Research on Contact Failure of Hermetically Sealed Electromagnetic Relay Applied in Space Vacuum Environment

Zhang Lei(1), Huang Juncai(2), Yang Jian(2), Xiao Zhongying(2)

(1)*China Academy of Space Technology*
Beijing, China 100029
rocky_ch_cn@163.com

(2)*Guizhou Space Appliance Co., Ltd.,*
Guiyang, China, 550009

ABSTRACT

Leakage rate is the inherent property of hermetically sealed electromagnetic relays. When the hermetically sealed electromagnetic relays are applied in space vacuum environment, pressure inside the relays reduces gradually due to gas leakage. And as a result, the relays' contacts work in a low pressure environment and contacts arcing failure may occur during load switching. In order to verify such mechanism, homemade relay samples are selected and researches on rules of the gas pressure inside the relays and contact arcing failure are carried out.

INTRODUCTION

A hermetically sealed electromagnetic relay is an essential component in an electronic circuit. The hermetically sealed electromagnetic relays widely used in the space projects at present are electromechanical components with motion mechanisms and electromagnetic structures. Contacts as actuating elements play a decisive role in the reliability and service life of the relays for space application. Once contacts fail in-orbit, not only the relay is damaged, but also the satellite's electrical control system is broken down, which will cause huge economic losses.

Gas exchanges between the relay's inner chamber and the outside environment due to a certain leakage rate. When the relay operates in-orbit, pressure of the gas initially packaged inside the relay will reduce gradually due to the external high vacuum environment. According to relevant data [1-2], inner gas pressure of relays with a leakage rate of 1×10^{-8}Pa.m^3/s will reach 1000Pa~5000Pa during less than 150 days, and the period of inner gas pressure reducing to the same range for relays with a leakage rate of 1×10^{-9}Pa.m^3/s will be extended to 4~7 years. According to researches carried out by Ph. D Alexander Teverovsk in NASA's Goddard Space Flight Center [3-4], when the relay's inner gas pressure reaches a certain low value, the breaking arcs will intensify if the contacts carry a certain amount of load. Such case is much more likely to occur under low gas pressure than in ambient air.

In order to verify above mechanism and further study rules of the gas pressure inside the relays and contact arcing failure, the homemade relay samples are selected and experimental researches are conducted.

EXPERIMENT PREPARATOIN

Establishment of Variable Gas Pressure Environment

An ultra-high vacuum temperature test chamber ZGD-600 is used to provide a low gas pressure environment. The test chamber is shown in the following Fig. 1 and the lowest vacuum degree of the test chamber can reach 10^{-4}Pa.

Fig. 1 ZGD-600 ultra high vacuum temperature test chamber

Before the experiment, a small hole is drilled on the top of the case of the relay sample to be tested. The drilling process and the small hole both have no influence on the relay's performance. The small hole is shown in the following Fig. 2.

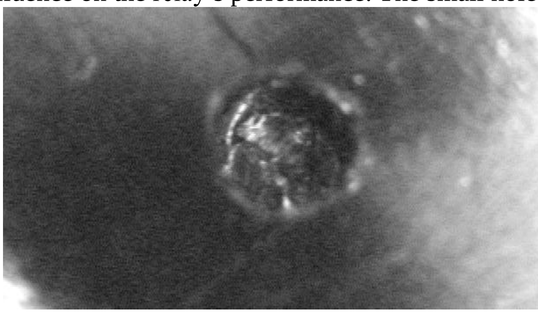

Fig. 2 Small hole on the top of the case of relay sample

Test Circuit

The test circuit is shown in the following Fig. 3.

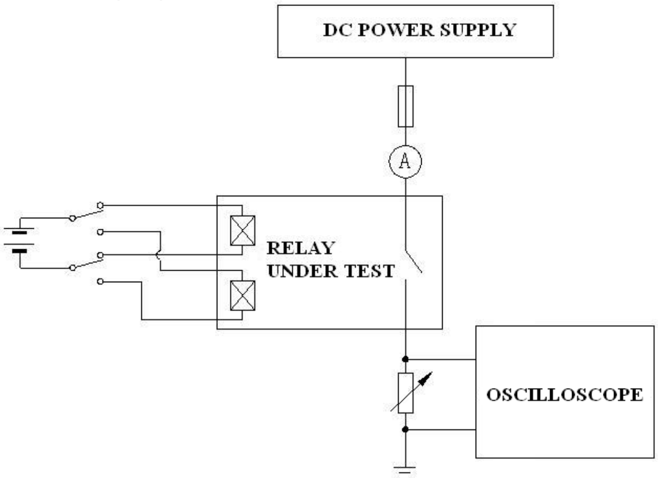

Fig. 3 Diagram of test circuit

In the test circuit, a 50V/50A stabilized DC power supply is selected as load power, and the relay's coils are energized by 28V DC power supply. The test sample with a small hole drilled on top of its case is placed in the vacuum test chamber after being connected into the test circuit shown in the Fig. 3. The terminals of the test sample are welded with wires and related test operation is performed outside the test chamber. After the vacuum degree inside the chamber is adjusted to a stable value, the relay is cycled to make, carry and break load. An oscilloscope is used to monitor the opening and closing of the contacts, record arcing waveform. The arcing time is measured.

Test Samples

The types of selected test samples are shown in Table 1. Before the test, initial electrical parameters of the test samples are measured to confirm that electrical properties of the samples are consistent with each other.

Table 1. Samples

S/N	Type	Parameters of Contacts
1	JMX-3025M	3 groups，25A
2	JMX-4010M	4 groups，10A
3	JMX-2010M	2 groups，10A

TEST AND ANALYSIS

Measuring of Contact Arcing Time under Different Low Gas Pressures

According to test scheme, each sample is tested for three times at each low gas pressure. The contact arcing waveform recorded by the oscilloscope is shown in the following Fig. 4.

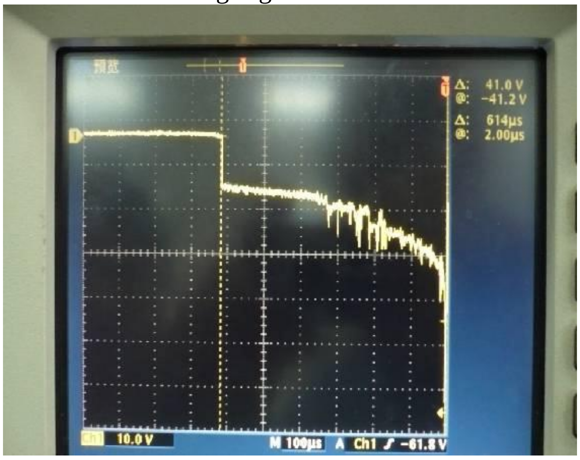

Fig. 4 Contact arcing waveform recorded by oscilloscope

The arcing time is measured according to the arcing waveform and a curve is drawn based on all measured arcing time data. For each type relay, the corresponding curve of pressure and arcing time is shown in the following Fig. 5.

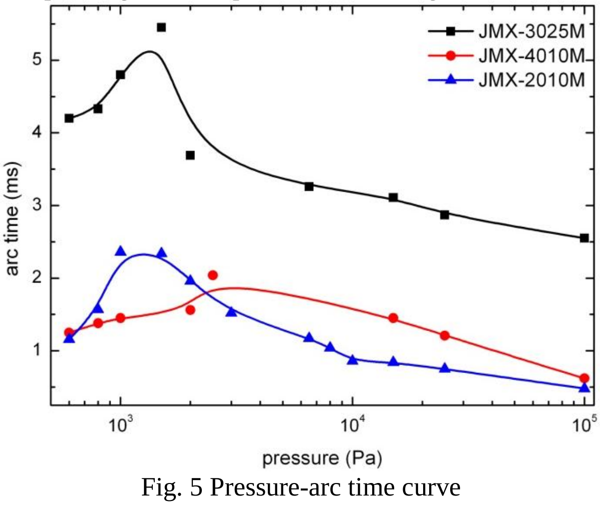

Fig. 5 Pressure-arc time curve

The electrical parameters of the tested samples are measured, compared with initial electrical parameters. It can be known that latch & reset voltage increase and other parameters have no significant changes after the test. Through disassembling and checking of the samples tested under the low gas pressure, it is found that different ablation marks are formed on the surfaces of the contacts. And the ablation morphologies on the surfaces of relay JMX-4010M contacts are shown in the Fig. 6.

Fig. 6 Morphologies on surface of relay JMX-4010M contacts (1- 4 group of contacts)

Life Test under *High-risk* Low Gas Pressure

It can be seen from the Fig. 5 that the longest arcing time of relay JMX-3025M is 5.45ms which happened at 1500Pa (about 11.3torr), the longest arcing time of relay JMX-4010M is 2.04ms which happened at 2500Pa (about 18.8torr), and the longest arcing time of relay JMX-2010M is about 2.42ms which happened at about 1200Pa (about 9torr). According to the data, the low gas pressure point with the longest arcing time can be regarded as ***high-risk*** low gas pressure environment for specific relay product.

Test samples of above type relays are selected and subjected to life test at rated load under high-risk low gas pressure. Occurring of contacts adhesion constitutes a relay failure and the cycle time is recorded. The test results are shown in Table 2. It can be seen from the test results that, the relay's life under high-risk low gas pressure environment is greatly shortened compared with the rated life under ambient pressure.

Table 2. Life test results under high-risk low gas pressure

Type	Test pressure	S/N	Operation life times	Remarks
JMX-3025M	1500Pa	3#	232	Rated life times under ambient pressure: 50,000
		4#	200	
		5#	352	
		6#	181	
		7#	658	
		8#	47	
JMX-4010M	2500Pa	13#	26531	Rated life times under ambient pressure: 100,000
		14#	34625	
		15#	17632	
		16#	46485	
		17#	34962	
		18#	26376	
JMX-2010M	1000Pa	106#	45388	Rated life times under ambient pressure: 100,000
		107#	38652	
		108#	35463	
		109#	29672	
		110#	36981	
		111#	36432	

CONCLUSIONS

Through above test results, the following conclusions can be obtained:

1) The arcing time of the relay is prolonged with the reducing of the gas pressure inside the relay, but is not infinitely prolonged with the reducing of the gas pressure inside the relay. When reaching one limit value, the arcing time of the relay is reduced. The relation between the arcing time and the pressure inside the relay is similar to a parabolic relation.

2) 700Pa~5000Pa (5.3torr-37.5.5torr) is a ***high-risk*** low gas pressure range for failures of homemade relays JMX-

3025M, JMX-4010M and JMX-2010M. Compared with NASA's report, a narrower high-risk pressure range is obtained for such type relays and the results can also be used as a basis for determining their safely operating time intervals in-orbit.

3) The rated life times of the relays under the high-risk low gas pressure environment are greatly reduced.

4) The larger the load carried by the relay is, the longer the arcing time under the same pressure is, and the larger the failure probability is.

5) The failures of the contacts of the relays under vacuum environment are mainly displayed as the following: contact ablation and metal transfer caused by the prolonging of the arcing time, which finally cause contacts adhesion and switching failure.

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