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Research on New Bimetallic Trigger

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Abstract

With the progress of technology and the improvement of environmental protection requirements, new energy vehicles ushered in a golden age of rapid development. But hot new energy vehicle brands such as Tesla continue to have battery short-circuit combustion accidents, which has cast a shadow on the development of new energy vehicle industry. As an important equipment of automobile power battery protection, high-speed disconnector can quickly cut off the current when the battery breaks, so it has become the research focus in recent years. However, at this stage, the high-speed disconnector can not be disconnected under the condition of small current, which will cause the battery system to work in the condition of higher than the rated current for a long time, resulting in security risks. In order to solve this problem, based on the electrothermal field equation and the material mechanics equation, a three-dimensional model of the new bimetallic flip-flop is established by using the COMSOL software, and the electric thermal coupling calculation is carried out. The temperature field, voltage and current at both ends of the flip-flop with small current are obtained. Based on the theoretical calculation, the simulation results verify the theoretical calculation results, and a bimetallic flip-flop structure with small current can be designed. Finally, the correctness of the model and theoretical calculation is verified by comparing with the experiment, which shows that the structure has a guiding role in the design of the new bimetallic flip-flop.

Keywords

Bimetallic strip, temperature distribution, trigger, structural design, small current.

1. INTRODUCTION

With the progress of technology and the improvement of environmental protection requirements, new energy vehicles ushered in a golden era of rapid development. But a hot new energy automobile brand like tesla spate of power battery short circuit accident of burning, for the development of new energy automotive industry casts a shadow, and as an important equipment of automobile power battery protection, high speed switching device can be rapidly interrupts the current flowing in the battery break occurs, thus become the research focus in recent years. However, there is a problem that the high-speed breaker cannot be switched off under the condition of low current (3 times rated current), which will cause the battery system to work for a long time above rated current and cause safety hazards.

The high-speed breaker and its parallel commutator branches and triggering device [1] constitute a hybrid current-limiting fuse [2-4]. In case of short circuit, the high speed breaker will break quickly and transfer the current to the commutator branch. However, whether the high-speed breaker can break quickly depends on whether the trigger device can detect the fault current quickly. Trigger[4] is a device that can detect the fault current. The arc pressure generated by the trigger is introduced into the gunpowder chamber and can ignite the

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gunpowder to cut off the circuit. It is an indispensable core component of hybrid current-limiting fuses. Due to trigger the throat diameter size is in accordance with the requirements for large current condition fast fuse design, can guarantee the large fault current fast fuse, but three times the rated current (a) in the small current conditions, current thermoelectric effect will not fuse trigger the throat diameter, system for a long time into the fault current will cause damage to components or even a serious accident. In order to solve the problem that the trigger cannot be fused in a small current, a narrow diameter is compressed by external force to reduce its cross section area to reach yield strength fracture. In this process, due to the smaller cross section area, the current density at the section will also increase, and the narrow diameter temperature will rise, which will accelerate the fracture of the narrow diameter, and under the mutual promotion of external force and temperature rise, the narrow diameter is more likely to fuse and generate arc. Therefore, a new flip-flop structure which can push the gate to squeeze the narrow diameter is designed in this paper.

Based on the electrothermal field equation and the material mechanics equation, the three-dimensional model of the new bimetallic flip-flop is established in this paper. Comsol software was used to calculate the electro-thermal coupling [5], and the temperature field, voltage and current at both ends of the flip-flop with time were obtained.

Based on the theoretical calculation and the simulation results, a bimetal flip-flop structure is designed which can break the narrow diameter of the flip-flop under the condition of small current. At last, the correctness of the model and theoretical calculation is verified by the comparison with the experiment, which shows that the structure is instructive for the design of new bimetallic flip-flop. According to this design method, we can solve the problem that the trigger cannot detect the fault current under the condition of small current, which provides a reference for the theoretical research and engineering application of high-speed breaker in the future.

2. STRUCTURE DESIGN OF BIMETALLIC FLIP-FLOP

The structure of the new double-gold [6] wafer flip-flop is shown in FIG. 1. Copper and epoxy resin are used in the flip-flop end row to fix both ends of the bimetal sheet. One end of the copper block is used because copper has a small thermal resistance, which is conducive to the heat conduction between the copper row and the double gold sheet. The other end adopts epoxy resin because of its insulation and great thermal resistance, which can insulate the bimetal sheet and copper strip, avoid the current on the copper strip being shred to the metal sheet, resulting in its heating, affecting the temperature distribution and destroying the relationship between the temperature of the bimetal sheet and the thrust. The two ends of the bimetal sheet are inserted into the groove of the two ends of the fixed block by means of clearance fit. The metal sheet can be freely deformed to a certain extent in the groove. The width of the two slots is larger than 0.5mm of the double gold sheet.

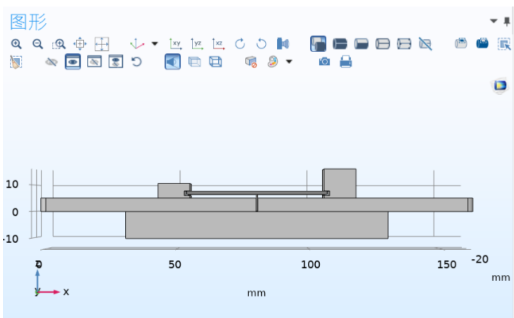

Fig 1. Structure of new bimetallic flip-flop

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2.1. The Theoretical Calculation

The thrust formula of single beam is known [7,8]:

$$F = \frac{KEbe^2 \Delta T}{4L} \tag{1}$$

The thrust formula of the double beam:

$$F = \frac{KEbe^2 \Delta T}{L} \tag{2}$$

By comparing the thrust formulas of single beam and double beam, it can be found that the thrust generated by the bimetallic sheet designed as double beam structure is 4 times that generated by the designed single beam structure. In order to make the bimetallic sheet produce greater thrust in the finite space, this study adopts the double-beam metal sheet structure. In order to obtain the specific design size, the simplified model is a double beam model.

The flip-flop designed in this paper is a narrow diameter with a thickness of 0.1mm* 1mm* 0.55mm,5 narrow necks in parallel, and the copper row distance of the breaker is calculated as 0.6mm. In the condition of room temperature is 22.7℃ (room temperature is 22.7℃) of the small resistance to 44 mu Ω. When the trigger is placed on a pressure machine, the pressure required for narrow fracture is measured at about 95N.

The designed flip-flop was put on a static pressure machine, and the force-traveling-resistance curve was measured to find out the pressure corresponding to the sudden change of resistance. It was considered that the pressure corresponded to the obvious deformation of the flip-flop's narrow diameter (when the narrow diameter became thinner, the resistance increased and the narrow diameter fuses faster).

Calculated according to the formula of deformation force, double fund piece temperature delta T, than the bending ratio K (this study USES is TB20110 brand of materials, because it has the larger than the bend curvature), double base metal thickness, thrust F (began to trigger the throat diameter significantly increased pressure), the elastic modulus E, the bimetallic strip length L and width b design. In order to ensure that the thrust generated by the bimetallic sheet can break the narrow diameter, 10% design margin is reserved when designing the bimetallic sheet size, and the thrust design standard of the bimetallic sheet is set as 110N.

$\rho c \frac{\partial T}{\partial t} = \nabla \left(\lambda \nabla T \right) + S_u$ Put the parameters into the thrust formula, and the thrust of the double beam is:

$$F = \frac{20.8 \times 10^{-6} \times 113000 \times b \times 80 \times 1.2^2}{L} = 95N \tag{3}$$

Plug in $b = 17mm$ Can solve $L = 48mm$. Therefore, the length of the bimetallic strip should be designed as $L = 48mm$, $b = 17mm$, Process bimetallic sheet according to this size.

2.2. Electrothermal Field Equation

The deformation and stress calculation of the bimetallic sheet involves temperature field, electric field and external circuit. The specific equations are as follows:

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(1) The temperature field

The whole process is a basic unsteady heat conduction process, the basic equation is as follows:

$$\rho c\frac{\partial T}{\partial t}=\nabla\left(\lambda\nabla T\right)+S_u \tag{4}$$

ρ is the density of silver, kg/m^3; c is the specific heat at constant pressure of silver, $J/(kg\cdot K)$; λ is the thermal conductivity of silver, γ is the conductivity of silver, S/m.

(2) Open circuit

Assuming that the shunt circuit branch resistance is much larger than that of the trigger branch resistance and the shunt commutator branch will not affect, it can be considered that the current into the trigger does not change with the temperature rise of the trigger. The current-voltage relationship is determined by the following formula:

$$U=R\times I \tag{5}$$

U is the voltage; I is the current; R is resistance.

The converter circuit model of the breaker is shown in Figure 4.

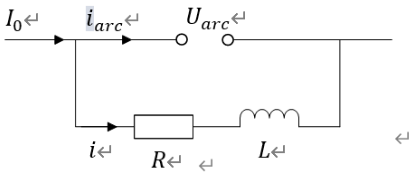

Fig 4. Circuit diagram of commutation process

To calculate the arc current, the calculation formula is as follows

$$U_{arc}=R\cdot i+L\frac{di}{dt} \tag{6}$$

$$i_{arc}=I_0-i \tag{7}$$

3. SIMULATION RESULTS AND ANALYSIS

According to the established mathematical model of bimetallic sheet design, the three-dimensional model of the new bimetallic sheet flip-flop was established by using comSOL software, and the electrothermal coupling calculation was carried out [9], The temperature field, voltage and current at both ends of the flip-flop with small current are obtained to analyze the influence of the main design parameters on the performance of the new bimetallic flip-flop.

3.1. The Simulation Results

In comsol software, 1400A current is applied to the flip-flops with a thickness of 0.1* width 1* length of 0.55mm and 5 narrow necks in parallel.

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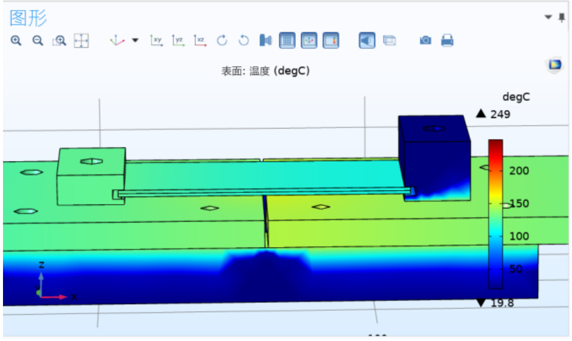

Fig 2. Temperature field simulation model of new bimetallic flip-flop

3.2. Analysis of Simulation Results

As can be seen from the temperature field simulation results in Figure 2, at 1400A and 140S, the temperature of the flip-flop copper row is 115 ° C, the temperature of the fixed side of the double-base metal copper block is 123 ° C, and the temperature of the epoxy resin side is 110 ° C. Therefore, the heat transfer between the copper row at both ends and the bimetal sheet is good. Moreover, the heat of the bimetallic sheet is mainly conducted by the side of the copper block, which leads to the high temperature of the side of the bimetallic sheet.

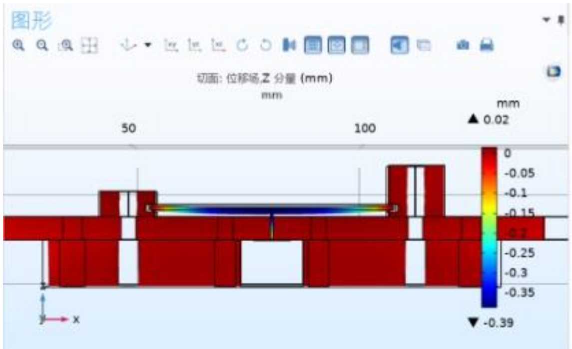

Fig 3. Displacement simulation of new bimetallic flip-flop

It can be seen from the displacement simulation results in Figure 3 that the simulated deformation of the bimetal sheet is 0.39mm, the theoretical calculated displacement is 0.8mm, and the deformation of the non-grid sheet of the bimetal sheet is 0.78mm. It can be seen that the interaction between the grid sheet used to break the narrow diameter and the bimetal sheet is a dynamic equilibrium process with the temperature of the bimetal sheet rising.

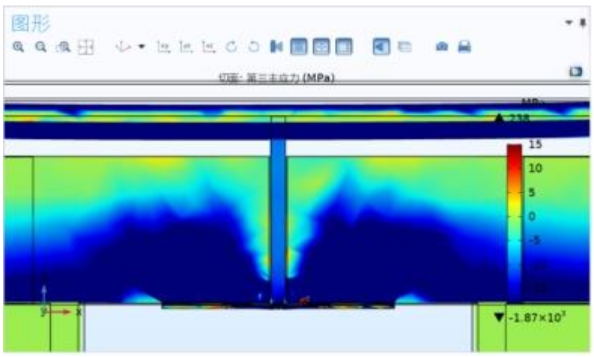

Fig 4. Stress simulation results of new bimetallic flip-flop

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It can be seen from the principal stress results in FIG. 4 that the stress of the part of the gate in contact with the narrow diameter is about 13MP.The estimated external force on the narrow diameter is:

$$F = \sigma \times S = 13 \times 7.5mm = 97.5MP$$

The fracture pressure of narrow diameter made by the press is about 95MP.It can be seen from the simulation results that, under the current of 1400A, the temperature of the narrow diameter of the trigger is 246 degrees Celsius, which does not reach the silver melting temperature. The average temperature of the bimetal plate is 115 degrees Celsius, the temperature near the fixed side of the copper block is 123 degrees Celsius, and the temperature near the Shanghai epoxy tree fixed block is 110 degrees Celsius.

4. COMPARISON AND ANALYSIS BETWEEN SIMULATION AND EXPERIMENT

In order to verify the correctness of the above model, relevant experimental platforms were established, including prototype of new bimetallic trigger, temperature and temperature inspection instrument, DC power supply, voltage and current detection and recording platform, 15 square cable, macro camera, oscilloscope and Hall sensor. A 15 square sectional cable is connected in parallel to both ends of the flip-flop as a commutator branch for narrow-diameter fuses. The macro camera can clearly capture the displacement of the bimetallic strip and the moment of narrow fracture. The voltage of Hall sensor measured by oscilloscope and voltage current detection and recording platform can be converted into the current of trigger. Large platform high precision probe can measure the voltage and current flowing through copper strip at both ends of trigger.

The specific experimental parameters are as follows: the DC power supply provides 1400A current for the circuit, making the trigger fuse and commutating to the branch.

The experimental platform for bimetallic flip-flop is shown in Figure 5.

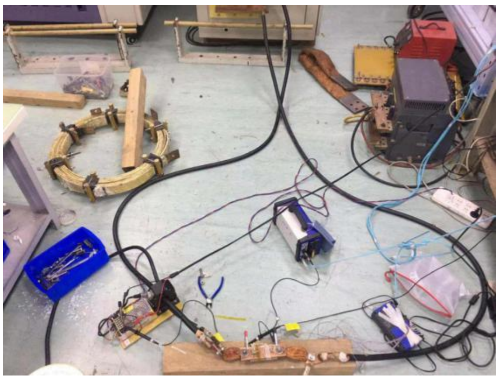

Fig 5. Bimetallic flip-flop experiment

Dc power output 1400 a dc current to trigger and converter branch of the parallel circuit, as a result of the converter circuit resistance is 60 m Ω, far more than 72 mu Ω trigger resistance, so that changing flow branch current is relatively small, with access to trigger temperature trigger current basically remain unchanged. The temperature measuring contact of the temperature patrol instrument measures the temperature of the copper strip in contact with the copper and epoxy fixed blocks and the temperature at both ends of the double gold metal sheet. At 140S, the narrow diameter of the trigger was broken, and the arc voltage was quickly established, and the short-circuit current was quickly converted to the parallel cable.

It can be seen from the above analysis that the theoretical formula calculation results are in good agreement with the experimental measurement results, thus proving the reliability of the model and the numerical calculation method. In addition, repeated tests were conducted on the same flip-flop. Under the same experimental conditions, the narrow diameter of the flip-flop was about 110 degrees Celsius, indicating the repeatability of the design method and the accuracy of small current breaking. The above analysis also shows that this model can provide a new way of thinking for the problem of trigger small current breaking. It provides a theoretical basis for optimizing the design of high-speed breaker.

5. CONCLUSION

(1) Based on the equation of material mechanics and the equation of transient electric heat field, a new mathematical model of bimetallic flip-flop is established.

(2) Under the condition of small current, the new flip-flop structure designed in this paper can make the temperature of the bimetal sheet reach the pre-designed temperature through heat conduction at the sub-minute level. Therefore, the design size should be based on the small current that the protected system can bear at the minute level as the design standard.

(3) Repeated experiments in this paper have verified that this design method is repeatable and has the potential of productization, and it is an effective method to solve the problem that small current cannot be broken.

REFERENCES

[1] Li Min, LI Yan, XU Dazheng, et al. Material selection and structure Design of Miniature Circuit Breakers [J]. Electric Appliance and Energy Efficiency Management Technology, 2014(14):31-34.

[2] Wang Chen, Zhuang Jinwu, Yuan Zhifang, et al.Design and Experiment of current limiting Fuse based on electromagnetic repulsion Breaker [J].Journal of electrical technology, 2013,28 (6) : 66-72.

[3] Chen Bo, ZHUANG Jinwu, XIAO Yiyang, et al. Analysis and Design of arc trigger for 10kV/2kA Hybrid Current Limiting Fuse [J]. High Voltage Technology, 038(8):1948-1955.

[4] Ge Hanming, XU Zhihong, YAO Guohua. Simulation and Analysis of Temperature Field of Conducting Circuit of Miniature Circuit Breaker [J]. Low Voltage Electrical Appliance, 2017, 000(004):35-40.

[5] Liu Luhui, YE Zhihao, FU Lijun, ET al. Research Status and Prospect of Fast DC Circuit breakers [J]. Chinese Journal of Electrical Engineering (4):5-17.

[6] Dai Chao.Research on hybrid current-limiting Fuses of warship low-voltage and high-current arc-Triggered type [D]. Wuhan: Naval Engineering University, 2010.

[7] Lu Jin-feng, Liang Hui-min, Qin Hong-Lei, et al. Mathematical Model and Equivalent Network of strip bimetallic Strip in bimetallic relay [J]. Journal of Harbin Institute of Technology, 2000, 32(4):75-75.

[8] He YA-yin, LIU Jia-gang, JIA Kun-rong. Research on shear stress and End deflection of bimetallic sheet [J]. Mechanical Design and Manufacturing, 2006(3):24-25.

[9] Bian Xueliang, Bian Desong, LIU Qian, ET al. Finite Element Simulation of Thermoelastic Displacement of Circuit breaker Bimetallic sheet [C]// National Academic Conference on Information Acquisition and Processing. 2008.