Research on damping addition and vibration reduction technology of frame aerospace electronic chassis

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Abstract. This paper poses a box instrumentation in aerospace electronic chassis TO-5 encapsulation relay under the action of impact environmental load state of reverse fault mode, by reasonable single frames of viscoelastic damping materials added, increasing box style structure between the PCB mechanical installation interface damping ratio and frequency ratio, finally realizes the transfer rate is reduced, achieve instrumentation relay PCB, lower impact acceleration response. By adding damping cushion to the frame machine installation interface, the load transfer path of impact mechanics is optimized to reduce the installation stiffness and change the fundamental frequency characteristics of the whole machine.

1. Introduction
With microelectronics technology, computer technology, modern communication technology, photoelectron technology and the development of space technology, the TO - 5 encapsulation relay as connected and open circuit signal load is an indispensable basic component of the whole system, but its resistance to vibration, shock, and acceleration under mechanical loading is more sensitive and weak, according to the U.S. air force aviation electronic system Integrity project (Avionics Integrity Program) statistics, mechanical electronic product failure caused by environmental factors accounted for close to 30% [1-2]. This kind of device is generally used as telemetry state switching device in the single aerospace power supply and distribution machine, but its mechanical sensitivity determines the reliability index of the single machine's structural resistance environmental design. Aerospace relay is a small electromechanical component, which is generally composed of electromagnetic system, contact spring system and sealing structure. In terms of structure and appearance, its components are only more than two dozen [3], which are relatively simple components. However, from the point of view of mechanics, it is a complex structure of mechanical force, magnetic force, electrical force as one of the force balance or non-force balance precision electromechanical components. In this paper a space power supply control kind of single machine in the process of mechanical impact test a lu yao abnormal measuring path on and off to carry out the research, put forward a kind of damping technology, solved the frame type within the aerospace electronic single TO - 5 encapsulation relay for mechanical environment due to the impact of load under the overload state "shake closed" and "shake off " the mechanical design problem, improve the structure of the frame type single product resistance reliability of learning environment design, through the test and fault state of repetition shows that the study of the technology measures are effective, the study has provided a means of technology of this kind of problem solving and technical parameters of the foundation.
2. Fault overview and analysis

In the process of impact Z direction test conducted by a single space distribution control machine, the third power relay K3 ground inspection equipment of the single power distribution machine showed that its telemetry state changed from closure to disconnection, while the oscilloscope showed no abnormality. This single machine is mainly responsible for receiving 100V primary power bus and 29V instruction bus provided by upstream products, realizing voltage transformation of 100V input and 28V output, controlling its power supply channel by receiving 1553B bus instructions, and collecting working status information to go up through 1553B bus. The single-machine structure layout is composed of high-power transformation module, distribution control module, auxiliary power supply module, intelligent module and other functions, as shown in FIG 1, in which the K3 power relay is installed in the distribution module, while the telemetry state relay is installed in the intelligent module.

The single-machine distribution control circuit mainly realizes the on-off control of 8-way 28V output power supply relay. In order to increase the closed reliability of 28V power supply bus switch control, two relays of the same power are used in parallel for each control switch. In order to realize the state detection of power relay, parallel connection between small relay line package and power relay line package is adopted, in which EL215 relay is used as 28V power supply control power relay and TO-5 encapsulated magnetic holding relay is used as switching state detection relay. The detection circuit of the relay uses +12V voltage output by the main backup auxiliary power source of the intelligent component as the voltage of the state relay contact voltage of the divider bus. In order to improve the reliability of state detection, the dividers are used in parallel.

In order to prevent misoperation of the relay, two sets of relay contacts are connected in series. In order to prevent the mistransmission of instructions, two latches with zero cleaning end are used to latch the data signals of the data bus of the single chip. Two NPN triode in series are driven
respectively. When the two triodes are triggered on at the same time, the electromagnetic relay will execute the action. The collector drives the electromagnetic relay wire package of the audion and controls the connection and disconnection of the two sets of parallel contacts. One end of the contact is connected to the instruction loop, and the other end is connected to the instruction output line to realize the output of the isolated negative pulse switch control instruction.

Mechanical failure of single-machine relay is manifested as the state reversal of the 3rd road remote measurement, and the state reversal of the state magnetic holding relay with the corresponding circuit bit number MK19 occurs; The reasons causing the state reversal and the analysis are mainly studied in the following aspects:

2.1 Faulty components of state magnetic latching relay cause misoperation
After the failure of single machine product, the state magnetic holding relay was detected and the failure analysis was carried out. The conclusion was as follows: no abnormalities were found in appearance inspection, X-ray inspection and power-on switching, and the results of electrical parameter test and PIND test met the requirements.

The internal inspection shows that the relay has no damage such as abnormal structure, deformation of parts, etc., and there is no defect of components in the state relay itself.

2.2 Under the action of impact mechanical environmental load, the state of the magnetic holding relay is overturned due to "chattering closure" due to insufficient mechanical design margin
The state magnetic holding relay MK19 in the stand-alone product was removed to verify the resistance of the relay and the impact test at the device level was carried out, as shown in FIG. 7. The impact test of magnitude 300g ~ 1800g was verified, and the verification results were shown in Table 2. State magnetic latching relay MK19 is located on the stand-alone intelligent component, as shown in FIG.8.

| Shock level | 300g | 400g | 500g | 600g | 700g | 800g | 1000g | 1300g | 1500g | 1800g |
|-------------|------|------|------|------|------|------|------|------|------|------|
| MK19 relay  | Norm | Norm | Norm | Norm | Norm | Norm | Norm | Norm | Norm | Norm |

Note: "Normal" in the table means that no rollover occurs during the relay test.

The mechanical simulation under the impact test condition of 1500g was carried out on the single machine, and the cloud map of the maximum response direction of the state relay MK19 on the printed board was extracted. The maximum response of state relay MK19 is about 633g, and the frequency domain curve of the response of state relay MK19 is extracted.
Through the research on the impact resistance margin of state relay, it is shown that the magnetic holding relay selected by state relay MK19 has a strong impact resistance capability. Under the installation environment of rigid fixtures, the shock absorption design of component level and single level shock resistance mechanics can meet the use demand of impact condition of 1500g. Impact mechanics simulation analysis of state relay MK19 showed that the maximum acceleration response was 633g. The impact mechanics design margin of the state relay MK19 in the product can meet the impact environment demand of 1500g, excluding the insufficient mechanical design margin of the state relay MK19; Therefore, in the early stage of product design, the design of endurance was taken as a key objective, and enough margin was set aside for the actual product application environment [4].

2.3 Under the impact mechanical environmental load, the command electromagnetic relay "chatters off" due to insufficient mechanical margin design, thus driving the state flip of the state magnetic holding relay.

The front end of the state magnetic holding relay is connected with the command electromagnetic relay in series. The command relay MK9_2 in the single machine is removed to verify the resistance of the electromagnetic relay to impact test, as shown in FIG. 11. The impact test of magnitude 300g ~ 1800g is verified, and the verification results are shown in Table 3.

| Shock level | 300g | 400g | 500g | 600g | 700g | 800g | 1000g | 1300g | 1500g | 1800g |
|-------------|------|------|------|------|------|------|-------|-------|-------|-------|
| MK9_2 relay | Normal | Normal | Normal | Shake off | Shake off | Shake off | Shake off | Shake off | Shake off | Shake off |

Note: "Normal" in the table means that there is no buffeting, buffeting and rollover phenomenon during the relay test.
Mechanical simulation was carried out on the single machine under the condition of impact test of 1500g, and the cloud map of the maximum response direction of the command electromagnetic relay MK9_2 on the printed board was extracted. The maximum response of command electromagnetic relay MK9_2 is about 631g, and the frequency domain curve of its response is extracted.

The research on the margin of the impact resistance of the instruction relay shows that the impact resistance of the instruction relay itself is relatively weak. Under the installation environment of rigid tooling, the design of shock resistance mechanics without component level or single level cannot meet the demand of 1500g impact condition. This type of electromagnetic relay has a high probability of buffeting (or buffeting) under the impact magnitude of 600g ~ 800g depending on its own shock resistance ability. Simulation results of impact mechanics of single machine of 1500g: the maximum impact acceleration response of command electromagnetic relay MK9_2 is 631g; The MK9_2 of single internal command electromagnetic relay has insufficient mechanical design margin under the condition of complete machine impact test of 1500g.

3. Failure recurrence
A laboratory test was carried out on the turn-over of the state relay MK19 magnetic latching relay caused by the pulse width time of the instruction relay MK9_2 chattering output. The test results showed that:

• The 0.3ms negative pulse signal output by instruction relay MK9_2 can trigger the flip of state relay MK19. The 0.3ms pulse width time is consistent with the chatter-closed output pulse width time of instruction relay MK9_2 in the component impact test.

• In the process of component impact test, the command relay MK9_2 chattered off output pulse width time is more than 0.3ms, but its effective pulse time within the pulse width time is relatively short (As shown in FIG. 15), so the state relay MK19 is not overturned.

• In the process of laboratory testing, the instruction relay MK9_2 chattered off output pulse width time is 0.3ms. Because its effective pulse time within the pulse width time is relatively long (As shown in FIG. 16), the state relay MK19 is overturned.

Products in the process of impact test instruction relay MK9_2 shake the pulse width of closed time has reached state trigger relay MK19 flip the pulse width of time, in view of the randomness and discreteness of impact test, once the pulse width of time effective pulse time longer will trigger the state relay MK19 flip, so can maintain problem phenomenon be repetition.
4. Measures and verification

At present, there are few relevant studies on relay endurance environment. In the industry, a certain mechanism analysis has been carried out on the failure modes that often appear in mechanical environment tests of relays, and it is believed that there are three main reasons for failure: installation mode, rigidity and damping [5]. In order to deal with the excessive response of the command relay under the impact mechanics load in a single machine, the measures taken are mainly as follows:

4.1 Damping rubber is added to the impact transmission path to change the damping and frequency characteristics of the PCB local area

Add damping between frame and PCB to increase the damping ratio between frame structure and PCB. Add damping rubber between relay and PCB to increase the local frequency ratio of relay. Finally, the transfer rate can be reduced, to reduce the impact acceleration response of relay mounted on PCB. In order to verify the effectiveness of damping addition, two groups of test components were designed to be placed on the impact test bed at the same time and given the same excitation, with the magnitude of impact ranging from 500g to 1800g. Wherein, state relay MK19 on the printed board of test module 1 is connected in series with instruction relay MK9_2, and a wire is connected to an oscilloscope, damping rubber is added, as shown in FIG. 17. The circuit state of test module 2 is consistent with that of test module 1, but no damping rubber is added, as shown in FIG. 18.

Table 4 Instruction relay MK9_2 trigger state relay MK19 flip test

| Waveform generator time (ms) | Command relay MK9_2 | Command relay MK9_2 Output signal time (ms) | State relay MK19 Motion state | Note |
|-----------------------------|---------------------|---------------------------------------------|-----------------------------|------|
| 1.5                         | Shake closed        | 0.35                                       | flip                        | The phenomenon of repetition |
| 1.4                         | Shake closed        | 0.30                                       | flip                        | The phenomenon of repetition |
| 1.3                         | Shake closed        | 0.22                                       | No action /                 |      |
| 1.2                         | Shake off           | /                                          | No action                   | /    |

FIG. 15 Impact test MK9_2 waveform

FIG. 16 Test experiment MK9_2 waveform

FIG. 17 Test kit 1

FIG. 18 Test kit 2
Starting from the impact level of 700g, the instruction relay MK9_2 is buffeted; Starting from 1300g impact level, the instruction relay MK9_2 is buffeted; The addition of damping is effective, and the mechanical design margin of relay is improved by about one time.

Table 5 Test results of two groups of test components

| Test kit 1 | Test kit 2 | 500g | 600g | 700g | 800g | 1000g | 1300g | 1500g | 1800g |
|------------|------------|------|------|------|------|-------|-------|-------|-------|
| MK9_2      | No shaking | No shaking | No shaking | No shaking | No shaking | Shake closed | Shake closed | Shake closed |
| No shaking | No shaking | No shaking | No shaking | No shaking | No shaking | Shake closed | Shake closed | Shake closed |

4.2 Damping cushion is added to the impact transmission interface to reduce the magnitude absolute value of single impact excitation

A vibration damping pad is added to the installation interface of a single machine to increase the energy dissipation on the interface of impact energy transfer and reduce the magnitude of the energy transferred to the internal impact excitation of a single machine; A 0.5mm thick rubber damping pad is added to the installation interface of the whole machine to carry out a special test on the effectiveness of vibration reduction. The test installation is shown in FIG. 20.

In order to increase the effectiveness of the test contrast, two kinds of test conditions were carried out respectively under the whole machine with and without damping cushion, and the same impact excitation was given. The effectiveness of the damping cushion is verified by quantitative analysis of the monitoring point response curve.

FIG. 20 Thermal insulation cushion damping test verification

FIG. 21 Curve of impact monitoring point of vibration damping pad without additional damping
FIG. 22 Curve of impact monitoring point of shock pad with added damping

Table 6 Response values of monitoring points in two working conditions (700HZ and 3200HZ)

|                  | Undamped damping pad | Add damping cushion |
|------------------|-----------------------|---------------------|
| 700HZ            | 696g                  | 538g                |
| 3200HZ           | 4364g                 | 3691g               |

When damping cushion is added to the mechanical installation interface of the whole machine, the response of the monitoring point attenuates by 20%, indicating that the damping cushion improves the damping of the single installation interface and increases the frequency ratio of shock energy transmission, thus reducing the transmission efficiency of shock energy excitation source.

5. Conclusion
In this paper, the state of To-5 encapsulated relay in a frame type aerospace electronic single machine is overturned for fault analysis and positioning. A large number of tests verify that the mechanical design margin of accurately locating the fault to the relay in a single machine is insufficient. By adding damping material, the damping of single machine is increased. Meanwhile, the energy filtering property and local stiffness reduction of viscoelastic damping material added between local frames are used to increase the frequency ratio. Finally, the energy transfer rate is reduced and the response attenuation of the relay at the fault position is more than 20%. The effectiveness of the measures is proved through a large number of effective tests, which improves the resistance environment design of this kind of aerospace electronic stand-alone products comprehensively, and provides a technical approach and technical parameter basis for solving this kind of problems.

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