

Monitoring Technology for Automobile Corrosive Environments

Yasuhiko Saijo, Mitsuhiko Ueki, Hirokazu Watanabe, and Yoichiro Tejima
Honda R&D Co., Ltd. Automobile R&D Cente

ABSTRACT

Honda developed a technology to quantify automotive steel corrosion from the rust reduction current detected by a proprietary developed sensor. The values calculated based on Faraday's law did not match the actual measured values for the mass loss of iron due to the added resistance of rust formed between electrodes on the sensor. It was determined that the resistance of rust depends on the environment, and this issue was resolved by setting the correction values for that influence. As a result of this research it was found that the values calculated from the sensor measurements matched those from the mass loss of test specimen on a vehicle. Honda is utilizing this newly developed technology for corrosion research and field data collection.

CITATION: Saijo, Y., Ueki, M., Watanabe, H., and Tejima, Y., "Monitoring Technology for Automobile Corrosive Environments," *SAE Int. J. Mater. Manf.* 8(2):2015, doi:10.4271/2015-01-0734.

1. PURPOSE

In order to predict the lifespan of new structures or materials within the automobile development process, it is important to attempt to develop a correlation between accelerated corrosion tests and corrosion behavior in the field. In this regard, it is essential to understand the corrosion environments that vehicles will encounter in the field. The purpose of this research was to quantify automotive corrosion environments in order to ensure a correlation between accelerated corrosion tests and field environments and to predict the lifespan of materials, resulting in the determination of optimal anti-rust specifications.

2. CHALLENGES

Since automobiles are influenced by driving conditions such as road splash, temperature, humidity, salt concentration; the amount of corrosion varies widely in the field. Road splash is considered in this research as the most influential factor in corrosion performance. Also, in order to quantitatively monitor the corrosion environment of automobiles, test specimens are installed on cars and trailers. However, test specimens installed on cars take time to evaluate the amount of corrosion, making it difficult to monitor the various corrosion conditions. Therefore, technologies for monitoring corrosion environments are required in order to enable the determination of optimal anti-rust specifications for unknown markets and new structures.

3. IMPLEMENTATION METHOD AND THEORY

The development concept of corrosion environment monitoring technology can be captured in the following 3 points:

1. Be able to measure various corrosion conditions.
2. Be applicable to any corrosion environment.
3. Be able to calculate material loss due to corrosion.

3.1. Corrosion Mechanism and Corrosion Environment

The corrosion mechanism of iron adopted for this research is shown in Fig. 1. As for the driving force of the corrosion of iron, the rust was considered to be main factor [1, 2].

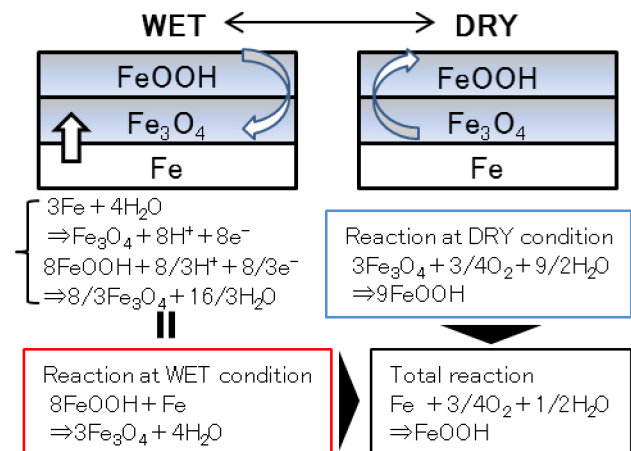


Fig. 1. Schematic image of Fe-corrosion

Iron dissolves electrochemically to Fe₃O₄ and FeOOH through a reduction reaction under wet conditions, Fe₃O₄ is chemically altered to FeOOH through an oxidation reaction under the dry condition. The total cyclic wet-dry process generates rust (FeOOH) from iron (Fe) by combining water and oxygen. Considering the above mention mechanism, by measuring the current of the reduction reaction of rust (FeOOH) one can infer the various wet-dry cyclic conditions.

According to this mechanism, a more severe corrosion environment generates larger amounts of rust, so the rust reduction current should also increase. The measurement of this reduction current is simple to perform in the laboratory; but requires an innovative electrochemical measuring device to be used in automotive applications.

3.2. Method for Measuring the Corrosion Environment

As reported in previous studies, the effectiveness of the Atmospheric Corrosion Monitor (ACM) sensor to easily measure the atmospheric corrosion environment caused by sea-salt particles on bridges, buildings, and other structures has been confirmed [3,4]. Figure 2 shows the structure of the ACM sensor. An overhead view is shown at the top of the figure, and a cross-sectional view at the bottom. The measurement principle of the ACM sensor is illustrated in Fig. 3. The ACM sensor measures the oxygen reduction current to determine the iron corrosion rate up to 90% confidence and therefore can be considered to be a successful technology for measuring atmospheric corrosion environment.

In severe corrosion environments, such as where de-icing agents are applied, large amounts of rust might inhibit the oxygen reduction reaction therefore compromising the accuracy of the measurements. For this reason, ACM sensors have not been used for measuring automotive corrosion environments. Given the simple device configuration of the ACM sensor, requiring only an ammeter and recorder, it seemed reasonable to try to adapt the sensor to be used even in the severe corrosion environments.

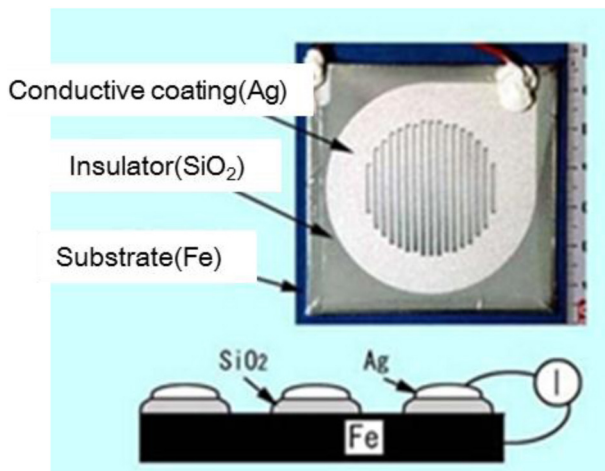


Fig. 2. Structure of ACM

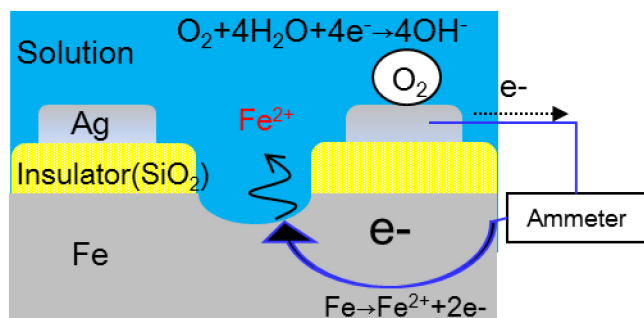


Fig. 3. Measurement principle of ACM

If corrosion mechanism of iron is present at the ACM sensor, it should be possible to retrieve the rust formation current. Figure 4 shows the polarization measurements of the ACM sensor electrodes initially and after corrosion. After corrosion, a large cathode current was confirmed on the Ag electrode. Because the rust is in contact with the Ag electrode, this was seen as a possible measurement of the rust reduction current. It was found that the rust reduction current density was different from the oxygen reduction current, and the iron rust was the dominant influence on the rate of iron mass loss. It was also found that the anodic polarization characteristics of the Fe electrode were not affected by the presence or absence of rust. Figure 5 shows a schematic sectional view of the reaction of the ACM sensor when rust is in contact with the Ag electrode.

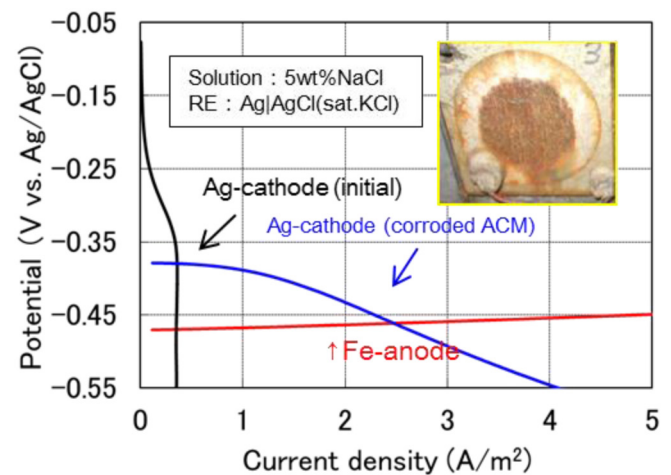


Fig. 4. Polarization measurement of corroded ACM sensor

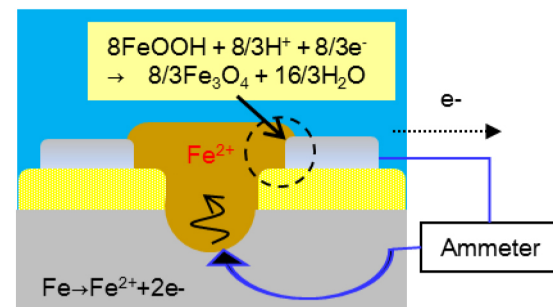


Fig. 5. Schematic image of reaction of corroded ACM

3.3. Method of Calculating the Amount of Corrosion

Results of sensor measurements in Honda's basic mode combined corrosion test ("CCT" below) revealed that the amount of corrosion calculated from the sensor output based on Faraday's law was not in agreement with the thickness reduction of iron on the test specimen. Fig. 6 shows the result.

It was considered that the measured values of the sensor outputs had been influenced by inter-electrode resistance in the galvanic corrosion current of iron rust and iron. Therefore, measurements were collected of both inter-electrode resistance and sensor outputs under wet-dry condition. Figure 7 shows the sensor output and inter-electrode resistance.