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Simulation Study on Critical Velocity of Longitudinal Ventilation Tunnel Fire

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Abstract

The critical velocity of tunnel fire of ten groups power from 10 to 100 MW were simulated using FDS. The critical velocities under different fire power were determined. For example 50MW tunnel fire. The inside the tunnel temperature, speed and visibility distribution at Y = 5m under the critical velocity were studied. Through the comparison of the gas average temperature of fire source upstream and downstream, and the average visibility of 0-195m,195-250m, 250-300m, 300-350m, 350-400m. The effects of the critical velocity to rescue and evacuation during tunnel fire were analyzed. The relationship curve between critical velocity and heat release rate was fitted out, and obtained that the simulation curve is closer to the results of Bettis by contrast with the empirical formula of Bettis and Thomas.

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Keywords: tunnel fire; critical velocity; FDS; longitudinal ventilation

Nomenclature

T	temperature(℃)
ρ	density(kg/m^3)
μ	molecular viscosity(kg/m.s)
C	specific heat(J/kg.K)
A	conductivity (W/m.K)

1. Introduction

In recent years, all over the world have occurred tunnel fire[1]. Tunnel is a long narrow confined space. Once the fire occurs, the internal temperature is higher; the heat is not easy to dissipate. The smoke diffusion and evacuation channel is single, fire fighting and evacuation is extremely difficult, often resulting in significant casualties and property losses [2]. Therefore, it's necessary for researchers to conduct scientific in-depth study on tunnel fire [3-4]. The main research methods of tunnel fire contain the full-size method, the laboratory experiment (scale model), the computer numerical simulation and other methods. Due to the high cost of operation, full scale fire experiment is restricted, and although model experimental study can effectively reduce the experiment cost, but the model proportion is constrained by the reliability of fire similarity. theory. In fact shrink size range very limited, to the existing technical conditions, the intensity range of tunnel fire is limited. Most of the studies have been done on the critical velocity of tunnel fire at home and abroad. On the basis of analyzing the law of flue gas countercurrent layer length variation, ZHAO Wangda [5]etc. established the relationship between flue gas countercurrent length and heat release rate of ignition source, ventilation rate and section equivalent diameter, obtained the formula of the length of flue gas countercurrent layer by data fitting. SHU Ning etc. [6] simulated the ventilation when the tunnel occured fire, and studied the flue gas spread characteristics in the tunnel. Using the 1000K as the high temperature

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point of the fire center, but didn't consider the dynamic characteristics of the fire. Bettis etc. [7-8] carried out the experiment of full-size mine tunnel fire. When the fire power is low, critical velocity and fire power is proportional to1/3 power. The American scholar [9] carried out the fire experiment of full-size tunnel in Memorial Tunnel. The study has shown that when the fire power is higher, the critical velocity obtained from the empirical formula higher than the experimental value 5% - 15%. Oka and Atkinson[10] studied the flue gas movement in horizontal tunnel using1/10 scale model, the research results has once again proven Bettis and others full-scale test results.

2. The Numerical Simulation of Tunnel Fire

2.1. Geometric model and fire scene

Tunnel size 400m×10m×10m, section with a rectangular, the fire source from tunnel entrance 200m, size 1m ×1m, using the steady-state fire source, the jet fan is set in tunnel entrance. Tunnel size and some calculation parameters as is shown in Table.1.

Table.1 Tunnel size and some calculation parameters

parameters		values
Tunnel size		400m×10m×10m
air	ρ	28.96kg/kmol
	μ	1.81×10^{-5}kg/m.s
	C	1006J/kg.K
	A	0.2637W/m.K
concrete	ρ	2300kg/m^3
	μ	840 J/kg.K
	C	1.6 J/kg.K
Heat transfer coefficient		Automatically set according to the ventilation

Undoubtedly the vehicle fire is more common in tunnel fire. According to the measured heat release of Switzerland and Norway, we estimate a car fire heat generated up to 5MW, the majority of bus and rail vehicles heat generated up to 15~20MW, the power of a fully loaded heavy-duty trucks is up to 100MW,as is shown in Table.2.

Table.2 The heat release rate of tunnel fire

The type of vehicles	The maximum temperature/℃	The maximum heat release rate / MW
Car	400~500	3~5
Bus or rail vehicle	700~800	15~20
Large truck or tanker	1000~1200	50~100

Here to study the flue gas flow of the 10-100 MW ten heat release rate of tunnel fire.

2.2. The curve of heat release rate

The Heat Release Rate (HRR) is a very central and important parameter when we study fire. This parameter describes the change process of the energy release in the process of fire. Therefore, it has important influence on other important parameters of the fire process, such as temperature, velocity, pressure, flame length, radiation, flame spread, fire duration, it is also the decision of the fire factors. Many scholars committed to study these parameters, in this paper, use the material combustion curve measured by Rickard Hansen, as shown in Fig.1.