Simulation Analysis and Structure Optimization of Mine Brake Disc

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Abstract

Analysis of the generation and conduction mechanism of heat of mining brake disc during braking and the braking process of the brake disc is simulated in workbench.The braking process of solid brake disc, continuous floor and continuous floor brkae disc is simulated in different initial braking speed. The nephogram of temperature distribution and its variation are obtained and the reason for the change was analyzed and the effect of application was obtained. It provides reference for the design optimization of brake disc.

Keywords

Mining brake disc; Simulation analysis; Temperature variation law; optimal design.

1. Introduction

The brake principle of mine disc brake is hydraulic brake and spring force braking, which depends on the friction of brake shoe and brake disc.The maximum temperature of the brake disc must not exceed 150 degrees per hour for continuous braking of 10 times and no spark can be generated in an explosion-proof environment. With the heat of friction will make the brake disc heat deformation, this will reduce the braking effect, so the thermal mechanical coupling of brake disc is studied to optimize brake disc structure and improve its heat dissipation. This work is of great significance.

2. Theoretical Analysis of Thermal Mechanical Coupling

The essence of brake is a process of energy conversion and the kinetic energy of a moving device is converted to heat by friction. There are three basic ways of heat dissipation: heat conduction, heat convection and heat radiation. In the process of heat transfer in the brake disc and the brake shoe, an increase in temperature will produce thermal deformation and the thermal deformation will cause the uneven distribution of brake pressure. The region with large brake pressure will produce more heat, and the temperature rise is more obvious, so it is necessary to study the thermal coupling of the brake disc.

3. Model Establishment and Theoretical Calculation

3.1 Model Simplification

In this paper, the air cooled YZ-80 disc brake is studied. Because of the nonlinear factors, some assumptions are made:

(1) The brake disc and brake shoe are the same material and the pressure is distributed evenly on the brake shoe during the braking process.

(2) The friction coefficient does not change during the braking process.

(3) the braking torque is constant and the brake pressure remains constant during braking.

4. Theoretical Calculation of Temperature Field Heat Transfer

According to the law of conservation of heat, the amount of heat absorbed by a change in temperature is equal to the amount of heat flowing through the boundary and the heat emitted by the heat source.

$$\frac{\partial u}{\partial t}-a^2\left(\frac{\partial^2 u}{\partial x^2}+\frac{\partial^2 u}{\partial x^2}+\frac{\partial^2 u}{\partial x^2}\right)=f\left(x,y,z,t\right) \tag{1}$$

In style: $a^2=\frac{k}{c\rho}$, $f=\frac{F}{c\rho}$, ρ——material density, kg/m^3; c——specific heat capacity of materials, $J/\left(kg\cdot K\right)$; k——thermal conductivity of materials, $W/\left(m\cdot K\right)$; T——temperature,℃; t——time,s; $F\left(x,y,z,t\right)$——intensity of heat source in an object, W/m^3.

The three-dimensional heat conduction equation is derived from the law of conservation of heat, the Fourier heat conduction law and the heat equation. There is no heat source in the braking process, $F\left(x,y,z,t\right)=0$, in the absence of initial conditions and boundary conditions, it has infinite solutions and in order to obtain its unique solution, it is necessary to set the boundary conditions. In this paper, second kinds of boundary conditions are given:

$$T_0=T\left(x,y,z,t\right)=C \tag{2}$$

$$q=k\frac{\partial T}{\partial n}=T_1\left(x,y,z,t\right) \tag{3}$$

5. Finite Element Analysis of Brake Disc

5.1 Three Dimensional Finite Element Model

In order to better model the thermal mechanical coupling analysis, under the premise of not affecting the mechanical performance.the brake is simplified and only the brake shoe and the brake disc are retained.

5.2 Parameter Setting

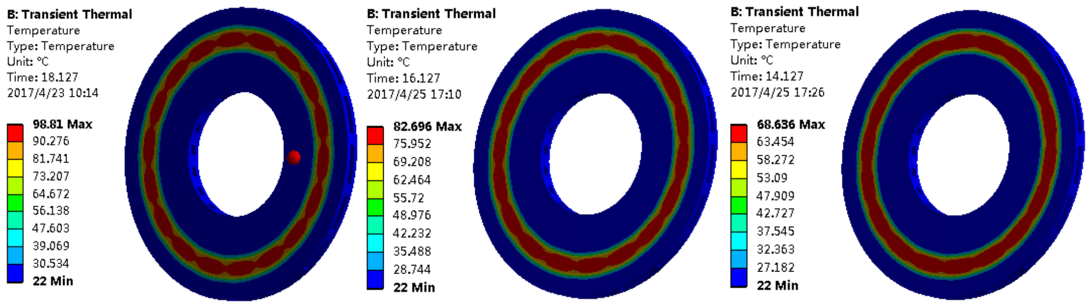
In this paper, the air cooled YZ-80 disc brake is studied. Analysis of temperature field of brake discs with different structures under different braking speeds. Friction coefficient $\mu=0.35$ between brake disc and brake shoe, brake logarithm $n=4$.

Table1. Thermophysical parameters of brake disc

parameters	density $/(kg\cdot m^{-3})$	thermal conductivity $/(W\cdot m^{-1}\cdot K^{-1})$	Specific heat capacity $/(J\cdot kg^{-1}\cdot K^{-1})$
numerical value	7850	56	435

5.3 Simulation Results Analysis

This paper focuses on the coupled thermal mechanical analysis of the continuous and discontinuous floor ventilation and solid structure brake disc disc under different initial braking speeds . The distribution and variation law of the temperature nephogram are obtained. As shown in Figure 1, the simulation results of different braking speeds:



(a) n=140r/min (b) n=120r/min (c)n=100r/min

Fig.1 Temperature nephogram at different speeds

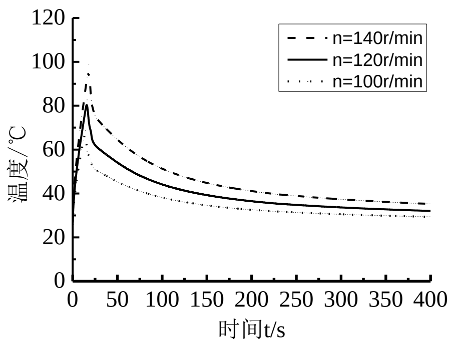
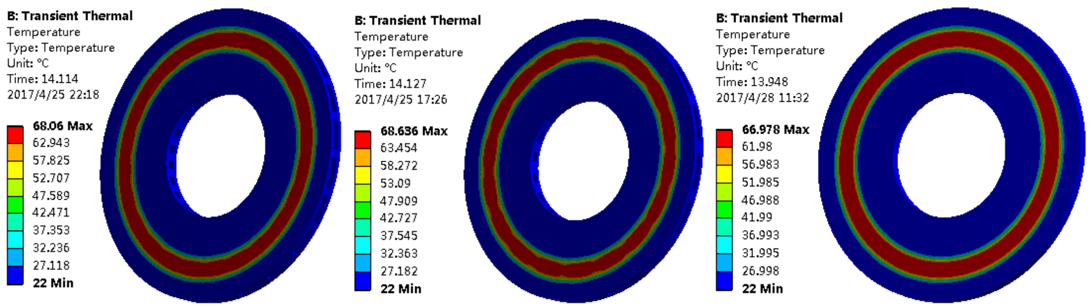


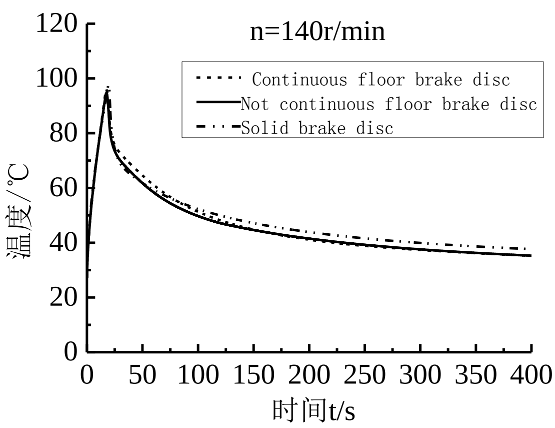
Fig.2 Temperature variation law

From Figure 1 and 2, the brake discs are braked at 140r/min, 120r/min, 100r/min rpm and the temperature profile is shown in Figure 1, the temperature variation is shown in Figure 2. Temperature changes in the braking phase, the temperature increased rapidly and the temperature of brake disc decreases gradually after braking. he maximum temperature is 98.81℃，82.696℃，68.636℃，The temperature difference is relatively large at different braking speeds.

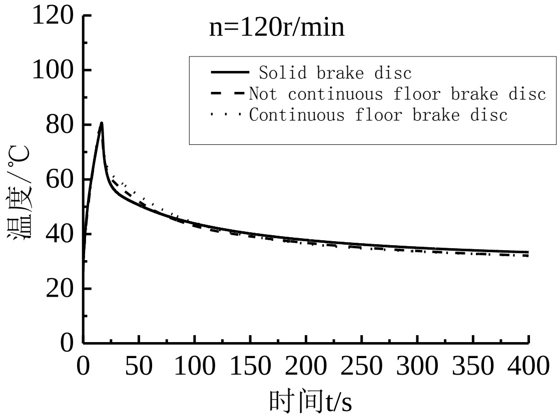


(a) Not continuous floor brake disc (b) Continuous floor brake disc (c) Solid brake disc

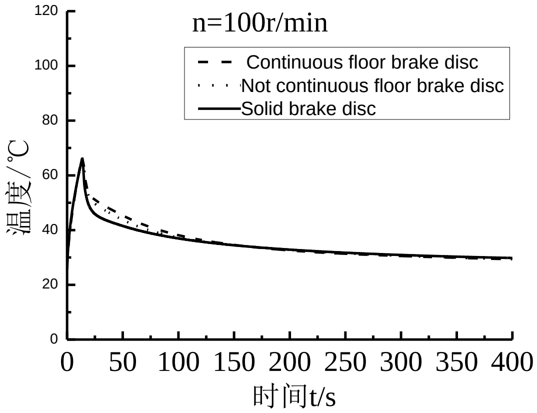
Fif.3 Temperature profile of different structures



(a)n=140r/min



(b) n=120r/min



(c)n=100r/min

Fig.4 Temperature variation of brake discs with different structures

As shown in Figure 3 and 4, brake discs with different structures are respectively under the initial speed of 140r/min, 120r/min and 100r/min.. The temperature profile is shown in Figure 3 and the temperature variation is shown in Figure 4. In the braking process, the maximum temperature of the solid disc is relatively low and the highest temperature of the ventilation disc is relatively high. Continuous floor of brake disc is relatively high, because in the braking process, the rate of heat transfer is greater than that of heat dissipation, but at the end of braking, the rate of continuous floor and continuous floor cooling is relatively fast. compared continuous floor and continuous floor, not continuous floor can more effectively resist deformation,so The braking effect of continuous floor is better.

6. Conclusion

In this paper, the theoretical analysis of the coupled heat engine is carried out and the theoretical model is established and calculated. The finite element simulation software Workbench was used to simulate the temperature change of the brake disc during braking and after the braking. The temperature distribution cloud chart and variation law of brake discs with different structures are obtained and the reasons for these changes are analyzed. The conclusions are as follows: at the beginning of the braking process, the temperature of the brake disc increases rapidly and the temperature decreases gradually after braking. Under different initial speed, the temperature difference is larger, the maximum temperature is proportional to the initial braking speed, the higher the initial speed, the greater the maximum temperature of the brake disc. On the premise of the same quality, the structure of the brake disc also affects the maximum temperature and heat transfer rate, the heat transfer rate of the solid disc is higher,but The cooling rate of the ventilated disc is faster.

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