Design of main drive unit of high-voltage circuit breaker high-power operating mechanism

Xiangqiang Meng [a], Cheng Guo, Pengpeng Li

Mechanical and Electronic Engineering Institute, Shandong University of Science and Technology, Shandong 266510, China.

[a]1414520083@qq.com

Abstract

In order to solve the problems of complex structure, high cost, and large maintenance of 252 kV high-voltage circuit breaker hydraulic actuators, a large output operating power and high stability spring operating mechanism was researched and designed. The use of the main drive unit components including the cam, the output shaft optimization design, to improve the structural strength of the main drive unit, to ensure the long-term operation of the high voltage circuit breaker stability and reliability requirements[1]. The ADAMS software was used to simulate the main transmission unit's motion characteristics of the high-voltage circuit breakers' high-power operating mechanism. The simulation results showed that the high-voltage circuit breaker high-power circuit breaker's main drive unit's optimization design effectively improved the high-power circuit breaker high-power operation. Institutional performance.

Keywords

Cam, Output shaft, Main drive unit, Closing.

1. Introduction

With the continuous development of the high-voltage circuit breaker self-energy interrupter technology, the operating power required by circuit breakers has gradually decreased, which makes it possible to use high-power or ultra-high voltage circuit breakers equipped with high-power spring operating mechanism[2] . When the high power spring operating mechanism is operated, it will bear a large load and impact. The main drive unit requires its structural strength to ensure that the high voltage circuit breaker can be used stably. Based on the spring operating mechanism of the existing 126kV three-phase circuit breaker, this paper optimizes the main drive unit components of the high-voltage circuit breaker high-power operating mechanism. The ADAMS software was used to simulate and analyze the main and back movement characteristics of the main drive unit of the high-voltage circuit breaker high-power operating mechanism[3]. Through the data comparison, the main drive unit components of the high-voltage circuit breaker high-power operating mechanism were optimized and designed. Improve the performance of high-power spring operating mechanism, can bear larger loads and impacts during the working process, and ensure high-voltage circuit breaker can be used stably.

2. Structure Characteristics of Main Drive Unit of High-voltage Breaker High-power Operating Mechanism

2.1 Structure

The main drive unit structure of the high-voltage circuit breaker high-power operating mechanism includes the energy storage shaft, the drive arm, the cam, the output shaft, etc. The role of these components is to transmit power, and is the main carrier for implementing the opening and closing action. Because of the large spring force during the closing and closing, in order to ensure the strength of the operating mechanism, the high-voltage circuit breaker high-power operating mechanism bracket is designed to be in pressure contact, and at the same time, in order to reduce the energy loss during the transmission, it is connected with a pull rod to be installed on the Actuator under the bracket. In order to improve the conversion efficiency of energy transmission, the transmission cam and the energy storage shaft are arranged coaxially. When the closing operation is performed, the energy storage shaft is driven by the closing spring to rotate so that the arm roller is impacted by the driving cam to achieve energy conversion. In addition, the output arm on the output shaft is directly connected with the opening spring, which saves the transmission link and reduces the energy loss during transmission[4]. Take the vertical structure to fix the operating mechanism, and use the side to support the fixed installation, the installation strength of the mechanism meets the requirements, to ensure the convenience of the organization of transportation, on-site installation and removal. The structural design of the spring operating mechanism is shown in Fig. 1.

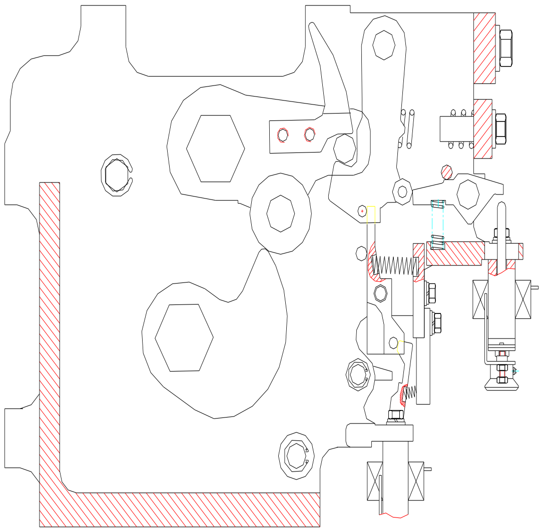

Fig. 1 Spring Operating Mechanism Structure Program

2.2 Working Principle

When the high-voltage circuit breaker is connected to the closing command, the closing gate is closed by the closing electromagnet, the energy storage keeps the buckles tripped, and the energy of the closing spring is released[5], so that the storage shaft is driven fast Rotate, at this time, the drive cam on the energy storage shaft quickly drives the roller on the arm, so that the drive arm swings up to 47°~49°, and the output arm of the coaxial arm of the drive arm rotates simultaneously and outputs The connecting rod spring connecting rod on the arm is pulling and pressing the tripping spring storage energy. When the transmission arm and the output arm are turned to the highest point, the tapping spring rod pulls the output arm and the output arm on the output shaft again. When it is turned back, when the buckle pin on the drive arm and the closing brake are held by the latch, the switch closes to keep the latch closed by the latch. Therefore, it can be seen that the output arm turns and turns and the energy stored in the sub-gate spring is compressed by the sub-bar spring pull rod to store energy as the energy required for sub-gate opening. The other end of the output arm is connected to the oil buffer to realize the buffering during the closing and closing process. The energy reduces mechanical collisions. It can be seen from the closing transmission process hat the closing process not only realizes the closing operation of the high-voltage circuit breaker, but also the opening spring stores the energy at the next opening time [6].

3. Design of Key Parts of Main Drive Unit Structure of High-voltage Breaker High-power Operating Mechanism

3.1 Actuator Cam Design

3.1.1 Cam Profile Curve Design

In the design of the spring operating mechanism for high voltage circuit breakers, the cam profile curve design is one of the most important design steps. The cam profile curve directly determines the output characteristics of the spring operating mechanism. The cam profile curve of the spring operating mechanism generally has a plurality of design methods such as a multi-segment arc fitting method, a multi-point smooth connection method, a mathematical function calculation method using a sine function, and the like. Because the sinusoidal function changes in the 0 to 1/4 cycle period, the output characteristics of the spring operating mechanism are well matched. Therefore, the sine function is used to design the cam profile of the spring operating mechanism. In order to better ensure the output characteristics of the spring operating mechanism, this paper also uses a sine function method to design the cam profile curve.

The curve function is:

$$R = 43 + \frac{55\sin 90 \bullet \left(\alpha - 23^{\circ}\right)}{127} \tag{1}$$

In the formula: $55° \leq \alpha \leq 150°$.

This function shows that when α is 55°, it is the starting point of the lift curve of the function. When α is 150°, it is the end point of the lift curve of the function, and the middle point α is obtained from different values. According to the design skills of this function, according to the structure of the cam and the pre-closing output characteristics requirements of the spring operating mechanism, the starting point of the function curve is initially set, and the function curve end point is determined according to the rotation angle of the closing spring and the swing angle of the output arm. , and then determine the range of function angles and the values within the function. The initial segment of the cam can be used to make a transition between an arc segment and a structural arc, and the end segment of the cam is a radius arc of the maximum value of the function. The specific structure is shown in Fig. 2.

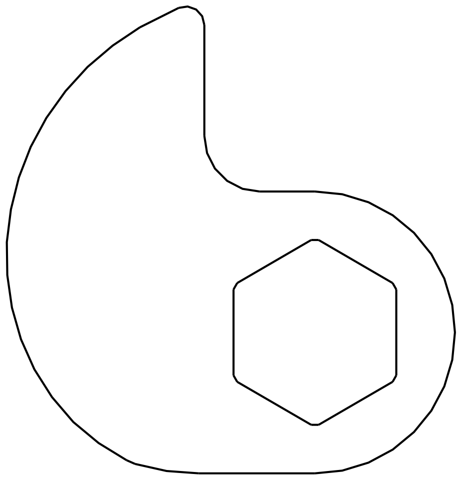

Fig. 2 Cam Shape

Draw the cam lift curve as shown in Fig. 3, according to the curve to improve the intersection of the outline of the smooth transition to eliminate abnormal smooth points. Then, according to the closing and closing operations and the moving mass, the closing speed is analyzed. As shown in Fig. 4, it is preliminarily measured whether the closing characteristic matches the requirement, and the poor matching is re-analyzed after the appropriate correction curve function [7].

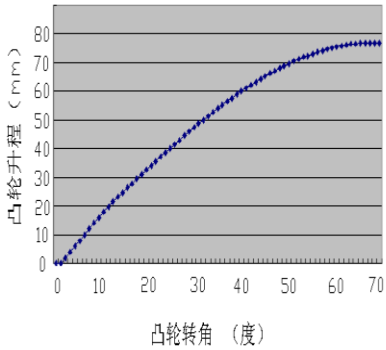

Fig. 3 Cam Rise Curve

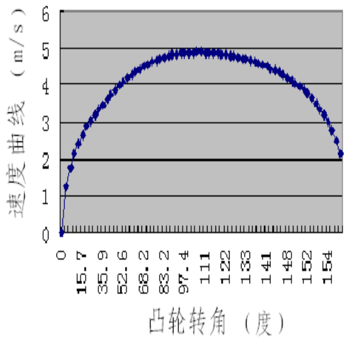

Fig. 4 Open Velocity

3.1.2 Cam Material, Processing Method and Structural Design

In the closing process of the cam, it needs to carry a large impact, and the friction conditions are more severe, so the cam requires high strength and wear resistance. The quenched and tempered 40Cr alloy material is used here, and high-frequency quenching is applied to the contour curve. Guaranteed comprehensive mechanical properties and high wear resistance of the profile. In addition, in order to ensure the matching strength between the cam and the shaft, a flange structure is added to the fitting hole.

3.2 Actuator Output Shaft Design

The output shaft is subjected to a large impact load during the opening and closing operations. The shaft structure is long and the force is complex. The shape, material selection, and heat treatment methods all have a great influence on the service life. Therefore, it is necessary to optimize the design from the aspects of material selection, structure optimization and heat treatment process.

3.2.1 Output Shaft Structure Design Analysis and Improvement Process

The outline of the initial output shaft is shown in Fig. 5, and the improved structure is shown in Fig. 6.

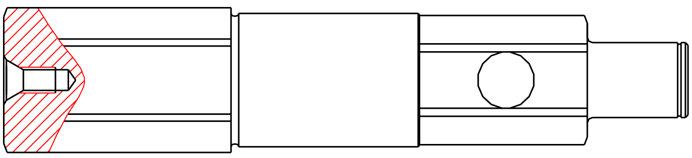

Fig. 5 First Configuration of Export Shaft

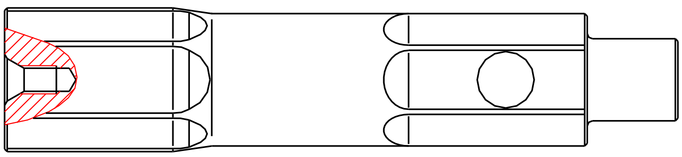

Fig.6 Improving of Export Shaft

By increasing the diameter of the main shaft of the shaft drive, and the smooth transition between the outer circle and the six sides using a slant and a circular arc, the stress concentration is significantly reduced. The cross-sectional area of the improved outer circle increases from 17452mm to 18702mm. From 19.98% to 12.01%.

3.2.2 Output Shaft Material Selection and Heat Treatment Analysis and Process Improvement

The initial material for the output shaft is 40Cr, which is later changed to 42CrMo alloy material. The performance of the two materials is compared:

Table 1 Contrast of Material Characteristics

material	40Cr	40Cr	42CrMo	42CrMo
Quenching temperature(°)	840	840	850	850
Tempering temperature(°)	450	510	480	560
tensile strength(Mpa)	1180	980	1350	1080
Yield Strength(Mpa)	1150	785	1250	930
After-break rate	/	9	10.5	12
After shrinkage	38	45	40	45
Shock absorption work(J)	42	47	45	65
Hardness HRC	40	33	40	33

By comparison, it can be seen that the overall performance of the 42CrMo material is relatively good, and the Mo element is added to the 42CrMo material, and the heat treatment performance is better. Therefore, the material of 42CrMo is changed to 42CrMo material.

Observe the fracture of the first prototype, no obvious deformation was found on the fracture surface, and no material defect was found. Therefore, fatigue fracture caused by multiple impact alternating loads can basically be judged, and not the overall mechanical strength is insufficient.

In this way, based on the initial life test and detailed force analysis, a secondary design improvement was made on this axis. The main improvement points are summarized as follows:

A. Increase the diameter of the main shaft of the output shaft, reduce the cross-section difference and increase the strength;

B. The smooth transition of slopes and arcs is adopted for the two changing sections, reducing the stress concentration;

C. The diameter of the small-section cylindrical surface is increased to increase the strength of the structure;

D. Change 40Cr material into 42CrMo alloy material with better strength, toughness and heat treatment performance.

After the actual follow-up life test and small batch production verification, the improvement is reliable and reasonable, and meets the requirements for use. Moreover, through the structural improvement, the stress generated by the heat treatment is also significantly reduced, so that the manufacturing difficulty and the quality instability are eliminated.

4. Analysis of Motion Simulation of High Power Circuit Breaker High Power Operating Mechanism

The ADAMS software was used to simulate the parameters before and after the optimization of the main drive unit of the high-voltage circuit breaker high-power operating mechanism. Fig. 7 shows the dynamic model of the operating mechanism, which can reflect the characteristics of the operating mechanism during the movement. Fig. 8 and Fig. 9 respectively reflect the opening and closing motion characteristics before and after optimization.

In the figure, the abscissa is time in ms, and the ordinate is speed and angular velocity. The waveforms include the spindle angle, the main contact stroke, the spindle angular velocity, and so on. Using the data obtained from ADAMS simulation, it can be seen that the average speed of the original operating mechanism at opening is 0.753 m/s, and the initial speed is about 0.982 m/s. The initial angular velocity of the main transmission shaft of the transmission unit is 7.79 rad/. s, the angular velocity changes to 8.21 rad/s at the end of the movement, which is relatively small and does not satisfy the use of high voltage circuit breakers.

Fig.7 Spring Operating Mechanism Kinetic Model

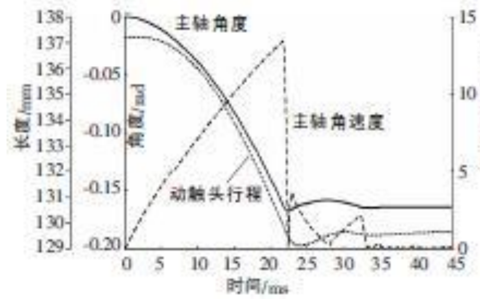

Fig. 8 Opening Characteristics before Optimization

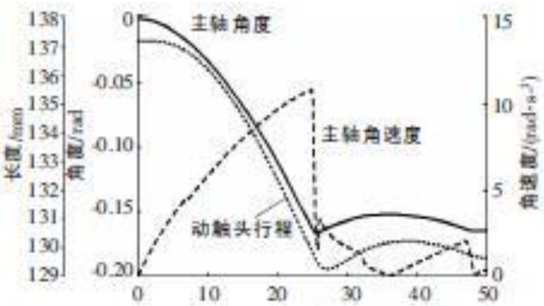

Fig. 9 Opening Characteristics after Optimization

In the figure, the optimized opening motion characteristics. Using the data obtained from ADAMS simulations, it can be seen that the average speed of the original operating mechanism at opening is 1.084 m/s, and the initial speed is approximately 1.123 m/s. The initial angular velocity of the main transmission shaft of the transmission unit is 8.39 rad/s, the angular velocity changes to 10.88 rad/s at the end of the movement. This speed has been significantly improved before optimization, and can meet the normal use of high voltage circuit breakers.

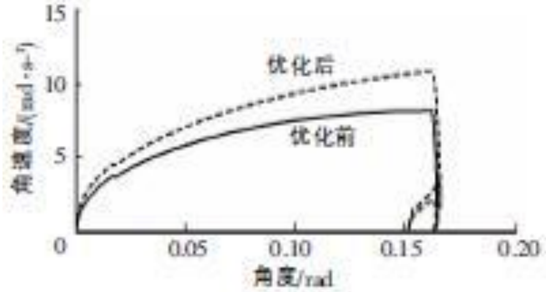

Fig.10 Before and After Optimization of Spindle Angular Velocity Changes

Fig. 10 shows the angular velocity changes of Zhuzhou before and after optimization. It can be seen from the comparison that after optimizing the cam and the main drive shaft in the high-voltage circuit breaker high-power operating mechanism transmission unit, the angular velocity of the main drive shaft is significantly improved. Optimize the correctness of the design.

5. Conclusion

The paper focuses on the optimization of the main components of the main drive unit of the high-power spring operating mechanism. First of all, for the optimal design of the cam, a sine function method is used to design the cam profile curve, as well as the design of materials and processing methods and mechanisms, to better ensure the output characteristics of the spring operating mechanism; then the output shaft structure is optimized, and at the same time, Output shaft material selection and heat treatment analysis and process improvement ensure that the output shaft can withstand large impact loads during the opening and closing operations. Finally, the ADAMS software was used to simulate the movement of the main components of the high power spring operating mechanism before and after optimization. The comparison of test data shows that the optimization of the main components of the main drive unit significantly improves the structural strength of the main drive unit. High voltage circuit breakers can be used for long periods of time.

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