Design of Energy Storage Unit of High Voltage Circuit Breaker Operating Mechanism

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Abstract

The energy storage unit is one of the most critical design points in the overall design of the operating mechanism and directly affects the reliability of the energy storage of the operating mechanism. This text mainly carries on the design analysis to the energy storage unit, first carries on the analysis to its working condition, including the kinetic energy calculation at the closing time, the energy that the opening gate spring needs to store, the closing spring storage energy and its design, then the main part of the energy storage unit Design and check: Through modeling, material definition and loading analysis, and through solidworks 3D rendering and strength check, optimize the energy storage shaft; through force analysis, mechanism design and check and optimization, Design and check the eccentric shaft of the actuator. Finally, a reliability design is carried out, which includes the issues of wear, resetting speed, assembly design of pawl and influence of energy storage speed, so as to increase the reliability of the energy storage unit.

Keywords

Spring actuator, energy storage unit, simulation analysis, design verification.

1. Introduction

In recent years, the spring operating mechanism has occupied a dominant position in the use of 126kV circuit breakers, and the use rate is not high in the 252kV circuit breaker associated operating mechanism. The main reason is that the spring operating mechanism is more than the output of the hydraulic operating mechanism. Power is small. The opening operation of the spring operating mechanism of the 126kV circuit breaker is about 1800J, and the opening operation of the new self-energizing 252kV circuit breaker is about 2500J, which makes it possible to use the spring operating mechanism for the 252kV circuit breaker[1]. The operating mechanism is the basic component of the reliability of the circuit breaker. The stability and controllability of the mechanical action are particularly important for the reliability of the high-voltage circuit breaker operation[2]. Therefore, the high reliability operating mechanism is designed and optimized for the high voltage. Circuit breaker design is crucial work. Although the hydraulic operation mechanism has a large output operation, the cost is relatively high[3], and the spring operating mechanism has a low cost, is simple to maintain, and is widely used.

The energy storage unit is one of the most critical design points in the overall design of the operating mechanism. The material selection and heat treatment methods of its components, the size of the return spring force, and the cooperation relationship directly affect the reliability of the energy storage of the operating mechanism in the spring[5]. Operating mechanism failure has always been a relatively large part.

2. Design Condition Analysis

2.1 The Energy Required to Store the Opening Spring

The energy of the opening gate spring is mainly used to ensure that each moving member reaches a sufficient opening speed[6]. When the opening speed needs to meet the small inductor, capacitor current, or short-circuit breaking current of the circuit breaker, the fracture has sufficient medium recovery strength. The fracture should have a sufficiently fast medium heat recovery rate[7]. These need to go through the open type test can be accurately determined, but according to experience, the average speed within 10ms after the opening of the general 220kV circuit breaker product needs to reach 8 ~ 9m / s, the maximum speed of about 10m / s.

Therefore, the kinetic energy of each moving member at the time of opening is

$$A_{f1} = \frac{1}{2} \cdot \mathrm{m} \cdot v_f^2 \approx 1149J \quad (1)$$

2.2 Calculation of Closing Spring Storage Energy and Design of Closing Spring

The stiffness of the large initial spring closing spring is 125 N/mm, and the maximum output force of the large spring is about 31250 N. The output work of the spring closing operation is 2500 J, and the stiffness of the closing spring is 68.8 N/mm. It can be concluded that the maximum output force of the small spring is approximately 17200N. The output work of the spring closing operation is 1376 J. Thus, the output work of the closing operation of the two closing springs is 2500+1376=3876 J in total. The circuit breaker requires the operating life of the operating mechanism to be more than 10,000 times, and the reliability requirements are high. Therefore, the best quality high-quality alloy spring material 60Si2CrVA is selected here. The performance parameters of this material are shown in Table 1.

Table 1. 60Si2CrVA Material Characteristics Chart

Young's Modulus	Poisson's ratio	Yield Strength	tensile strength
206000	0.3	1570	1364

The design result is 80mm preload for the gate spring, 120 mm stroke, and 142 N/mm stiffness. The maximum force of the gate spring is 28400 N. The diameter of the spring wire is 25 mm. The effective number of turns is 11 circles. The diameter of the spring is 135 mm, as shown in Figure 1.

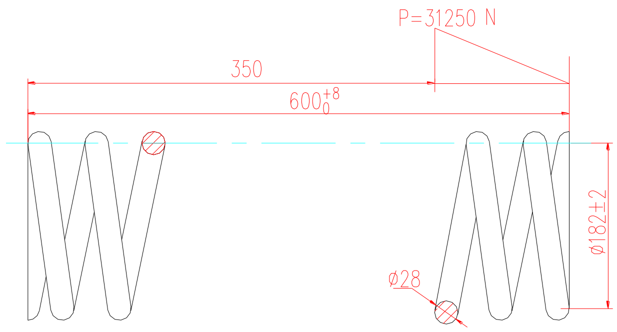

Fig.1 Closing Spring Sketch Map

3. Design and Check of Energy Storage Axes of Control Mechanisms

3.1 Energy Storage Shaft Material Selection

When the high-voltage circuit breaker is in working state, the closing spring of the operating mechanism stays fully loaded for a long time, ie it is in a compressed state for a long time, resulting in the energy storage shaft being subject to the force of the closing spring for a long time[8]. During the closing operation, the energy storage shaft acts as the main transmission shaft of the spring operating mechanism and also bears the largest impact load and static load of the mechanism. Due to the design requirements, the operating power of the spring operating mechanism is increased by a large amount. The spring force will also increase a lot. Therefore, higher requirements are placed on the stress check, material selection, and heat treatment methods of the energy storage shaft so that it has better comprehensive mechanical properties[9]. In order to enable the energy storage shaft to carry a large load and prevent fatigue fracture, the storage shaft is required to have good strength and impact toughness. For this purpose, carburizing alloy steel 20CrNiMo is selected as a part material, and the heat treatment method is selected after carburizing.

3.2 Modeling and Loading

According to the initial design structure and design dimensions of the energy storage shaft, three-dimensional solid modeling using solidworks software is performed. The model is shown in Figure 2.

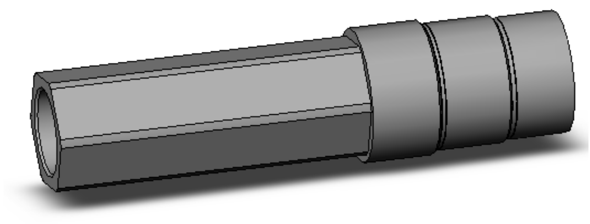

Fig. 2 Stereo Model of Energy Storage Shaft

3.3 Strength Check

Cosmosworks software was used to check the stress status and stress concentration and stress distribution were analyzed, as shown in Figure 3.

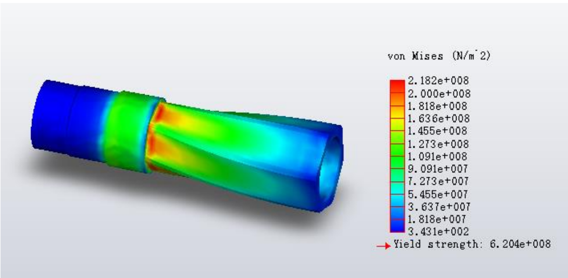

Fig. 3 Load Bearing Stress Diagram of Energy Storage

According to the calculated stress distribution, analyze the dangerous section or part of the energy storage shaft, and then continue to improve its structure, increase the fillet, change the model and re-check, the improved energy storage shaft through the prototype test, have a better resistance Impact performance and tensile strength fully validated the design's reliability.

4. Mechanical Property Test

4.1 Simulation Analysis of Reset Acceleration

The mechanical characteristic test is a very important part of the delivery test of the spring operating mechanism and is a necessary means to determine the stability of the operating mechanism. The mechanical characteristic test mainly includes the closing and closing time and the closing and closing speed test. The operating mechanism uses a Wuhan mechanical characteristic tester.

When the closing command is issued by the mechanical characteristic meter, the characteristic meter can automatically detect the current of the closing coil, and the characteristic meter will automatically record the starting point of the measurement time and start the timing[10]. The recorded time period can be Set the length. During the opening and closing operation, the moving part drives the rotation sensor to rotate, and the sensor transmits the detected data to the processing unit of the mechanical characteristic instrument, and the output characteristic curve diagram is calculated, and then various characteristics can be analyzed on the curve diagram.

The closing characteristic curve is shown in Figure 4, and the opening characteristic curve is shown in Figure 5.

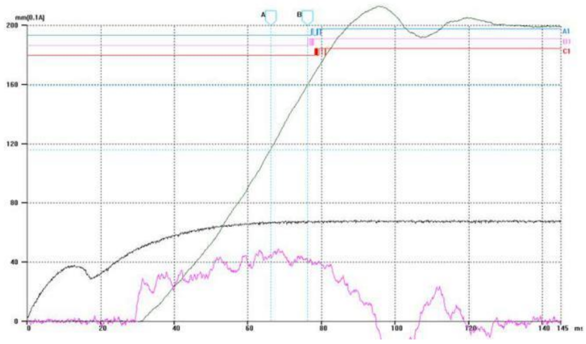

Fig. 4 Closing Characteristic Curve.

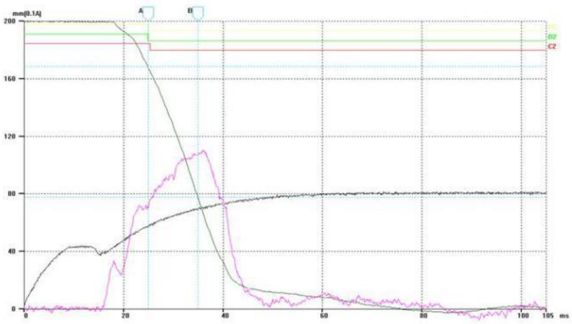

Fig.5 Opening Characteristic Curve

Through the analysis of the start-up time and waveform of the coil, and through multiple measurements and comparisons, the output characteristics of the actuator coincide with the needs of the circuit breaker, fully meeting the requirements of breaking, and successfully passing all types of test items.

5. Conclusion

The energy storage unit of the high-power spring operating mechanism used in the 252 kV circuit breaker was designed and developed, and the main components of the mechanism were designed, checked and tested for mechanical properties. The energy storage unit of the operating mechanism has a large output operation power, a simple overall structure, a low manufacturing cost, a good overall mechanical performance, a high reliability, a high life cycle stability, a convenient maintenance after a problem, and an effective solution to high-voltage circuit breakers. The control mechanism for the device has a complicated structure and a large amount of maintenance. The high power spring operating mechanism satisfies the design requirements and has good economic and social benefits.

References

[1] Jia Lili. High-voltage circuit breaker high-power spring actuator design [D]. Qingdao: Shandong University of Science and Technology, 2014, 77 (06): 18-19.

[2] Jia Lili, Cao Lianmin, Liang Chuantao, Optimization design of Yamaha electromagnet for high voltage circuit breaker [J] .COAL MINE Machinery, 2014,35 (06): 165-166.

[3] Yang Zhiyi, Jiang Shu. Design and Analysis of Cam Mechanism of High Power Spring Actuator [J]. Machine Design ＆ Research, 2017,33 (03): 1-5.

[4] Zhang Hao, Zhao Lihua, Jing Wei, et al.Study on dynamic mathematical model of electromagnet of high voltage circuit breaker spring mechanism [J] .High Voltage Apparatus. 2016 (07)): 110-115.

[5] Zhang Yingzhong, Xu Kexin, Yan Chongyi, Luo Xiaofang. Optimization and simulation of high-voltage circuit breaker spring operating mechanism [J] .High Voltage Apparatus, 2014,50 (04): 66-71.

[6] Zhao Lihua, Rong Qiang, Jing Wei, et al.State evaluation of operating mechanism of high voltage circuit breaker based on LabVIEW [J]. Journal of Electric Instruments and Measurement. 2016,53 (22): 54-59.

[7] Liu Wei, Xu Bing, Yang Huayong, .Analysis of characteristics of hydraulic actuator for high voltage circuit breaker [J] .Journal of Mechanical Engineering. 2010 (10): 148-155.

[8] Lin Xin, Ma Xizhi, Li Haomin. Dynamic Simulation and Experimental Research on Motor Operation Mechanism of 126kV Vacuum Circuit Breaker [J] .High Voltage Apparatus, 2015,51 (09): 9-16.

[9] Pu Jixing, Zhu Peng, Xu Guozheng, et al .Experimental study on the operating characteristics of high voltage circuit breakers electromagnets [J] .Journal of Tsinghua University (Science and Technology). 2006 (10): 1669-1672 + 1676.

[10] Zhang Yingzhong, Xu Kexin, Yan Chongyi. Optimization and simulation of high-voltage circuit breaker spring operating mechanism [J] .High Voltage Apparatus, 2014,50 (04): 66-71.