partial}{\partial x_j}\left(D\frac{\partial C_i}{\partial x_j}\right)+\frac{\partial}{\partial x_j}(-\rho\overline{c_i' u_j'})+\mathrm{S}_c \tag{8-3}$$

In the above equation, D represents mass distribution and S_c represents the source and species including the penultimate equation for the following models:

$$\rho \overline{c_i' u_j'} = \rho \frac{\nu_t}{Sc_t} \frac{\partial C_i}{\partial x_j} \quad (9\text{-}3)$$

In the above equation, Sct represents Schmidt number and numeric value that is equal to 0.7. Stated above equations using in software FLUENT solver Airpak been resolved. In the solver, the pressure of the first order is used for discretization and other sentences using upwind order accuracy are two discrete. After discretization of the governing equations, the solver FLUENT is used to solve the equations.

Using the solver equations are solved in succession. After the equation of conservation of mass, pressure correction equation and then the energy equation, confusion and impurities diffusion dissolved. In FLUENT solver, relate the pressure and mass conservation equations SIMPLE algorithm is used. This algorithm is a correct method for calculating the pressure and mass conservation. So using this algorithm speed and pressure correction equations are connected.

The pressure correction SIMPLE algorithm is as follows, first, the velocity and pressure fields guessed momentum equations are solved using the initial guess. Then strain and quickly obtained from the momentum equations used to correct initial guess, the corrected values are considered as the initial guess. Following the above process is repeated until convergence is achieved. The boundary conditions used in this study included air intakes ventilation, walls, contaminated air out of the tunnel and the source of the fire. Entrance to the ventilation air velocity inlet boundary condition is used.

The amount of pressure and temperature in tunnel entrance to the atmospheric pressure and ambient temperature (approximately K 300) and the amount of turbulence intensity equal to 10% in input is selected. Another boundary walls of the tunnel are intended temperature equal to the ambient temperature and for each parameter in the vicinity of the boundary condition wall function is used. Given that the source of fire in the middle of the tunnel and gradient flow in this region has most of its value, selected finer mesh in this area and the start and end of the tunnel in areas of coarse mesh is used.

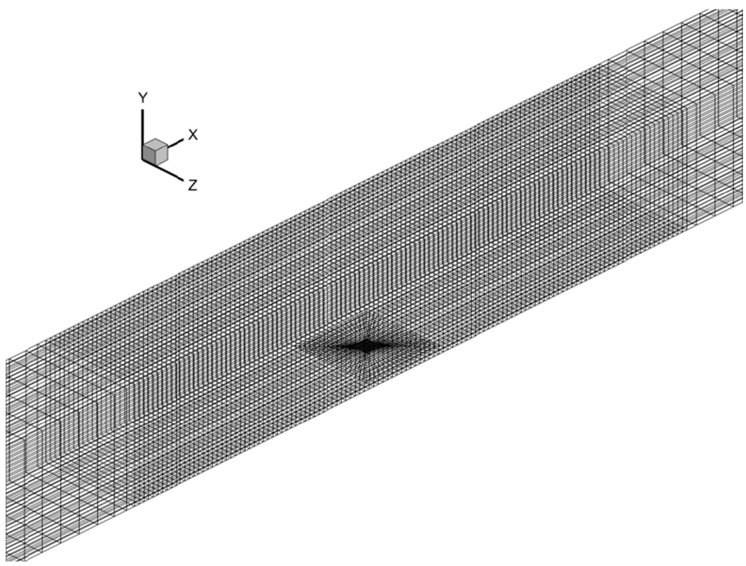

Figure 1. View of the mesh near the fire source and the walls of the tunnel

3. Numerical Results

3.1 The Effect of Distance from the Wall of on the Critical Velocity Ventilation the Fire Source

Tunnel 15 meters long, 54 cm high and 48 cm wide. The fire source was a square of dimensions 8 × 8 cm and the heat output of mass flow output equal to 1.59 kW and it is equal to 0.03. The distance from the wall to the center tunnel fire source has changed. A view of the fire from the walls of the tunnel are shown in Figure 1.

The results of the numerical solution are shown in Table 1. As Table 1 shows, whatever distance between the sources of the fire wall is less than the critical speed and ventilation more critical with increasing distance from the source of fire ventilation rate has fallen from the wall. The reason for this phenomenon is that the sides of the tunnel due to and development boundary layer flow (a flow of air parabolic profile) and the effect of wall friction on the flow rate, flow rate is lower.

So to prevent back flow, needs to increase the speed of input current to flow on effects of friction and overcome the effects of the wall. Results Table 1 shows that in values of 16 and 20 cm, ventilation critical velocity is roughly the size of critical velocity obtained in the ground state in the study [46, 47] is obtained.

This phenomenon is remarkable in the sense that the ventilation flow in the core of the tunnel and have a uniform steady state and as a result be a source of fire in any part of the central core, the ventilation rate will be fixed. So the results of this section are fully consistent with the physics of flow in the channel.

Table 1. The effect of distance on speed critical source of tunnel ventilation

Critical velocity of ventilation	Distance between source and wall
0.85	4
0.72	8
0.66	12
0.5	16
0.48	20

Results Table 1 shows that the first critical velocity ventilation in the ground state can be expressed as follows.

$$\frac{V_c}{V_{c,base}} = 3x^2 - 4.0615x + 2.1475$$

Base Velocity crisis on($V_{c,base} = 0.461$) (Weng et al., 2015) where X represents a dimensionless distance from the wall of a tunnel fire source (in meters) that is obtained by dividing x on hydraulic diameter tunnel.

According to Figure 1 If the ventilation flow rate is lower than the critical velocity, temperature distribution in side view of the fire source in a manner that is visible in even higher heights. In other words flowing toward higher altitudes and moves upstream. This phenomenon in side view of the fire source is not visible in Figure 2. The reason for this is that the flow of ventilation from the fire source to the output of all heat and mass moved downstream and thus in the side view is not a trace of heat distribution at higher altitudes.

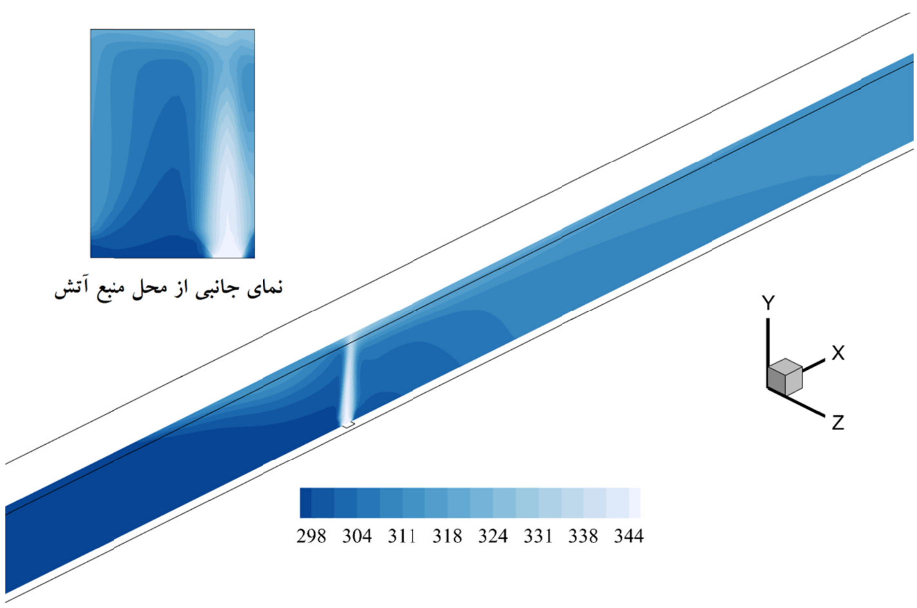

Figure 2. Temperature distribution in the tunnel, an isometric view, in speed is lower than the critical speed ventilation

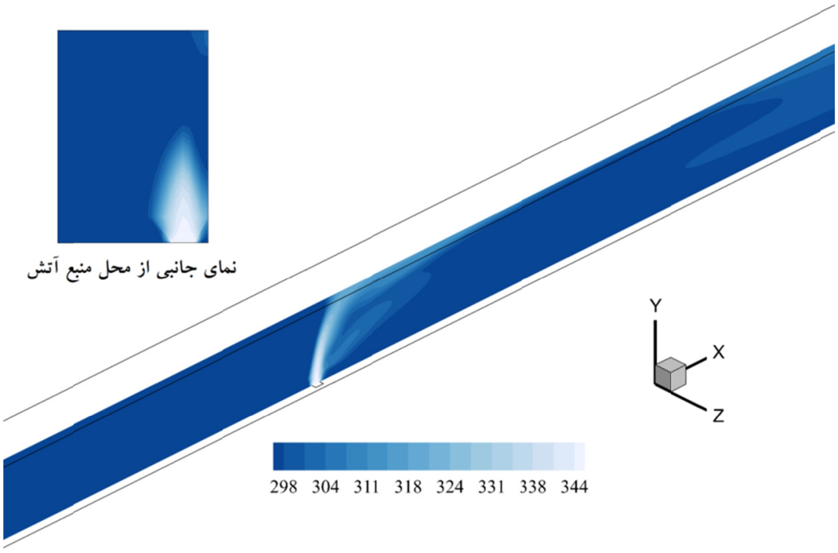

Figure 3. Temperature distribution in the tunnel, an isometric view, in critical velocity ventilation

3.2 The Effect of Existence Obstacle before and after the Fire

Existence barrier before and after the fire, a condition that occurs when fires in road tunnels. To investigate the effect of preventing both before and after the fire source is considered twice and four times the height of the fire source. In all cases the fire has 1590 watts of heat release rate of 8 × 8 cm and 8 cm side cube is placed on the block.

In all cases, the longitudinal distance between the center of the fire source and cube blocks equal to 25 cm. It is expected that barrier, causing ventilation flow resistance and require more ventilation flow compared to the base. On the other hand fire source position on the blocks with dimensions of 8 cm, causing smoke plume quickly reached the roof of the tunnel and in the upstream and downstream spread.

So there is ventilation flow resistance and also the ceiling near the fire source is a factor that increases ventilation flow rate. This phenomenon has been observed in numerical simulation study. The amount equal to 0.7 speed (to prevent fire four times) and 0.62 (To prevent fire twice) meters per second can be achieved. In temperature in the presence of two figures below contour is simulated.

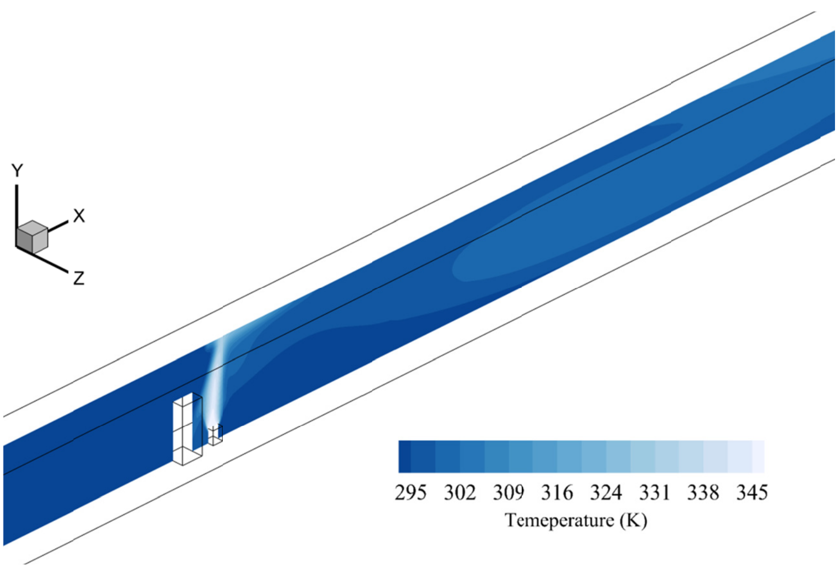

Figure 4. Contour temperature mode (to prevent fire four times), existence the barrier before the fire source

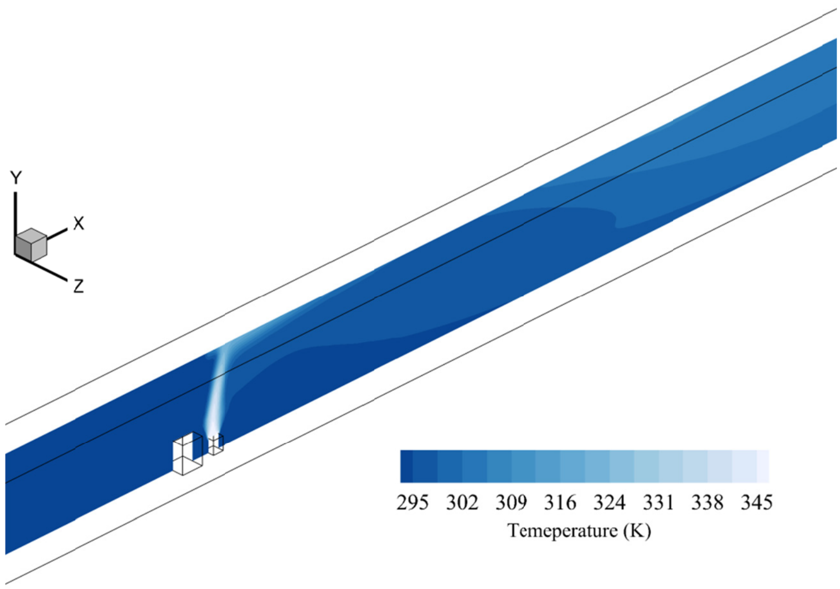

Figure 5. Temperature contour mode (to prevent fire twice), existence barrier before the fire source

In the second case, the barrier after the fire source and tunnels it was like before the eclipse. It is expected that prevents ventilation flow resistance causing by the need for more ventilation flow compared to the base. Also near the source of fire to the roof of the tunnel is another factor to faster reaching to the ceiling and spread fire effects faster upstream of the ventilation.

In this case, critical velocity ventilation 0.62 and 0.6 respectively obtained that expresses the effects of existence obstacle after the fire source. In other words, the most important factor that increases critical velocity relative to the base case and as a result the height of the fire source close to the ceiling and spread of fire in the upstream flow. Temperature contour is simulated in two forms.

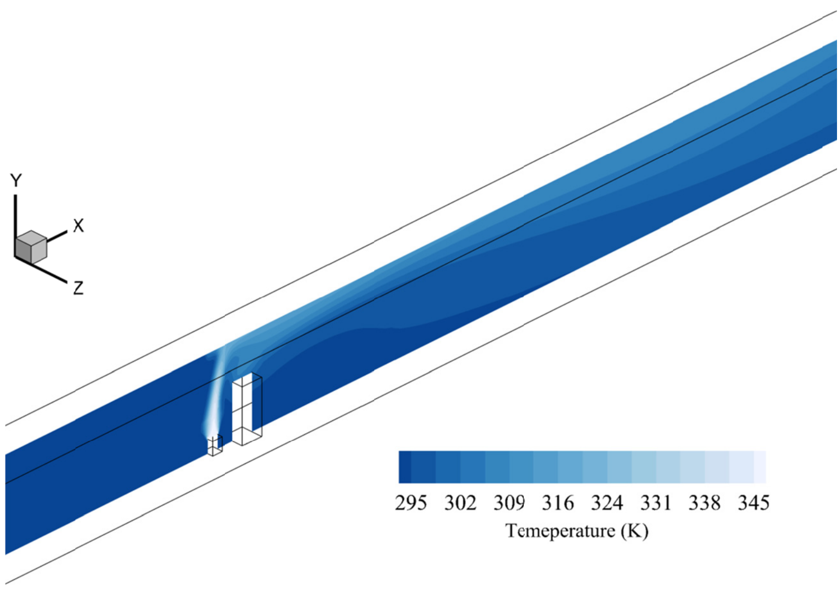

Figure 6. Temperature contour mode (to prevent fire four times), existence barrier after the fire

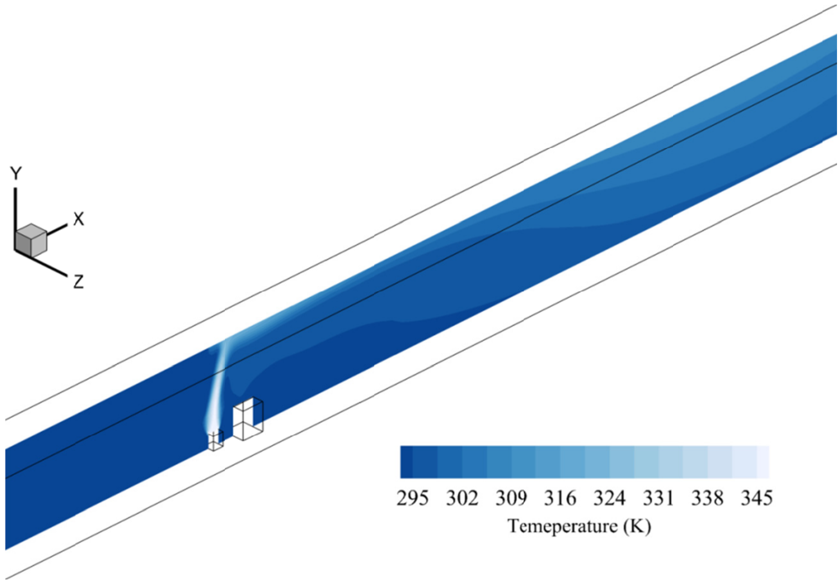

Figure 7. Temperature contour mode (to prevent fire twice), existence the barrier after the fire

3.3 Effects Existence Two Sources of Fire in the Tunnel

Existence several sources of fire in the tunnel parameter that probability is a lot of road and rail tunnels. To investigate this phenomenon, the fire source 8 × 8 cm in size as the original source on the center tunnel and other fire sources are located that in different distances from the source is used.

In this case, as the base case, finer mesh near the fire source was chosen. This mode amount of heat output of 1590 watts each ignition sources equal to and in accordance with Wong and colleagues measured baseline. The second fire source away from the first source, respectively, 0, 1.5, 3, 4.5 and 6 meters downstream of the first source and second source always is. The results of the numerical solution in this case is shown in Table 2.

Table 2. Effect of two sources on critical velocity in tunnel ventilation

Critical velocity of ventilation	Distance between resources
0.82	0
0.71	1.5
0.61	3
0.56	4.5
0.5	6

Existence two sources of fire near each other to strengthen the fire source and to overcome the crisis quickly ventilation should be increased. Whatever reinforcing effect on each other ignition sources are trimmed away from each other and therefore less ventilation flow to guide them towards the downstream exhaust heat is required. Existence two sources of fire in the tunnel and the distance between them due to on critical velocity, it is estimated using quadratic following:

$$V_c = 0.005x^2 - 0.081x + 0.82$$

Temperature contour is simulated in following figures.

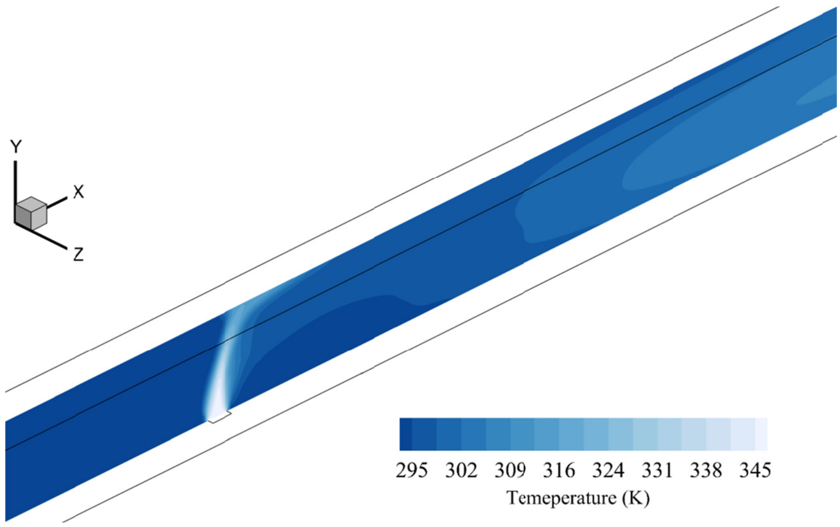

Figure 8. Contour temperature in the tunnel with two fire source, x = 0

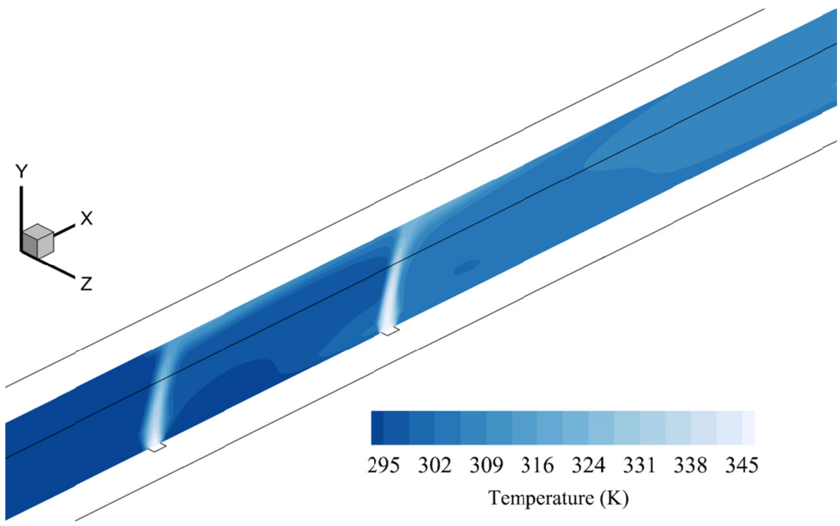

Figure 9. Contour temperature in the tunnel with two fire source, x = 1.5

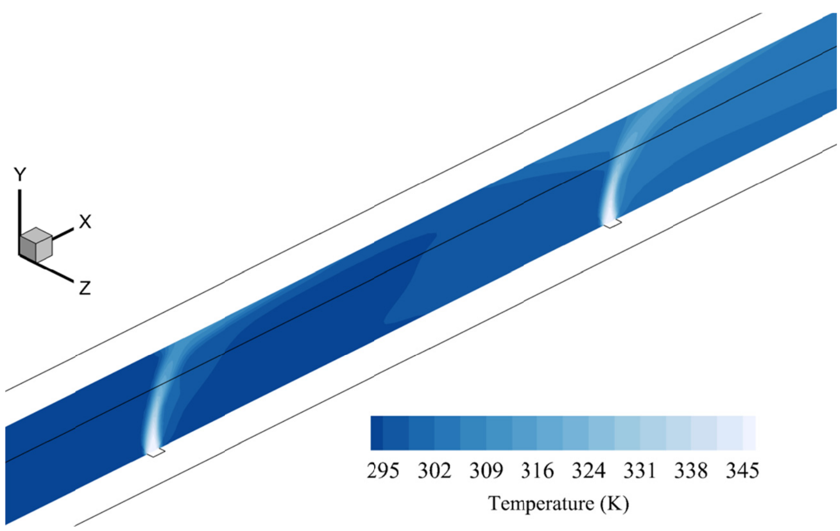

Figure 10. Contour temperature in the tunnel with two fire source, x = 3

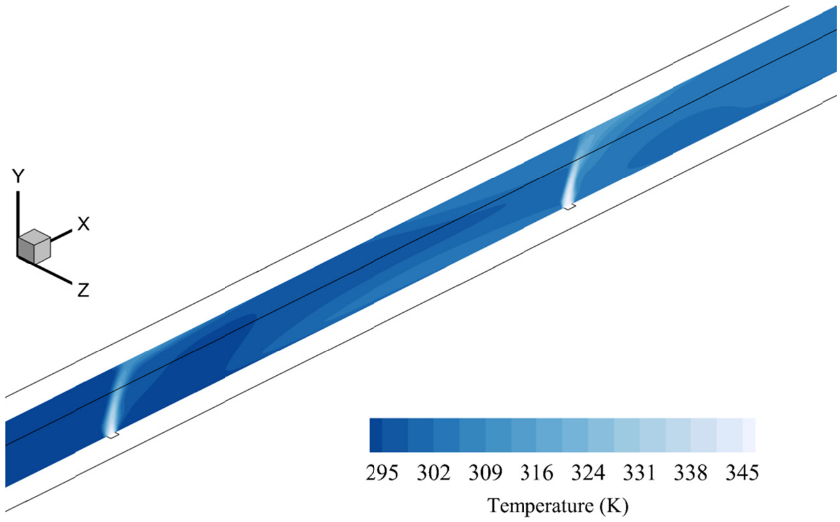

Figure 11. Contour temperature in the tunnel with two fire source, x = 4.5

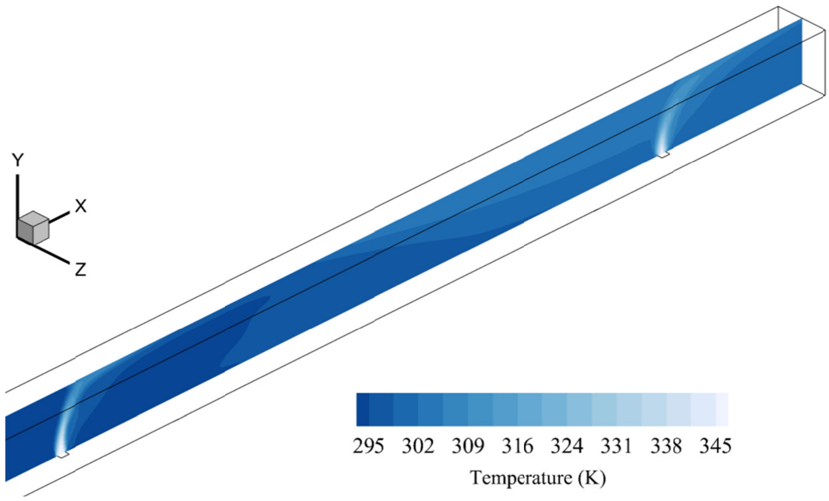

Figure 12. Contour temperature in the tunnel with two fire source, x = 6

Ventilation critical velocity changes $V_c = 0.23Q^{1/3} + 0.156$ with distance between the source of fire and changes critical velocity ventilation with heat release rate changes no later in this study has been examined. The distance between fire sources considered equal to 1.5 meters and the size of the fire source 8 × 8 cm to 20 cm in 15 and the amount of heat released from 3190 to 12380 watts changed.

3.4 Review the Chimney Effect between Tunnels

Longitudinal ventilation in tunnels with a length alone when the fire is not able to provide good air quality. Transverse or semi-transverse ventilation why such methods are used for tunnel ventilation. In this section combines the effects ventilation and ventilation longitudinal and transverse used were investigated. In order to better heat and pollutants out of the tunnel from a chimney in roof of the tunnel is used.

Chimney above the fire source is placed in different positions and its effects on critical velocity ventilation in the tunnel is investigated. To investigate the effect of these parameters on critical velocity ventilation and to the side of the chimney with a square cross-section hydraulic tunnel has been half the diameter that on various occasions been the source of fire. Fire source with dimensions 8 × 8 cm and the rate of release of 1590 watts in the middle of the tunnel, between tunnels and chimneys in the distance x from it.

As shown in Table 3 existence two sources of ventilation in the tunnel is visible on critical velocity, increase the distance between the fire and the chimney ventilation has been critical speeds. In other words, existence a chimney near the fire caused smoke and heat conditions at the exit of the tunnel and the distance from each source is high chimney fire, the chimney effects existence reduced.

Table 3. Existence effect of two sources on critical velocity in tunnel ventilation

Critical velocity of ventilation	Distance between chimney and fire resource
0.24	0
0.36	1.5
0.44	3
0.51	4.5
0.52	6

Results can be expressed using the critical velocity without a chimney ventilation in the tunnels (0.48 meters per second) and non-dimensional equation $\frac{V_c}{V_{c,base}} = -0.0152x^2 + 0.19 + 0.5$. This equation is important in terms of analysis, because it can be based on the distance at which the slowest speed required ventilation is critical, according to acquire the base tunnel. If that is the least critical velocity ventilation, energy consumption is also reduced.

4. Conclusion

According to the simulation results, the effect parameters of the tunnel away from the fire source, existence barrier before and after the fire, existence several sources of fire in the tunnel and ventilation shaft of the tunnel on critical velocity was investigated. The results are the effect of the fire on the wall shows the critical speed, the distance of the fire source from the wall is less, more critical velocity ventilation and ventilation rate with increasing distance from the wall of a critical source of fire is reduced. The temperature distribution in side view of the fire source in a manner that is visible in higher altitudes.

In other words flowing moves toward higher altitudes and upstream. Also numerical results show that the effect of the source of the fire source, existence barrier causing ventilation flow resistance and require more ventilation flow. The speed amount is equal to 0.7 (to prevent fire four times) and 0.62 (To prevent fire twice) meters per second, respectively. Then, when the fire was prevented after the critical speed of 0.62 and 0.6 respectively ventilation is achieved.

existence two sources of fire in the tunnel was the result of the review, existence two sources of fire near each other to strengthen the fire source and to overcome the crisis quickly ventilation should be increased. Whatever ignition sources are to be cut apart is required critical velocity. Finally, existence a chimney near the fire caused smoke and heat conditions at the exit of the tunnel and the distance from each source is high chimney fire, the chimney effects existence reduced.

References

Atkinson, G., & Wu, Y. (1996). Smoke control in sloping tunnels. *Fire Safety Journal, 27,* 335-341.

Ballesteros, T. R., Santolaria, -M. C., & Blanco, M. E. (2006). Influence of the slope in the ventilation semi-transversal system of an urban tunnel. *Tunnelling and Underground Space Technology, 21*, 21-28.

Carvel, R., & Beard, A. N. (2005). The handbook of tunnel fire safety, Thomas Telford.

Chen, F., Chien, S. W., Jang, H. M., & Chang, W. J. (2003). Stack effects on smoke propagation in subway stations. *Continuum Mechanics and Thermodynamics, 15*, 425-440.

Chen, L., Hu, L., Zhang, X., Zhang, X., Zhang, X., & Yang, L. (2015). Thermal buoyant smoke back-layering flow length in a longitudinal ventilated tunnel with ceiling extraction at difference distance from heat source. *Applied Thermal Engineering, 78*, 129-135.

Colella, F., Rein, G., Borchiellini, R., Carvel, R., Torero, J. L., & Verda, V. (2009). Calculation and design of tunnel ventilation systems using a two-scale modelling approach. *Building and Environment, 44,* 2357-2367.

DiNenno, P. J. (2015). SFPE Handbook of fire protection engineering. In M. J. Hurley, D. T. Gottuk, J. R. Hall Jr, K. Harada, E. D. Kuligowski, M. Puchovsky, J. M. Watts Jr, & C. J. Wieczorek (Eds.). Springe.

Elahinia, M., Moghaddam, N. S., Andani, M. T., Amerinatanzi, A., Bimber, B. A., & Hamilton, R. F. (2016).

Fabrication of NiTi through additive manufacturing: A review. *Progress in Materials Science, 83*, 630-663.

Fan, C., Ji, J., Gao, Z., & Sun, J. (2013). Experimental study on transverse smoke temperature distribution in road tunnel fires. *Tunnelling and Underground Space Technology, 37*, 89-95.

Haack, A. (2002). Current safety issues in traffic tunnels. *Tunnelling and Underground Space Technology, 17*, 117-127.

Hanson, H. P., Bradley, M. M., Bossert, J. E., Linn, R. R., & Younker, L. W. (2000). The potential and promise of physics-based wildfire simulation. *Environmental Science & Policy*, 3161-172.

Harish, R., & Venkatasubbaiah, K. (2014). Effects of buoyancy induced roof ventilation systems for smoke removal in tunnel fires. *Tunnelling and Underground Space Technology, 42,* 195-205.

Hu, L., Chen, L., Wu, L., Li, Y., Zhang, J., Meng, N. (2013). An experimental investigation and correlation on buoyant gas temperature below ceiling in a slopping tunnel fire. *Applied Thermal Engineering, 51*, 246-254.

Hu, L., Huo, R., & Chow, W. (2008). Studies on buoyancy-driven back-layering flow in tunnel fires. *Experimental Thermal and Fluid Science, 32*, 1468-1483.

Hu, L., Huo, R., Peng, W., Chow, W., & Yang, R. (2006). On the maximum smoke temperature under the ceiling in tunnel fires. *Tunnelling and Underground Space Technology, 21*, 650-655.

Hu, L., Huo, R., Wang, H., Li, Y., & Yang, R. (2007). Experimental studies on fire-induced buoyant smoke temperature distribution along tunnel ceiling. *Building and Environment, 42,* 3905-3915.

Hu, L., Peng, W., & Huo, R. (2008). Critical wind velocity for arresting upwind gas and smoke dispersion induced by near-wall fire in a road tunnel. *Journal of Hazardous Materials, 150*, 68-75.

Kang, K. (2010). Characteristic length scale of critical ventilation velocity in tunnel smoke control. *Tunnelling and Underground Space Technology, 25*, 205-211.

Karlsson, B., & Quintiere, J. (1999). Enclosure fire dynamics, CRC press.

Kunsch, J. (1998). Critical velocity and range of a fire-gas plume in a ventilated tunnel. *Atmospheric Environment, 33*, 13-24.

Le, C. J., Salizzoni, P., Creyssels, M., Mehaddi, R., Candelier, F., & Vauquelin, O. (2014). Aerodynamics of buoyant releases within a longitudinally ventilated tunnel. *Experimental Thermal and Fluid Science, 57*, 121-127.

Lee, S. R., & Ryou, H. S. (2005). An experimental study of the effect of the aspect ratio on the critical velocity in longitudinal ventilation tunnel fires. *Journal of Fire Sciences, 23*, 119-138.

Lee, Y. P., Tsai, K. C. (2012). Effect of vehicular blockage on critical ventilation velocity and tunnel fire behavior in longitudinally ventilated tunnels, Fire safety journal, 53, 35-42.

Li, J. S., & Chow, W. (2003). Numerical studies on performance evaluation of tunnel ventilation safety systems. *Tunnelling and underground space technology, 18,* 435-452.

Li, Y. Z., Lei, B., & Ingason, H. (2010). Study of critical velocity and backlayering length in longitudinally ventilated tunnel fires. *Fire Safety Journal, 45*, 361-370.

Liu, Y., & Cassady, S. (2014). A modified critical velocity for road tunnel fire smoke management with dedicated smoke extraction configuration. *Case Studies in Fire Safety, 2*, 16-27.

Modic, J. (2003). Fire simulation in road tunnels. *Tunnelling and underground space technology, 18,* 525-530.

Moghaddam, N. S., Jahadakbar. A., Amerinatanzi, A., Elahinia, M., Miller, M., & Dean, D. (2016). Metallic Fixation of Mandibular Segmental Defects: Graft Immobilization and Orofacial Functional Maintenance, Plastic and Reconstructive Surgery–Global Open.

Moghaddam, N. S., Skoracki, R., Miller, M., Elahinia, M., & Dean, D. (2016). Three dimensional printing of stiffness-tuned, nitinol skeletal fixation hardware with an example of mandibular segmental defect repair, Procedia CIRP, 4945-50.

Nfpa, N. (2003). 130-Standard for Fixed Guideway Transit System, National Fire Protection Association,

Niknam, B., Madani, H., & Salarirad, S. (2012). Determining Critical Wind Velocity during Fire Accident in Alborz Tunnel.

Novozhilov, V. (2001). Computational fluid dynamics modeling of compartment fires. *Progress in Energy and*

Combustion science, 27, 611-666.

Oka, Y., & Atkinson, G. T. (1995). Control of smoke flow in tunnel fires. *Fire Safety Journal, 25,* 305-322.

Raad, B., Moghaddam, N. S., & Elahinia, M. (2016). A numerical simulation of the effect of using porous superelastic Nitinol and stiff Titanium fixation hardware on the bone remodeling, in: SPIE Smart Structures and Materials+ Nondestructive Evaluation and Health Monitoring, International Society for Optics and Photonics, pp. 98021T-98021T-98029.

Rahmanian, R., Moghaddam, N. S., Haberland, C., Dean, D., Miller, M., & Elahinia, M. (2014). Load bearing and stiffness tailored niti implants produced by additive manufacturing: a simulation study, in: SPIE Smart Structures and Materials+ Nondestructive Evaluation and Health Monitoring, International Society for Optics and Photonics, pp. 905814-905814-905818.

Roh, J. S., Yang, S. S., Ryou, H. S., Yoon, M. O., & Jeong, Y. T. (2008). An experimental study on the effect of ventilation velocity on burning rate in tunnel fires—heptane pool fire case. *Building and Environment, 43*, 1225-1231.

Shayesteh, M. N. (2015). Toward Patient Specific Long Lasting Metallic Implants for Mandibular Segmental Defects, University of Toledo.

Tanaka, F., Majima, S., Kato, M., & Kawabata, N. (2015). Performance validation of a hybrid ventilation strategy comprising longitudinal and point ventilation by a fire experiment using a model-scale tunnel. *Fire Safety Journal, 71*, 287-298.

Thomas, P. H. (1968). The movement of smoke in horizontal passages against an air flow. *Fire Safety Science,* 723.

Tilley, N., Rauwoens, P., & Merci, B. (2011). Verification of the accuracy of CFD simulations in small-scale tunnel and atrium fire configurations. *Fire Safety Journal, 46,* 186-193.

Tsai, K. C., Chen, . H. H., & Lee, S. K. (2010). Critical ventilation velocity for multi-source tunnel fires. *Journal of Wind Engineering and Industrial Aerodynamics, 98*, 650-660.

Tsai, K. C., Lee, Y. P., & Lee, S. K. (2011). Critical ventilation velocity for tunnel fires occurring near tunnel exits, Fire Safety Journal, 46, 556-557.

Vega, M. G., Díaz, K. M. A., Oro, J. M. F., Tajadura, R. B., & Morros, C. S. (2008). Numerical 3D simulation of a longitudinal ventilation system: memorial tunnel case. *Tunnelling and Underground Space Technology, 23*, 539-551.

Weng, M. C., Lu, X. L., Liu, F., Shi, X. P., & Yu, L. X. (2015). Prediction of backlayering length and critical velocity in metro tunnel fires. *Tunnelling and Underground Space Technology, 47*, 64-72.

Willemann, D., & Sanchez, J. G. (2002). Computer modeling techniques and analysis used in design of tunnel ventilation fan plants for the New York City Subway, in: ASME/IEEE joint railroad conference, 73-80.

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

Yuan, F. D., You, S. J. (2007). CFD simulation and optimization of the ventilation for subway side-platform. *Tunnelling and Underground Space Technology, 22,* 474-482.

Copyrights