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Lifetime prediction of electrical connectors under multiple environment stresses of temperature and particulate contamination

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Abstract

Electrical connectors play a significant role in the electronic and communication systems. As they are often exposed in the atmosphere environment, it is extremely easy for them to cause electrical contact failure. It is essential to carry out the reliability modeling and predict the lifetime. In the present work, the accelerated lifetime testing method which is on account of the uniform design method was designed to obtain the degradation data under multiple environmental stresses of temperature and particulate contamination for electrical connectors. Based on the degradation data, the pseudo life can be acquired. Then the reliability model was established by analyzing the pseudo life. Accordingly, the reliability function and reliable lifetime function were set up, and the reliable lifetime of the connectors under the multiple environment stresses of temperature and particulate contamination could be predicted for electrical connectors.

Keywords electrical connectors, accelerated lifetime testing, lifetime prediction

1 Introduction

Electrical connectors are extensively used in communication systems to transmit signals between the electrical equipments. They are widely used in fields of communications, electronics, aerospace, and so on. As the scientific progress and social development, higher requests have been made for the electrical connectors. The electrical connectors are often exposed in the atmosphere environment and subjected to the different kinds of the environmental factors, so the reliability research and lifetime prediction of the electrical connectors under multiple stresses have become the essential research topics [1]. The investigation on the electrical connectors showed that environmental loadings were the significant considerations which affect the reliability and lifetime of them, such as temperature, humidity, particulate contamination, insert and draw frequency, vibration, and so on [2]. Moreover, the failure mechanisms of environmental loadings for electrical connectors were investigated. Paul et al. [3] summarized the theory of electrical contact and analyzed the mechanisms of connectors contact failure. Zhang [4] studied the characteristics of dust particles, including the composition of materials in dust and the mechanical, electrical, and chemical characteristics. Also, the conditions required for the dust to cause contact failure were discussed. The contact interface is covered by continuous collected and accumulated small particles caused by micro motion, which lead to the high and erratic contact resistance. The particles are embedded into or adhered to the plating's surface, which decrease the actual contact area. The contact resistance will increase and cause the contact failure. Moreover, the increase of temperature will accelerate the oxidation at the contact surface, which speeds up the formation of oxide film in the contact surface. This also causes the increase of contact resistance and lead to connector failure. Therefore, a better understanding of the influence of particulate contamination and temperature on reliable lifetime is of substantial value.

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The relationship between electrical connectors' lifetime and local stresses can be obtained by the analysis of failure mechanisms and accelerated lifetime testing. Husnayain et al. [5] predicted the lifetime of transformer oil by conducting the accelerated thermal aging experiments and using Arrhenius law. Huang [6] studied the aerospace relay accelerated test methods and storage life prediction methods on account of the relay storage failure mechanism analysis. The researcher carried out the lifetime prediction of aerospace relay under temperature. Wang et al. [7] studied the degradation mechanism of aerospace relay in long-term storage. They built the storage reliability statistical degradation failure model and contact life distribution function. Zhu et al. [8] proposed a method based on finite element simulation and physics failure equation to quantify the vibration response and lifetime of electrical connectors. They established the relationship between local vibration response and external vibration excitation. They also set up an equation between lifetime of electrical connector and external vibration excitation combined with physics failure equation. Ren et al. [9] conducted a multiple stress accelerated degradation testing (ADT) on a typical circular electrical connectors. They employed a statistical-physical degradation distribution model, which was used to support the ADT results, from which a model was built to evaluate the reliability at normal operation conditions. Nevertheless, there has been little research reported on lifetime prediction of electrical connectors under multiple environment stresses of temperature and particulate contamination.

In this work, the N-type connectors are selected as the research subjects. The accelerated lifetime testing is designed to obtain the degraded data under multiple stresses of temperature and particulate contamination. The pseudo lifetime is gained based on the fitting function about the contact resistance of connectors and measured time under multiple stresses. The reliability modeling is established to illustrate the performance of connectors. Finally, the reliability function and reliable lifetime function are set up based on estimating the modeling parameters.

2 Experiment

2.1 Specimen obtained

The N-type connectors, which are widely used in radio frequency (RF) equipment and base station systems, were chosen as the samples considered in this study. Moreover, N series RF coaxial connectors are popular in international markets. They feature optical anti-corrosion capability, high reliability, and excellent mechanical and electrical performance. For the N-type connector, its characteristic resistance is 50 Ω. It could be operated in the frequencies range from 0 to 11 GHz. Its central conductor is consist of pin and receptacle whose material is brass gold coating and phosphor bronze or beryllium bronze gold coating, respectively. The brass has good performances including high strength, hardness and strong corrosive. The phosphor bronze has excellent mechanical properties and processing performance into crumbs, and beryllium bronze has many superior characteristics such as abrasive resistance and low temperature, respectively. Whereas its shell and other metal components have different materials. The insulator, cable clamp and sealing ring are polytetrafluoroethylene, brass nickel plating and silicon rubber, respectively.

The samples are divided into two parts, the pin (male connectors) and the receptacles (female connectors). Two pins are inserted into the two sides of one receptacle, which combine the device under test (DUT). A four-point measurement method is adopted in order to measure contact resistance of N-type connector.

The lifetime of N-type connector will be influenced by many factors, such as environmental stresses (temperature, humidity, atmospheric corrosion, particulate contaminant, vibration and so on), own performance (material and structure), which will lead to the increase of the contact resistance and cause contact failure. In this paper, the temperature and particulate contaminant were mainly considered. As the silicon dioxide (SiO_2) particles are the highest content in the dust and the small particles with size of 1 μm and high electric charge amount may easily cause fault, the silicon dioxide particles with the diameter of 1 μm were selected as particulate stress in this work.

2.2 Selection of stresses and levels

A fractional factorial design named 'uniform design' was used in the experiment for this study. Since it was proposed by Fang and Wang in 1980, it has been widely used in multiple areas, such as monitored control system, chemical engineering, quality engineering, system engineering, computer sciences, natural sciences, etc. Its main function is to make the experimental points evenly