Experimental Study of the Vibration-induced Fretting of Silver-plated High Power Automotive Connectors

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Abstract—**Relatively little is known about the fretting mechanism of high power connectors used in hybrid vehicles, even though the vehicles are widely being introduced to the market. This work experimentally investigates the fretting mechanisms of silver-plated high power connectors caused by vibrations. In order to emulate operational and environmental effects, a test stand was designed that is capable of measuring ECR, relative displacement and connector temperature. The experimental results show that the variation of electrical contact resistance (ECR) of connectors subject to vibration is primarily due to periodic changes of contact area caused by relative motion between the contact interfaces, rather than other fretting corrosions. This finding is reinforced by observing a good correlation between relative motion and the increase of ECR under vibration. When a vibration stopped, the ECR decreased to a value that is slightly larger than the original value. A surface analysis showed no obvious corrosion until the coating was worn away.**

Keywords —high power automotive connectors, fretting, silver coating, vibrations, dynamic response.

I. Introduction

Hybrid and electrical vehicles (HEV) are the next evolutionary step of the automobile, but there are a few limiting technologies that delay widespread HEV success, which includes the battery, power electronics and connectors. Automotive connectors are very important and critical to any vehicle containing electrical components. A well designed and fabricated connector will be durable and easily disconnected so that electrical components can be easily replaced or repaired.

Automotive connectors experience a harsh environment comprised of vibrations induced by the engine, thermal cycling as the vehicle starts up and shuts down, and a corrosive environment which can cause the formation of undesired oxides [1]-[2]. These conditions are very demanding on the reliability of connectors and often lead to their degradation and failure. A vehicle may have more than 400 connectors with 3000 individual terminals but field data has shown that connector degradations and failures contribute to 30–60% of the electrical problems [3]-[4]. This requires investigations on connector behavior under vehicle conditions and studies on its degradation mechanisms so that connectors perform on an acceptable level.

For connectors subject to vibration, a main degradation mechanism is considered to be fretting, which is a relative cyclic motion with small amplitude that occurs between two oscillating surfaces, defined by Waterhouse [5]. Varenberg et al. provide a method for characterizing fretting in terms of the local relative motion [6]. In another paper, fretting is shown to cause intermittent electrical contact, wear and corrosion on contact materials and in turn results in variations of electrical contact resistance (ECR) such as an increase, fluctuation or intermittence [7]. Therefore, connector temperature will increase due to the increase in ECR based on the process of Joule hearting. These mechanisms could accelerate connector degradation.

Tin-plated connectors have been widely used in motor vehicles for their low cost and the relative low ECR due to its softness. However, tin plating is often criticized for its high failure rate [8]. Its degradation mechanism, generally considered to be fretting corrosion, has been extensively investigated by many researchers. During fretting corrosion, fretting wear repeatedly exposes fresh metal to the atmosphere which causes oxidation and the accumulation of debris on the contact interface. This continuously reduces the electrical conducting area and conductivity [9]-[11]. Consequently, when vibration is applied to tin-plated connectors the ECR will continue to increase nominally and gradually with time [8]-[9], [11]-[16]. This gradual increase of ECR under fretting has been found for other contact materials, such as copper-tin alloys [13] and gold [15]. Many works report that the degradation of the contact interface will cause the ECR to increase greatly with sudden failure after a certain number of vibration cycles [9], [13]-[15].

In the current work, the results do not agree with the results of connectors with tin and other conventional coatings, whose ECRs gradually and significantly increase along with vibration [8]-[9], [11]-[16]. Examination of worn surfaces demonstrates that wear exists on silver-plated connectors, but no obvious fretting corrosion and oxidation build-up is found. It is the relatively stable property of silver that makes the test results so different compared with other coating materials. The test results from Hubner-Obenland and J. Minuth also supported the benefits of silver contacts [15]. Their work showed that the silver-to-silver contact has the lowest ECR increase after 31 hours of vibration, compared to other combinations of male and female contact materials, including tin, silver, and gold.

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