

# Development of Positioning Corrosion Monitoring Sensor applied for Offshore Steel Structure

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**1. Introduction** The durability of steel structures used in the bay environment faces challenges from tidal erosion, marine organisms, and other issues. Although anti-corrosion coatings are generally used on the surface of steel structures to prevent and slow down corrosion, when the coating is damaged, the corrosion of the damaged coating will develop very rapidly, which will affect the safety of the structure and make the failure of the coating film in other areas. Most existing corrosion monitoring sensors used on steel structures, such as field signature method <sup>1)</sup> and ultrasonic monitoring <sup>2)</sup> have complex devices and high costs. Positional corrosion monitoring (PCM) sensors are expected to be developed as a screening and low-cost device embedded under coatings to monitor the location and extent of steel corrosion progression.

The schematic diagram of the PCM sensor setup is shown in Fig.1. Steel structure, PCM sensor and anti-corrosion coating form a sandwich structure. The sensor is laid in the form of mesh and insulated. The sensors will be laid at a higher density in part in the area affected by the tide. The corrosion detection mechanism of the PCM sensor is shown in Fig.2. When the surface coating of the steel structure is damaged, a corrosion spot will appear. As the corrosion spreads, the corroded area affects the  $x_1$  and  $y_2$  sensors' resistance. By analyzing the characteristics of the resistance change of sensors, the location of the damaged steel structure could be judged. This research presents the progress in developing corrosion sensors under alternate immersion conditions.

## 2. Experiment method

**2.1 Sensor tape design** The PCM sensor used in the fundamental experiment is shown in Fig.3 (a). The width of the tape is 19mm, the thickness is 0.5mm, the overall length is 320mm, and the length of the resistance test area is 300mm. Both ends of the sensor are wire connection areas. Due to the limitation of experimental conditions, only the middle 100mm is selected as the test area. Fig.3(b) shows the fabrication process of the PCM sensor for the alternate immersion test: (1) Solder the wires at both ends of the sensor for resistance measurement; (2) bend sensors into a "U" shape; (3) Waterproof treatment by silicon sealant on the non-exposed part. Two types of sensors were designed with different exposed area: Sensor 1 has two circular defects on silicone sealant with diameter of 10 mm and distance of 60 mm, Sensor 2 is a nude type sensor with an exposed length of 100 mm.

**2.2 Sensor monitor** The resistance logger used in this experiment is SRCM-301 (Engineering machine, Syrinx Inc.). The data logger uses the four-terminal method to measure the resistance <sup>2)</sup>, which can measure the resistance value more accurately. The thermometer used in the experiment is TR-72nw (T&D corporation).

**2.3 Alternate immersion test** To simulate the resistance change behavior of the sensor in the tidal environment of the harbor virtual environment, The process of alternate immersion cycle refers to ISO 11130-2010. Each cycle lasts one hour, including 10 min of immersing and 50 min of drying time. The concentration of the solution used for impregnation is 3.5 wt% NaCl aq.

**3. Results and discussion** The alternate immersion test lasted for 60 days, and the data from days 0-3 and days 57-60 were selected for comparison. In Fig. 6 (a), the general resistance change of the sensor was shown.  $R$  (m $\Omega$ ) is sensor resistance.  $R_0(im)$  is the initial resistance of the PCM sensor in the submerged state, and  $R_0(dry)$  is the initial resistance in the dry state.  $T$  ( $^{\circ}C$ ) is the air temperature of the atmospheric environment where the sensor is located. The resistance of the two sensors is linearly increasing with elapsed time This is consistent with Eq.(1) in the case of uniform thinning, where  $R$ : resistance;  $l$ : sensor length;  $S$ : sensor cross-sectional area. At the same time, the ambient temperature is decreasing, which means the rising trend of sensor resistance will not be excessively affected by atmospheric temperature.

$$R = \rho l / S \quad (1)$$

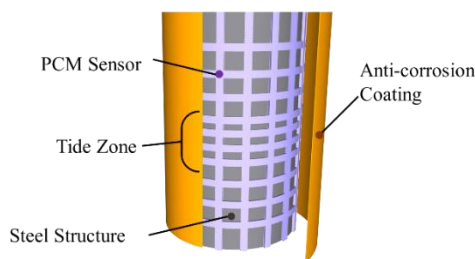


Fig. 1 setup of PCM sensor

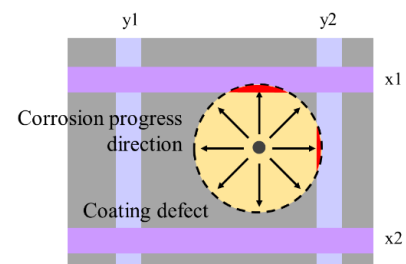


Fig. 2 Corrosion detection concept of PCM sensor

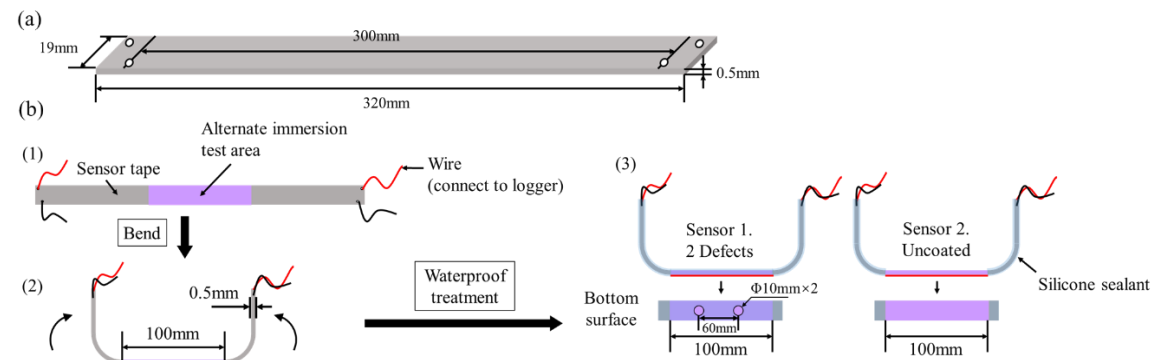


Fig. 3 Schematic diagram of (a) PCM sensor and (b) Fabrication process

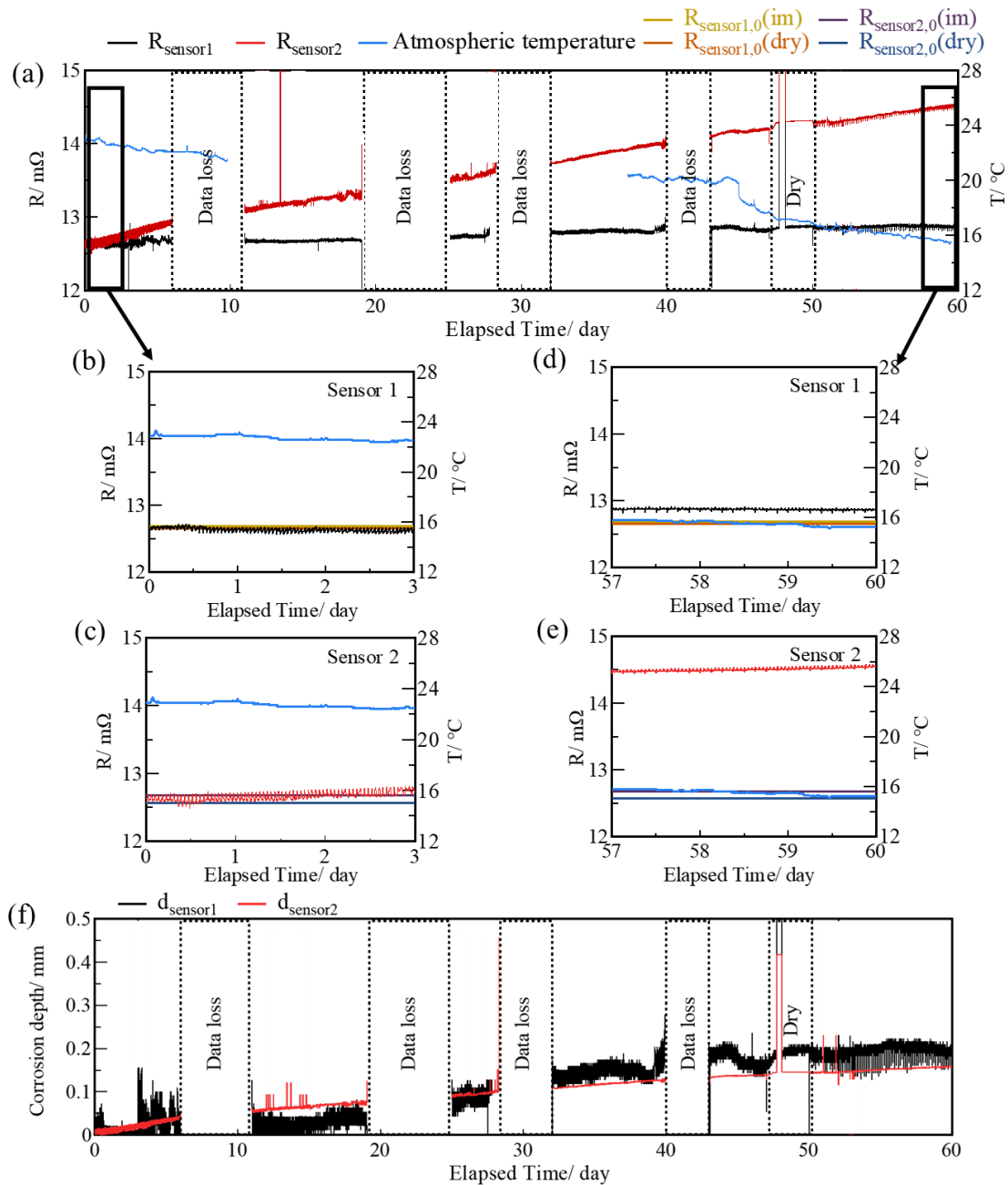


Fig. 6 PCM sensor's resistance change; (a) General trend; (b) Resistance change of sensor 1 in days 0-3; (c) Resistance change of sensor 2 in days 0-3; (d) Resistance change of sensor 1 in days 57-60; (e) Resistance change of sensor 2 in days 57-60; (f) Calculated corrosion depth

When the sensor length and resistivity remain unchanged, the conductor cross-sectional area decreases and the resistance increases. However, the change in resistance over time will be affected by whether the sensor is in water. As shown in fig.6 (b) and (c), the resistance of the sensor will be influenced by the change of dry and wet conditions. This is especially evident at the beginning of the experiment. As the experiment progressed, the resistance changes decreased, as shown in fig.6 (d) and (e). The specific change mechanism of the resistance here will be discussed in future research. Fig.6 (f) shows the average corrosion depth using the sensor calculated using Equation 1. The corrosion depth increases approximately uniformly in both cases for sensor1 and sensor2. The corrosion rate is 1.20mm/a (sensor1) and 0.938mm/a (sensor2).

**4. Conclusion** This study describes a PCM corrosion sensor under development that is characterized by low cost and easy installation. The following conclusions can be drawn from the experimental results: (1) the resistance of the sensor is less affected by atmospheric temperature; (2) the resistance of the sensor in the early stage of corrosion is easily affected by dry and wet conditions, and this effect will decrease as the corrosion progresses. This property can be used to detect corrosion initiation caused by early coating damage.

#### References

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