Study on Thermal Performance of Silicon Oil Clutch for a Cooling Fan

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Abstract. In this paper, a silicone oil fan clutch is taken as the research object. The finite element model of the clutch is established in the form of hexahedral mesh by using HyperMesh software. The thermal field and flow field are coupled in the model and simulated. The temperature distribution of the front and rear ends of the clutch is simulated and analyzed. The relationship between the number of radiating ribs and the temperature distribution of the front and rear ends of the clutch is analyzed. The temperature distribution of the front and rear ends of the clutch is tested by the silicone oil fan clutch performance test rig. The experimental results are consistent with the simulation results, and which shows that the finite element model is feasible. The influence of the number of radiating ribs and the internal structure of the clutch on the heat dissipation performance of the silicone oil fan clutch is calculated and studied. The results have important guiding significance for improving the silicone oil fan clutch and shortening the development cycle of the clutch.

1. Introduction
Silicone oil fan clutch is a liquid viscous transmission device which uses silicone oil as medium to transfer torque by its high viscous characteristics. It is a clutch device between automotive engine and cooling fan. In order to make the car comfortable, a lot of analysis and research on fan clutch have been done at home and abroad in recent years[1].

The main structure of the silicone oil fan clutch is shown in Figure 1. Silicone oil clutch uses silicone oil as working medium and uses its high viscosity characteristics to transfer torque. When the engine temperature rises to a certain value, the thermostat is heated and deformed to drive the valve piece to open, the silicone oil flows to the working chamber[2], and the driving plate meshes with the driven body, thus driving the fan to run at high speed. When the temperature decreases, the temperature sensor feels low temperature, the valve disc closes, the silicone oil in the working chamber returns to the oil storage chamber through the oil return hole under centrifugal force, and the clutch is in a separate state[3]. Silicone oil fan clutch can make the engine work at the optimum temperature and reduce the power consumption of the fan effectively by realizing the interaction between engine temperature and fan speed.
At present, the research on silicone oil fan clutch mainly focuses on the clutch structure parameters, transmission torque and the analysis of speed regulation acuity and so on, while the heat dissipation performance of the coupling calculation and analysis of thermal field and flow field on the clutch outer surface is relatively small[4]. Silicone oil fan clutch is a new type of transmission device which uses the viscous shearing force of silicone oil to transfer torque. With the increase of temperature, the viscosity of silicone oil decreases and the viscous shearing force decreases[5-6]. At high temperature, the clutch and the fan can not be effectively engaged, which affects the cooling intensity of the fan clutch, so that the noise and energy consumption of the fan will increase. Therefore, it is of great practical significance to analyze the heat dissipation of silicone oil fan clutch and to study its heat dissipation performance parameters.

This paper takes a silicone oil fan clutch as the research object, establishes its finite element model and calculates and analyses it with fluent software, and obtains the temperature value of the clutch surface. The heat dissipation performance of the silicone oil fan clutch is analyzed, and the influence of different parameters on its heat dissipation performance is compared. Finally, the correctness of the simulation model is proved by comparing the experimental and calculated values of the performance of the silicone oil fan clutch.

2. Model establishment

2.1. Finite element model of silicone oil fan clutch
The outer diameter of the silicone oil fan clutch is about 184 mm, the height of the radiating rib on the front end is 18 mm, the height of the radiating rib on the back end is 14 mm, and the thickness of the rib is 1.2 mm. Considering the air flow in the rotating process of the radiator, a grid of flow field area is needed outside the radiator. A cylindrical pipe with a radius of 200 mm and a length of 1000 mm is set up in the flow field.

On the premise of guaranteeing the mechanical characteristics and calculation accuracy of the clutch, it is necessary to simplify the actual structure so that it can be easily modeled and solved and conform to the actual situation. The finite element model is shown in Figure 2. In this paper, the finite element model of the clutch is established in the form of hexahedral mesh by using HyperMesh software. There are 20148 mesh elements in the model, and the mesh size is in the range of 0.6-2 mm.

2.2. Boundary conditions for simulated computation
The input load including heat source load, clutch speed and the thermophysical parameters of material must be determined first in the simulation calculation of heat dissipation[4]. The fan clutch is driven by the crankshaft of the engine in the working process, so the speed of the fan clutch is set to be close
to that of the crankshaft, the speed of the crankshaft is 2000 r/min. The silicone oil in the working chamber is used as the boundary condition of the heat source, and the heat flux is used as the heat load input. The heat flux is the heat flux passing through the unit area in a unit time[7]. For the solid heat source in the silicone oil fan clutch, i.e. the heat flux of the silicone oil heat source, this paper defines the heat flux as the heat generated per unit volume of the heat source body.

In the finite element analysis of the temperature of silicone oil fan clutch, it is very important to make the loaded boundary conditions reflect the real working conditions correctly. In the simulation calculation, the outer surface of the clutch is taken as the thermal convection boundary condition, and the outer surface is set as the coupling surface of the flow field and the thermal field; the turbulence specification of the inlet and outlet is input by the method of strength and hydraulic diameter, the inlet is taken as the wind speed of 1m/s, and the outlet is set as the pressure outlet; the pipe wall can be regarded as the wall boundary condition and set as the adiabatic surface; and the ambient temperature is set at 30.7℃.

2.3. Calculation and analysis

Figure 2 (a) is the temperature distribution cloud of the front end of the clutch, and Figure 2 (b) is the temperature distribution cloud of the rear end of the clutch. From Figure 4, it can be seen that the temperature of the clutch shell surface is in the range of 46℃-52℃, and the temperature difference is in the range of 5℃-7℃. The temperature of the front end of the clutch is similar to that of the back end housing, while the temperature of the front end housing is lower. The temperature of the front end rib is obviously lower than that of the rear end rib, because the front end of the clutch is windward, and the height of the front end rib is slightly higher than that of the back end rib by 2 cm.

The nephogram of temperature distribution at the local surface of the silicone oil fan clutch shell is shown in Figure 3 (a), and the temperature distribution nephogram at the cross section of the clutch in the pipeline flow field is shown in Figure 3 (b). Figure 3 shows that the temperature of the groove between the surface radiator rib and the radiator rib of the clutch shell is the highest, while the temperature from the transition between the surface radiator rib and the radiator rib to the top of the radiator rib decreases gradually (the temperature decreases by 7℃). This shows that the radiator rib on the surface plays an important role in the radiation of the clutch.
2.4. Discussion the results of experiments and calculations

Silicone oil fan clutch performance test-bed includes mechanical transmission part and control system part. The control system mainly includes temperature control and input speed control. The main purpose of the test-bed is to simulate the working condition of the engine, create a similar working condition with the engine on the test-bed, and determine the performance index of the silicone oil fan clutch.

In the experiment, the speed of the clutch is controlled by the control system to about 2000 r/min, and the temperature of the outer surface of the clutch is relatively stable by the temperature sensor. Stop the operation of the motor and use the infrared thermometer to get the temperature value at the observation point. The observation point is shown in Figure 4. The observation point 6 in Figure 4 uses the thermistor temperature sensor to go deep into the silicone oil chamber to measure the silicone oil temperature value. The obtained temperature values are compared with the corresponding temperature values of the calculated results, as shown in Figure 5.

Figure 3. Cloud image of temperature distribution on the outer surface and cross section of clutch

Figure 4. Temperature Observation Points in the Test
Figure 5. Comparisons between calculated and measured results

Figure 5 compares the finite element calculation and experimental measurement of the temperature at the observation point of the silicone oil fan clutch. From the comparative analysis of Figure 5, it can be seen that the calculated results have the same trend as the measured temperature values, which shows that the simulation model of silicone oil fan clutch heat dissipation conforms to the actual working situation of silicone oil fan clutch heat dissipation.

3. Effects of various parameters on the thermal performance

By changing the structure parameters, such as quantity, clutch surface ribs clutch internal structure, analysis of the effects of various parameters on the thermal performance, which can provide the data basis for design.

3.1. Number of radiating ribs

Setting radiating ribs on the surface of the clutch shell is one of the structural measures to improve the heat dissipation and ventilation of the clutch. The number of radiating ribs on the clutch shell surface in model 1 is reduced by 1/2 (hereinafter referred to as model 2). The temperature values of the corresponding observation points on the clutch surface calculated are shown in Figure 6. It can be seen from the graph that the temperature of the clutch outer surface increases obviously with the decrease of the number of clutch upper ribs, and the average temperature increases by 20-30°C. So the number of radiating ribs has an important impact on the heat dissipation effect of the clutch.
3.2. Clutch internal structure

From the structural analysis of the working chamber in the clutch, it can be seen that the discharge pressure has a great relationship with the clearance between the active plate and the shell. On the basis of model 1, which is the original model, the clutch finite element models of model 3, model 4 and model 5 are established, as shown in Figure 8. The heat source volume of model 2 is changed to 1/4 of the original volume, and is biased to the front end. The heat source volume of model 3 is about 2 times of the original volume and the stepped height of the inner surface of the clutch is reduced from 3 mm to 1 mm. The heat source volume of model 5 is about 1/2 of the original volume and the stepped height of the clutch is stretched 1 mm. According to the calculation results, as shown in Figure 8, the surface temperature of the clutch in model 3, 4, 5 has little change compared with that in model 1. It can be concluded that the influence of the internal structure of the clutch on the heat dissipation effect of the clutch is not obvious.

4. Concluding

In this paper, the finite element model of the clutch is established. The temperature of the silicone oil fan clutch after heat dissipation stabilization is calculated by CFD. The feasibility of this calculation scheme is verified by the performance test of silicone oil fan clutch. After a lot of calculation experiments, the influence of geometric structure transformation on the calculation results of heat dissipation is analyzed through the transformation model structure, such as the number of heat sinks on the surface of clutch, the internal structure of clutch, and the analysis and summary of the influence of environmental temperature, pipe diameter, clutch speed, radiation model and other parameters on the calculation results are made. The reasons for the deficiencies and the areas needing improvement are found out. The results of calculation are all within the allowable range of Engineering errors, so
the calculation method of heat dissipation of silicone oil fan clutch has reference value, and the calculation results have important guiding significance for shortening the production cycle of products.

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