Development of Evaluation System for Automobile Corrosion Environment

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With the global changes of the automobile market, the design and development of an automobile in consideration of various corrosive environments are required. It is necessary to immediately grasp the corrosive environment of the automobile market quantitatively. Therefore, even a system that could measure the corrosive environment of transit-time has been developed. Various areas of a corrosive environment were measured continuously and quantitatively by using this system, and every the side of the automobile could be evaluated. In this study, the result of the measurement of an ACM sensor (Atmospheric Corrosion Monitor Sensor) that estimated the corrosive environment in particular to automobiles is reported.

1. Introduction

With the global expansion of the automobile market, automobiles within severely corrosive environments have been increasing. Table I shows an example of the corrosion environment and the factor for the automobile. It is necessary to inspect by the corrosion evaluation test method that had a high reproducibility and facilitated the development of an automobile which adapted to various corroding environments.

Thus, it was necessary to develop a system that estimated the corrosion level of each part of the automobile and evaluated it. By calculating specific corrosion factors, the authors could design vehicles suitable for each market. The authors developed a system to measure the corrosion environment of vehicles. This system recorded corrosion speed as corrosion electrical quantities using an ACM sensor [1], that can use measurements of details, such as weather, driving condition and so on, to estimate and assess the corrosion level of each part of the car [2,3,4]. In this paper, the effect of the different monitoring tests in three climate regions (snowy region, coastal region, warm region) and analysis results of the corrosive environment through the difference of the climates are reported.

Table I. Example of the corrosive environment caused by corrosive factors in the Automobile.

<table>
<thead>
<tr>
<th>Location &amp; Climate</th>
<th>Corrosive environment</th>
<th>Corrosive factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tropical region</td>
<td>Hot and humid climate</td>
<td></td>
</tr>
<tr>
<td>Snowy region</td>
<td>NaCl and CaCl which are sprinkled on the street as an antifreeze</td>
<td></td>
</tr>
<tr>
<td>Coastal region</td>
<td>Salt air, Seawater</td>
<td></td>
</tr>
<tr>
<td>Hot-spring region</td>
<td>Sulfur compounds generated in a hot spring</td>
<td></td>
</tr>
<tr>
<td>Use</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fishery-work</td>
<td>The seawater due to transportation of seafood</td>
<td></td>
</tr>
<tr>
<td>Factory-work</td>
<td>Corrosive chemical substance included in the exhaust-gas from a factory</td>
<td></td>
</tr>
</tbody>
</table>
2. Monitoring of the corrosive environment

2.1 ACM sensor

Fig. 1 shows an ACM sensor. An ACM sensor is the formation of the conductive paste and insulating paste on the substrate in a comb shape. If rainfall results in water condensing over the sensor, the exposed portion of the substrate becomes the anode. Then the conductive paste corrosion current flows in that area to become the cathode. The increase or decrease of the current is due to the effects of the adhesion amount of relative humidity and salt. In other words, by analyzing the average daily electric quantity, which is calculated from the output behavior and its current value, the corrosion current can monitor the time and quantity of corrosive environments [5,6,7].

![Fig. 1. Schematic illustration of ACM sensor.](image)
(a) Plane view.

(b) Cross section along the line A-A'.

2.2 The system

Fig. 2 shows an overview of the “In-vehicle corrosion environmental measurement system”. The ACM sensor, temperature and humidity sensor (Temperature sensor and humidity sensor were installed on the same substrate, and waterproofing was made on them), and the cameras will at the record a variety of data simultaneously. The authors aim to clarify the mechanism of corrosion on the basis of the data that the ACM sensor outputs. Also, the authors aspire to clarify the correlation of corrosion and local corrosion data. In addition, by the accumulation of corrosion environment data, the authors are able to predict the corrosion level from the sensor near the exposure specimen in the region. Table II shows the possible measurement items in this system.

![Fig. 2. In-vehicle corrosion environmental measurement system.](image)
2.3 Test method

Fig. 3 provides an overview of the measurement system used. The ACM sensor and a temperature and humidity sensor and the specimen, were set up on the roof and the rear floor. The test set was installed on the roof so that the surface of the sensor was facing upward. The test set on the rear floor was installed so that the surface was facing downward.

![Fig. 3. Installation position of ACM sensor, Temp./Hum. sensor & specimen.](image)

### Table II. Measurement items for the system.

<table>
<thead>
<tr>
<th>Items</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACM sensor</td>
<td>Corrosion speed</td>
</tr>
<tr>
<td>Temp./Hum. sensor</td>
<td>Condensation/Deliquescence condition</td>
</tr>
<tr>
<td>CAN signal</td>
<td>Driving condition</td>
</tr>
<tr>
<td>GPS signal</td>
<td>Environmental condition</td>
</tr>
<tr>
<td></td>
<td>(Measurement time, Driving area)</td>
</tr>
<tr>
<td>Cameras</td>
<td>Weather/road condition</td>
</tr>
<tr>
<td><em>Rec. Sensor data</em></td>
<td><em>Mechanism of corrosion</em></td>
</tr>
<tr>
<td><em>Exposed Specimen</em></td>
<td><em>Corrosion level</em></td>
</tr>
</tbody>
</table>

2.4 Result

Fig. 4 shows the results of the ACM test while driving. The change of the ACM output data of ①, ②, ③ and ④ in the figure depends on the following reason.

① The sensor became dry by running in the clear sky, the output decreased on the roof.
② The sensor became wet through rainfall, the output increased on the roof.
③ Road rainwater was whirled up into a fog form, and the sensor got wet with running at high speed, output increased on the rear floor (under floor, following rear floor).
④ It rained during a stationary period, the output was maintained on the roof and decreased on the rear floor.

The results indicate that the running state changes the corrosive environment in different conditions. Not only weather, climate, and road conditions but also through vehicles with a complicated structure, there is a difference in the corrosion tendency of each part.
3. Analysis results and discussion

The monitored results were examined in three regions (Snowy region// Aomori; Coastal region// Okinawa; Warm region// Shizuoka). Fig.5 shows average daily figures of the monthly temperature and humidity of the three regions. The ACM sensor output varies depending on rainfall-time and condensation-time. Each term of condensation, desiccation and the rainfall is known to be able to be detected [8]. Also, it is important to acknowledge that the evaluation of environmental corrosive nature requires the wetting time (Duration: temperature// more than 0℃, humidity// more than 80%) to be considered a the time when a water screen is formed. The ACM output fluctuates depending on thickness of the water screen like a real corrosion mechanism [9]. The analysis result of the monitoring test in the three regions are shown below.

![Fig. 4. The results of the ACM test while driving.](image)

![Fig. 5. Average monthly temperature and humidity in three regions.](image)
3.1 Corrosion of electrical quantities and corrosion penetration

Fig.6 shows driving in different conditions. The vertical axis is the corrosion penetration of the specimen. The horizontal axis shows the corrosion electrical quantities per year resulting from the ACM output. This experimental result shows the data of the ACM sensor installation point besides the roof and the rear floor. All regions increase the quantity of rust so that the corrosion of electrical quantities rises, which clearly shows a correlation between the two. In other words, interrelation is shown. While the warm region data is distributed widely, the data of the snowy and coastal regions are concentrated around the high numbers. Thus, the corrosion rate of the specimen can be predicted by measuring the corrosion of electrical quantities.

3.2 Regional factor

Fig.7 shows the regional factor. The vertical axis indicates corrosion electrical quantities per year. The horizontal axis shows parts of the roof and rear floor divided into the three regions. There was a difference in the corrosion electrical quantities per year in every region. A tendency to corrosion similar to real market corrosion conditions can be shown with a digit value.
3.3 Seasonal factor

Fig. 8 shows the seasonal factor. From December to March, the snowy region had higher corrosion electrical quantities than the warm region and coastal region. It is found that regional specific corrosive environments have an effect on the corrosion electrical quantities. With regards to the snowy region, it can be inferred that the corrosion electrical quantity became higher by NaCl, CaCl and others being sprinkled on the road as a snow melting agent used in the winter season. Results from the coastal region showed that, the corrosion electrical quantity is higher compared to the warm region throughout the year. This might have resulted from the special briny air, high temperatures and humid climate in the costal region. Thus, the difference of the corrosion rate by the season can be shown trough the measurement of the corrosion electrical quantities.

![Fig. 8. Seasonal variation of corrosion electrical quantities.](image)

4. Conclusion

With the corrosive environment evaluation system established in this study, it was confirmed that quantification of the wide corrosive environment was possible. In addition, an evaluation of the corrosive environment by weather, season and area was provided by analyzing the results of the measurements. Furthermore, the authors were able to develop design guidelines which consider corrosion in an automobile design to allow more complicated construction. It is necessary to pay attention to corrosion when joining dissimilar materials [10] of the hybrid body [11] to improve the quality of automobiles in the future. The contribution of this study is outlined by the technological development of the accelerated corrosion test which helps to reproduce an actual environment which is indispensable.

Acknowledgment

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References


[9] K. Fukuda et al., “Analysis result of the monitoring that was examined below in 3 territories is shown”. 2015 JSAE Annual Congress (Spring), S384, (2015)