Analysis of Motor Operating Mechanism in Separation Test of Coal Mine Isolation Switch

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Abstract

In order to improve the technical level of the separation test of the coal mine isolation switch and realize intelligence of the whole operation process, the operating mechanism of the brushless DC motor is put forward. For the coal mine isolation switch breaking test motor operating mechanism, we designed controllable testing system based on the theoretical analysis of motor operating controllability of mechanism, and testing in the way of different duty cycle test many times. The test results show that the slope (velocity) of the curve is changed with the duty cycle, which proves the controllability of the running process of the motor operating mechanism.

Keywords

Coal mine; isolation switch; motor operating mechanism; controllability.

1. Introduction

In China, the energy structure continuous optimization, hydropower, wind, solar and biomass and other non fossil energy gradually entered the industrialization development mode. However, the energy resources characteristics of rich in coal, poor in oil and gas decided coal still is the main energy in our country. According to the energy development strategy action plan (2014-2020) requirements, by 2020, China's total energy consumption will be controlled at about 480 million tons of standard coal, coal total consumption 420 million tons.

Due to the bad working environment of coal mine, requirements about the reliability and stability of electrical equipment is higher. According to GB/T5590-2008 Mining explosion-proof low voltage electromagnetic starter and MT111-2011 Mining explosion-proof low voltage alternating vacuum electromagnetic starter, the isolation switch must have the ability of breaking current, and the test condition is positive and reverse each operation 3 times. The traditional coal mine isolation switch has backward technical level, poor reliability, and low controllability. Therefore, it is the development trend of coal mine electrical equipment inspection field to study the new operating mechanism to meet the requirement of the separation of the coal mine.

2. Coal Mine Isolation Switch

Coal mine isolation switch is the important components of flameproof type vacuum electromagnetic starter, mining flameproof type coal electric drill transformer integrated protection device, mine flame proof type multi loop combination switch and mine flame proof and intrinsically safe type soft starter and other electrical equipment. Playing the function of to breaking fault current (if contactor failure, no breaking current), electrical isolation and no load commutation in coal mine power grid. According to the coal mine electrical equipment of rated voltage and rated current situation, coal mine isolation switch

rated voltage grade is divided to 660V, 1140V and 3300kV, rated current of divided 80A, 160A, 200A, 315A, 400A and 630A, figure 1 shows the physical map of GHK-400/1140V type mine isolation switch.

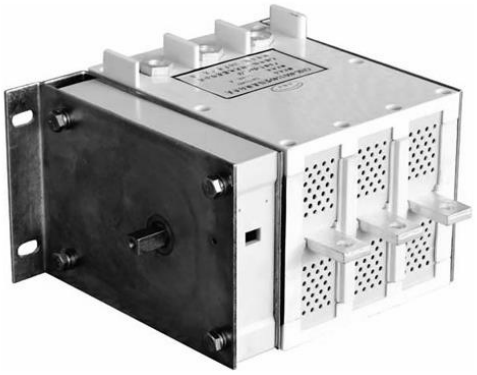

Fig. 1 Physical map of GHK-400/1140V type mine isolation switch

3. Controllability Analysis

In order to facilitate the quantitative analysis of the controllability of the motor mechanism, the magnetic saturation effect, cogging effect, permanent magnet role in blocking, armature reaction, magnetic and eddy current loss is neglected, and motor mechanism is the ideal state (Three phase winding is completely symmetrical, and the inner surface of the stator is smooth and uniform). The three-phase winding voltage balance equation can be expressed as:

$$\begin{bmatrix} u_a \\ u_b \\ u_c \end{bmatrix} = \begin{bmatrix} r & 0 & 0 \\ 0 & r & 0 \\ 0 & 0 & r \end{bmatrix} \begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix} + p \begin{bmatrix} L-M & 0 & 0 \\ 0 & L-M & 0 \\ 0 & 0 & L-M \end{bmatrix} \begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix} + \begin{bmatrix} e_a \\ e_b \\ e_c \end{bmatrix} \tag{1}$$

In the above equation, u_a, u_b, u_c is three phase winding voltage, r is three-phase stator of each phase in the resistance, and i_a, i_b, i_c is three-phase stator winding phase current; e_a, e_b, e_c is three-phase stator winding anti electric motive force. The equivalent circuit of the voltage equation is shown in Figure 2.

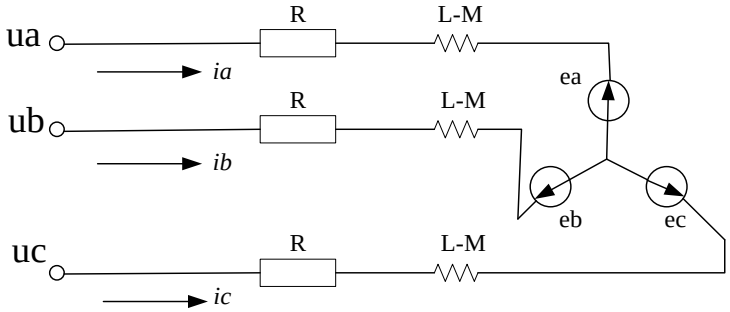

Fig. 2 Brushless motor voltage equation equivalent model

The three-phase winding of the motor mechanism adopts star connection mode, and the working mode adopts the two-phase winding, and the induction electromotive force is composed of two phase windings. Therefore, there is a counter electromotive force equation:

$$E = 2e = 2C_e\phi_m n \tag{2}$$

In the above equation, C_e is inverse electromotive force coefficient, ϕ_m is flux.

Brushless DC motor electromotive force balance equation:

$$U_d = E + I_d R_\Sigma + 2\Delta U \tag{3}$$

In the above equation, U_d is end voltage of the winding when the two phase conduction; E is brushless DC motor counter electromotive force; R_Σ is motor stator armature circuit total resistance; I_d is motor stator armature circuit current; ΔU is voltage drop at the ends of power device.

According to the equation (2) and (3), the speed equation of the brushless DC motor can be expressed as follows:

$$n = \frac{U_d - I_d R_\Sigma - 2\Delta U}{C_e \phi_m} \tag{4}$$

According to the equation (4), we can known that for the specific motor, the loop resistance R_Σ ,the loop current I_d and voltage ΔU drop are constant, if the magnetic flux remained constant, changing the armature voltage can achieve the purpose of speed regulation, that is, through changing PWM signal pulse duty ratio electric armature winding at both ends of the voltage regulation, achieving the purpose of dynamic speed regulation of the motor.

4. Controllability Test

4.1 Designing of Test System

Coal mine isolation switch motor operating mechanism controlled test system using the powerful data processing capability of digital signal processor (DSP). It can capture the external input instruction, and according to the position of motor operating mechanism transmitting control signal to drive the motor to move. Meanwhile changing control signal cycle and getting motor travel characteristic curve, and then testing controllability. The testing system mainly includes the control panel, power module, DSP, three phase bridge inverter circuit, rectifier circuit, stroke detection unit and motor mechanism and so on. Its structure is shown in figure 3.

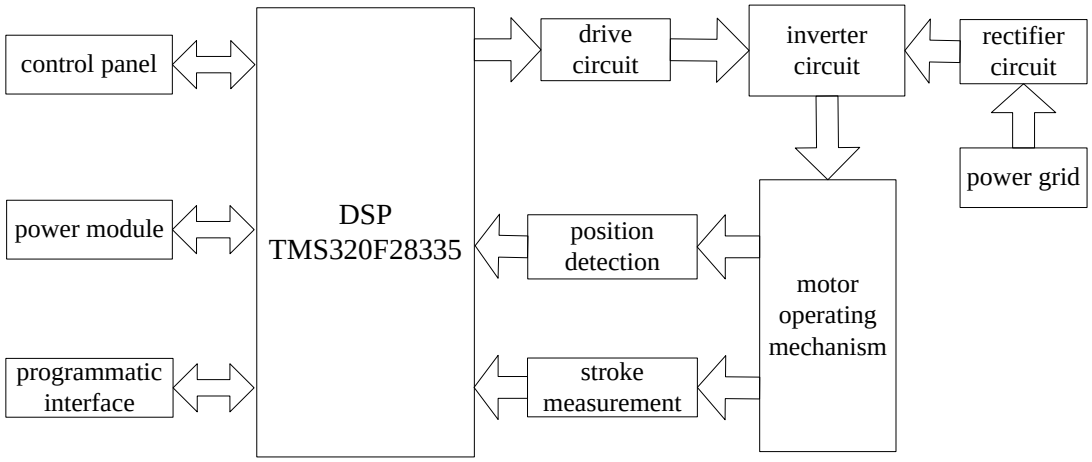

Fig. 3 Structure diagram of control system for motor operating mechanism

4.2 Controllability Test

In order to verify the controllability of the motor operating mechanism of the coal mine isolation switch, the test is divided into two ways: different duty cycle multiple tests and different duty cycle single test. The duty cycle of the former is 90%, 75%, 65%, 60%, respectively. And the motor motion travel curve is collected, as shown in figure 4. It can be drawn from the chart that the larger the duty cycle, the greater the rise slope of the travel curve, that is, the greater the motor speed; with the decrease of the duty cycle, the slope of the travel curve becomes smaller, that is, the motor speed becomes smaller.

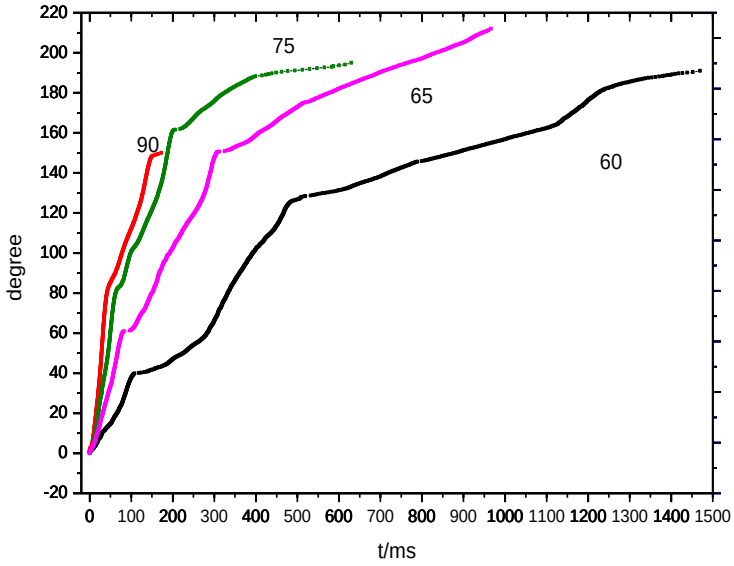

Fig. 4 Contact stroke curve under different duty ratio

5. Conclusion

With the increase capacity of coal mine electrical equipment, higher requirements of the security of the power supply system is put forward. Breaking test is an important index to measure the performance of coal mine isolated switch and related products. According to the motor operating mechanism of the coal mine isolation switch, we designed controllability test system based on the theory of mine coal isolation switch structure, working principle and the controllability of the motor operating mechanism. The experimental results show that the motor operating mechanism movement process is completely controllable, and it lays the foundation for the development of the synchronous separation technology of the coal mine isolation switch.

Acknowledgements

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