Structure Simulation Analysis of Pneumatic Mechanical Bypass Switch

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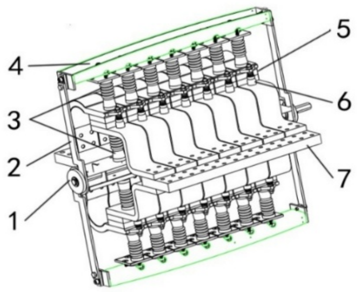
Abstract: Mechanical bypass switch is a powerful guarantee for maintenance and fault operation in power transmission and distribution lines. Analysis of its opening and closing action characteristics is of great significance for improving its property. In this paper, aiming at the structural damage of the pneumatic mechanical bypass switch transmission mechanism, the kinematic and dynamic simulation analysis of the pre-developed product is carried out. The stress time history of dangerous parts is obtained, and the rationality of product structure design is checked. These provide reliable and effective technical support for later product development

1. Introduction

With the development of transmission and distribution voltage level and capacity, the reliability and economic requirements of power grid are also increasing [1]. Mechanical bypass switch, as an important link, is an important guarantee for maintenance and fault operation in high-voltage transmission and distribution system [2], and its structural reliability plays a decisive role in it. The transmission mechanism of the pneumatic mechanical bypass switch is the most easily damaged part [3]. In this paper, a dynamic simulation method of the action process of the pneumatic mechanical bypass switch is proposed. the stress time history of the key parts is obtained, and the rationality of the design is checked.

2. Calculation input

The transmission part of mechanical bypass switch is a crank slider mechanism driven by pneumatic switch [4], which drives the action of connecting rod, crossbeam, insulation and moving contact (Figure 1). The main action characteristic requirements are: opening time≤450ms, closing time≤500ms, closing jitter time ±5ms, mechanical life 2000 times.



1-drive plate, 2-connecting rod, 3-insulation support, 4-steel beam, 5-moving contact, 6-static contact, 7-connection terminals

Figure 1 Three-dimensional model of mechanical bypass switch

The driving plate and connecting rod are relatively weak components in the mechanical bypass switch, and the stress level in the process of single opening and closing action is related to the closing and opening time [5]. The opening process of mechanical bypass switch is simulated in ADAMS, and the force-time curve of driving disk and connecting rod is obtained. Then the finite element model is established in ANSYS to analyze the stress time history, obtaining the stress level of the transmission part of the mechanical bypass switch in the process of opening and closing, and check the strength of its key components.

3. Simulation calculation

3.1 Model simplification

Simplify the opening and closing drive system in Section 1 to Adams kinematic calculation model shown in Figure 3. The model is composed of five parts, which are two driving plates, two connecting rods and one crossbeam. The size, mass and relative position of each part are the same as the design scheme. Attach all the masses of the upper moving contact and related parts (Fig.2) to the beam equally, and apply X-direction moving pair between it and the ground. Then add rotating pair at the corresponding positions of connecting rod and crossbeam, connecting rod and drive plate and add rotating pair between drive plate and ground. The drive is applied to the rotating pairs of the two drive discs and the ground. Because the motion characteristic of the cylinder driving rotation in the existing model is not clear, the opening and closing process of the switch is first photographed by the high-speed camera, and the angular velocity curve of the driving disk is obtained as the motion simulation input [6].

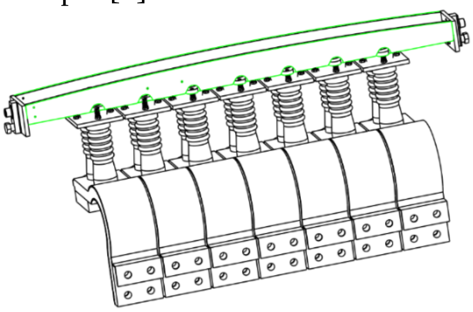


Figure 2 Upper moving contact and related parts

3.2 Establishment of collision model

The collision model of arc contact and main contact is involved in the process of closing. ADAMS can be used to solve the collision problem of rigid body conveniently. There are two ways to define collision force in ADAMS: One is the compensation method; the other is the impact function method [7]. The impact function method is based on the impact function to calculate the impact force between two components, which is composed of two parts: One is the elastic force due to the mutual cutting between two components; the other is the damping force due to the relative speed.

$$F\_impact = \begin{cases} o \\ k(q_0 - q)^e - c_{\max} \cdot (dq/dt) \cdot step(q, q_0 - d, 1, q_0, 0) \end{cases} \tag{1}$$

q_0 is the initial distance between two objects to be collided; q is the actual distance between two objects in collision; d_q/d_t is the rate of change of distance between two objects with time, i.e. speed; K is the stiffness coefficient, e is the impact index; c_{max} is the maximum damping coefficient, d is the cut in depth. In order to prevent the discontinuity of damping force in the process of collision, step function is used in the formula, and its form is *step*(*x*, *x* ,*h* , *x* ,*h*), which should be calculated according to formula (2).

$$step = \begin{cases} h_0 & x \le x_0 \\ h_0 + a \cdot \Delta^2 (3 - 2\Delta) & x_0 \le x < x_1 \\ h_1 & x \ge x_1 \end{cases} \tag{2}$$

$$a = h_1 - h_0, \quad \Delta = (x - x_0) \ / (x_1 - x_0).$$

4. Simulation results

In the second section of the model, the motion characteristics of the system under three different opening times are calculated, focusing on the force of the driving disk and the connecting rod in the process of action.

(1) When the rotating speed of the drive disk is 7.06rad/s, the opening time is 450ms, and the motion characteristics of the system are as follows:

Table 2 System motion characteristics when opening time is 450ms

Time(ms)	Opening stroke(mm)	FX at the upper end of the connecting rod (N)	FZ at the upper end of the connecting rod(N)	F at the upper end of the connecting rod(N)
0	0	843	8	845
215	40	725	64	730
330	80	581	40	583
450	100	495	4	496

The time curves of driving disk and connecting rod are extracted. Then the finite element model is established in ANSYS and the stress time history analysis is carried out. Therefore, the structural stress nephogram at the maximum stress moment is obtained respectively.

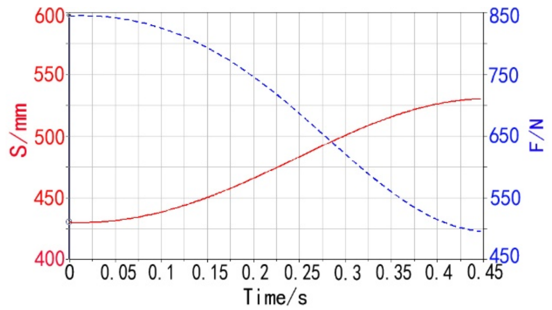


Fig. 3 Time history curve of contact displacement and connecting rod force when opening time is 450ms

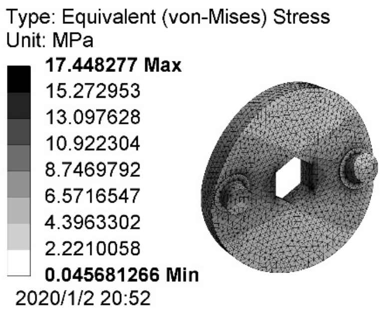
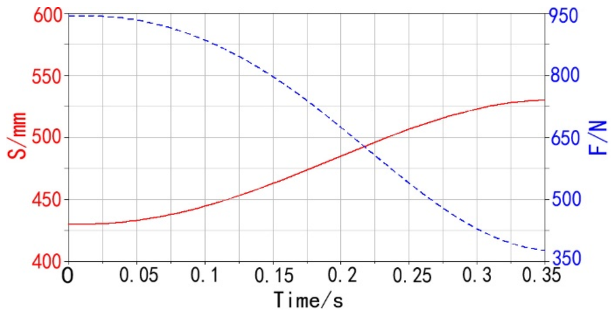


Fig. 4 Maximum stress nephogram of Drive Plate when opening time is 450ms

(2) When the speed of the drive disk is 8.97rad/s, the opening time is 350ms, and the motion characteristics of the system are as follows:

Table 2 System motion characteristics when opening time is 350ms

Time(ms)	Opening stroke(mm)	FX at the upper end of the connecting rod(N)	FZ at the upper end of the connecting rod(N)	F at the upper end of the connecting rod(N)
0	0	944	2	945
170	40	748	67	752
260	80	512	35	515
350	100	375	3	377



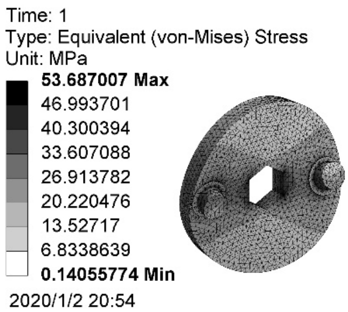


Fig. 5 Time history curve of contact displacement and connecting rod force when

opening time is 350ms

Fig. 6 Maximum stress nephogram of Drive

Plate when opening time is 350ms

(3) When the rotating speed of the drive disk is 10.5rad/s, the opening time is 300ms, and the motion characteristics of the system are as follows:

Table 2 System motion characteristics when opening time is 300ms

Time(ms)	Opening stroke(mm)	FX at the upper end of the connecting rod(N)	FZ at the upper end of the connecting rod(N)	F at the upper end of the connecting rod(N)
0	0	1037	10	1038
145	40	774	67	778
223	80	452	32	454
300	100	265	2	265

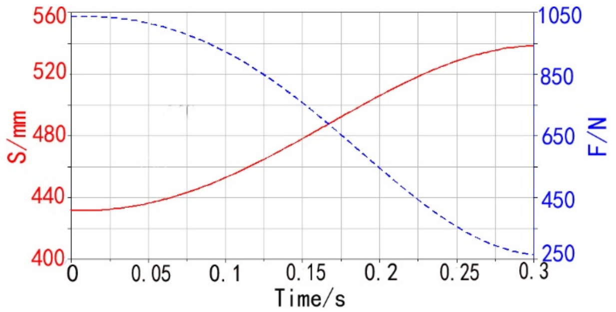


Fig. 7 Time history curve of contact displacement and connecting rod force when opening time is 300ms

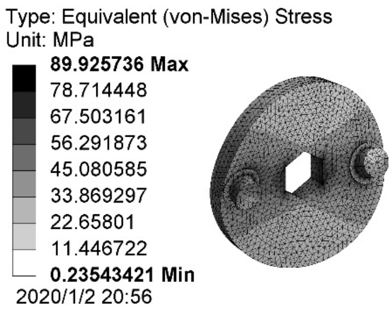


Fig. 8 Maximum stress nephogram of drive plate when opening time is 300ms

5. Conclusion

(1) The stress and structural stress of the key moving components (driving plate and connecting rod) of the mechanical bypass switch increase with the decrease of the opening time (the increase of the rotating speed of the driving shaft of the pneumatic switch);

(2) The maximum stress area of the driving disk is the two round bosses connecting the connecting rod and the connecting part area, and the maximum stress area of the connecting rod is the connecting part with the driving disk;

(3) When the opening time is 450ms, 350ms and 300ms, the stress level of key moving components (driving plate and connecting rod) is low. When the opening time is 300ms, the maximum stress of the drive plate is 89.9MPa, the maximum stress of the connecting rod is 31.4MPa, and the part material is 45 steel (the yield limit is 355MPa, and the allowable stress value is 142MPa). The part meets the strength design requirements.

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