MAGNETIC FLUID SEAL FOR SWITCHGEAR

Yi RAO, Xiaohui YAN, Linhuan LUO, Fangzhou HAO, Chao SHEN, Chaopin LEI, Yongjun WU

(Guangzhou Power Supply Co., Ltd., China Southern Power Grid, Guangzhou, 510000, China)

(E-mail address: 744634517@qq.com)

ABSTRACT

The magnetic fluid sealing device is composed of non-magnetic seat, bearing, magnetic pole, permanent magnet, magnetic axis and magnetic fluid. Under the action of uniform and stable magnetic field, the magnetic fluid is filled in the set space and a multi-stage "O-ring" is established. In this article, the main components of magnetic fluid seals are studied experimentally, and the factors affecting the sealing ability of magnetic fluid seals, including the performance of magnetic rings and magnetic fluids, are analyzed. Through the analysis of experimental data, the reliability of magnetic fluid seal used in SF6 insulated switchgear is summarized.

INTRODUCTION

Gas or (SF6 gas) is widely adopted for high-voltage switch elements and integrated switch devices as the arc-extinguishing medium and insulation medium, therefore, seal, especially the rotary seal, is the key technology to ensure product quality.

As long as the following measures are taken, it's basically reliable for adopting annular rubber seal:

I Ethylene-propylene rubber (EPD) O-ring seal is adopted;
II The compression ratio of O-ring seal is 15-20%;
III The sealing surface is ensured to be smooth and flat.

However, there is still rejection ratio of 0.5% in ex-factory inspection.

Because the rotary seal connecting the main shaft inside, the inflated enclosure and the external mechanism has the dual-task of transmitting operational work and ensuring sealing (dual contradiction), if the rotary sealing element of traditional assembly is adopted, the rubber product will gradually age and brittle when stored for long period of time under normal pressure and temperature due to the restriction from structure (mainly the shaft-sleeve structure), element quality (mainly the quality of rubber rotary shaft lip seal), and processing quality; if the rubber product is stored under long-term compressed status, permanent deformation (or called as residual deformation) will occur which directly impacts the sealing effect, emerging issues such as journal sticking under low temperature, serious wearing, and increased leakage rate etc., which results in high scrapping rate of sealing assembly and high rework rate of processing and assembling. It not only causes inconvenience to production, but also impacts the improvement of product quality.

The emergence of new magnetic fluid seal structure has significantly improved the switch rotary seal.

Ferrofluid/magnetic fluid (or called as magnetic liquid) is a new type of functional material, which possesses not only the fluidity of liquids but also the magnetism of solid magnetic materials. It's a type of stabilized colloidal liquid mixed by magnetic solid particles with diameter of nanometer scale (below 10 nanometer), base solution (also called as medium), and surfactant. The fluid has no magnetic attraction force at static state, and only shows magnetism under the effect of external magnetic field. Under the effect of magnetic field, the annular space is fully filled by magnetic fluid, and a series of "O-ring seals" are established, thus realizing the sealing effect. Therefore, it has wide application in reality. The magnetic fluid made of nano-metal and alloy powder has outstanding performance, which can be widely applied in the magnetic fluid sealing field under various severe conditions.

The magnetic fluid sealing device is made of non-magnetic-conductive seat, bearing, magnetic pole, permanent magnet, magnetic-conductive shaft, and magnetic fluid. Under the effect of magnetic field, the annular space is fully filled by magnetic fluid, and a series of "O-ring seals" are established, thus realizing the sealing effect.

1. The Principle of Magnetic Fluid Sealing

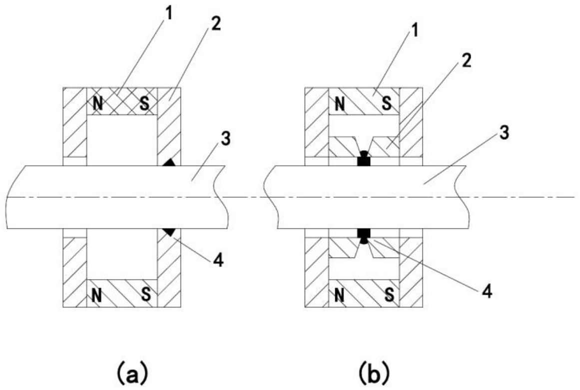

Figure 1. The Principle and Mode of Magnetic Fluid Sealing

1--Permanent magenet; 2--Pole shoe ;3--Rotary shaft; 4--Magnet fluid

The principle of magnetic fluid sealing is shown in Figure 1. Ring-shaped permanent magnet 1, pole shoe 2, and rotary shaft 3 are composed into the magnetic circuit. The magnetic field generated from the magnet concentrates magnetic fluid 4 into the crevice between the shaft and the top of pole shoe, forming a so-called magnetic fluid O-ring seal, thus realizing the sealing effect. The material of the rotary shaft can be magnetic substance (Figure 1(a)) or non-magnetic substance (Figure 1(b)); under the former condition, the magnetic bundles are concentrated in the crevice, and are composed into the magnetic circuit through rotary shaft; under the latter condition, the magnetic circuit is formed through the magnetic fluid in the sealing crevice instead of through the rotary shaft.

2. Magnetic Fluid Sealing Structure

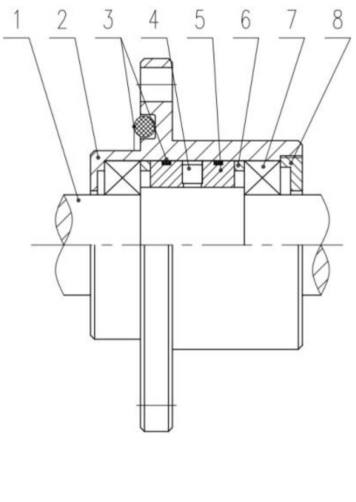

Figure 2. Structural Diagram of Magnetic Fluid Sealing

1. Rotary shaft; 2. Shell; 3. O-ring seal; 4. Permanent magnet; 5. Magnetic pole; 6. Spacer bush; 7. Bearing; 8. End cover

This structure is normally applied in the switch device where the pressure of SF6 in gas cell is ≤0.2MPa.
When the pressure of SF6 gas cell is higher than 0.2MPa, the internal basic structure is as shown in Figure 2. Compared with Figure I, when the pressure of SF6 gas cell is increased, mainly the quantity of magnetic poles and permanent magnets is increased, i.e. the axial length of magnetic fluid sealing is increased. The specific quantity of increased permanent magnets and magnetic poles depends on pressure. The higher the pressure is, the more the quantity of magnetic poles and permanent magnets will be.

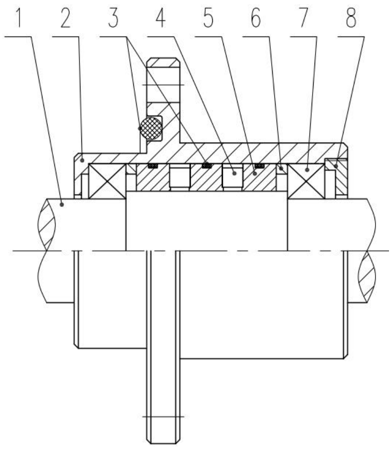

Figure 3. Structural Diagram of Magnetic Fluid Sealing

1. Rotary shaft; 2. Shell; 3. O-ring seal; 4. Permanent magnet; 5. Magnetic pole; 6. Spacer bush; 7. Bearing; 8. End cover

3.Pressure Withstanding Capacity of Magnetic Fluid Sealing

The differential pressure Δp undertaken by both sides of magnetic fluid depends on the field intensity at both sides of the magnetic fluid, i.e. depending on the axial thickness on magnetic fluid, while the axial thickness depends on the injection amount of magnetic fluid. The experimental curve between the pressure withstanding capacity and injection amount of magnetic fluid is as shown in Figure 4. It can be seen that, the injection amount of magnetic fluid is increased at the beginning, and the pressure withstanding capacity shows linear increasing; however, when the injection amount reaches certain value, the pressure withstanding capacity does not increase any more, but becomes stabilized at certain constant state. As shown in the figure, after the injection amount becomes 6 times, the pressure withstanding value of single pole shoe is balanced at 0.02MPa.

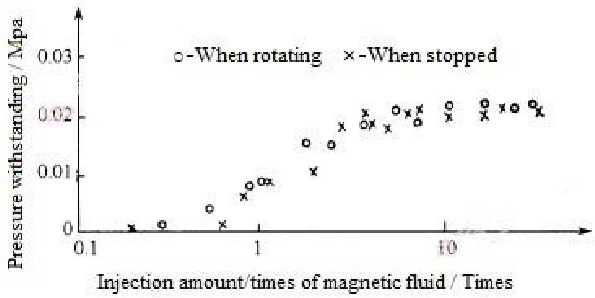

Figure 4. The Relationship between Injection Amount and Pressure Withstanding Capacity of Magnetic Fluid

Single-side crevice：0.15mm
Pole-shoe thickness :1mm
Shaft diameter ：ϕ30mm
The Pressure Withstanding Value of Bevel-Tooth Type Pole Shoe Shown in Figure 4
When the field of magnet is very strong, it can be calculated according to the calculation formula:

$$\triangle p = \frac{\text{Bi H}}{4\pi}$$

△ p —Differential pressure
Bi —Polarization intensity of magnetic fluid
H— Intensity of magnetic field

By increasing Bi, higher differential pressure Δp can be sealed. Because the value of Bi depends on the type of magnetic fluid, the maximum pressure withstanding capacity of single pole shoe is confirmed after the type of magnetic fluid for sealing device is selected under certain magnetic field.

4. Advantages of the magnetic fluid seal

① Tight sealing performance
At present, the ester-base magnetic fluid adopted can perform tight and stabilized dynamic sealing for the medium (atmosphere or inert gas).

② Zero leak rate
The mass spectra method is used to detect the leak rate of sealed medium under the extreme condition of 1×10-11std·cc/s He , no leakage is detected, and usually people calls magnetic liquid sealing as zero leakage.

③ Long life span
The base solution for the magnetic liquid used in vacuum circumstances is a type of diester-based organic substance, with extremely low volatility.

④ High reliability
When the magnetic fluid sealing part is broken-through by the instantaneous overpressure caused under positive pressure, the sealing effect can still remain once the pressure drops to the extent which can be undertaken by the sealing.

⑤ Basically no pollution
Because there is no mechanical wearing in the sealing part itself and the saturated vapor pressure of magnetic liquid is extremely low, it will cause no pollution even using it under high vacuum status.

⑥ Low friction, low wearing, low heat generation
In the sealing part installed with bearing, except for the mechanical wearing of the bearing in the process of rotation, the magnetic core component does not directly contact the rotary shaft; therefore, there is low friction, small wearing, low heat generation, needing small power for running.

⑦ Good reparability
In the process of using, if the magnetic fluid sealing fails due to some reason, it can be repaired in the field in shorter period of time as long as the function of internal components is normal.

⑧ Omni-directional sealing
If needing to change the pressure withstanding direction, for magnetic fluid sealing part, it can be accomplished without needing to add any components.

⑨ It can work normally from -100℃ to +100℃.

5.Application of Magnetic Fluid Seals

The reliability, stability, and service life of magnetic fluid sealing part not only depends on the environment and condition where it is applied, but also closely depends on the quality of magnetic fluid injected, the structural design effect of magnetic fluid sealing part, as well as the quality of processing and manufacturing. There are mainly 2 indexes for evaluating the quality of magnetic fluid: The first is the saturation magnetization of magnetic fluid, and the second is the stability of magnetic fluid. Structural design mainly means selection of materials for various components of magnetic fluid, the type of teeth in the pole shoe, designation for the crevice between pole shoe and flux sleeve, determination of the quantity for pressure withstanding poles & reasonable calculation of magnetic circuits, and the relative position between bearing assembly and magnetic core etc. The quality of processing and manufacturing mainly means the process measures and testing methods adopted to ensure the designed dimensional tolerance and form & location tolerance. It should be said that, for good magnetic fluid sealing, the pressure withstanding capacity of each stage should ≥ 0.2 atmospheres absolute (ATA). The overall pressure withstanding capacity basically equals to the sum of pressure withstanding capacity of each stage. Seeing from the structure of sealing assembly, if divided by teeth position, there are two types of forms, one type is that the teeth are opened at the pole shoes, and the other type is that the teeth are opened at the flux sleeve or rotary shaft. If divided by the relationship between magnet and pole shoe, the forms include single-magnet + double-pole shoe and multi-magnet + multi-pole shoe. While the form of the magnet proper include one-piece magnet ring, magnetic column, and small discs assembly. The structural form of sealing assembly is normally determined according to the user's effect condition.

Research shows that: The differential pressure of magnetic fluid sealing can reach 1.54Mpa, which is much higher than the requirement in high-voltage switch at 0.8Mpa, fully meeting the requirement of all types of 3.6-1000kV high-voltage switches. The magnetic fluid sealing has been massively applied in 12KV SF6 load switches since 2002, applied in-batch in 40.5kVC-GIS since 2005. Through 80,000 times of mechanical operation tests, the performance still remains stabilized, much higher than the technical requirement of 10,000 times.

REFERENCES

[1] Ruijing.Wang, Changbin.Wang. Industrial Application of Magnetic fluid Technology, Mechanics and Practice 2004.12 26（6）8-13.

[2] Decai.Li. Theory and Application of Magnetic Fluids [J] Beijing Science and Technology Press.

[3] Jibin.Zou, Yongping.Lu. Principle and Design of Magnetic Fluid Seals [M] Beijing, National Defense Industry Press 2000.

[4] Ning.Fei, Zhihua.liang. The Principle and Application of Magnetic Fluid Seal [J] Vacuum, 2001 (1) 46-48.

[5] Ling.Xu, Sunqu.Xu. Application of magnetic fluids seals [J] Mechanical Engineer, 2000 (6) 24-26.