POF センサーを利用した鋼構造物の腐食モニタリングに関する基礎的研究

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1.Introduction

Health monitoring of engineering infrastructure has received more and more extensive attention. Steel corrosion is known as one of the major structural defects for steel structures such as pipes and plates. Although various methods such as measuring weight loss and electrical approaches have been utilized for steel corrosion detection, the lack of real-time corrosion measurement approaches limits their application. The corrosion can be monitored by detecting the change in color. The plastic optic fiber (POF) can detect the color and has ability to provide real-time monitoring. Therefore, the POF sensor could be a potential candidate for steel corrosion detection. In this article, a corrosion detection approach is developed using POF sensors. The sensing principle and laboratory accelerated corrosion tests are discussed. The relationship between the corrosion patterns and sensor signals is investigated and validated through experiments. Accelerated laboratory corrosion tests are implemented to validate the feasibility of the proposed sensing system. With validation, the results of this study could be extended to multiple types of application such as steel pipe and steel plate.

2. Principle of plastic optical fiber sensor

For sensor 1, shown in Fig.1, two POFs are aligned linearly with a gap of some distance. Of the light that reaches the front face of the first fiber, another part may hit surface of pipe inner wall with intensity L2, with a part of which actually getting into the second fiber. Sum of these grows to have intensity L4 and travels back to a photo sensor to be recorded. By the detecting the color of the inner wall, the progress of corrosion into the depth of steel pipe can be monitored. For sensor 2, shown in Fig.2, a POF sensor is not watching corroded surface directly, but it is rather watching color change caused by flow and penetration of the corrosion-colored liquid. Sensors 1 and 2 are used to monitor the steel pipe specimen. For sensor 3, shown in Fig.3, LED-generated light is sent into the first fiber, whose light flux, or in another word, intensity is depicted as L1. Of the light that gets out of the first fiber, a part of it, shown as L2, hits an arbitrary object just in front of the fiber tip (or front face). A part of the reflected light hits the front face of the second fiber, yielding eventually the light with intensity L4 to travel back to a photo sensor through the second fiber. The properties of the returning light (intensity and color) are affected by many factors telling the story of what is happening at the tip of the fibers. The sensor 3 is used to monitor steel plate.

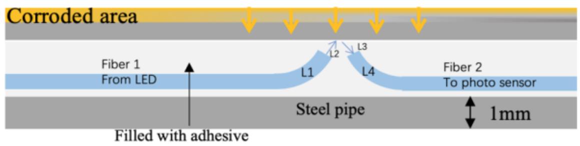

Fig.1　Sensor 1 for steel pipe

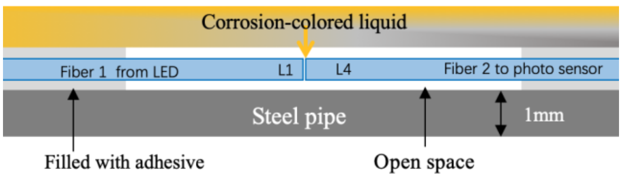

Fig.2　Sensor 2 for steel pipe

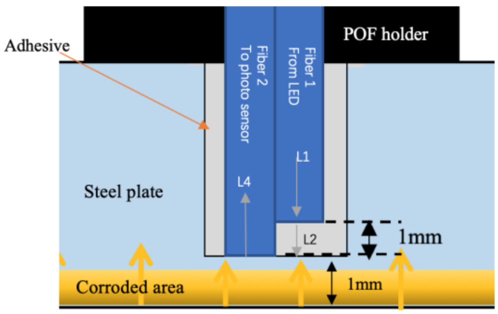

Fig.3　Sensor 3 for steel plate

Keyword　Corrosion,　Steel pipe,　Steel plate,　Monitoring, Plastic optic fiber
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3. Electric corrosion experiment

Three electrolytic corrosion experiments were conducted. They continued for about 2 to 10 days when the corrosion of the steel specimen progressed sufficiently. The experiment setup is shown in Figs 4 and 5.

As shown in Fig.6, the analysis of the experiment 1(using sensor 1) can be divided into two parts. In the first part t_1 , the position of the sensor barely changed so that the light has hardly changed. In the second part t_2, the corrosion arrived at the pipe inner wall. Meanwhile, some deformation in the inner wall caused the value of light intensity fluctuating. Besides, the time that corrosion arrived at the inner wall is inferred to be at the beginning of t_2.

As shown in Fig.7, the experiment 2 lasted for about 7 hours. It is very interesting in this experiment that without the adhesive in the tip of plastic optic fiber, the value of light intensity is very large (above measurable limits). the time that the corrosion-colored liquid penetrated and flew towards the tip of the sensor is supposed to be t_1. In this experiment, after t_1 the water might enter open space which leads to the value of light intensity which became bigger and then dropped quickly. From the results of this experiment, it can be found that the progress of corrosion into the depth of steel can be monitored by using the POF sensor.

Fig.8 shows the result of the experiment 3(using sensor 3). The time that corrosion arrived at the detected area is inferred to be t_1 ,t_2 t_3 and t_4. Besides, the corrosion arrival timings are not consistent. Therefore, the process of corrosion is not uniform. Additional observation of the results indicates that the light intensities before the corrosion arrivals change to some extent due to, at this stage, unknown reasons.

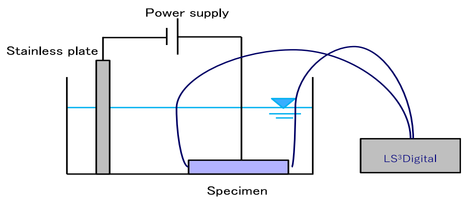

Fig.4 Overview of the steel pipe experiment

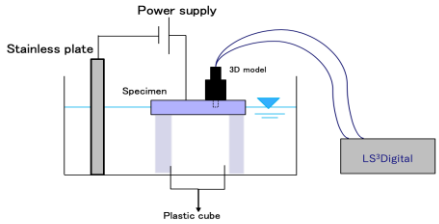

Fig.5 Overview of the steel plate experiment

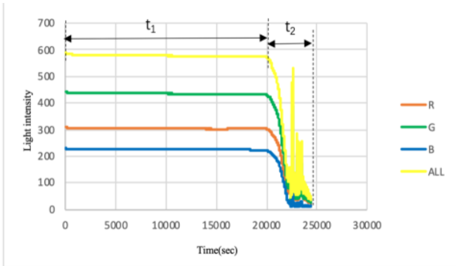

Fig.6 Experiment 1 detected by sensor 1

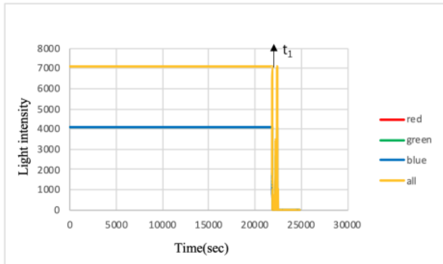

Fig.7 Experiment 2 detected by sensor 2

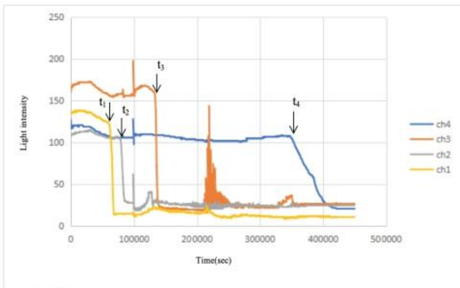

Fig.8 Experiment 3 detected by sensor 3

4. Summary

As a result of the experiment, it was found that progress of corrosion into the depth of steel could be sufficiently monitored whether the detected area was covered by adhesive or not. However, there could be a possible factor that affects this measurement which is temperature. All of the experiments in this paper have not considered the effect of temperature. In a future research, the temperature factor would be considered. Although this research is still developing and has many issues, we hope that it will be applied in the future projects by enhancing the research based on the above-mentioned problems.

5. Reference

1) Akutagawa, S., Machijima, Y., Sato, T. and Takahashi, A. 2017. Experimental characterization of movement of water and air in granular material by using optic fiber sensor with an emphasis on refractive index of light, Proceedings of the 51st US Rock Mechanics / Geomechanics Symposium, ARMA 17-313, San Francisco.