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Research Progress on the Damage Rule of Ventilation Network Caused by External Fire in Mine

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Abstract: based on the conclusion and summary of the theoretical research, experimental research and computer numerical simulation of the propagation and destruction law of mine fire along the ventilation network, the research method and future research direction of the propagation and destruction law of mine fire on the ventilation network are analyzed.

1. Introduction

External fire accident is one of the most serious coal mine accidents in China.After the occurrence of mine fire, the fire develops rapidly, changes complex and affects a wide range, often causing a large number of casualties and property losses.Statistical data of accidents in China's coal mines over the years show that more than 90% of major malignant coal mine fire accidents are caused by external fires.With the increasing degree of mine mechanization and electrification, the risk and consequence of fire accidents have increased significantly.

2. Hazards caused by fire outside the mine

In case of underground fire, all the people on the downwind side of the fire area are in the danger zone of being polluted or possibly polluted by smoke flow.External underground fire hazards include burns, poisoning or suffocation, disruption of normal ventilation, obstruction of vision, deflagration or explosion, and even secondary disasters, disrupting the normal production order [1].

1) burns.The space of downhole smoke flow is limited, the heat generated by combustion cannot spread around, and the temperature of smoke flow can reach hundreds or even thousands of degrees.During the fire period, the temperature of smoke flow can still reach more than 343K within a range of tens or even hundreds of meters downwind side of the fire area.People who enter the hot smoke stream area are easy to burn, and people who stay in the smoke stream above body temperature for a long time are easy to get fever.

2) poisoning or suffocation.During the fire period, a large amount of CO_2, CO, HCl, NOx and other toxic and harmful gases are generated by the combustion of combustibles.The concentration of toxic and harmful gases in the smoke stream varies with the intensity of combustion.Combustion increases the concentration of toxic and harmful gases in the wind flow, and O_2 concentration drops to less than 12%, which may lead to suffocation or even death in a short time.

3) Destroy the normal ventilation state.The heat energy generated by the fire is converted into the fire wind pressure, which adds ventilation power to the original ventilation system. The destruction of the roadway and the throttling effect will change the structure of the original ventilation system, causing the disorder of the air flow in the shaft and causing difficulties for personnel escape and fire fighting. 4) Block vision.Combustion produces a large amount of dust and water vapor, and mixed with the wind flow through the fire area, forming a fire smoke stream.The visibility of smoke flow is very low, dust and toxic and harmful gases in the smoke flow on people's eyes, nose, respiratory system and skin have a strong irritation. 5) Deflagration or explosion. Deflagration is a kind of fire burning phenomenon, which can damage the surrounding facilities.Deflagration wave propagation speed is very fast, can make the fire area in a short time to expand. Deflagration heat energy is easy to cause gas or dust explosion. There are many inflammable and explosive gases and inflammable dust in the smoke stream with incomplete combustion of combustibles. 6) Cause secondary disasters.There are a lot of inflammable and explosive gases such as gas in the restricted space of underground coal mine.

3. Theoretical study on the propagation law of mine external fireIn the period of mine fire

The ventilator and the hot wind pressure caused by the change of wind temperature act together to provide the power of wind flow, thus destroying the balance between the original ventilation power and the wind network state under the normal state, leading to the reversal of wind direction in part of the mine roadway and the drastic change of wind flow in the roadway.With the continuous development and change of fire along the roadway, the smoke flow of fire moves forward continuously along the roof of the roadway under the action of buoyancy, external wind pressure and fire wind pressure, and spreads rapidly to the entire ventilation network.In recent years, more and more scholars tend to use computer simulation analysis technology to enrich the study on the damage rule of the influence of mine external fire on ventilation network.The simulation of wind flow state in the period of mine fire is a technology that USES computer numerical analysis method to calculate the dynamic change under the influence of fire and the position, time and influence of wind flow reversal in each branch of mine ventilation network, including air volume, air temperature, air pressure, concentration of harmful gas, node pressure and ventilator working condition.The destruction of ventilation network by fire is generally studied by scholars at home and abroad based on the principles of fluid kinematics and thermophysics to establish a mathematical model of air flow in the network during fire, and then simulate the influence range of smoke flow dynamically.Zhu etal [2] took the air flow in the wind network as the unsteady flow of a one-dimensional compressible fluid and proposed a new model for calculating the fire wind pressure, which could be automatically added into the network solution model.Jia etal the analysis of fire in the period of romantic state[3], established the mathematical model of mine fire period, including the ascertainment of the range of pollution (depth-first search method), the highest temperature fire area, within the scope of pollution plume temperature distribution of roadway, in several aspects, such as node temperature calculation system and merry time interval method is used to simulate the fire period the trend of the change of state.Wen Hu [4] studied the distribution of smoke flow temperature within the pollution range of inclined roadway and horizontal roadway, and calculated the smoke flow thermometer formula of each well roadway at the outflow point.According to the theory of tunnel wind structure and the theory of axisymmetric heat convection in the neutral layer of thermal buoyancy, the theoretical model of formation of countercurrent layer of fire smoke flow in horizontal roadway is established, and the formula of theoretical criterion is given.A mathematical model of tunnel fire combustion based on O_2 concentration in smoke plume is proposed.According to the combustion law of mine fire and the characteristics of wind flow in the network, the mathematical model of mine fire combustion and the equations of wind flow instability are established, the calculating method is given, and the computer simulation software for simulating the combustion process of mine fire and wind flow instability is developed.

Fu peifang etal [5] analyzed the relationship between thermal force and thermal resistance in the combustion zone by applying one-dimensional compressible unsteady flow theory on the basis of full-size tunnel fire test data of unsteady flow.Based on the theoretical knowledge of fuel combustion and the change rule of oxygen concentration in the flue gas monitored in the combustion process with time, a formula for calculating the fuel combustion rate, heat release rate and heat absorption rate of the medium at a certain moment is presented.The research shows that in the fire of near horizontal or horizontal roadway, in addition to expansion thermal resistance and viscous thermal resistance, there is also lateral floating resistance perpendicular to the flow direction.Studied the throttling effect occurs in the process of actual tunnel fire smoke temperature, concentration, namely the entrance to the exit velocity and fan change characteristics of wind pressure, produce throttle when accelerating combustion was the main cause of transverse lifting resistance, thermal resistance, heat resistance and viscous expansion with the pressure of the ventilation system, fire wind pressure and the location of the fire.The relative wind speed to restrain the counter-current diffusion of the smoke flow at the top should be greater than 1.5m/s.Zhou fubao [6] deduced the mutation potential function of airflow reversal in the downstream ventilation trunk wind road by applying the mutation theory, revealed that the reversal process had mutation characteristics, and analyzed the non-linear characteristics of airflow reversal such as abrupt jump, bifurcation, unreachable, hysteresis and multi-mode.

4. Experimental study on propagation rule of external fire in ventilation network

The main combustible materials for external fire include coal, wood, rubber belt, cable, oil and so on.The understanding of combustion characteristics of underground combustibles mainly comes from combustion experiments of combustibles.The initial fire experiment only tested the basic combustion properties of various materials, but did not consider the interaction of various factors in the fire process.In order to better understand the combustion characteristics of mine fire, all countries in the world attach great importance to the experimental work of mine fire.The experimental study on the fire of the cable in coal mine shows that the fire spreads faster and releases a large amount of flammable gas and thick black smoke, which flows around after preheating.The belt slip experiment of belt conveyor shows that the possibility of the belt flame burning directly caused by the belt slip on the main roller is very small.Wang Gang [7] used a cone calorimeter to determine the combustion characteristics of combustible materials used in mining, and conducted comparative experiments on several different types of conveyor belt and wood used in mining. The results showed that: conveyor belt with non-flame retardant has the highest release rate of heat, and the flame retardant belt produces the most harmful gas.The combustion experiment shows that the fire resistance has an obvious effect on throttling the roadway air flow. Throttling occurs with the occurrence of fire and increases with the development of fire. The larger the combustion scale is, the more obvious throttling effect is.The fire development rate of rubber belt fire in different stages increases with the increase of wind speed.Zhang xingkai [8-9] simulated the combustion process of mine fire, the changes of downwind side smoke flow temperature and wind flow resistance in fire area, analyzed the relationship between hot wind resistance, wind speed and smoke flow temperature in fire area, and obtained the calculation formula of temperature distribution of combustion zone and maximum smoke flow temperature in mine fire.Fire experiments were carried out in the experimental roadway to study the change of reaction rate constant of combustion conversion: in the combustion process, the reduced reaction rate constant of combustion conversion decreased with the increase of fire time, and the rate of wood was higher than that of coal.Under the condition of oxygen-enriched combustion, the combustion conversion reaction rate constant is less affected by the inlet wind speed and fuel placement

5. Conclusions and prospects

Great progress has been made in the study of the airflow state in the period of coal mine fire in China. There have been in-depth studies on the combustion characteristics of the smoke flow in the period of disaster, the distribution law of the smoke flow, the reversal of the wind flow, and the numerical simulation of the fire flow state.However, the understanding of the combustion characteristics of underground combustibles mainly comes from the combustion experiments of combustibles. The initial fire experiments only tested the basic combustion properties of various materials, but did not consider the interaction of various factors in the fire process.Due to the complexity of mine ventilation network, the development rules of each mine under the disaster situation are different, and there is still a big gap with the research results of developed countries abroad.The experimental study is limited to small-scale mine fire experimental study, which is quite different from the propagation damage rule in actual mine fire disaster.In the future should be constantly enrich and perfect the theory of mine fire romantic state, analyzing the flow dynamic change law of fire according to the characteristics of underground fire process in different fuel and combustion characteristic, adopt the method of qualitative analysis and quantitative calculation, the calculation of ventilation network, and based on the analysis of the disaster ventilation, to the mine fire to the mine roadway network and the influence of damage on a large scale software simulation, the mine ventilation network catastrophe of simulation analysis, the rule of wind flow for mine emergency relief ways and means to provide auxiliary decision making.

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