Feasibility Study of Carbon Fiber Ceramic Matrix Composites Used in Mechanical Seal Friction Pairs

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Abstract. The choice of mechanical seal friction material has great influence on the sealing performance. As a new composite material, carbon fiber ceramic matrix composites have excellent corrosion resistance, high mechanical strength, good heat resistance and heat transfer performance, is the good choice of mechanical seal matching material. In the paper, the temperature field and leakage value are simulated by computer when carbon fiber ceramic matrix composites are applied to the friction pair. And the simulation results are verified by experiments. Studies have shown that when carbon fiber ceramic matrix composites are used in mechanical seal friction pairs, the sealing performance is significantly improved, including reducing temperature rise, leakage and wear.

1. Introduction

The material of the mechanical seal friction pair has a great influence on the sealing effect [1]. Carbon fiber ceramic matrix composites is a new type of composite material. It has low density, good thermal conductivity and corrosion resistance. The good thermal conductivity significantly reduces the temperature rise of the sealed end face, prevents the thermal damage of the sealed end face, and is advantageous to the stability of the liquid film between the friction pairs, thereby avoiding the sealing failure. Smaller density increasess follow-up to moving parts, and good wear resistance can extend the life of the seal ring. In summary, there are many benefits to using this material for sealing friction pairs. In this paper, ANSYS software is used to study the temperature field between the static and dynamic rings of the friction face. First, the temperature field under different materials is studied; then, the speed and pressure of the friction pair are changed respectively to obtain the corresponding temperature field; finally, the temperature of several points is measured by a mechanical seal test bench to verify the accuracy of the numerical simulation.

2. CFD model

This article chooses SG04U type mechanical seal structure. Figure 1 shows the structure. And the seal area ratio is 1.2952. The seal spring specific pressure is 0.15 MPa. The axial thickness of the moving ring is 24mm. The axial thickness of the stationary ring is 30mm. The medium is 20# mechanical oil. The thickness of the liquid film is 4μm. And the flow state is laminar [2-3].

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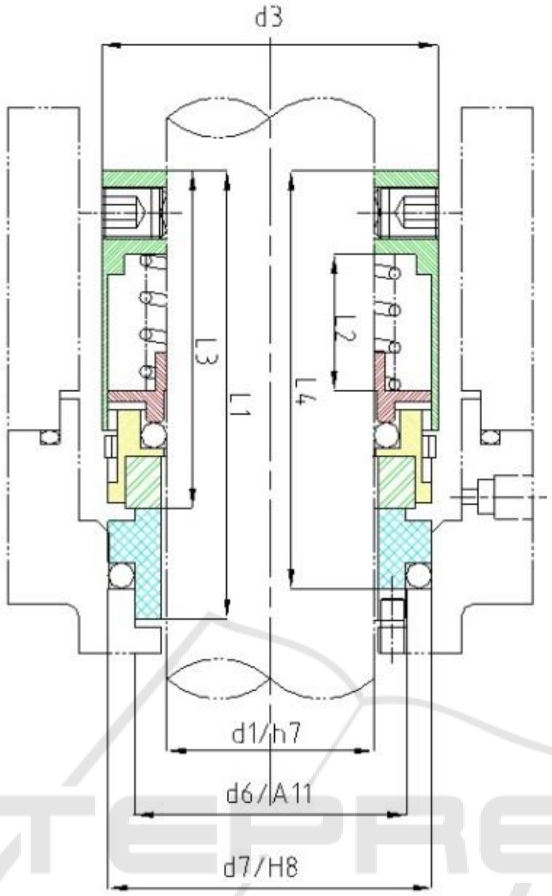

Figure 1. SG04U type mechanical seal structure.

The following assumptions are made in the calculation:
1 The temperature field distribution is steady;
2 The temperature field is axisymmetric;
3 The heat flux density is evenly distributed on the sealing surface;
4 Consider only convection heat transfer and neglect heat radiation;
5 Fluid parameters do not change with temperature.

3. Result and discussion

3.1. Material

The following figure 2 and 3 are radial temperature distribution curves of the mechanical seal and static ring end face obtained by using origin data processing software. There are four groups of matching materials. The first group is carbon fiber ceramic matrix composites and graphite. The second group is hard alloy and graphite. The third group is carbon fiber ceramic matrix composites and hard alloy. The fourth group is SiC and hard alloy. The sealing shaft speed is 2000r/min. The pressure in the sealing chamber is 0.4Mpa. The sealing medium is 20# mechanical oil. And the sealing chamber temperature is 30℃. In the figure, the abscissa represents the temperature measurement point number of the seal ring from the outer diameter to the inner diameter, and the ordinate represents the magnitude of the temperature value.

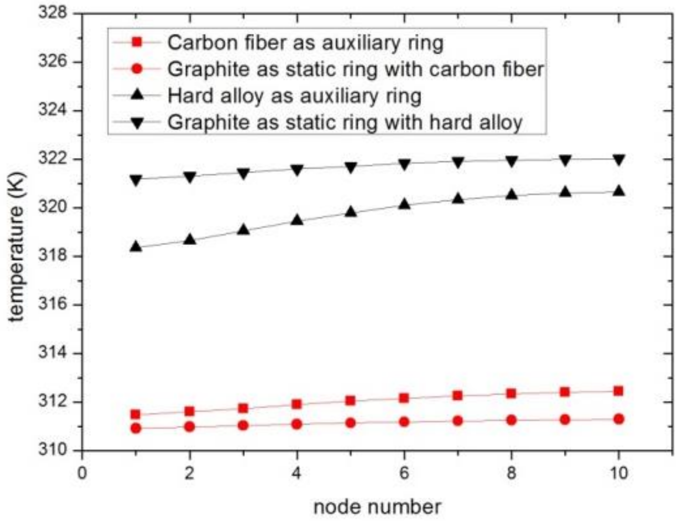

Figure 2. Temperature field paired with hard material.

Referring to Figure 2, when the moving ring is graphite, the stationary ring is respectively the carbon fiber ceramic matrix composite and hard alloy. Also, the carbon fiber ceramic matrix composite performs better as a static ring. At this circumstance, the temperature field between the sealing faces is lower than the temperature field of the hard alloy.

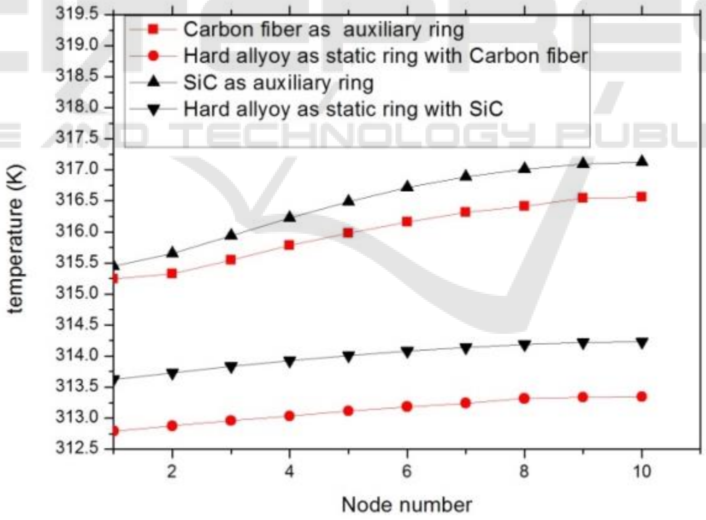

Figure 3. Temperature field paired with soft material.

Referring to Figure 3, when the moving ring is a hard alloy, the stationary ring is a carbon fiber ceramic matrix composite material and a silicon carbide alloy respectively. And carbon fiber ceramic matrix composites perform better than silicon carbide.

In summary, it can be concluded that the carbon fiber ceramic matrix composite material performs excellently under the condition of soft-to-hard material pairing in the absence of abrasive particles or slurry in the sealing medium. This material makes the temperature drop very obvious and the radial temperature change is small.

3.2. Presure

Figures 4 and 5 below show the sealed end surface temperature field when the seal chamber pressure is changed using origin data processing software. The pressure in the sealing chamber was 0.2 MPa, 0.3 MPa, 0.4 MPa, 0.5 MPa, and 0.6 MPa, respectively. The sealing medium is 20# mechanical oil. In the figure, the abscissa represents the temperature measurement point number of the seal ring from the outer diameter to the inner diameter, and the ordinate represents the value of the temperature value (unit: K).

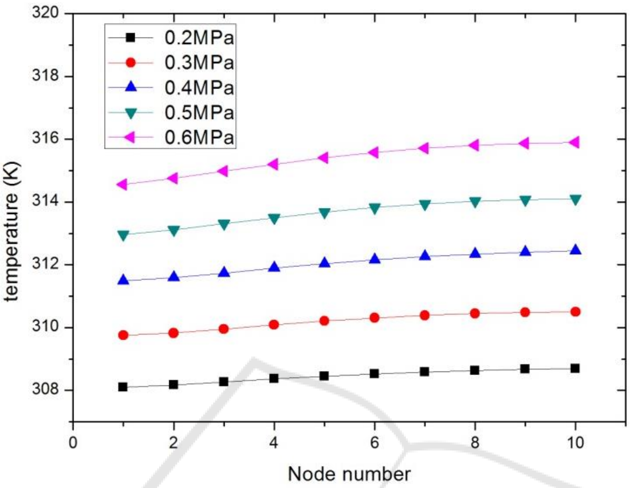

Figure 4. Moving ring temperature under different pressures.

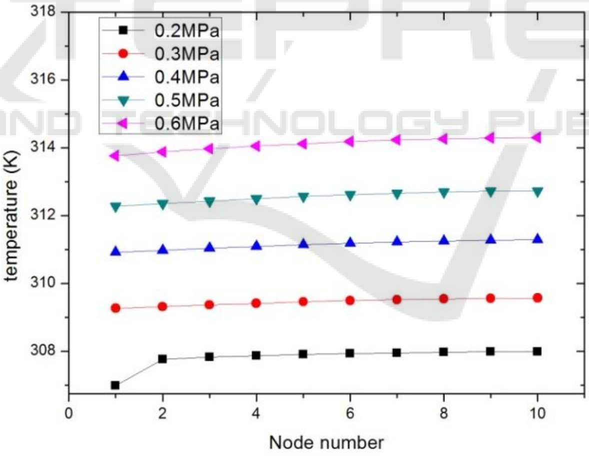

Figure 5. Stationary ring temperature under different pressures.

It can be concluded that carbon fiber ceramic matrix composites are used to material of the seal friction pair. When the pressure in the seal chamber increases, the temperature of the contact surface of the seal friction pair also increases. The reason is that the increase in pressure in the sealing chamber leads to an increase in the heat flux of the sealing face. This leads to an increase in the heat flux density of the ring annulus. Finally, the temperature of the end surface rises.

3.3. Rotating speed

Figures 6 and 7 below show the seal face temperature field for changing the seal speed. The rotation speeds were 1000 r/min, 1500 r/min, 2000 r/min, 2500 r/min, and 3000 r/min, respectively. The sealing medium is 20# mechanical oil. In the figure, the abscissa indicates the temperature measurement points of the seal ring from the outer diameter to the inner diameter, and the ordinate indicates the temperature value (unit: K).

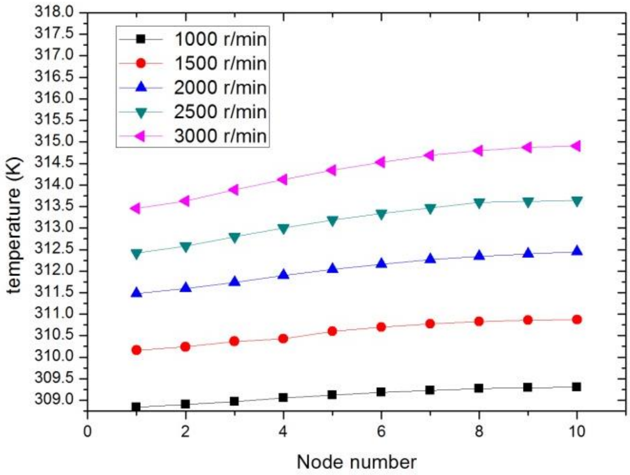

Figure 6. Moving ring temperature at different rotation speeds.

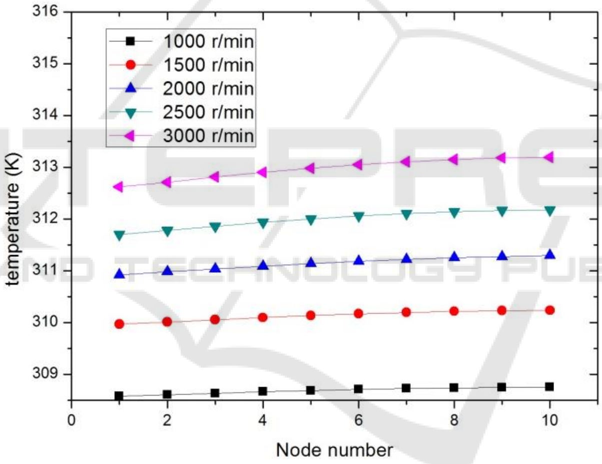

Figure 7. Stationary ring temperature at different rotation speeds.

It can be found that changes in the rotational speed of the seal shaft directly affect the flow state of the medium. The convective heat transfer coefficient of the friction ring changes. The higher the speed, the more heat is generated. Therefore, the higher the seal shaft speed, the higher the seal ring face temperature.

4. Experimental

The accuracy of the simulation results is verified experimentally. The static ring center temperature of the mechanical seal of the carbon fiber ceramic matrix composite was tested under two conditions.

Experiment one: The sealing medium is 20# mechanical oil. The pressure in the sealing chamber is 0.4 MPa. Sealing chamber temperature 30 ℃. Carbon fiber ceramic matrix composites are moving ring materials. Graphite is a stationary ring material. Change the seal shaft speed (1000r/min, 1500r/min, 2000r/min, 2500r/min, 3000r/min) to obtain the static ring center temperature.

Experiment 2: The seal medium is 20# mechanical oil. Sealed shaft speed 2000r/min. Sealing chamber temperature 30 ℃. Carbon fiber ceramic matrix composites are moving ring materials. Graphite is a stationary ring material. Change the pressure in the sealed chamber (0.2MPa, 0.3MPa, 0.4MPa, 0.5MPa, 0.6MPa) to obtain the center temperature of the stationary ring.

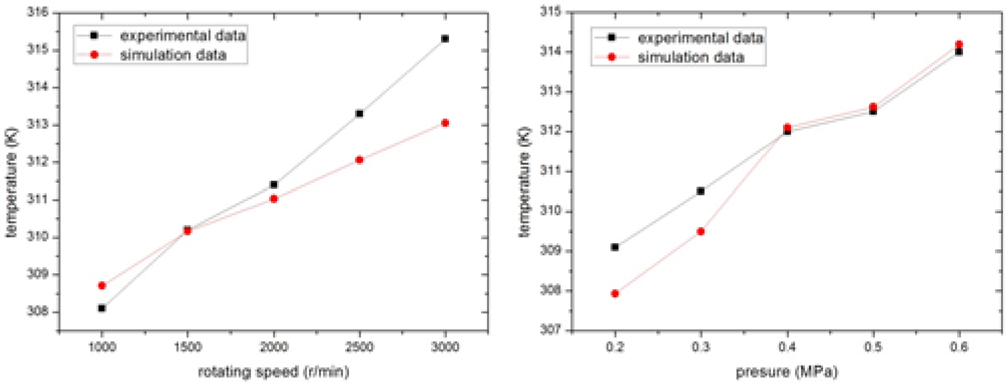

Figure 8. Comparison of experimental and simulated data.

By comparing the curves in the figure 8, the numerical simulation data is accurate. First of all, the trend of temperature change under pressure change and speed change is consistent. Second, there is a small difference between the simulated and experimental values of the sample points. Therefore, the simulation results have strong persuasive power.

5. Conclusions

As a mechanical seal friction pair material, carbon fiber ceramic matrix composites meet the basic sealing requirements.

Whether it is with soft materials or hard materials, carbon fiber ceramic matrix composites perform better. The temperature is lower, and the temperature field is more even and has a better sealing effect.

Carbon fiber ceramic matrix composites are more suitable for hard to soft sealing conditions. Under this condition, the temperature drop is even more pronounced.

The pressure in the seal chamber and the speed of the seal shaft have a great influence on the temperature of the end face. The face temperature increases as the pressure in the seal chamber increases. The face temperature increases as the rotational speed of the seal shaft increases.

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