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Original Research

Combined effects of fretting and pollutant particles on the contact resistance of the electrical connectors

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ABSTRACT

Usually, when electrical connectors operate in vibration environments, fretting will be produced at the contact interfaces. In addition, serious environmental pollution particles will affect contact resistance of the connectors. The fretting will worsen the reliability of connectors with the pollutant particles. The combined effects of fretting and quartz particles on the contact resistance of the gold plating connectors are studied with a fretting test system. The results show that the frequencies have obvious effect on the contact resistance. The higher the frequency, the higher the contact resistance is. The quartz particles cause serious wear of gold plating, which make the nickel and copper layer exposed quickly to increase the contact resistance. Especially in high humidity environments, water supply certain adhesion function and make quartz particles easy to insert or cover the contact surfaces, and even cause opening resistance.

1. Introduction

Electrical contact failure often occurs when the connectors are working. There are some factors, such as environmental vibration, contamination and the changes of temperature, can result in electrical contact failure. Especially in vibration environments, fretting will be produced [1]. Fretting wear of contact interface will occur during vibration. The fretting action can induce physical and chemical changes and the formation of metallic oxide [2]. For precious metal plated contact interfaces, such as Au plated contact interfaces, fretting wear will cause Au removed from the surface, producing lots of wear debris [3]. For non-precious metal plated surface, fretting can cause metal surface to oxidation, which can increase the contact resistance [4].

In addition, pollutant particle existed at the contact interface is an important cause of electrical contact failure, especially in some harsh environment. The pollutant particles in the environment can enter the contact interface through the gap of the connectors. Some previous studies show that there are more than tens of different materials in pollutant particles and corrosion products on contact surface contain elements of pollutant particles [5-8]. Because the gap of the electronic connectors is small, so the pollutant particles deposited in the interior of electronic connectors are small and the size range from 10 to 200 μm [9,10]. Some pollutant particles are hard and can insert into the metal surface. Others may be soft and can be crushed [11]. In addition, some pollutant particles can cause corrosion, but the corrosion caused by pollutant particles can be distinguished from the corrosive gas corrosion, because the elements of pollutant particles can be found in corrosion products [12,13].

When pollutant particles are deposited on the plating in the humid environment, they may cause corrosion because of the effect of water-soluble salts and corrosion can result in high contact resistance [14,15]. Some previous investigation shows that the contact resistance increases quickly, which can result in connector contact failure [16]. When pollutant particles exist at contact interfaces, the contact resistance will increase and even the circuit will be open because pollutant particles are insulator. For the large particles, they can make the contact interfaces separated and directly result in contact failure. For small particles, they can also reduce the actual contact area and increase the contact resistance to result in contact failure finally. Among these pollutant particles, quartz is common in nature and industrial environments and its hardness is very high.

Fretting and pollutant particles can affect the reliability of contact connectors respectively. When fretting and pollutant particles exist at the same time, the effect will be complicated. The contact resistance on the pollutant areas may appear rapid change. It would affect the reliability of the connector, especially for the high frequency connectors. In this paper, the combined effects of fretting and pollutant particles on the reliability of high frequency connectors are studied.

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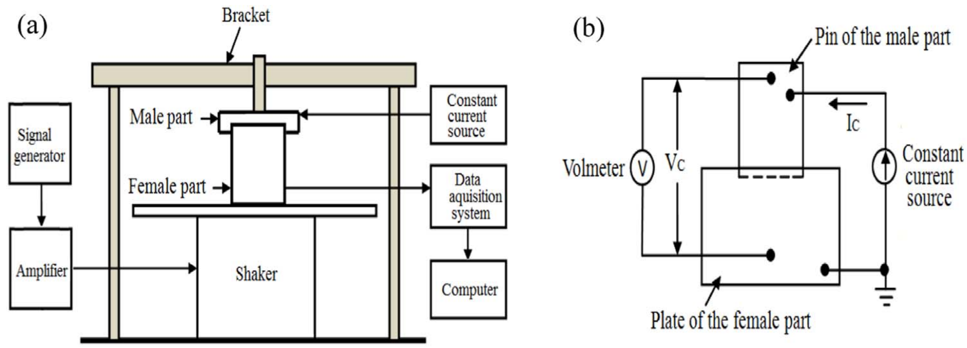

Fig. 1. Photograph of the experimental setup, (a) Operating principle of fretting equipment; (b) Resistance measurement principle.

2. Experimental configuration

To study the effect of fretting and pollutant particles on electrical contact, the quartz particles (SiO_2) were selected to fall on the gold plating and a test setup was used to produce fretting between the pins of the male part and the plate of the female part in the electronic connector.

Fig. 1 shows photograph of the fretting setup. The system includes a signal generator, an amplifier, a shaker, a constant current source, a data acquisition system, and a computer. The contact resistance was measured by four-point method as a function of test cycles at room temperatures and the lead resistance is eliminated. A constant current 300 mA could be given by a constant current source and the opening voltage was set at 1 V. The normal force between the pins and the plate of the connectors was 0.7 N. The change of contact resistances was obtained by Labview software. The data were collected at a 1 s sampling rate using a National Instruments USB-6000 data acquisition. This was done for different vibration frequencies(1 Hz, 3 Hz, 5 Hz) and the amplitude was 800 µm.

The thickness of gold plating of contact surface was about 0.76 µm. Nickel was the intermediate layer and phosphor bronze was the substrate. Previous failure results show that the size of most particles deposited on the contact area is less than 50 µm [9]. In this paper, quartz particles with a size of 10–30 µm are selected as the deposited pollutant particles, as shown in Fig. 2. There are 2 fans which can work in a closed environment to make quartz particles evenly distributed at the contact interfaces.

Some test equipments and methods were used in this paper. The topography of contact surfaces were observed by scanning electron microscope (SEM) after fretting test. The elements of the wear tracks and debris were detected by energy dispersive spectroscope (EDS).

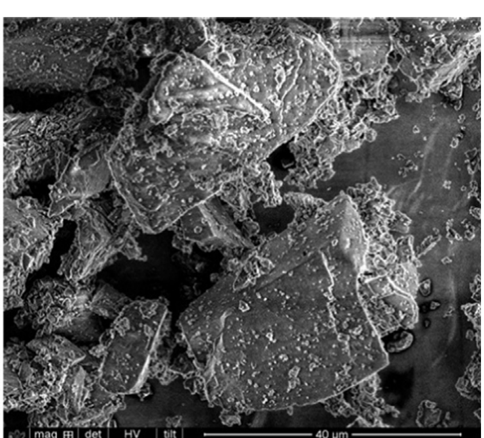

Fig. 2. Quartz particles on the contact surface.

3. Results and discussion

3.1. Fretting test of connectors at different frequencies

Fig. 3 shows the contact resistance change during 50,000 test cycles. The test frequencies were 1 Hz, 3 Hz and 5 Hz respectively, and the unit of contact resistance was milliohm. Table 1 summarizes the contact resistance behaviour of contact pairs, including cycles to attain 10 mΩ, 100 mΩ and 1000 mΩ respectively, and the maximum contact resistance by 50,000 cycles.

In the initial stage, the contact resistances of the three contact pairs were just several milliohms because of the good conductivity of gold plating. For the test of 1 Hz, as shown in Fig. 3(a), the maximum contact resistance was slightly more than 10 mΩ until the end of the test. In order to express the test results more clearly, the original contact resistance was changed to the average contact resistance and the average contact resistances were obtained every 200 resistance values. Fig. 3(b) shows the average resistance curve. It can be seen that the contact resistance under the condition of 1 Hz has good behaviours, since the average resistance is no more than 10 mΩ until the end of 50,000 test cycles. By comparison, it can be found that Fig. 3(b) can be used to substitute for Fig. 3(a) well.

For the test of 3 Hz, the contact resistance was less than 10 mΩ before 11,400 cycles, as shown in Fig. 3(c). It increased to 82 mΩ rapidly when the fretting cycle was 11,900 and then the resistance droped again. The contact resistance changed oscillatory, and increased to more than 100mΩ when the fretting cycle was 22,600 and then increased continuously to more than 1000 mΩ. The maximum contact resistance attained 2460 mΩ. For the test of 5 Hz, as shown in Fig. 3(d), the contact resistance attained 10 mΩ and 100 mΩ when the fretting cycles were 7700 and 13,100, respectively. After then, it is only 7000 cycles later that the contact resistance increased rapidly to more than 1000 mΩ until the end of the test and the maximum contact resistance attained 3170 mΩ. The result shows that the fretting resistance behaviour under the condition of 3 Hz and 5 Hz are much worse than that of 1 Hz. It can be deduced that the frequency has a very significant effect on the contact resistances.

Fig. 4 shows the morphology of wear track after fretting test with different frequencies. The wear tracks of male part and female part are shown in left and right of the figure respectively. It can be seen from Fig. 4 that there are grey areas and dark areas on the contact surface. Usually, the chemical composition of the wear tracks after fretting test can be observed with EDS. EDS investigation result is illustrated in Table 2. It shows that the gold content is obviously different in different areas. The gold content can show the wear degree, and O content shows the quantities of metallic oxides. The wear degree of the black area is more serious than the grey area, because its gold content is much lower, and O content is much higher than the grey area. At the same time, there are more nickel and copper in the dark area than the grey area due to the more losses of gold plating after fretting.

For 1 Hz test, there were large grey area and small dark area on the