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A Case Study of Contact Failure of Oil Temperature Sensor for Automotive Transmission

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Abstract: **In this study, we investigated the cause of the contact failure phenomenon of the oil temperature sensor whose signal error occurred intermittently during vehicle driving. The electrical contact failed sensor was disassembled and observed the contact surfaces with a scanning electron microscope (SEM). In the case of the present oil temperature sensor, the difference in thermal expansion coefficient of the male-female terminal and the vibration during driving cause fretting corrosion at the contact area. Fretting corrosion causes the signal error intermittently. It is judged that the lead wire composed of the flexible thin plate is structurally vulnerable to vibrations during driving, which further causes fretting of the contact point. Therefore, it is necessary to design an additional structural supplement to fix the flexible terminal of the sensor system.**

Keywords: **Oil Temperature Sensor, Automotive Transmission, scanning electron microscope (SEM).**

1. INTRODUCTION

In recent years, advanced electronic control systems that can improve the limitations of existing mechanical devices in various comfort and safety device systems in automobiles are rapidly being applied. As these systems become complicated, the number of connectors for connecting electronic control devices, sensors, and electronic components is about 3,000 in automobiles, and the number of components is continuously increasing.

In the electronic control system of a car, if there is a contact failure at the connector contact points, a serious accident may occur in the moving vehicle [1]. One of the main causes of the factors causing the failure of the electronic and electrical connectors is fretting corrosion caused by the tiny wear due to friction or temperature change when the two contacts of the connector are in contact with each other [2-5]. In the case of automobiles, the vibration and temperature change during vehicle operation cause movement of contact point of connector. In addition, in the case of the connector terminal, there arises a problem that the contact resistance is abruptly changed due to oxide film formation, dust, impurities, and etc. Failure due to contact failure of the connector terminal is directly related to the safety of the driver.

In this study, we investigated the cause of the contact failure phenomenon of the automobile connector which often occurred in the field. The object of this study was the oil temperature sensor, and it was found that the signal error occurred intermittently during vehicle driving. In order to investigate the cause of the failure, the electrical contact failed sensor was disassembled and observed the contact surfaces with a scanning electron microscope (SEM). Through this, we identify the cause of contact failure and provide this information as basic data to reflect in the design.

2. BACKGROUND OF THE SENSOR CONNECTOR

The object of this study is oil temperature sensor equipped in an automatic transmission, as shown in Fig. 1. It was found that the signal error occurred intermittently during driving. When an abnormality signal is generated from the sensor during driving, this problem can be solved if the connector of this sensor is pulled out from the female connector and is inserted again at the maintenance site. Thus, it is difficult to identify the cause of the trouble at the maintenance shop or the manufacturer. Such a phenomenon is due to the fact that the contact areas of the sensor are very tiny, considering the dimensional tolerances of the male and female connectors. It is believed that at the time of reinserting after detachment, the male and female connectors cannot be mated at the exact position where the fretting occurred initially and that the oxide is not present. That is, it is difficult to grasp the problem because another contact point is made at a new clean surface after the connector is inserted in the female connector again.

3. FAILURE ANALYSIS

The effect of temperature change, which is the main cause of fretting in the present oil temperature sensor, was examined. As a result of confirming the structure of the oil temperature sensor system, as shown in Fig. 1, there is a possibility of fretting displacement due to difference of thermal expansion of material. The female terminal contact is a polymer with tin coating and the male terminal contact is made of brass with tin plating. The thermal expansion coefficient of the two materials is large. The coefficient of thermal expansion (α) is about 8×10^{-5} for polymer and about 2×10^{-5} for brass [6]. The polymer was assumed to be a pure polymer due to its thin coating of tin. The temperature difference is assumed to be 70°C, considering the winter season, if the maximum operating temperature of the transmission oil is assumed to be 60°C. The dimensions of the male-female terminal contacts are shown in Fig. 2. In this case, the length of the female terminal is 6 mm, and the total length of the contact part from the middle branching point to both ends is about 8.5 mm. If the temperature difference (ΔT) is 70 °C, the length (l_o) is 8.5 mm, and the thermal expansion coefficient (α) is 8 x 10^{-5}, the final thermal expansion length ($\Delta l = \alpha \Delta T l_o$) is 47.6 μm. The length (l_o) of the male terminal is 3 mm and the final thermal expansion length (Δl) is 4.2 μm at the same temperature condition. The relative displacement due to thermal expansion of the male-female terminal contact corresponds to 43.4 μm. Therefore, it is possible to cause fretting due to a full temperature change.

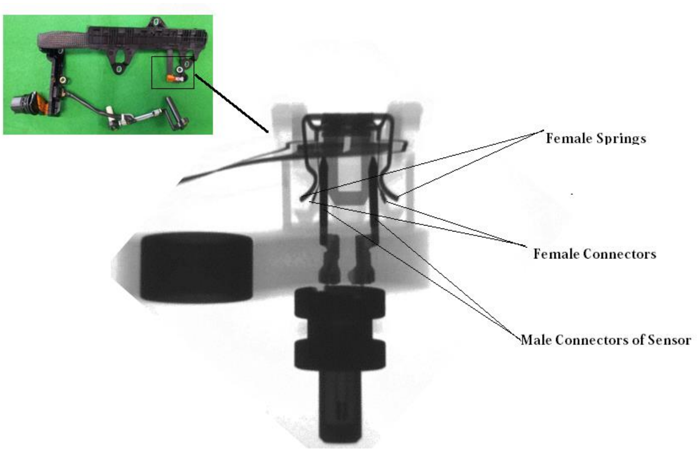

Fig 1: Transmission oil temperature sensor and its connector system

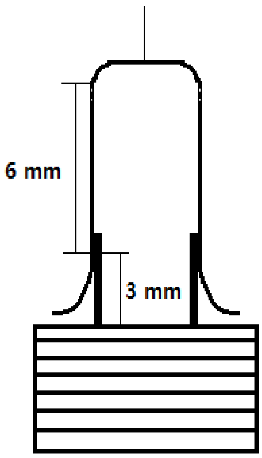

Fig 2: Dimensions and contact area of the female and male terminals

On the other hand, the contact point of the terminal which has a failure was observed by using a scanning electron microscope. The sensor was disassembled, as shown in Fig. 3. Fig. 4 is a photograph taken by a surface corresponding to the male terminal contact area. From the SEM microscope, as shown in Fig. 4, a slightly rough surface indicated by a circle of the male terminal is judged as the real contact area. That is, it was observed that the contact was not made in a wide part but only in some projections. For this reason, it is judged that the contact load is dispersed in two places because the shape of the spring that gives the contact load of the female terminal is slit in the middle. A slight scratch in the vertical direction of the lower part is judged as a scratch in the insertion or removal process.

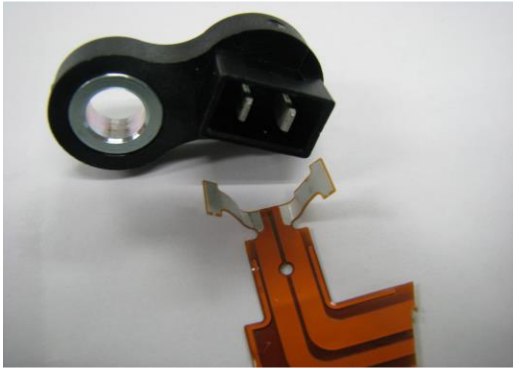

Fig 3: Male and female terminals of the oil sensor for SEM observation

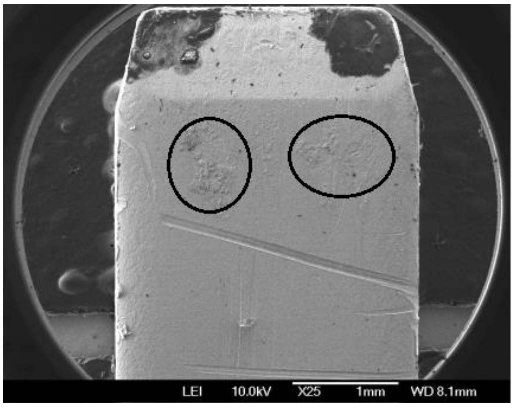

Fig 4: Surface of the fretting corroded male terminal

Fig. 5 is the magnified the surface of the fretting corroded male terminal in Fig. 4, showing that the tin oxide, which caused the fretting corrosion phenomenon, is accumulated on the surfaces. As a result, it is judged that an abnormal signal is generated due to an increase in contact resistance. Another male terminal was also observed to have slightly accumulated oxide layers in the middle. In the case of a tin-plated connector where fretting corrosion phenomenon occurs, it is common that small tin oxide debris is scattered on the terminal surfaces. However, small oxide debris was not observed on the oil temperature sensor terminal. It is presumed that the oil mist in the automatic transmission suppresses oxidization of the terminal surface.

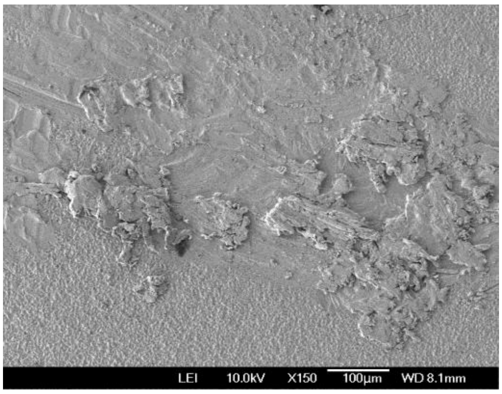

Fig 5: Magnified the surface of the fretting corroded male terminal in Fig. 4.

Fig. 6 is the surface for the flexible part of the female terminal, where the smooth part of the right region of the picture is actually bent so that it is in contact with the male contact part. Fig. 7 shows the magnified surface of the fretting corroded flexible female terminal in Fig. 6. From Fig. 7, the width of contact with the male terminal was observed to be more than 100 µm. This distance is greater than 49.8 µm due to pure thermal expansion. This fact suggests that there are other factors that cause other movements such as vibration in addition to thermal expansion. In the case of the present oil temperature sensor system, it is judged that the lead wire composed of the flexible thin plate is structurally vulnerable to vibrations during driving, which further causes fretting of the contact point. In addition, it was observed that a relatively small accumulation of oxides was observed in the female terminal as compared to the male terminal. The non-contact region is covered with small projections, as shown in Fig. 8. The original coat is a slightly silvery color when observed with the naked eye. However, after fretting corrosion, the contact area changes to a slightly blackish coating.

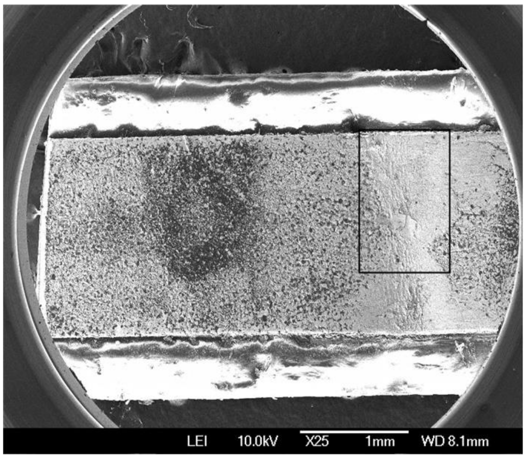

Fig 6: Surface of the fretting corroded flexible female terminal

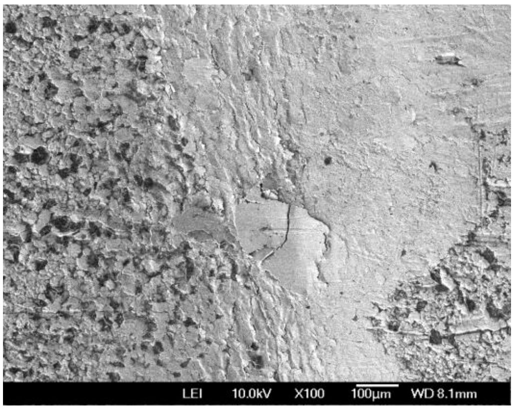

Fig 7: Magnified the surface of the fretting corroded flexible female terminal in Fig. 6

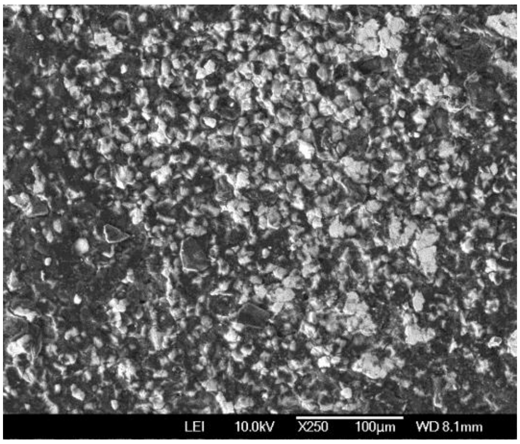

Fig 8: Magnified the non-contacted surface of the flexible female terminal in Fig. 6

4. CONCLUSION

In this study, we investigated the cause of contact failure of the oil temperature sensor installed in the automotive automatic transmission. Intermittent signal error occurred in the sensor during driving. The terminal contact area of the failed sensor was observed with a scanning electron microscope (SEM). The terminal surface is made to be macroscopically flat and used. But in practice, it is microscopically confirmed that the terminal acts as a contact at a limited portion by the projection. In the case of the present oil temperature sensor, the difference in thermal expansion coefficient of the male-female terminal and the vibration during driving cause fretting corrosion at the contact area. Fretting corrosion causes the signal error intermittently. In the case of the present oil temperature sensor system, it is judged that the lead wire composed of the flexible thin plate is structurally vulnerable to vibrations during driving, which further causes fretting of the contact point. Therefore, it is necessary to design an additional structural supplement to fix the flexible terminal of the sensor system.

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