Design of closing electromagnet of high power spring operating mechanism

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Abstract

High-voltage circuit breaker high-power spring operating mechanism design Ansys software simulation analysis of the electromagnet, and the transmission characteristics of the analysis and calculation, the reliability of the actuator mechanism for the design provides a theoretical basis, and the use of Ansys software on The electric field analysis of the arc extinguishing chamber provided the design basis for the determination of the closing characteristics of the operating mechanism. Finally, the feasibility, mechanical characteristics and reliability of the operating mechanism were fully verified by the prototype production and testing. Meet the characteristics of high-power spring actuator requirements.And high-voltage circuit breaker high-power spring operating mechanism convenient maintenance, no leakage risks, has long been praised by users, the development of this spring operating mechanism closing solenoid, the test can provide sufficient suction, and the action Short time, stable and reliable.

Key words

High-voltage circuit breakers; Spring control mechanism;Closing electromagnet.

1. introduction

High voltage circuit breaker is the most important key control device in the power grid system. It plays the role of control and protection in the power grid. Its reliability is directly related to the reliability of the power grid operation[1]. The operating mechanism plays the role of a driving component in the circuit breaker, and the reliability of the circuit breaker is reliable, which is mainly determined by the reliability of the operating mechanism in terms of mechanical properties. For a long time, the research and design level of the high-voltage switch industry in China has lagged behind the international advanced level and lags behind the development speed of China's switch body, especially in the field of high-power actuators for UHV and UHV circuit breakers and the international advanced The horizontal gap is much larger and there is less research on design theory[2].

According to market research and analysis of high-voltage switch tender documents in recent years, the results show that in the application of high-voltage circuit breakers with voltage ratings of 126 kV, circuit breakers with spring-operated mechanisms have already dominated[3]. With the continuous development and application of self-extinguishing arc chamber technology, the operating requirements of the operating mechanism of the SF6 circuit breaker arc extinguishing chamber are gradually reduced. This makes R&D more powerful than the past but less effective than the hydraulic mechanism. The spring-operated mechanism makes it possible to distribute products with voltage ratings of 220 kV and above[4]. At present, according to market analysis, most users have gradually accepted that 252 kV circuit breakers are equipped with spring-operated mechanisms. However, only a few foreign companies and joint ventures can now produce 252 kV circuit breakers equipped with spring-operated actuators. The spring operating mechanism has been praised by users for a long time because of its easy maintenance and no hidden dangers[5]. For this kind of organization, it is very convenient for maintenance, and it does not leak and other related hidden dangers. After a long period of use and identification, the user has affirmed and praised it. In the environment where the spring operating mechanism occupies a dominant position, the research in this paper must be done to meet the needs of various markets, and through this method to enhance the competitiveness of the market. For now, most manufacturers with some experience in high-voltage switching are also developing and researching such products to win opportunities to control the entire market and eventually dominate the entire industry.

In the closing control unit of the high power spring operating mechanism, the closing electromagnet is used as the main core component. Therefore, the electromagnet is optimized in this paper.

2. Optimum Design of Closing Electromagnet

The high-power spring operating mechanism mentioned in this article has extremely strict requirements in terms of closing, must include enough time, and the closing force must be large enough at closing, so the closing solenoid in this article The shape is similar to Yamagata, also known as Yamagata electromagnets, and the schematic diagram of the structure is shown in Figure 1 below. In the device of the spring operating mechanism, an electromagnet serves as a tripping power element. After the power is applied, a current is generated in the coil, and the moving core of the electromagnet is controlled to perform a sucking operation. The accurate tripping of the snap fastener of the operating mechanism utilizes the moving force of the moving core to achieve the closing operation of the mechanism.

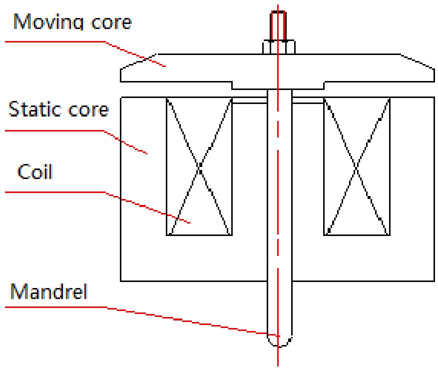

Fig.1 Closing Solenoid Structure Diagram

2.1 Establishing an Electromagnet Mathematical Model

Coil circuit voltage equation

$$U = IR + \frac{d\phi}{dt} \tag{1}$$

In the formula

U—Coil voltage，V;

I—Current through the coil，I;

R—Coil resistance，Ω;

Φ—Magnetic flux，Wb，$\phi = \frac{IN}{R(x)}$

$R(x)$——The total reluctance, the total reluctance is determined as a function of the stroke of the moving core after the structure is determined.

Therefore, it is also a function of the current and the moving core stroke, and its function express-ion

$$\phi = \phi(N, I, X) \tag{2}$$

In the formula

N—Number of coil turns;

x—Dynamic core travel，m.

Electromagnet suction equation

$$F = \frac{1}{2} \cdot I^2 \cdot \frac{\mathrm{d}L(\mathrm{x})}{\mathrm{dx}} \tag{3}$$

In the formula

$L(x)$——Electromagnet inductance, other related parameters as described above.

Easy to get, the suction of the electromagnet is a function of current, moving core stroke, and inductance.

2.2 Establishing an Electromagnet Simulation Model

Ansys software is used to establish a simulation model. The model established is shown in Fig. 2. Therefore, the air gap and the ampere-turn number can be used as solution variables between the moving iron core and the static iron core in the solution process. The object of the solution is the electromagnet suction.

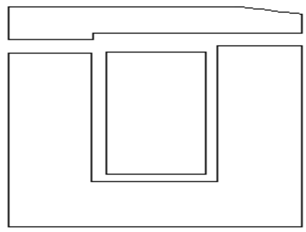

Fig.2 Electromagnet Simulation Model

The determination of the relationship between the electromagnet suction force and the air gap between the moving and stationary cores and the number of coil ampere turns is obtained through the simulation of the electromagnet by Ansys software, as shown in Figure 3 (suction force: N, air gap: mm), The magnetic field lines of the electromagnet are shown in Figure 4.

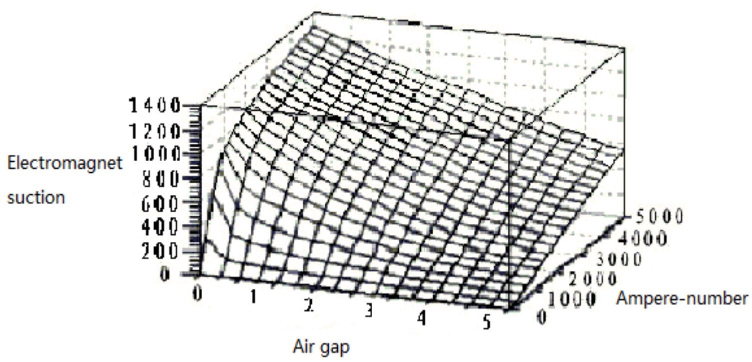

Fig.3 Electromagnet Suction and Air Gap and the Number of Ampere Turns

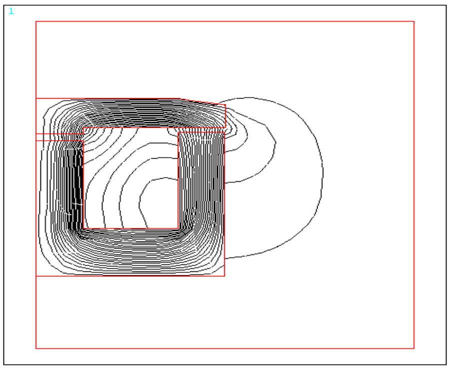

Fig.4 Solenoid Line of Force

2.3 Analysis of Simulation Results and Structural Improvement

Based on the above simulation results, the following conclusion can be drawn: In the case where the degree of core saturation is not considered, the suction force of the electromagnet is positively related to the number of ampere-turns. Therefore, if we want to increase the attraction of the electromagnet, we can achieve it by increasing the ampere-turns[6]. According to the relevant national standards for electric power, the current of the solenoid coil has a standard, and its maximum current is about 2.5 A, which cannot be very high. Therefore, increasing suction by increasing the number of coil turns has become an almost unique method. Through the magnetic field diagram of the electromagnet in the figure above, it can be clearly known that the magnetic field strength inside the coil is the largest and the scattered magnetic flux is the smallest. Therefore, the maximum suction force is when the air gap is at the innermost position of the coil.

As a result of the above analysis, the structure of the conventional coil needs to be improved, and the number of turns of the coil wound on the magnet also needs to be increased. The number of turns of the coil is increased by 300 from the original 1700 to 2000 . As the number of turns increases, the inner hole of the coil becomes smaller. Of course, the reduction of the inner hole means that the distance between the inner core and the core is reduced, and the coil is also upgraded from the internal fixation to the external fixation. The skeleton of the coil is improved before and after it is made as shown in FIG. 5 Comparison chart. Another improvement is that the air gap of the magnetic pole is placed in the middle part of the coil, and the comparison diagram shown in Figure 6 is made before and after the improvement of the iron core.

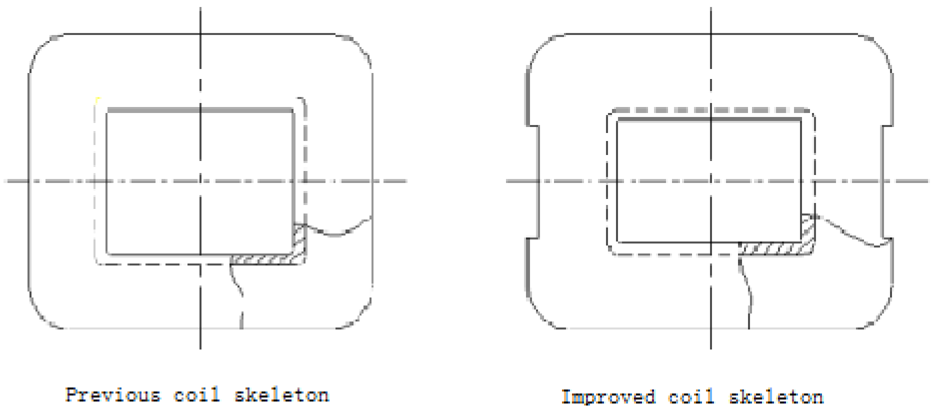

Fig.5 Comparison of Improved Coil Bobbin

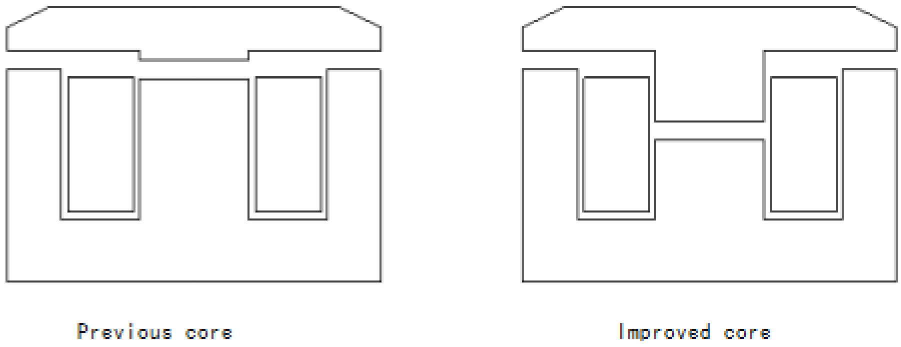

Fig.6 Core Improvement before and after Contrast

Through the above improvements, we once again establish a new model for the original program and the improved program. Through the final determination of the number of ampere turns, the suction force under different air gaps can be further solved. Finally make the graph shown in Figure 7.

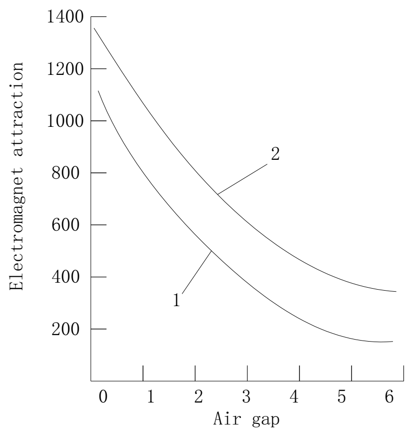

Fig.7 Comparison of Suction Results Before and after Improvement1 Means Improved Front Suction; 2 Means Improved Suction

3. Prototype Experiment Verification

The output force of the electromagnet is the total suction force of the electromagnet minus the frictional resistance minus the reset spring force. The stability of the dynamic characteristics of the electromagnet is closely related to the magnitude of the frictional resistance, so the friction resistance of the electromagnet is reduced. Of particular importance. For this reason, the solution proposed in this paper is to increase the oil-free bearings so that the frictional resistance can be reduced to a minimum. Before and after the improvement, the friction structure was tested and compared. It can be seen that the improved structure is better. Whether it is in dust resistance or sand resistance, such an organization is not prone to rust even if it is used for a long time. Of course, it is not because of life. Rust and frictional resistance increase. After a series of improvements in the above scenarios, this article designed and manufactured a specific sample, and we conducted a series of related force tests on this sample, and obtained a series of results plotted as follows. From the approximation of the two curves in Figure 8, we can easily see that this improvement has had a great effect and has basically met our requirements.

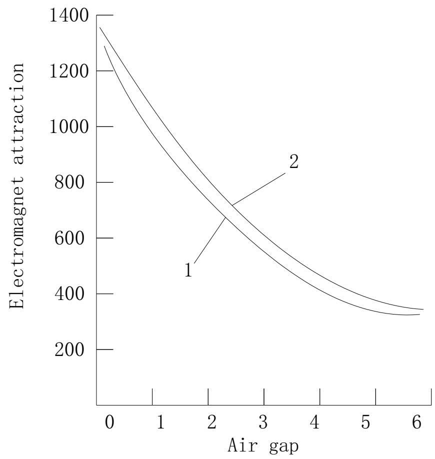

Fig.8 Sample Test Results and the Results of the Comparison1 Represents Measured Force Value; 2 Represents Solution Force Value

The prototype of the design was installed in a high-power spring control mechanism. The closing mechanical characteristic curve is shown in Figure 9. The waveforms in the figure include the fracture line, speed curve, stroke curve and coil current curve. According to the figure, we then take the 50% trip point before the closing fracture point and the closing fracture respectively. The instrument will automatically calculate the precise speed of closing at the left side of 4 m/s, and the precise time for the closing time is 76 ms.

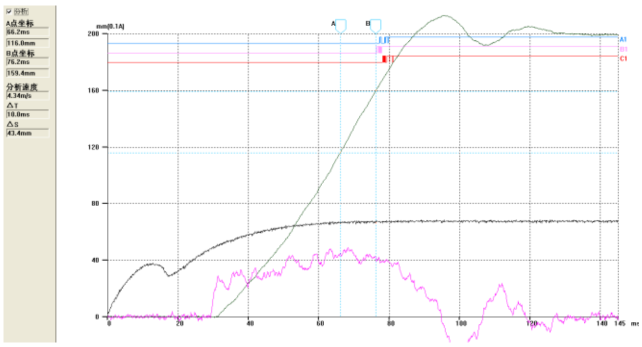

Fig.9 Closing Characteristic Curve

4. Conclusion

This article first establishes and utilizes ansys software to solve the magnetic field simulation model through the mathematical model of the closing electromagnet in the closing mechanism, and obtains the relationship between the electromagnet suction force and the air gap and the number of turns. Due to the external force of the closing electromagnet, the suction force needs to be subtracted from the friction force, so the structure of the closing electromagnet is newly designed, and the friction is minimized by using an oil-free bearing, and the original method is improved by this method. Electromagnetic suction effect results. This completely satisfies the requirements for the use of high-voltage circuit breaker spring operating mechanisms. The simulation results are similar to the experimental results. The method used in the design of the closing electromagnet is not only applicable to the design of this paper. This idea of optimizing the design through simple and effective simulation analysis also provides great help in other related industries.

References

[1] LIANG Chuan-tao.Study on Design of Hydraulic Spring Actuator of EHV Circuit Breaker. Qingdao: Shandong University of Science and Technology, 2014.

[2] Ye Hongbo, Wu Jianmin.Development of on-line monitoring system for LV11-252 SF_6 high voltage circuit breaker [J] .East China Electric Power, 2009,37 (07): 1084-1086.
[3] Wu Zhongyu. Research on Characteristics of Hydraulic Actuation Mechanism of Ultrahigh Voltage Circuit Breaker [D] .Zhejiang University, 2008.
[4] Jia Lili, Cao Lianmin, Liang Chuantao, et al.Optimization design of Yamaha electromagnet for high voltage circuit breaker [J] .Melting Machinery. 2014,35 (06): 165-166.
[5] M Yu, L Wang, T Chu et al. An LMI Approach to Networked Control Systems with DataDropout and Transmission Delays[J]. International Journal of Hybrid Systems, 2003, 3:291-303.
[6] Tipsuwan,Yodyium,Chow,Mo-Yuen.Control methodologies in networked control systems. Control Engineering Practice,2003,11(10):1099-1111.