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A Research on Stray-Current Corrosion Mechanism of High Voltage Cable Connector on Electrification Vehicles

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Considering the tendency of development of electrification vehicles, development and verification of new evaluation technology is needed because of new technology applications. Recently, as the battery package is set outdoors of an electric vehicle, such vehicles are exposed to corrosive environments. Among major components connected to the battery package, rust prevention of high-voltage cables and connectors is considered the most important issue. For example, if corrosion of high voltage cable connectors occurs, the corrosion durability assessment of using an electric vehicle will be different from general environmental corrosion phenomena. The purpose of this study is to investigate the corrosion mechanism of high voltage cable connectors of an electric vehicle under various driving environments (road surface vibration, corrosion environment, current conduction by stray current, etc.) and develop an optimal rust prevention solution. To improve our parts test method, we have proposed a realistic test method to reproduce actual electric vehicle corrosion issues based on the principle test.

Keywords: *Stray current corrosion, High voltage cable, Electrification vehicle, Fretting*

1. Introduction

Corrosion of the vehicle is very different depending on the local environment and the characteristics of the vehicle, so it is very important to secure the rustproof performance to match the characteristics. Especially, considering development trend of electric vehicles, it is necessary to develop preliminary evaluation technology and verify the rust prevention. In the case of an electric vehicle, the battery package is set outdoors in order to secure an in-cabin space and a distance to travel, which is detrimental to corrosion. Therefore, among the major components connected to the battery package, the rust prevention of high-voltage cables and connectors is considered as the most important consideration. This is due to accelerated corrosion when unexpected external currents are drawn in the automotive parts are exposed to the corrosive environment, which results in the effect of lowering the free energy in the corrosion kinetics.

If corrosion of high voltage cable connectors occurs, corrosion durability assessment using an electric vehicle will be different from general environmental corrosion phenomena. This is because when the stray current is generated through the shielding line of the high-voltage cable applied to the vehicle, it affects peripheral components (Fig. 1).

Therefore, if the factor causing corrosion in various complex driving environments is identified and the factors promoting corrosion are removed, the rustproofing of the vehicle will be ensured. Research is needed to prevent road vibration, corrosive environments, and high voltage battery cable currents from occurring during vehicle travel, which would otherwise cause stray-current corrosion. To this end, it is necessary to identify the effect on the

Fig. 1 High voltage cable and Stray-Current Corrosion in electric vehicles.

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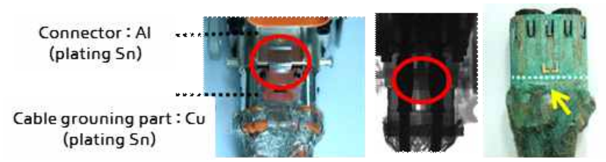


Fig. 2 Connector / High voltage cable Heterogeneous contact after friction wear

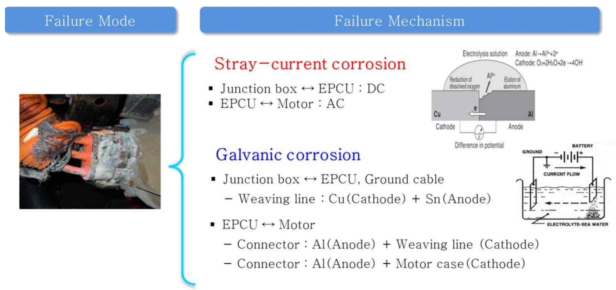


Fig. 3 Stray-current corrosion and galvanic corrosion mechanism between connector and high-voltage cable.

corrosion mechanism of the connector and present an optimal anti-rust solution.

The purpose of this study is to establish the mechanism for the prevention of the stray-current corrosion of joints connected with the high voltage cable of the electric vehicle and to set the test method through the principle test.

2. Experimental Method

2.1 Sample preparation

High-voltage cables and connectors for use in electric vehicles and aluminum brackets were prepared. In the case of high-voltage cables, it is composed of a shielding material and a ground cable, and is plated with tin (Sn) on copper (Cu). The connector bracket is made of tin (Sn) plated aluminum die casting.

2.2 Surface analysis

When the corrosion principles were evaluated using the new and corroded products, the surface was analyzed by scanning electron microscopy and energy dispersive spectrometer analysis.

2.3 Cyclic corrosion test

Principle tests were conducted on stray-current corrosion in cyclic corrosion test to control the temperature and humidity of the running condition of the vehicle and to accelerate corrosion by the set test method.

3. Results and Discussion

3.1 Corrosion environment analysis on High-voltage cable

The high voltage cable is located in the lower part of the vehicle or in the engine room, and is highly affected by the moisture generated during running. In addition, vibration generated in various road surfaces is added to the fastening contact portion of the connector, so that the contact portion is physically damaged. As a result, the plating layer of the fastening portion is easily damaged, and the galvanic corrosion caused by the heterojunction(Exposure of material after abrasion due to vibration between ground connection part (base material Cu + plating Sn) and connector (base material Al + plating Sn)) is promoted. (Fig. 2). In addition, high-voltage cables are characterized by the application of minute leakage currents to the periphery, such as connectors and shielding materials, due to the flow of large energy currents.

The galvanic corrosion is promoted when the plating layer is damaged by the vibration of the high-voltage cable and the connector connection and the corrosion environment is formed, and the possibility of the stray-current corrosion is confirmed by the leakage current from the outside. Three factors must be met for stray-current corrosion. An external current must be supplied to the corrosion site and the surface of the electrode should be exposed to the electrolyte and a low overhead electrochemical cell should be constructed [1].

3.2 Stray-current corrosion test

In order to confirm such an estimation mechanism, first, the vibration phenomenon between the cable and the connector was reproduced through ISO-16750-3 (vehicle electronic vibration condition on the road) vibration test. The reason why the ISO standard was adopted was that the input load of the durability test using the actual vehicle was higher than that of the durability test, and to verify in a harsh environment. Mounted like an actual fastening, vibration was applied in three axes of X, Y, Z axis, causing

Fig. 4 Vibration testing machine.

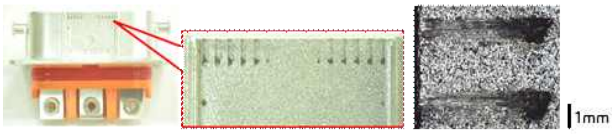


Fig. 5 Reproducibility test of friction wear in connector.

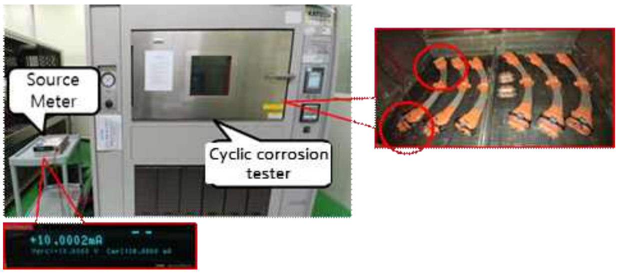


Fig. 6 Current application equipment and cyclic corrosion tester.

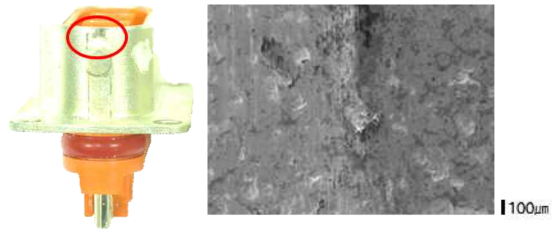
fretting wear of connector joint (Fig. 5).

Fig. 5 is a shape of completed vibration test. It was confirmed that fretting wear occurred at the contact portion between the connector and the cable, and the aluminum base material was directly exposed. in the presence of vibrating conditions, it is expected that galvanic corrosion will occur due to the direct contact between aluminum as the connector material and copper as the cable material.

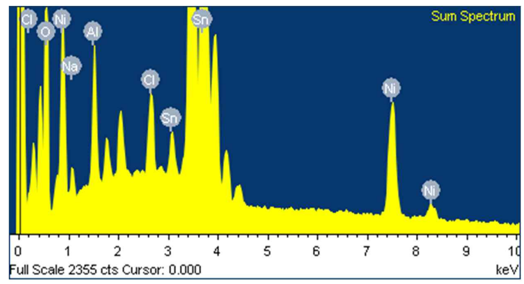
The high-voltage cable and the connection part of the connector were found to cause fretting wear in the vehicle vibration condition, and the principle test for the stray-current corrosion was conducted in cyclic corrosion test with corrosion environment and leakage current. Current was applied to confirm the effect of leakage current on corrosion. The test is carried out with DC current with a current density (10 mA/cm^2) at which stray-current corrosion could occur in a state where the connector and the cable were fastened (Fig. 6). This set the conditions based on the literature on corrosion. According to the literature, current density is 3 ~ 80 mA/cm^2 for AC and 0.01 ~ 10 mA/cm^2 for DC in order to cause stray-current corrosion [2,3].

As shown in Fig. 7, when the CCT test was conducted with the vibration test, nickel (Ni) and aluminum (Al) were detected. Here, nickel is plating on a base layer on an aluminum base. As a result of fretting wear between connector and cable, the aluminum material of the connector and the copper material of the cable connection portion are connected to each other to have a hetero-junction structure. This accelerates galvanic corrosion.

In this study, it was confirmed that the external current affects corrosion when the plating layer is broken. Compared to the conditions under which only the vibration test was conducted without current condition, it increased from 2.07% to 6.60% for aluminum and from 12.75% to 44.84% for nickel. Therefore, it was confirmed that when the plating layer was damaged by the vibration test, the difference in corrosion rate was considerably large depending on the presence or absence of leakage current.



(a)



(b)

Fig. 7 Evaluation results in vibration and cyclic corrosion test; (a) Connector fretting wear / cyclic corrosion test area, (b) Oxide analysis after wear / cyclic corrosion test.

4. Conclusion

(1) The mechanism of galvanic corrosion and stray-current corrosion under various road surface conditions of high - voltage cable and connector joints was verified. In the case of the cable and the connector which are separately connected without considering the actual driving condition, vibration, the tin plating layer was not broken, so corrosion hardly occurred. Since it is considered that the effect of galvanic corrosion will be insignificant when the aluminum base material is not exposed, it is necessary to apply a structure for reducing the vibration to the fastening portion or to secure the water tightness so as not to be exposed to the corrosive environment.

(2) Test conditions were set so that stray-current corrosion could be reproduced in single item test. Basically, three test factors must be considered. First, fretting wear is added through vibration like running road surface, conducting cyclic corrosion test with stray-current can make possible to verifying corrosion resistance.

References

1. D. A. Jones, *Principles and Prevention of Corrosion, 2nd ed.*, pp. 464 − 465, Prentice Hall, NJ, USA (1996).
2. S. Goidanich, L. Lazzari, and M. Ormellese, *Corros. Sci.*, **52**, 916 (2010).
3. C. Yang, G. Cui, Z. Li, Y. Zhao, and C. Zhang, *Int. J. Electrochem. Sci.*, **10**, 10223 (2015).