Temperature field study of hot water circulation pump shaft system

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Abstract. In the process of engineering application under the condition of hot water circulation pump, problems of stress concentration caused by the temperature rise may happen. In order to study the temperature field in bearing and electric motor chamber of the hot water circulation pump and optimize the structure, in present paper, the model of the shaft system is created through CREO. The model is analyzed by ANSYS workbench, in which the thermal boundary conditions are applied to calculate, which include the calorific values from the bearings, the thermal loss from electric motor and the temperature from the transporting medium. From the result, the finite element model can reflect the distribution of thermal field in hot water circulation pump. Further, the results show that the maximum temperature locates in the bearing chamber.The theoretical guidance for the electric motor heat dissipation design of the hot water circulation pump can be achieved.

1. Introduction

It is significant to explore the internal temperature distribution of the bearing chamber in the study of hot water circulating pump, because mechanical seals and bearings are most easily going wrong in the process of daily use.

Andrzej Sluialec[1] studied the thermoelectric problems in using process of inductive bearings, and built the heat transfer of electromagnetic field and temperature field equations analysis of inductive bearings. The relationship between bearing speed, frequency and temperature field was obtained by numerical calculation analysis. A. Dadouche et al[2] analyzed the characteristics of thrust bearing in fixed equipment, and studied experiments to verify thermal-fluid model of the thrust bearing, discussed respectively the effects of the load, rotation speed and temperature on the thrust bearing performance. Ryosuke Shiraishi et al[3] estimated the speed decline amplitude of bearing rotor through coupled numerical simulation of the electromagnetic field and heat transfer of superconducting magnetic bearings, according to the temperature increase caused the uneven distribution of the magnetic field so that the superconducting magnetic bearing rotor generated imbalance electromagnetic torque. Gong Enxiang[4] used probability design system(PDS) provided by ANSYS software，and analysed the probabilistic of shaft based on APDL parametric modeling ,and obtained the probability distribution.

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Aiming at the study of LPm125 type hot water circulating pump bearing chamber structure characteristics, the shafting temperature field and stress field including motor rotor were studied, considering mainly the heat generated in the bearing and motor operates. Hot water circulating pump shaft system studied in this paper includes mainly pump bracket, a pair of deep groove ball bearings, motor cover, motor rotor and the motor shaft.

2. The basic theory to calculate bearing heat[5]

2.1. Bearing heat calculation
Bearing system of LPm125 type hot water circulating pump in the study is a pair of single row radial ball bearings, and model is 6202-2RZ, with thin oil lubrication. The calculation of the bearing heat is particularly important, which is calculated by the following formula:

$$Q = 1.05 \times 10^{-4} M_n \tag{1}$$

where Q is bearing heat(kW), M_n is bearing friction torque(N m).

2.2. Rolling friction torque
Palmgren[6] obtained the empirical formula from the summarized result in the measurement by different loads and different lubricant viscosity, as well as the conditions under different speed of the bearing friction torque. However, the 6202-2RZ deep groove ball bearing in this paper is a standard part. The calculation of the friction torque is given in Eq. (2) as:

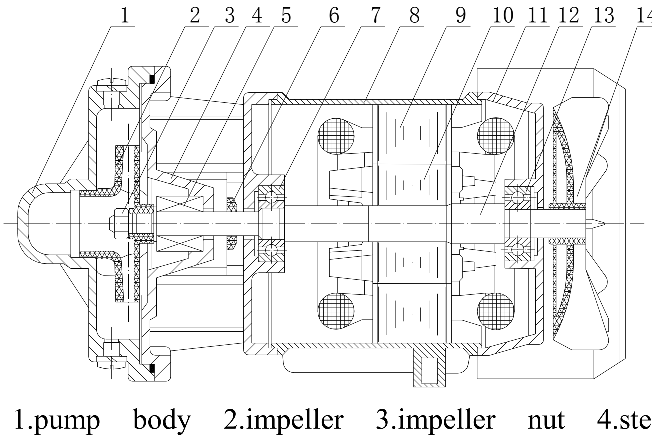
$$M = 0.5 \mu P d \tag{2}$$

where M is bearing friction torque(N m), μ is bearing friction coefficient, P is bearing equivalent dynamic load(N), d is bearing nominal bore(mm).

2.3. Equivalent dynamic load calculation of bearing
The 6202-2RZ deep groove ball bearings of the hot water circulation pump in this paper mainly take radial load Fr effect, its equivalent dynamic load P is expressed as:

$$P = f_p F_r \tag{3}$$

Where fp is load factor concern with the machinery smooth operation.



1.pump body 2.impeller 3.impeller nut 4.stent 5.mechanical seal 6.water deflector 7.front bearing 8.motor shell 9.motor stator 10.motor rotor 11.motor rear cover 12.pump shaft 13.back-end bearing 14.blade
Figure 1. structure assembly drawings of LPm125 type hot water circulation pump

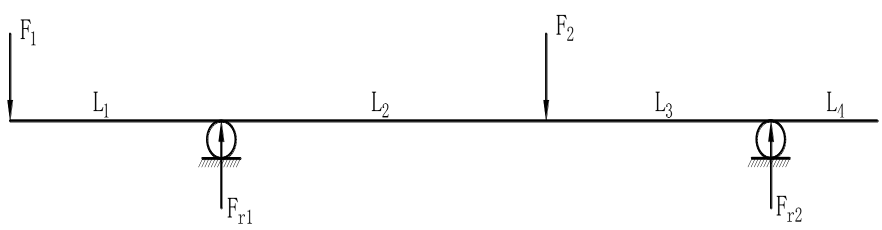


Figure 2. simplified hot water circulation pump rotor system

Figure. 1 shows the structure assembly drawings of LPm125 type hot water circulation pump .The rotor system of hot water circulation pump should be simplified when calculates radial load of bearing. Figure. 2 shows the simplified hot water circulation pump rotor system.

3. Hot water circulation pump shaft system temperature field calculation

3.1. Establishment of three-dimensional model and meshing of hot water circulation pump shaft system

The chamber temperature field which consists of LPm125 type hot water circulating pump shaft system is studied, and the three dimensional model of the hot water circulation pump shaft structure is built by Pro / E software. Using Workbench automatic mesh partition function generates its solid domain grid which resolution is moderate, with a total number of 461,217 grid cells, and the number of nodes is 791,199.Hot water circulating pump shaft structured grid shown in Figure 3.

Figure 3. Hot water circulating pump shaft structured grid

3.2. Loading conditions imposed

The load which is in the process of finite element simulation analysis and calculation contains not only the force acting on the finite element model function, but also the constraints imposed by the finite element model. The load which is applied in the finite element calculation, includes two ways entity model load and finite element model load. ANSYS-Workbench finite element analysis software is used to simulate shaft temperature field of hot water circulation pump in this paper and thermal load applied method of those is solid loading. That is the thermal load of the steady temperature field model loaded directly on the physical model (the main load on the face of the solid model unit).

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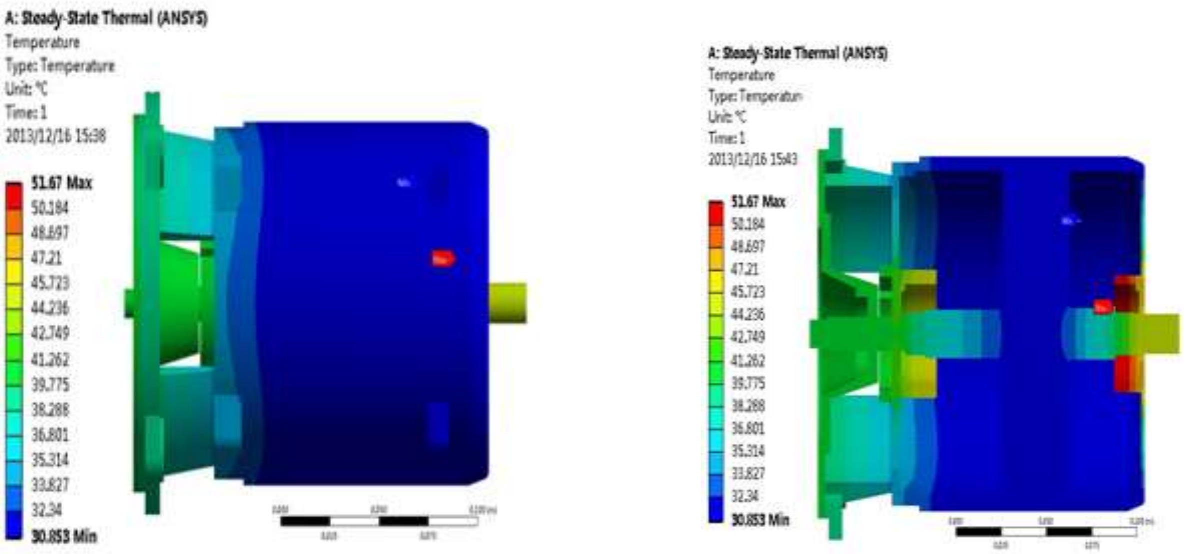
The thermal load of Simulation of hot water circulation pump shaft system temperature field includes the heat flux when bearing working, which is applied in two rolling interior chamber. The process of applying the thermal load on the bearing should pay attention to load respectively heat flux in the two bearing chamber .Due to thermal convection heat generated by the motor during operation, the convection of heat boundary conditions is applied on the motor chamber surface, that the convective heat transfer coefficient h is 27.1573 $W/(m^2 \cdot k)$ .Because some parts of bracket contact with the transport medium ,which possess a certain temperature, the medium temperature is 40 ℃, and the temperature load is applied directly to the contact structure surface of bracket and transport medium.

4. Results and discussion

4.1. Analysis of shaft structure steady temperature field

The shaft structure steady temperature field is analyzed by the steady-state thermal analysis module of ANSYS-Workbench. In calculation, the materials of pump bracket, motor housing, motor cover are gray cast iron, and the materials of shaft and rotor are stainless steel. The most important parameter of structural materials in calculation of steady temperature field is thermal conductivity of materials. The thermal conductivity of gray cast iron and stainless steel is respectively 52 and 15.1 $W/(m \cdot k)$.



(a) whole structure (b)sectional structure

Figure 4. Temperature field contour of hot water circulating pump shaft system

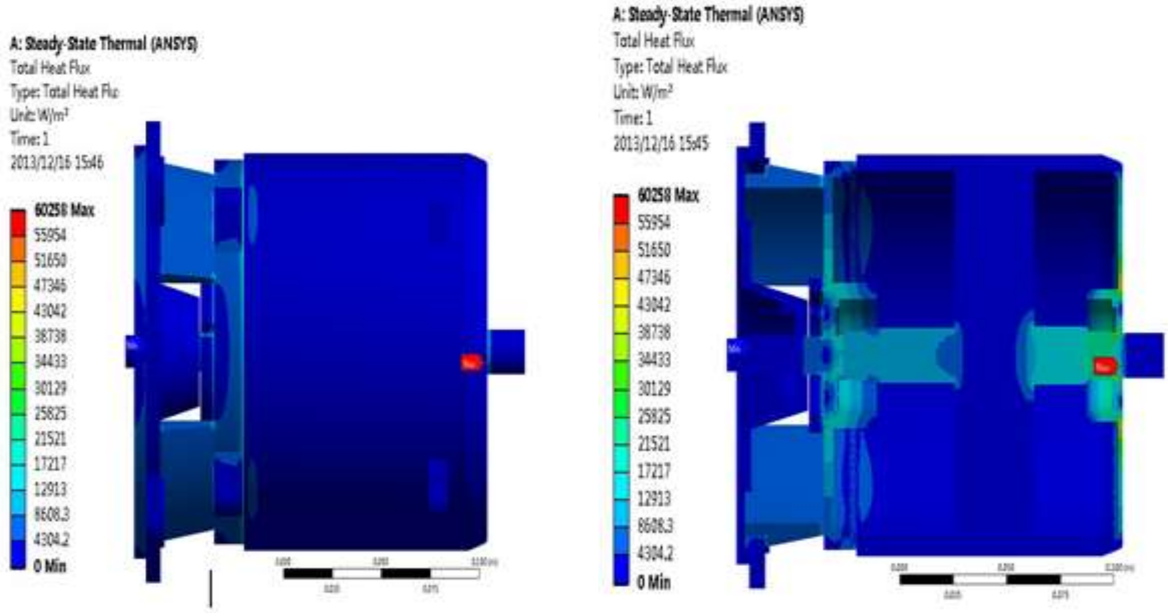
Figure 4 shows the temperature distribution nephogram of hot water circulation pump shaft structure when medium temperature is 40℃.In Figure 4(a), the temperature gradient contacting with the motor and external environment is small. The temperature of the motor cover and pump bracket junction is the range of 32 ℃ ~ 35 ℃, and away from the pump bracket is 30 ℃ ~ 32 ℃. It is that the temperature close to the motor is slightly higher than away pump bracket, and the temperature difference is the range of 2 ~ 3 ℃.There is a conclusion that the temperature of the hot water circulation pump transmission medium has some influence on the temperature field of the motor.

Figure 4(b) shows that the maximum temperature of the shaft structure is 51.67 ℃, appeared at the back end of the bearing chamber (near the motor blade),therefore the motor ends need to be air-cooled.

The minimum temperature is 30.855 ℃, located at the connecting flange between the motor rear cover and the middle of the post-motor.

In Figure 4, because the temperature value of bearing chamber is larger than other shaft structure, it is important to calculate temperature field of bearing chamber. Although the temperature of motor rear cover changes relatively large after the bearing chamber, the motor rear cover which has an additional air-cooling blade will reduce here temperature in practical application, and here's temperature and changes tend to stable.

4.2. Analysis of shaft structure heat flux



(a) whole structure (b)sectional structure

Figure 5. Heat flux contour of hot water circulating pump shaft system

Figure 5 shows the heat flux density of hot water circulation pump shaft structure when medium temperature is 40℃.In Figure 5(a), the heat flux is well distributed and there is no great mutation. The values of heat flux in stent is greater than motor structure. In Figure 5(b), the values of heat flux in pump shaft is slightly greater than other shaft structure, and there is a gradient values change. The maximum heat flux is 60258W/m2 located on the inner of rear bearing chamber, which is the same position of maximum temperature of the shaft system structure, consistent with the theory of heat transfer. The minimum heat flux is located on the pump shaft of inside mechanical seal chamber in stent. From Figure 4 analysis, the temperature of mechanical shaft seal chamber inner and pump shaft is well distributed, and the values remained at 41.25 ℃, with a small temperature difference, resulting in a smaller heat flux values there.

5. Conclusions

The shafting structure steady temperature field and structure field ,which consist of bearing chamber, stator and rotor, and hot water circulation pump of LPm125 type, were numerically calculated, and the shafting structure temperature field and the heat flux were analyzed in this paper.

It is found from calculation of the shafting structure steady temperature field that the motor temperature closed pump stent is slightly higher than away from stent. The medium temperature of hot water circulation pump transmission has certain effect to the motor temperature field. The temperature values of bearing chamber is greater than shafting structure. The heat flux of shafting structure is well distributed with no significant mutation. The heat flux of pump shaft is generally larger than the other.

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Because the influence of the medium temperature, the heat flux values of stent is greater than the motor.

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