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Original Paper

Numerical Simulation of Fluid-Solid Coupling Heat Transfer in Excavating Roadway

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Abstract

Heat damage is an urgent problem to be solved in deep mining. The relevant factors in the excavation roadway significantly affect the cooling effect in the roadway. In this paper, the fluid-solid coupling heat transfer model of excavating roadway is established using numerical simulation, and the influence of inlet air temperature, wind speed, original rock temperature and surrounding rock thermal conductivity on roadway temperature is studied. The results show that the larger the initial rock temperature, the higher the airflow temperature in the roadway, and the greater the decrease of the airflow temperature after ventilation. The lower the inlet air temperature, the more significant the decrease in the airflow temperature in the roadway after ventilation, and the airflow temperature in the roadway gradually stabilizes with the extension of the ventilation time. The greater the wind speed, the lower the airflow temperature in the roadway, and the more significant the decrease of the airflow temperature in the roadway after ventilation. When the wind speed reaches a specific value, the cooling effect of ventilation is minimal. The higher the thermal conductivity of the surrounding rock, the higher the outlet temperature simultaneously.

Keywords

excavating roadway, mine heat damage, coupling heat transfer, numerical simulation, temperature field

1. Introduction

With the completion of shallow mineral mining, mine production extends to the deep. When the mining depth increases by 100 m, the temperature of the primary rock will generally increase by 1~3 ℃. The relative humidity of deep, healthy air is above 90%. When workers work in a high temperature and humidity environment, the physical strength of workers will decrease, the cardiovascular and digestive systems will also change, and the risk of accidents will increase. The thermal damage of the mine is caused by the heat loss of multiple heat sources, such as surrounding rock mechanical and electrical equipment. In the mine ventilation roadway, the rock wrapped in the roadway is constantly cooled, and the mechanical and electrical equipment and hot water in the roadway heat the air so that the air changes in heat and humidity. Therefore, it is of great significance to study the fluid-solid coupling heat transfer law in the excavation roadway for the treatment of heat damage in deep mines.

The fluid-solid coupling heat transfer process of roadway is complex, and many scholars at home and abroad have done much research on it. Some scholars have developed a mine roadway environment simulation device by combining experiments with Computational Fluid Dynamics (CFD) to help researchers better study the environmental changes in the roadway. For example, Liu et al. (Liu, Du, Wang, Chen, Yang, & Jin, 2023) developed a mine roadway environment simulation device by combining experiments with Computational Fluid Dynamics (CFD). The device can control temperature, humidity and wind speed parameters to replicate the mine roadway environment fully. It provides a reasonable and scientific test environment for designing and developing high-precision wind speed sensors. Some scholars have also found that geothermal water has a significant impact on the thermal environment of the mine through research. Such as Bian et al. (Bian & Dong, 2022). In this paper, the geothermal water roadway and the mine car are taken as the research object, and the thermal-fluid-solid coupling analysis of the roadway is carried out. The study found that geothermal water has a significant impact on the thermal environment of the mine. When the wind speed reaches a specific value, the cooling effect of ventilation is minimal. Some scholars have studied roadway ventilation's influence on miners' thermal comfort based on numerical simulation and field measurement. For example, Nie et al. (Nie, Feng, Shudu, & Quan, 2019) used Fluent software to simulate the roadway's temperature and wind speed fields. They studied the influence of roadway ventilation on the thermal comfort of miners. The results show that the thermal comfort of miners can be effectively improved when dynamic ventilation control is adopted. In addition, some scholars have studied roadway ventilation's dynamic heat transfer process and introduced dynamic mesh to solve it. For example, Xu et al. (Xu, Li, Li, Jalilinasrabady, Zhai, Chen, & Wang, 2023) proposed a method of approximating the ventilation roadway as a one-dimensional line element to analyze the dynamic heat transfer process of the mine ventilation roadway. The results show that the surrounding rock of the roadway regulates the underground thermal environment through heat absorption or heat release. The temperature distribution of the surrounding rock is a "V" shape in winter and a "W" shape in summer. Li et al. (Li, Liu, Xu, Li, Jia, & Zhang, 2021) used the fully coupled model combined with the dynamic grid method to study the excavation roadway's thermal characteristics and evolution law. The results show that increasing the air volume has a specific limit on the cooling effect of the roadway, and reducing the diameter of the air duct or the distance between the air duct outlet and the working face will aggravate the thermal hazard of the roadway. The heat release of roadway walls increases with the increasing working face advancing speed and roadway section size. Xu et al. (Xu, Li, Liu, Jia, Wang, Zhang, & Xu, 2021) established a fully coupled model of moving mesh method considering convective heat transfer between surrounding rock and airflow, unsteady heat transfer of surrounding rock and non-isothermal flow of roadway. The results show that the air temperature in the roadway is related to the airflow characteristics, and there is a local high-temperature zone in the vortex area. Lu et al. (LU, LIU, SUN, & XING, 2022) used the dynamic mesh function in ANSYS finite element analysis software to dynamically simulate the movement of the scraper in the roadway. They studied the heat dissipation effect of the deep well scraper during operation. The results show that the scraper impacts the thermal environment within 25 ~ 30 m of the roadway, and the impact of the upwind operation is much broader than that of the downwind operation. Some scholars have studied the relationship between inlet air temperature, air volume, roadway section, ventilation pipe position and roadway temperature. For example, Wang et al. (Wang, Du, & Wang, 2021) numerically simulated the temperature distribution in the excavation roadway and ventilation pipe under different ventilation parameters. The results show that the ventilation temperature has the most significant influence on the air temperature in the roadway, followed by the ventilation flow and the position of the ventilation pipe. Wei et al. (Wei, Du, Xu, & Zhang, 2019) used the cooling rate as an evaluation index to analyze the main factors affecting the roadway temperature. The results show that the ratio of the inlet air volume to the cross-sectional area of the roadway has the most significant influence on the roadway temperature, followed by the cross-sectional area of the roadway, and finally, the difference between the air temperature and the wall temperature. Huang et al. (Huang, Shen, Wu, & Li, 2020) studied the influence of altitude and ventilation conditions on heat loss along the roadway by means of unified design and regression analysis. The results show that the heat loss along the road is negatively correlated with altitude and positively correlated with inlet flow and convective temperature difference. The main factors affecting the heat loss of roadways are convective temperature difference, air volume, roadway length, and altitude. Sun et al. (Sun, Yan, Cao, & Zhang, 2023) established a model test system to study high-temperature tunnels' initial temperature field distribution. The experimental results show that the temperature at the entrance and end of the roadway is low, and the middle temperature is high. The periodic boundary conditions have a significant effect on the distribution of the temperature field.

In summary, scholars at home and abroad have done much research on the change in the law of roadways after short-term ventilation, but further research is still needed in the long-term ventilation and cooling of roadways. Based on previous studies, this paper establishes a fluid-solid coupling heat transfer model of excavation roadway, analyzes the relationship between the temperature of excavation roadway and wind speed, inlet air temperature, original rock temperature, and surrounding rock thermal conductivity under long-term ventilation, and provides theoretical guidance for the treatment of heat damage in deep mines.

2. Numerical Simulation

2.1 Basic Assumptions

In order to facilitate analysis and calculation, the surrounding rock of the roadway is reasonably assumed as follows:

(1) The heat is only transmitted along the radial direction of the roadway, and there is no internal heat source.

(2) The rock mass is isotropic and the thermophysical properties are stable.

(3) Heat transfer process does not consider the thermal radiation, no phase change.

(4) The heat exchange between surrounding rock and airflow is a one-dimensional unsteady process along the radial direction.

2.2 Model Establishment

Based on the above assumptions, the heat transfer model of surrounding rock matrix and roadway airflow is simplified into a two-dimensional plane model, as shown in Fig.1. The length of the model L_1 is 1040 m, the length of the roadway L_2 is 1000 m, the length of the air duct $L_{3\text{-}1}$ is 990 m, the distance between the end of the air duct and the head $L_{3\text{-}2}$ is 10 m. The range of the surrounding rock heat transfer zone W_1 is generally 15 m ~ 40 m, and the model takes 40 m. The width of the roadway W_2 is 4 m, and the radius of the air duct r is 0.2 m.

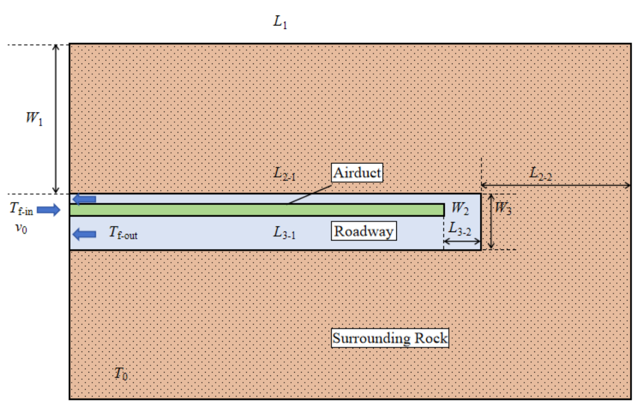


Figure 1. Fluid-Structure Coupling Heat Transfer Model of Excavation Roadway

2.3 Boundary Conditions

The roadway wall is a non-slip boundary; the wall of the air duct is a thin layer of the inner wall, and the outer boundary of the model is a thermal insulation boundary. The left side of the air duct is measured as the airflow inlet, and the left side of the roadway is the airflow outlet. The initial temperature of surrounding rock and roadway air is T_0 (30 ℃ ~ 60 ℃). The inlet air temperature $T_{\text{f-in}}$ of roadway is 10 ℃ ~ 25 ℃ ; the inlet wind speed v_0 is 5m/s ~ 20m/s. Other parameters are shown in Table 1.

Table 1. Numerical Simulation Parameter Detting

Model Parameter	Symbol	Value	Unit	Remarks
Thermal conductivity of surrounding rock	λ_r	1.5~3.0	W/(m·K)	variable
Density of surrounding rock	ρ_r	2710	kg/m^3	N/A
Specific heat capacity of surrounding rock	c_r	750	J/(kg·K)	N/A
Air thermal conductivity of roadway	λ_{air}	0.0259	W/(m·K)	N/A
Air density	ρ_{air}	1.205	kg/m3	N/A
Air specific heat capacity	c_{air}	1005	J/(kg·K)	N/A
aerodynamic viscosity	μ_{air}	18.1×10^{-6}	Pa·s	N/A
Inlet air temperature	$T_{\mathrm{f\text{-}in}}$	10~25	°C	variable
wind velocity	v_0	5~20	m/s	variable
Original rock temperature	T_0	30~60	°C	variable
Thermal conductivity of air duct	λ_w	0.171	W/(m·K)	N/A
Density of air duct	ρ_w	1400	kg/m^3	N/A
Specific heat capacity of air duct	c_w	1161	J/(kg·K)	N/A

3. Scheme of Numerical Simulation

In order to analyze the formation mechanism of thermal damage in deep mine heading face, five sets of simulation schemes are designed, as shown in Table 2. Among them, group one is the basic model, which simulates the change of airflow temperature field when the original rock temperature T_0 is 50 °C, the inlet air temperature $T_{\mathrm{f\text{-}in}}$ is 20 °C, and the wind speed v_0 is 15 m / s. Group 2 to group 4 are comparative models. Group 2 simulates the influence of wind speed v_0 on the temperature field of wind flow. Group 3 simulates the influence of inlet air temperature $T_{\mathrm{f\text{-}in}}$ on the airflow temperature field. Group 4 simulates the influence of the original rock temperature T_0 on the wind flow temperature field. Group 5 simulates the. influence of thermal conductivity λ_r of surrounding rock on the temperature field of wind flow.

Table 2. Scheme of Numerical Simulation

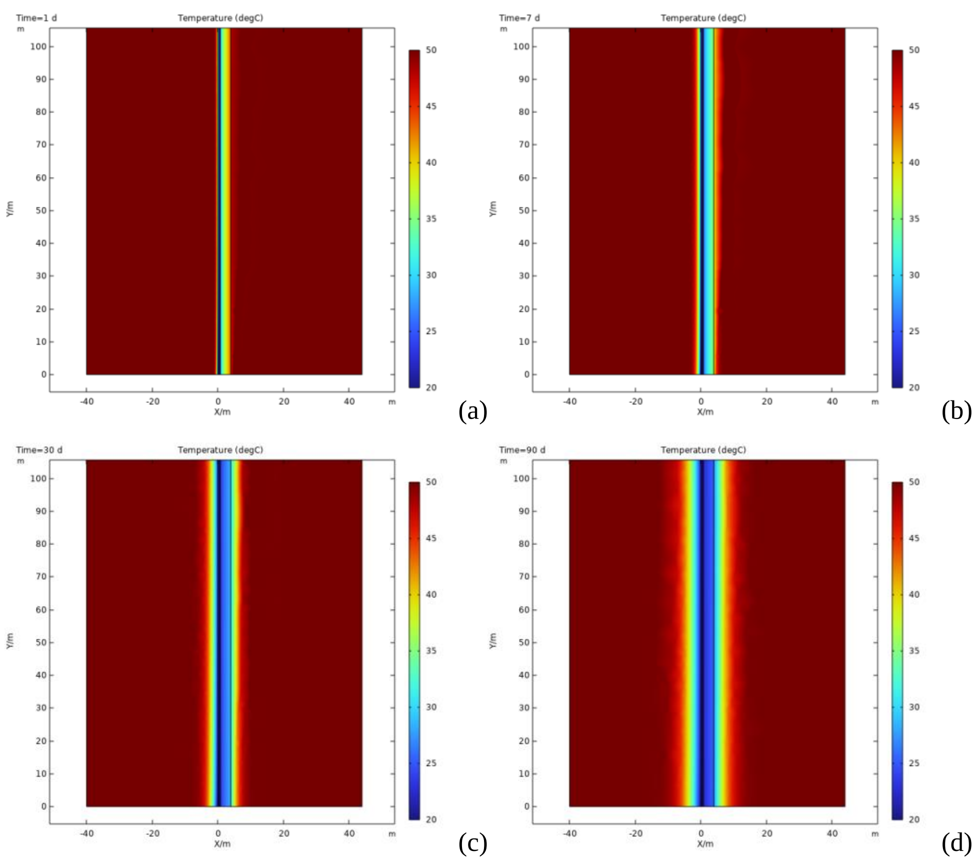
Group	T_0 (°C)	λ_r (W/(m·K))	$T_{\mathrm{f\text{-}in}}$ (°C)	v_0 (m/s)
Group 1	50	2.5	20	15
Group 2	range(30,10,60)	2.5	20	15
Group 3	50	2.5	range(10,5,25)	15
Group 4	50	2.5	20	range(5,5,20)

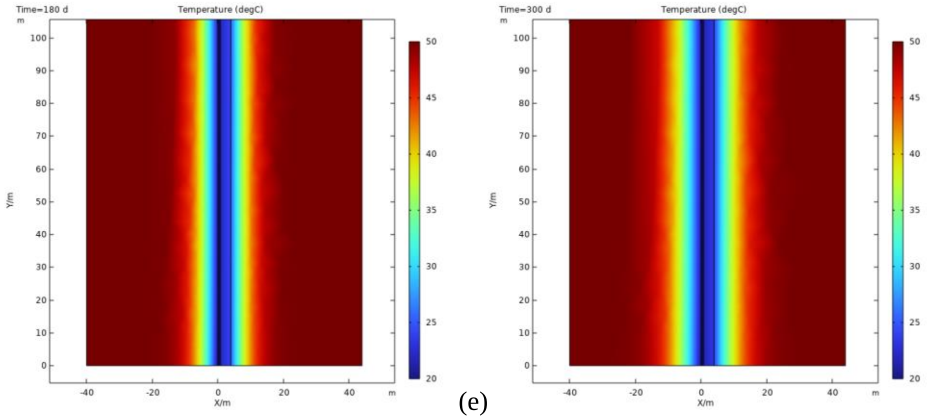
Group 5	50	range(1.5,0.5,3.0)	20	15

4. Numerical Simulation Results

4.1 Headwind Temperature of roadway and Its Variation Law

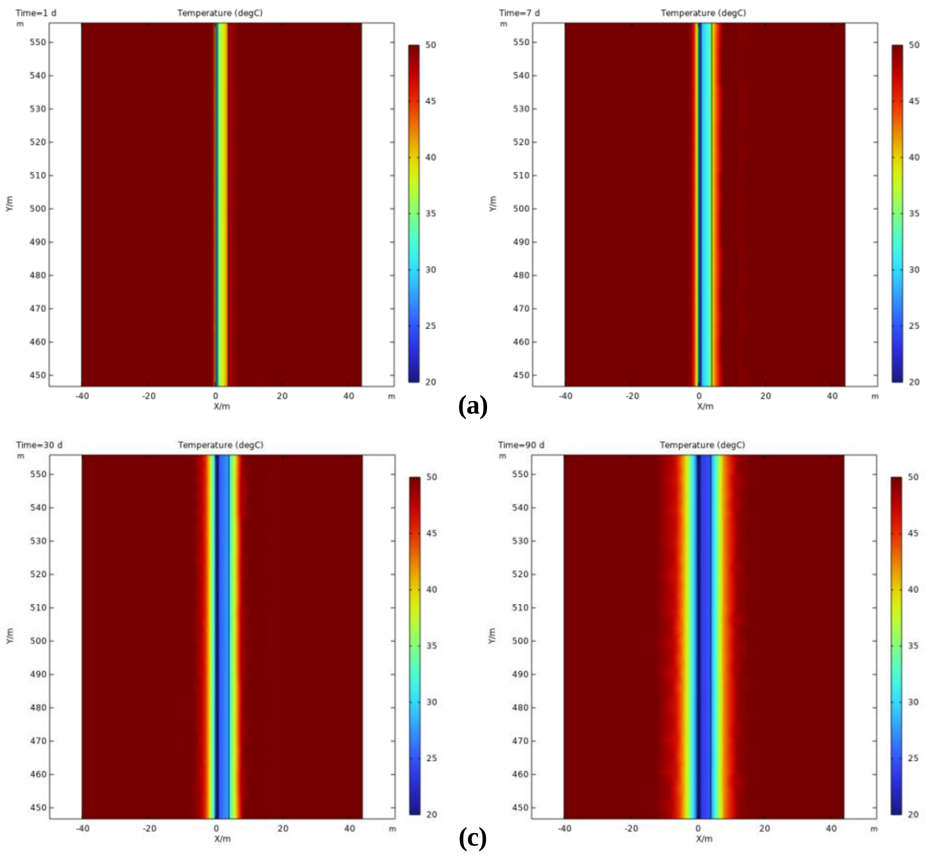
Figure 2 (a)~(f) is the temperature distribution cloud map of the basic model roadway in the range of 0 ~ 100 m during 0 ~ 300 d. It can be seen that after the ventilation of the roadway, the original thermal equilibrium state of the surrounding rock is broken, and the convective heat transfer between the roadway wall and the airflow is carried out due to the temperature difference, resulting in the heat of the roadway wall being taken away by the airflow and the temperature decreasing. With the extension of ventilation time, the heat of the roadway wall is continuously taken away, which makes the wall temperature and the air flow temperature gradually close, and the heat transfer efficiency between the air flow and the surrounding rock decreases. As the heat exchange process progresses, the temperature disturbance range inside the surrounding rock gradually extends to its interior, but the extension rate gradually decreases until a new thermal equilibrium state is reached.





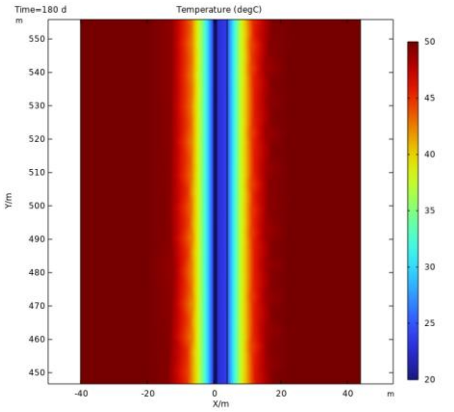
(e) (f)

Figure 2. Temperature Distribution Cloud Image of Roadway 0~100 m in Basic Model

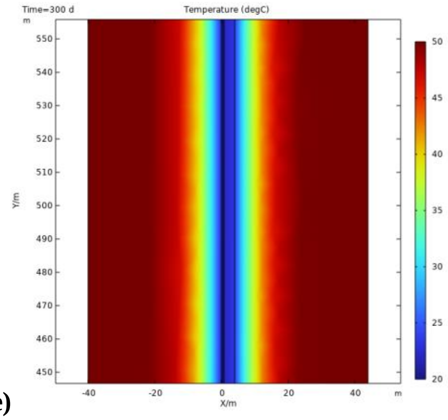


(a) **(b)**

(c) **(d)**



(e)

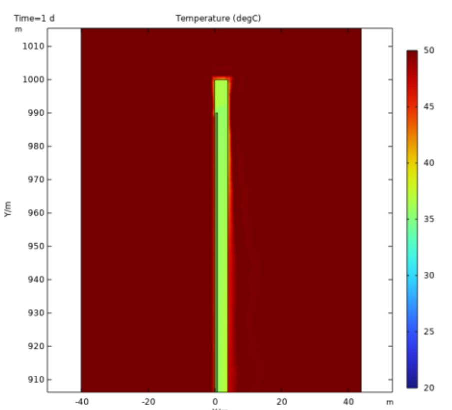


(f)

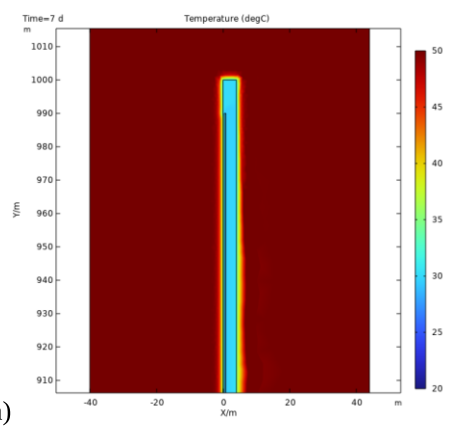
Figure 3. Temperature Distribution Cloud Image of Roadway 450~550 m in Basic Model

Figure 3 (a) ~ (f) is the temperature distribution cloud map of the basic model roadway in the range of 450 m ~ 550 m during 0 ~ 300 d. It can be seen that after the roadway is ventilated, the air flow absorbs the heat emitted by the surrounding rock along the way, resulting in a higher temperature of the roadway air flow in the area in the early stage of ventilation. With the extension of ventilation time, the surrounding rock in the front section of the roadway is gradually cooled, and the heat exchange efficiency between the surrounding rock and the airflow is gradually reduced. Therefore, the airflow temperature of the roadway in this area gradually decreases. The airflow temperature at 300 d is higher than that in the range of 0 ~ 100 m.

Figure 4 (a) ~ (f) is the temperature distribution cloud map of the basic model roadway in the range of 910 m ~ 1100 m during 0 ~ 300 d. It can be seen that the temperature of roadway airflow in this area is higher than that of the former two. With the extension of ventilation time, the decrease rate of airflow temperature and surrounding rock temperature is small. This shows that with the excavation of the roadway, the ventilation path gradually becomes longer, and the temperature at the end of the airflow gradually increases.



(a)



(b)

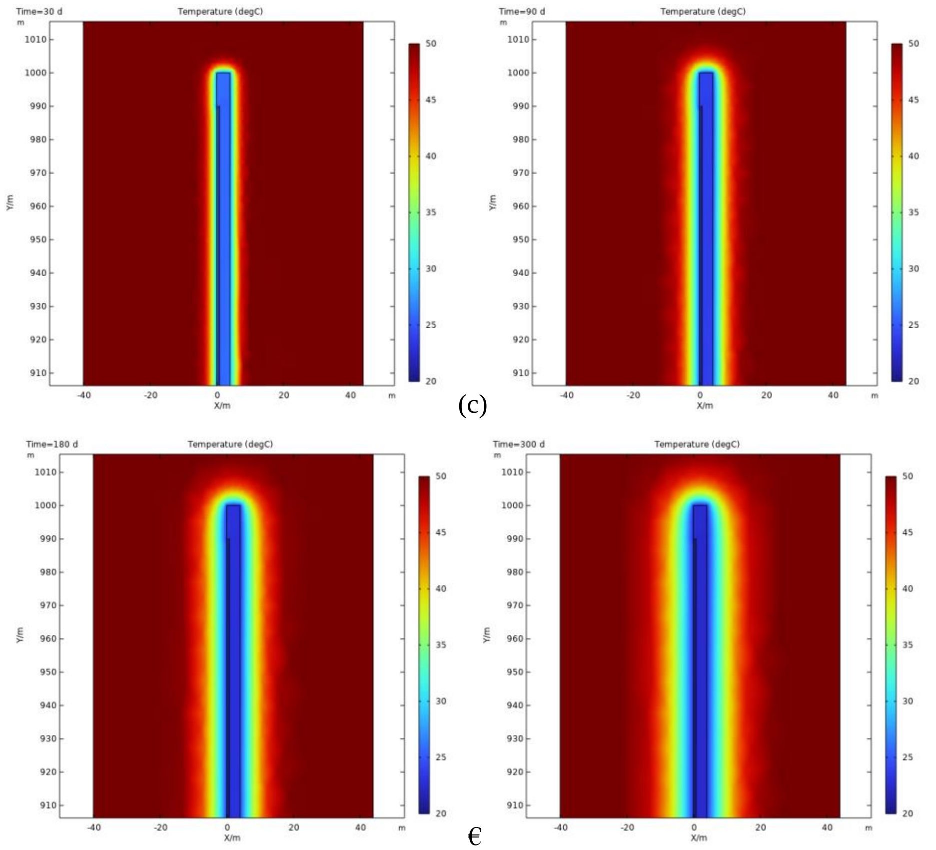


Figure 4. Temperature Distribution Cloud Image of Roadway 910~1100 m in Basic Model

Figure 5 is the change curve of the wind temperature at the head of the basic model roadway with time. It can be seen that after the ventilation starts, the airflow temperature at the outlet of the roadway continues to decrease with time due to the airflow taking away the heat inside the roadway, and the rate of change continues to decrease, and the airflow temperature gradually stabilizes with the extension of ventilation time. At the same time, the air temperature at the outlet of the roadway decreased from 50 ℃ to 22.8 ℃ within 300 days, which was 54.4 % lower than the initial value.

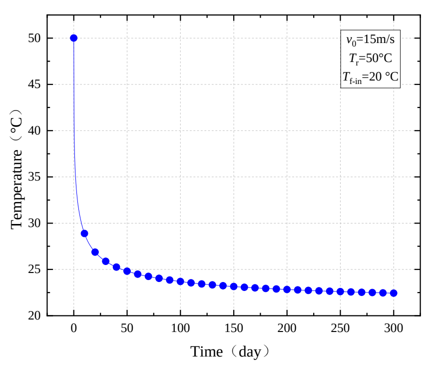


Figure 5. The Wind Temperature of Roadway Head Changes with Time

Figure 6 shows the transient distribution curves of wind temperature along the roadway when the ventilation time of the basic model is 1 d, 7 d, 30 d, 90 d, 180 d and 300 d. It can be seen that after the airflow flows out of the air duct into the roadway, the heat exchange between the roadway and the surrounding rock wall caused by the head-on backflow of the roadway makes the air temperature rise along the way. At the beginning of ventilation, the air temperature distribution along the roadway is a nonlinear curve. With the extension of ventilation time, the above nonlinear curve distribution pattern begins to develop into a linear distribution pattern. For example, the air temperature along the roadway with 300 days of ventilation is basically linear. At the same time, it can also be seen that on the spatial scale, along the roadway ventilation path, the airflow temperature gradually increases, but the rate of increase gradually decreases. On the time scale, with the extension of ventilation time, the temperature difference of airflow along the roadway gradually decreases. When the ventilation is 1 d, 7 d, 30 d, 90 d, 180 d and 300 d, the wind temperature of the roadway head is 39.63 ℃, 31.40 ℃, 26.66 ℃, 24.42 ℃, 23.41 ℃ and 22.84 ℃, respectively, which is 20.7 %, 37.2 %, 46.7 %, 51.2 %, 53.2 % and 54.3 % lower than the initial rock temperature T_0 (50 ℃).

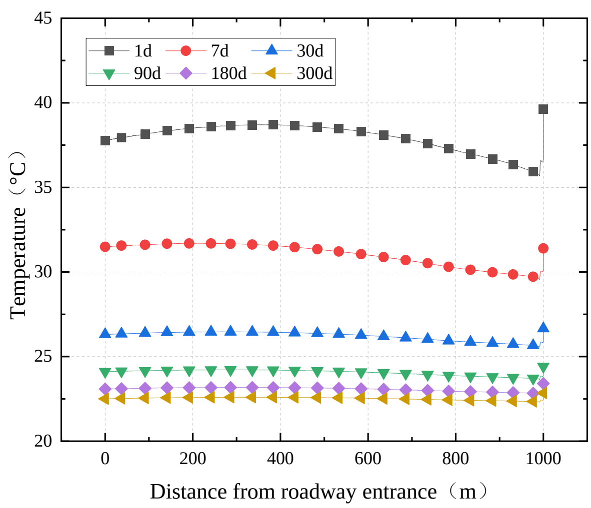


Figure 6. Transient Distribution Curve of Wind Temperature along the Roadway of Basic Model

4.2 Influence of Surrounding Rock Temperature on Air Flow Temperature Field

Fig 7 is the change curve of the wind temperature of the roadway under different surrounding rock temperatures. It can be seen that the air temperature in the roadway before ventilation is equal to the initial rock temperature. After the ventilation starts, the airflow temperature at the head of the roadway continues to decrease with time, but the rate of change gradually decreases. When the initial rock temperature is 30 ℃, the wind temperature at the head of the roadway decreases from 30 ℃ to 21.2 ℃ within 300 days, which is 29.3 % lower than the initial value. When the initial rock temperature is 40 ℃, the wind temperature at the head of the roadway decreases from 40 ℃ to 21.8 ℃ within 300 days, which is 45.4 % lower than the initial value. When the initial rock temperature is 50 ℃, the wind temperature at the head of the roadway decreases from 50 ℃ to 22.5 ℃ within 300 days, which is 55.1 % lower than the initial value. When the initial rock temperature is 60 ℃, the wind temperature of the roadway head decreases from 60 ℃ to 23.1 ℃ within 300 days, which is 61.6 % lower than the initial value. The greater the initial rock temperature is, the greater the airflow temperature is, and the greater the decrease of the airflow temperature at the head of the roadway after ventilation is.

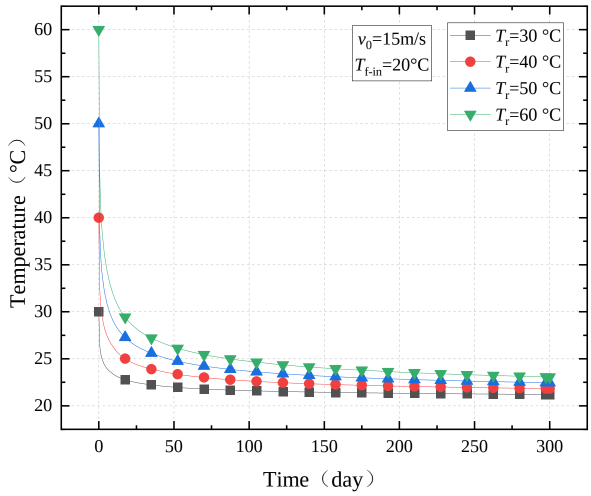


Figure 7. Variation Curve of Roadway Head-on Wind Temperature under Different Surrounding Rock Temperatures

Figure 8 (a) ~ (f) is the transient distribution curve of air temperature along the roadway when the ventilation time is 1 d, 7 d, 30 d, 90 d, 180 d and 300 d respectively. It can be seen that the heat exchange between the air flow with an initial temperature of 20 ℃ and the wall of the surrounding rock after entering the roadway makes the air temperature rise along the way. The greater the rock temperature, the greater the temperature rise of the air flow and the faster the temperature rise rate. At the beginning of ventilation, the distribution pattern of wind temperature along the roadway is a nonlinear curve. With the extension of ventilation time, the distribution pattern of the above nonlinear curve begins to develop into a linear distribution pattern. For example, when the original rock temperature is 30 ℃, the wind temperature along the roadway with ventilation for 300 days is basically linear.

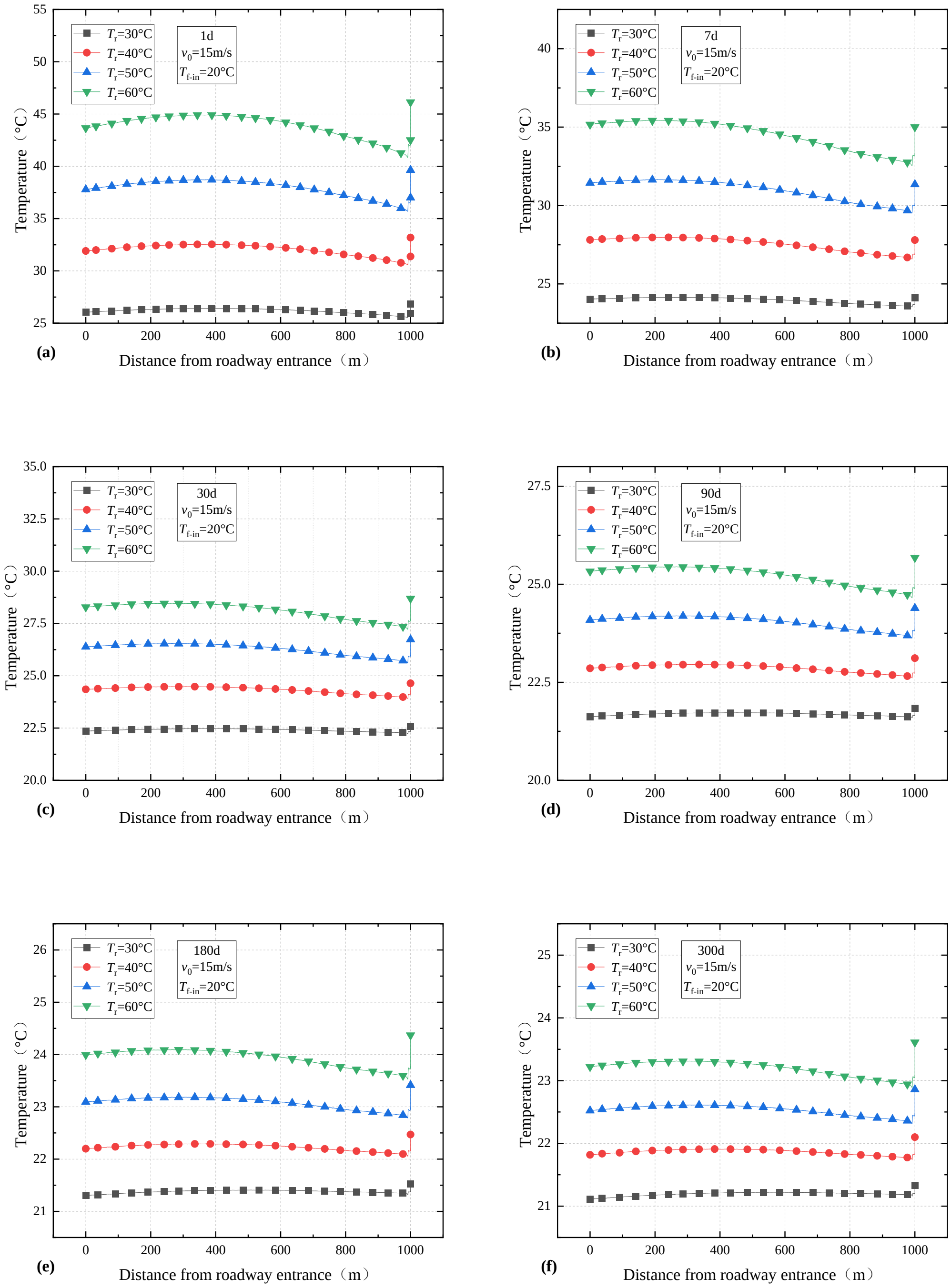


Figure 8. Transient Distribution Curve of Wind Temperature along the Distance under Different Surrounding Rock Temperatures

4.3 Influence of Inlet Air Temperature on Air Flow Temperature Field

Figure 9 is the wind temperature change curve of the roadway head under different inlet wind temperatures. It can be seen that after the start of ventilation, due to the airflow taking away the heat inside the roadway, the airflow temperature at the head of the roadway continues to decrease with time, but the rate of change is decreasing. When the inlet air temperature is 10 ℃, the wind temperature at the head of the roadway decreases from 50 ℃ to 13.5 ℃ within 300 days, which is 73.1 % lower than the initial value. When the inlet air temperature is 15 ℃, the wind temperature at the head of the roadway decreases from 50 ℃ to 64.1 ℃ within 300 days, which is 64.1 % lower than the initial value. When the inlet air temperature is 20 ℃, the wind temperature at the head of the roadway decreases from 50 ℃ to 22.4 ℃ within 300 days, which is 55.1 % lower than the initial value. When the inlet air temperature is 25 ℃, the wind temperature at the head of the roadway decreases from 50 ℃ to 26.9 ℃ within 300 days, which is 46.2 % lower than the initial value. The lower the inlet air temperature, the lower the air flow temperature, and the greater the decrease of the air flow temperature in the roadway after ventilation, and the air flow temperature gradually stabilizes with the extension of ventilation time.

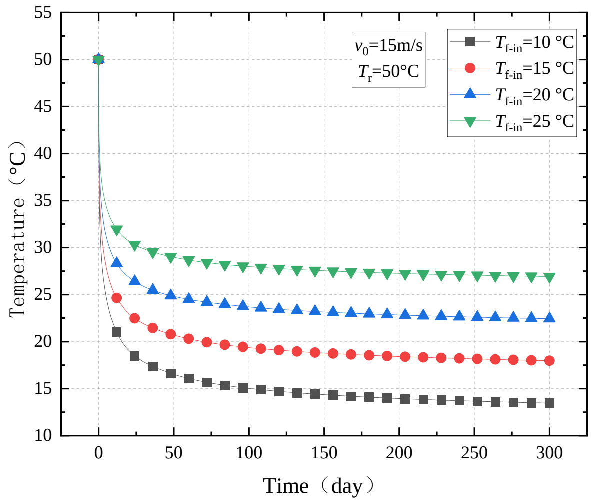


Figure 9. Variation Curve of Roadway Head-on Wind Temperature under Differentinlet Air Temperature

Figure 10 (a) ~ (f) is the transient distribution curve of air temperature along the roadway when the ventilation time is 1 d, 7 d, 30 d, 90 d, 180 d and 300 d respectively. It can be seen that the heat exchange between the air flow and the wall of the surrounding rock after entering the roadway makes the air temperature rise along the way. On the spatial scale, the lower the inlet air temperature is, the larger the temperature rise of the airflow is, and the faster the temperature rise rate is. The lower the inlet air temperature, the greater the temperature difference between the air and the roadway wall, and the higher the heat exchange efficiency. On the time scale, at the beginning of ventilation, the distribution pattern of wind temperature along the roadway is a nonlinear curve. With the extension of ventilation time, the distribution pattern of the above nonlinear curve begins to develop into a linear distribution pattern.

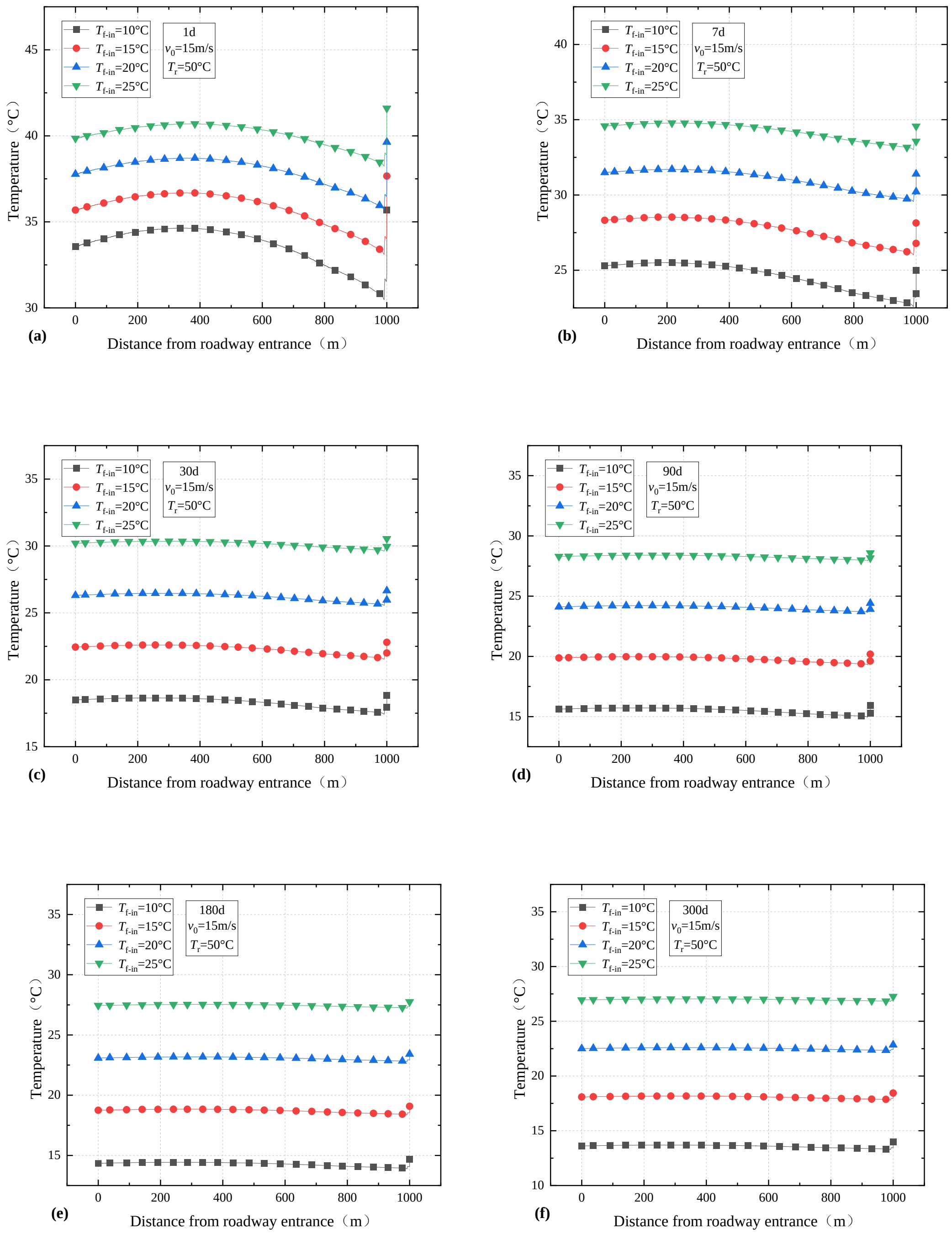


Figure 10. Transient Distribution Curve of Wind Temperature Along the Distance under Different inlet Air Temperature

4.4 Influence of Wind Velocity on Air Flow Temperature Field

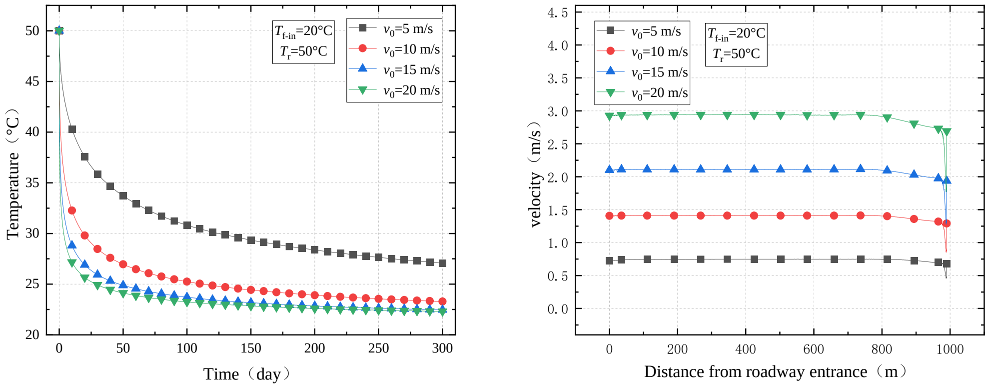


Figure 11. Variation Curve of Roadway Head-on Wind Temperature/Velocity under Different Wind Velocity

Figure 11 is the change curve of the wind temperature in the roadway / the change curve of the wind speed in the roadway under different wind speeds. It can be seen that after ventilation, because the airflow takes away the heat inside the roadway, the airflow temperature at the head of the roadway continues to decrease with time, but the rate of change is decreasing. When the wind speed of the air duct is 5 m/s, the wind speed in the roadway is 0.7 m/s, and the wind temperature at the head of the roadway decreases from 50 ℃ to 27.1 ℃ within 300 days, which is 45.9 % lower than the initial value. When the wind speed is 10 m/s, the wind speed in the roadway is 1.4 m/s, and the wind temperature in the roadway decreases from 50 ℃ to 23.3 ℃ within 300 days, which is 53.4 % lower than the initial value. When the wind speed is 15 m/s, the wind speed in the roadway is 2.1 m/s, and the wind temperature in the roadway decreases from 50 ℃ to 22.5 ℃ within 300 days, which is 55.1 % lower than the initial value. When the wind speed is 20 m/s, the wind speed in the roadway is 2.9 m/s, and the wind temperature at the head of the roadway decreases from 50 ℃ to 22.3 ℃ within 300 days, which is 55.4 % lower than the initial value. The greater the wind speed, the lower the airflow temperature, and the greater the decrease of the airflow temperature at the head of the roadway after ventilation, the airflow temperature gradually stabilized with the extension of ventilation time.

Figure 12 (a) ~ (f) is the transient distribution curve of air temperature along the roadway when the ventilation time is 1 d, 7 d, 30 d, 90 d, 180 d and 300 d respectively. It can be seen that the heat exchange between the air flow and the wall of the surrounding rock after entering the roadway makes the air temperature rise along the way. On the spatial scale, the smaller the wind speed, the greater the temperature rise of the wind flow, and the faster the temperature rise rate. At the beginning of ventilation, the distribution of wind temperature along the roadway is a nonlinear curve. With the extension of ventilation time, the distribution of the above nonlinear curve begins to develop into a linear distribution.

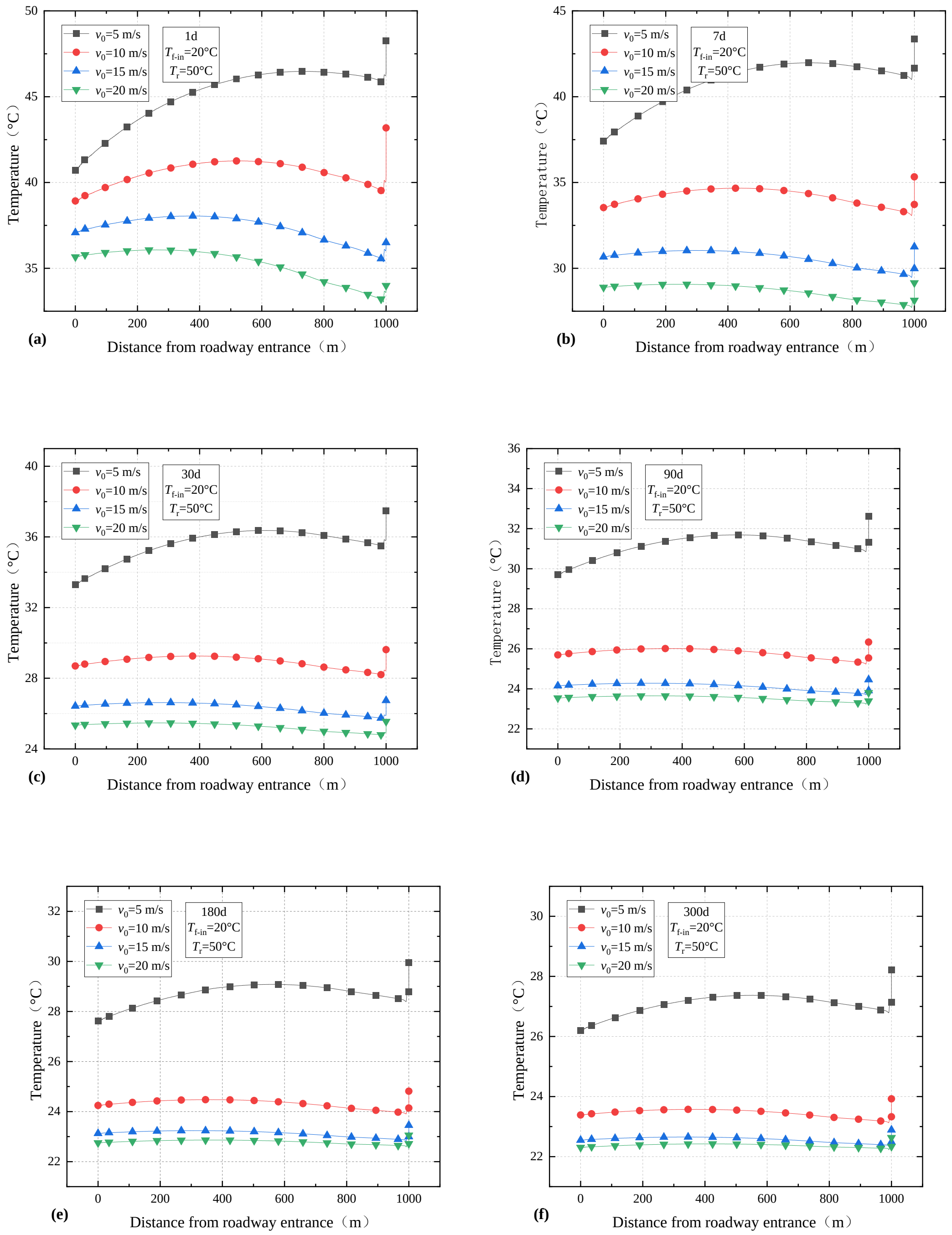


Figure 12. Transient Distribution Curve of Wind Temperature along the Distance under Differentinlet Wind Velocity

4.5 Influence of Thermal Conductivity of Surrounding Rock on Air Flow Temperature Field

Figure 13 shows the variation curve of wind temperature at the head of roadway under different thermal conductivity of surrounding rock. It can be seen that with the increase of the thermal conductivity of the surrounding rock, the temperature of the outlet increases gradually at the same time.

After the ventilation starts, due to the airflow taking away the heat inside the roadway, the airflow temperature at the head of the roadway continues to decrease with time, but the rate of change is decreasing. When the thermal conductivity of the surrounding rock is 1.5 W/(m·K), the wind temperature at the head of the roadway decreases from 50 ℃ to 22.0 ℃ within 300 days, which is 28 ℃ lower than the initial value. When the thermal conductivity of the surrounding rock is 2.0 W/(m·K), the wind temperature at the head of the roadway decreases from 50 ℃ to 22.2 ℃ within 300 days, which is 27.8 ℃ lower than the initial value. When the thermal conductivity of surrounding rock is 2.5 W/(m·K), the wind temperature at the head of roadway decreases from 50 ℃ to 22.4 ℃ within 300 days, which is 27.6 ℃ lower than the initial value. When the thermal conductivity of surrounding rock is 3.0 W/(m·K), the wind temperature at the head of roadway decreases from 50 ℃ to 22.5 ℃ within 300 days, which is 27.5 ℃ lower than the initial value.

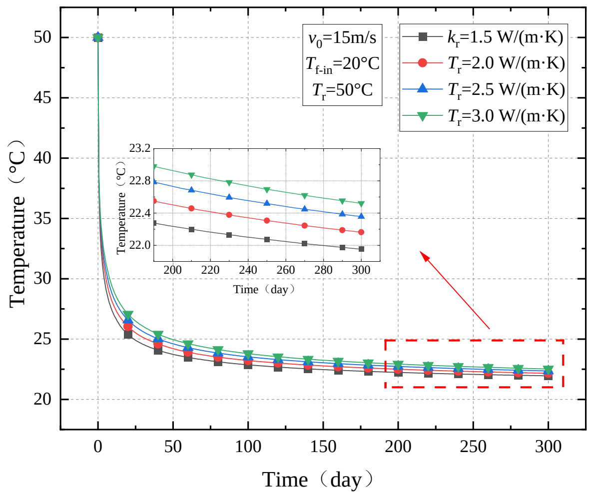


Figure 13. Variation Curve of Roadway Head-on Wind Temperature under Different Thermal Conductivity of Surrounding Rock

Figure 14 (a) ~ (f) is the transient distribution curve of air temperature along the roadway when the ventilation time is 1 d, 7 d, 30 d, 90 d, 180 d and 300 d respectively. It can be seen that the heat exchange between the air flow and the wall of the surrounding rock after entering the roadway makes the air temperature rise along the way. On the spatial scale, the smaller the wind speed, the greater the temperature rise of the wind flow, and the faster the temperature rise rate. At the beginning of ventilation, the distribution of air temperature along the roadway is a nonlinear curve. With the extension of ventilation time, the distribution of the above nonlinear curve begins to develop into a linear distribution.

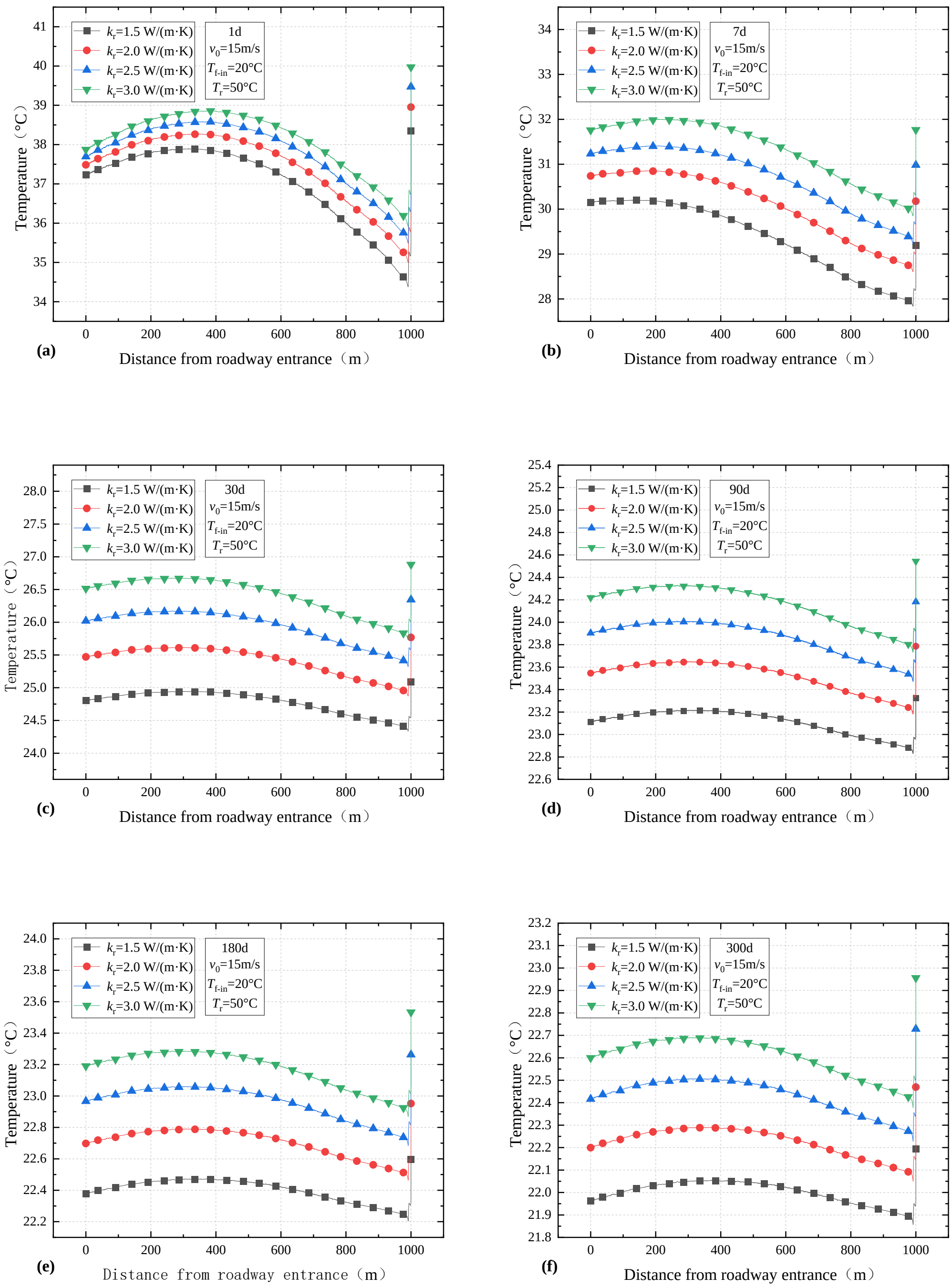


Figure 14. Transient Distribution Curve of Wind Temperature along the Distance under Different Thermal Conductivity of Surrounding Rock

5. Conclusion

In this paper, the relationship between tunneling roadway and wind speed, inlet air temperature, original rock temperature, and thermal conductivity of surrounding rock under long-term ventilation is studied by establishing a fluid-solid coupling heat transfer model of tunneling roadway. From the simulation results, the following conclusions can be drawn:

(1) Air temperature is a crucial factor affecting the temperature of the roadway. Reducing the air temperature at the entrance of the roadway is an effective way to alleviate the high-temperature heat damage in the underground working space. At the same time, the more significant the temperature difference between the wind temperature and the heat source, the greater the heat transfer power. Reasonable control of temperature difference is conducive to reducing cold air thermal pollution.

(2) Wind speed also has a significant impact on the temperature of the roadway. Increasing the ventilation rate is also an effective way to alleviate the high-temperature heat damage in the underground working space.

(3) High ground temperature and high thermal conductivity are important reasons for the high temperature of underground working space.

Data Availability

The experimental data and simulation data used to support the findings of this study are included within the article.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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