Analysis of Transient Temperature Field of Automobile Ventilated Disc Brake

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Abstract: The front wheel disc brake with a common ventilation domestic car used as the research object, using ANSYS workbench to establish the finite element model of ventilated disc brakes, using direct coupling thermal structure to obtain the 10s average rate in the continuous downhill temperature field under braking, and the temperature field under the conditions of the distribution and change characteristics. At the same time, the bench tests under the same working conditions are carried out, and the experimental results are compared with the numerical results to verify the correctness of the model and the constraints imposed.
Keywords: Ventilated disc brake, Finite element model, Temperature field
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1. INTRODUCTION

Automobile braking is the use of friction between the brake friction, so as to drive the kinetic energy of the vehicle into heat energy, to reduce the speed of the car. Disc brake is widely used in automobile brake because of its stability, controllability and wide range of braking torque. In the braking process, 90% of the vehicle's kinetic energy is converted into heat energy, most of which is absorbed by the brake disc, and then the heat on the brake disc is scattered to the surrounding air by convection heat dissipation. As the top speed of the car continues to increase, the car will produce a lot of heat during the braking process, resulting in overheating of the brake disc. The heat dissipation of automobile brake disc has become the most important problem in the braking system of automobile. Therefore one has good heat dissipation performance of brake disc brake to avoid overheating caused due to some problems, such as local "hotspots", during the braking process "hot recession" phenomenon, the thermal stress caused by thermal fatigue crack and deformation caused by thermal jitter. In order to ensure the stability of the brake, it is necessary to analyze the braking process of the transient temperature field, the establishment of 3 dimensional geometric model and finite element model of ventilated brake disc by using the commercial finite element analysis software ANSYS Workbench, and transient temperature field analysis.

The front wheel disc brake ventilation based on the ordinary domestic car used as the research object, using direct coupling thermal structure to obtain the distribution characteristics and variation characteristics of temperature field during the emergency braking, and bench test under the same conditions of the project, and the experimental results were compared with the results of numerical calculation.

2. A PHYSICAL MODEL OF A VENTILATED DISC BRAKE

The physical model of the ventilated disc brake is mainly used to calculate the transient temperature field of the ventilation disc. In order to take into account the accuracy and efficiency of numerical calculation, the structure of the brake is simplified, the flange structure of the ventilation disk is omitted, and the part of the chamfer which has little influence on the calculation results is omitted. Fig. 1 is a three-dimensional geometry model of ventilated disc brakes and friction discs after simplification.

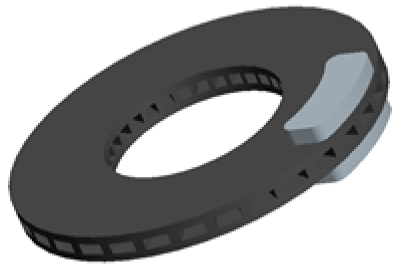


Fig. 1 A three-dimensional geometry model of ventilated disc brakes

3. FINITE ELEMENT MODEL OF VENTILATED DISC BRAKE

(1) Basic assumptions of the model

By using direct coupling thermal structure method of transient temperature field in a ventilated disc brake braking conditions are analyzed, and in the actual process of the transient temperature field will be affected by many factors, ignoring some factors that influence the small premise in accords with the actual working condition of the brake, so the basic assumptions in are as follows analysis before:

(a) In the analysis, not considering the possible

vehicle wheel locking during braking drag state of slide or roll slide.
(b) Assume that the pressure acting on the friction plate is constant and uniformly distributed throughout the braking process.
(c) Assume that the material that makes up the brake disc and friction plate is isotropic elastic material.
(d) The wear of the friction plate and the brake disc is not considered during the analysis.
(e) Considering the influence of heat radiation on the transient temperature field of the brake disc is small and the calculation is complex, and the time of the emergency braking is usually very short, so the thermal radiation is not considered in the analysis.

(2) Mesh generation of ventilated disc brakes
In order to ensure the efficiency and convergence of iterative calculation, element partition and local optimization using solid model to divide the model hexahedral mesh, mesh using the neutral axis sweep algorithm, classification, the final classification results as shown in figure 2. Among them, the number of units is 17370, and the number of nodes is 25821.

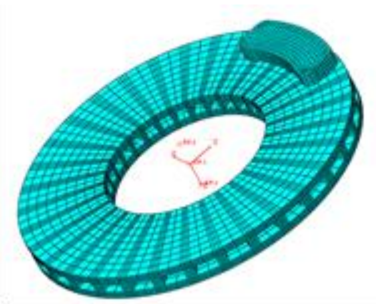


Fig. 2 Sketch map of mesh generation

4. DETERMINATION OF BOUNDARY CONDITIONS AND CALCULATION DATA

(1) Heat transfer equation of ventilated disc brake
The three-dimensional transient temperature field of the brake disc and the friction plate:

$$\rho_d c_d \frac{\partial T_d}{\partial t} = k_d \left[\frac{\partial}{\partial x}(\frac{\partial T_d}{\partial x}) + \frac{\partial}{\partial y}(\frac{\partial T_d}{\partial y}) + \frac{\partial}{\partial z}(\frac{\partial T_d}{\partial z}) \right]$$

$$\rho_p c_p \frac{\partial T_p}{\partial t} = k_p \left[\frac{\partial}{\partial x}(\frac{\partial T_p}{\partial x}) + \frac{\partial}{\partial y}(\frac{\partial T_p}{\partial y}) + \frac{\partial}{\partial z}(\frac{\partial T_p}{\partial z}) \right]$$

(2) Thermal boundary of ventilated disc brake
In order to make the heat conduction equation have unique solution, it must satisfy the single value condition: the initial condition is the temperature of the brake disc and the friction plate at any time and at any point (known as the temperature boundary).

$$T = T_0$$

Second boundary conditions assume that the normal derivatives of the boundary variables of the brake disc and friction plate are known (given heat flow boundary).

$$q(x,y,t) = \lambda(\frac{\partial T}{\partial x} + \frac{\partial T}{\partial y} + \frac{\partial T}{\partial y})$$

The third boundary condition is that the heat transfer condition of the brake disc and friction plate at any point and at any time is known (convection heat transfer boundary).

$$q = h(T - T_C)$$

Where h is the convection heat transfer coefficient, and Tc is the external environment temperature.
(3) Calculation of thermal load of ventilated disc brake
The heat flux density of the friction input between the brake disc and the friction plate is satisfied:

$$q(x,y,t) = \mu p(x,y,t) v(x,y,t) = \mu \frac{F(x,y,t)}{A}$$

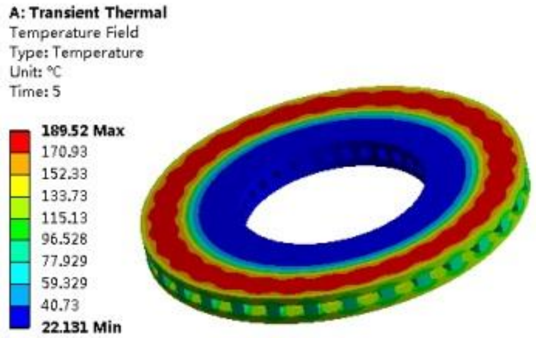
Where q (x, y, t) is the input heat flux friction; friction coefficient mu; p (x, y, t) is the friction surface pressure; v (x, y, t) is the relative speed of the brake disc and friction plate; F (x, y, t) is the brake pressure; A is the brake disc and the friction contact area; ω (x, y, t) is the angular velocity of rotation of the brake disc.
η is the heat flux distribution coefficient of brake disc and brake:

$$\eta = \sqrt{\frac{\rho_d c_d \lambda_d}{\rho_p c_p \lambda_p}}$$

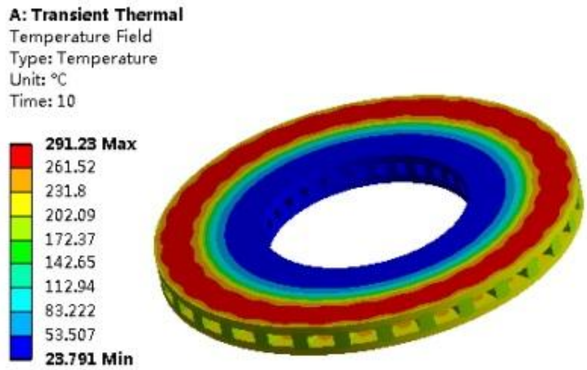
(4) Braking condition setting
The total time of heat transfer analysis under braking condition is 120s, and the time step is 1s. The temperature distribution of the model under the braking condition of the continuous 10s average speed downhill is calculated.
(5) Model constraints and loads
According to the actual situation, the friction plate does not move, and the brake disc moves in a circle. Therefore, the two sides of the X and Y axes are fixed on the back of the friction plate. The central plane of the disk is axially fixed along the Z direction. Since the inner hole of the disc is connected with the shaft, a fixed constraint of the Z axis is applied on the inner side of the disk. For the reference points established in order to simulate the deceleration motion, only the degree of freedom of the circumferential rotation is released, and the freedom of the other directions is restrained. The load of the whole model is only applying pressure load on the back of the friction plate.

5. SIMULATION AND ANALYSIS OF TEMPERATURE FIELD OF BRAKE

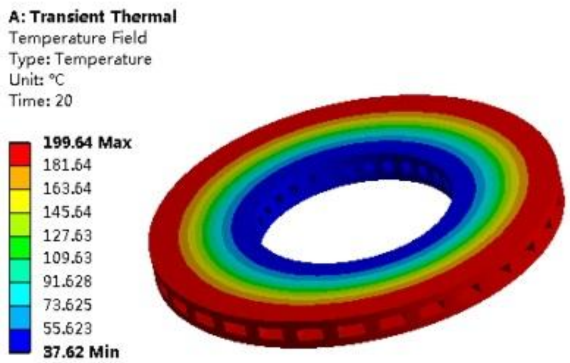
The transient temperature field of the ventilation disc can be obtained by the finite element calculation, as shown in figure 3. The figure can be seen in different times of the temperature field of ventilated discs showed significant differences, the conduction rate conduction rate temperature in the axial direction is larger than the radial direction; when the heat load of the stop input, as time went on, the convection heat transfer effect is more obvious; at the moment of 80s appeared obvious "hot spot temperature" phenomenon; affected by the distribution of the heat transfer coefficient of convection ventilation space, and 120s disk in 100s times of the diameter temperature is greater than the diameter of temperature.



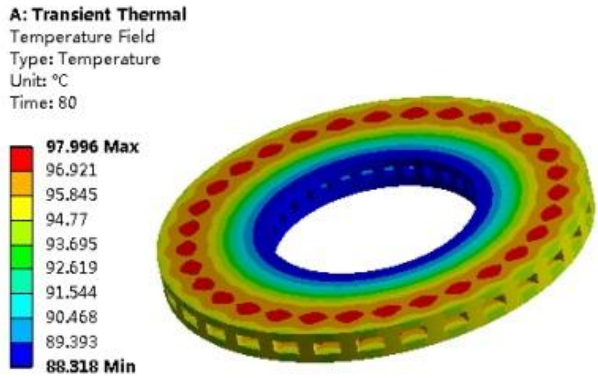
(a) 5s



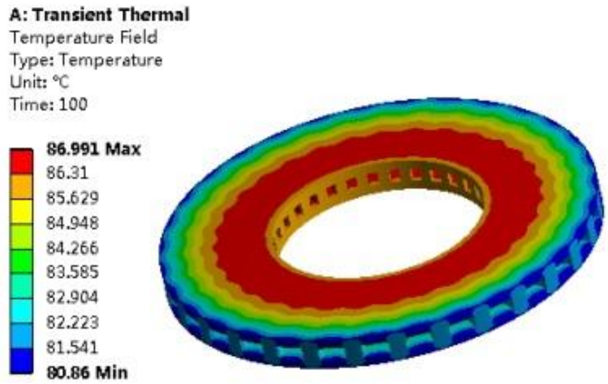
(b) 10s



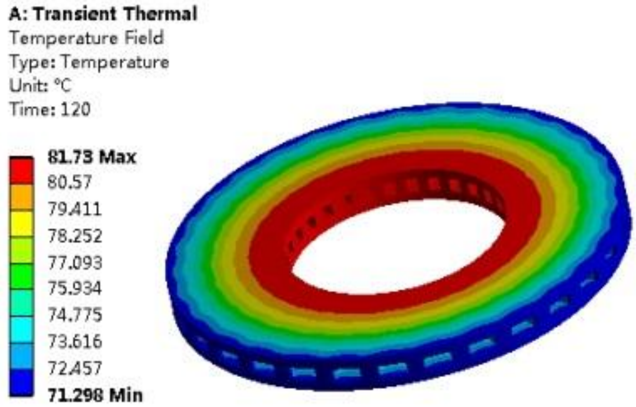
(c) 20s



(d) 80s



(e)100s



(f) 120s

Figure 3: nephogram of temperature field of ventilation plate at different time

In the 0~10s period, the maximum temperature Tmax and the minimum temperature Tmin change curve on the surface of the draft tray are shown in figure 4. The figure can be seen: Tmax heating rate in 0~1s very fast, Tmax heating rate in 1~10s stable; Tmax heating rate in 10~13s in rapid cooling rate; Tmin in the whole process showed first increased and then decreased, at 81s, Tmax and Tmin value to the after show gradually away from friction surface temperature is greater than the friction surface temperature near the position of the phenomenon.

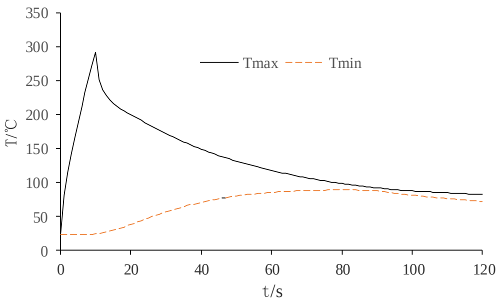


Fig. 4 Extreme temperature variation curve

6. EXPERIMENTAL VERIFICATION

In order to verify the simulation results, the research on ventilated disc brake of the brake test bench under the same conditions with the simulation in the radial direction of the brake disc is arranged on the measuring point to obtain the temperature value. Fig. 5 is a comparison between the measured temperature of the temperature measuring point and the corresponding simulation value of the finite element. The maximum error between the measured temperature and the simulation value appears at the initial point, the maximum error is 20 degrees centigrade, and the average error of the temperature is within 11 degrees. The test results verify the reliability of the simulation.

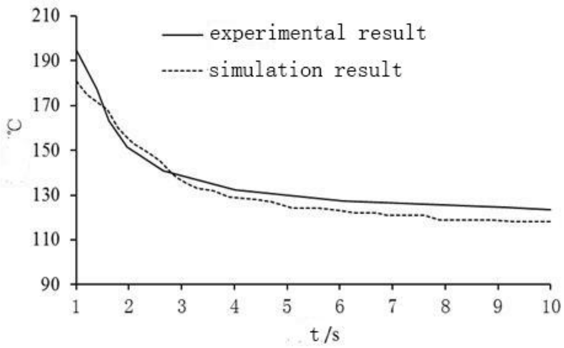


Fig. 5 Comparison of simulation results and test results

CONCLUSION

The three-dimensional geometric model and finite element model of disc brake are established in this paper. The transient temperature field of the brake disc in the braking process is solved, and the conclusions are as follows:

①ventilated disc brake disc brake in the process of the early transfer rate of temperature in the axial direction of the transmission rate is greater than the radial direction; when the brake after the end, with the time extension, the convection heat transfer effect is more apparent, at time 80s appeared obvious temperature "hot" phenomenon, influenced by the distribution of the heat transfer coefficient of convection space ventilation, disk in 100s and 120s moment under the temperature is greater than the temperature outside diameter.

②the maximum temperature of the surface of the ventilation disc is 0~1s, the heating rate is very fast, and soon reaches the highest temperature on the surface of the ventilation tray, and remains stable in 1~10s. The cooling rate is faster within 10~13s, and then gradually tends to be gradual.At the same time a bench test under the same conditions of ventilated disc brakes, and the experimental results are compared with numerical results, verify the correctness of the model and constraints, provides a theoretical basis for future research on ventilated disc brake.

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