The Theoretical and Experimental Research on Magnetic Fluid Large Gap Rotary Sealing

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ABSTRACT

It was designed a magnetic fluid rotation sealing for high power electric motor of large vessels equipment, the structure is suitable for large gap magnetic fluid sealing applications, the pressure formula were derived theoretically, the pressure capacity was related with saturation magnetization of the magnetic fluid, the yield stress of the magnetic grease the magnetic field gradients in the sealing gap and other factors. It used Ansys to make the finite element analysis for the magnetic field distribution within seal gap, it also made the pressure experiments on the sealing bench, the experimental results showed that when the maximum gap was 0.7mm, the single-stage pressure capacity could meet 18KPa-.¹

KEYWORDS

Magnetic Fluid; Magnetic Grease; Sealing; Large Gap; Experimental Study

INTRODUCTION

Magnetic liquid sealing relies on the way that the liquid material fills the sealing gap to achieve the sealing function, which has the advantage that many traditional mechanical seals cannot be surpassed. The design of the magnetic liquid sealing structure mainly refers to the material selection of the components of the magnetic liquid sealing member, the design of the pole piece tooth shape, the gap selection of the pole piece and the magnetic bushing, the determination of the withstand voltage

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level and the reasonable calculation of the magnetic circuit, and the bearing assembly. Relative position with the magnetic core [1-3].

At present, sealing liquid media with ordinary magnetic liquid is still an unsolved problem. The main reason is the miscibility caused by interface instability and the mutual solubility of the magnetic liquid-based carrier liquid and the sealing medium [4, 5]. In this regard, various solutions have been proposed, such as air isolation, rubber-assisted sealing isolation, mercury ring isolation, etc. [6,7].

**STRUCTURE DESIGN**

Due to the high rollability of large ships, the power equipment is determined. The engine has super power, and the motor generates high heat during the operation of the motor. The cooling medium is required to cool it. The magnetic liquid sealing device designed according to this requirement has a gap of 0.7 mm, and the gap of the currently developed magnetic liquid sealing device is often only 0.1 to 0.3 mm, and the sealing of large gaps is rare.

Three permanent magnets are used, and each permanent magnet and its corresponding pole shoe form a plurality of magnetic circuits. The pole teeth are triangular, and the number of teeth is 12. Considering the magnetic collecting effect, the angle of the triangular teeth is 30°, and the teeth are the same size, forming 4 slots. 5-pole 9-tooth sealing structure.

**FINITE ELEMENT ANALYSIS**

The ANSYS finite element analysis software is used to analyze the magnetic field distribution in the structure to obtain the magnetic induction intensity, the magnetic field line equivalence distribution of the magnetic circuit and the magnetic field strength vector distribution, ignoring the effect of centrifugal force.

**Equipotential Line Analysis**

Figure 1 shows the distribution of magnetic field lines at a gap of 0.7 mm. It can be seen from the image that the distribution of the magnetic flux density at the gap between the pole teeth and the two sides of the gap is obviously gradient, and the larger the gradient, the more the pressure resistance of the seal is. Large, it can also be found that the magnetic flux leakage is mainly on the inner and outer sides of the permanent magnet.
Figure 1. The magnetic field distribution.

Figure 2. The axial magnetic field distribution.

Trajectory Analysis

Axial trajectories are defined in the ANSYS postprocessor. The axial magnetic field strength change directly determines the sealing capacity. The value of the magnetic field strength is mapped on this trajectory. In order to more clearly see the change of the magnetic field at the pole tooth, when defining the axial trajectory, define a point at the end of each pole tooth, adjacent to the two The number of point interpolation is 20, the length of the trajectory is s, as shown in Fig.2, the gap is 0.4-0.7mm, and the magnetic field strength difference under the pole teeth of the outermost two pole shoes is significantly smaller than that under the inner pole teeth. Therefore, the main sealing effect is the difference in magnetic field strength generated under the middle eight pole teeth.

When the sealing gap is 0.7mm, the pressure resistance formula of the single-stage approximation by static sealing, the finite element analysis results, the total withstand voltage value, the saturation magnetization of the ester-based magnetic liquid, $\mu_0 = 300$ Gs
\[
P_{\text{R}} = 2 \times 4\pi \times 10^{-7} \times \frac{300 \times 10^{-4}}{4\pi \times 10^{-2}} \times (339360 - 1002) + (385450 - 1002) + (363470 - 1002) + (212530 - 93152) + (212530 - 167870) \approx 1.12 \mu \text{m}
\]

(1)

PRESSURE RESISTANCE TEST

The physical diagram of the designed sealing device and the experimental bench constructed are shown in Figures 3. In the test, the helium mass spectrometer leak detector has a vacuum of 3×10⁻³ Pa, the minimum measured leak rate, and the response time is less than 3 s.

![Figure 3. The sealing experimental bench.](image)

The experiment used a laboratory-prepared ester-based magnetic liquid and a magnetic grease. The pole teeth near the freon side were injected with about 1 ml of magnetic grease, and the remaining pole teeth were injected with a total of about 5 ml of magnetic liquid. The first part of the experiment is pressurization and the second part is leak detection. Different sealing gaps are obtained by machining the central shaft. The gap is 0.3, 0.4, 0.5, 0.6, and 0.7 mm. After each time the magnetic liquid was filled, it was left to stand for about 12 hours, and the pressure resistance value which can be maintained by self-repair after the magnetic liquid was filled was recorded.

For a typical seal gap of 0.15mm, the single-stage seal can withstand a pressure of about 22KPa. The sealing structure of this design, when the gap is 0.4mm, can withstand a pressure of about 38KPa. As the seal gap increases, the withstand voltage value gradually decreases. When the maximum clearance is 0.7mm, the single-stage pressure resistance can still reach 18KPa. In addition, the magnetic liquid large gap seal also has a self-repairing function, and the ester-based magnetic liquid can maintain a certain pressure resistance after being crushed by high pressure.
CONCLUSIONS

A large-gap magnetic liquid sealing device is designed, which is derived from the theoretical withstand voltage formula. The pressure resistance is related to the saturation magnetization of the magnetic liquid, the yield stress of the magnetic grease, and the magnetic field gradient in the sealing gap. Through the finite element analysis calculation and experimental verification, the sealing device has good pressure resistance effect. When the experimental data shows that the maximum clearance is 0.7mm, the single-stage dynamic sealing pressure resistance can still reach 18KPa.

REFERENCES