Probability of Detection in Corrosion Monitoring with Fe-C Coated LPFG Sensors

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INTRODUCTION

This project aims to develop two statistical methods for determining the probability of detection in corrosion monitoring using long period fiber gratings (LPFG) sensors with thin Fe-C coating, validate these methods from independent laboratory tests, and determine the steel mass loss at 90% probability of detection and the largest steel mass loss that may miss from a corrosion inspection at 95% upper confidence bounds. LPFG sensors could reflect the corrosion process by the wavelength shift in the transmission spectrum due to the change of the refractive index of the Fe-C coating. POD is a method used to determine the capability of an inspection as a function of defect type and defect size. The two statistical methods are referred to as the Mass Loss-at-Detection (MLaD) method and the Random-Effects Generalization (REG) method.

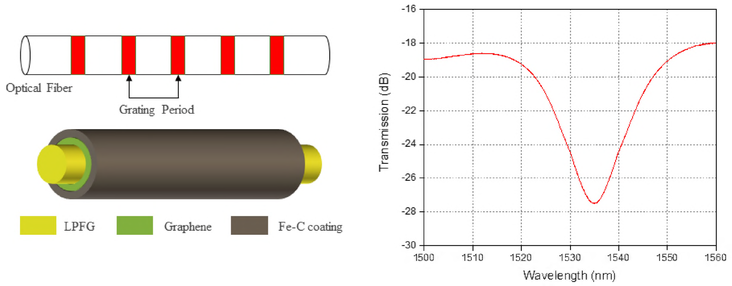

Figure 1. Schematic illustration and the spectrum of the Fe-C coated LPFG sensor

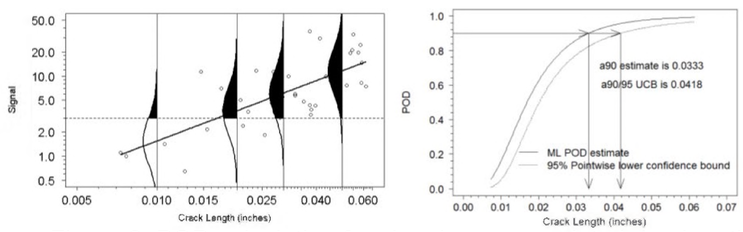

Figure 2. POD calculation for signal-response data based on the linear regression model

METHODS

Ten LPFG sensors were immersed in 3.5 wt.% NaCl solution and the spectra were recorded by the optical interrogator every hour until the signal did not change. To get the relationship between the corrosion degree and the wavelength shift, a corrosion characteristic curve was acquired based on previous research work. After the test results were applied by this curve, POD curves of MLaD and REG methods were calculated.

RESULTS

The wavelength shift increased with the accumulated mass loss of Fe-C, and the relationship between them was near linear. The POD curves were calculated selecting 3 nm as the detection threshold. The results showed that the a90 of REG is about 45%, smaller than the value of MLaD..

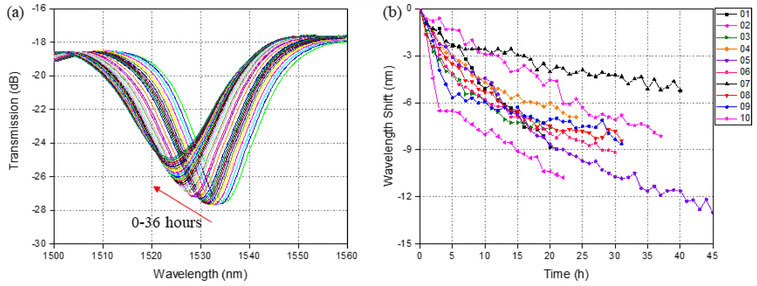

Figure 3. Transmission spectra of a Fe-C coated LPFG sensor in 3.5 wt. % NaCl solution for 36 h, and (b) Wavelength shift of the selected Fe-C coated LPFG sensors

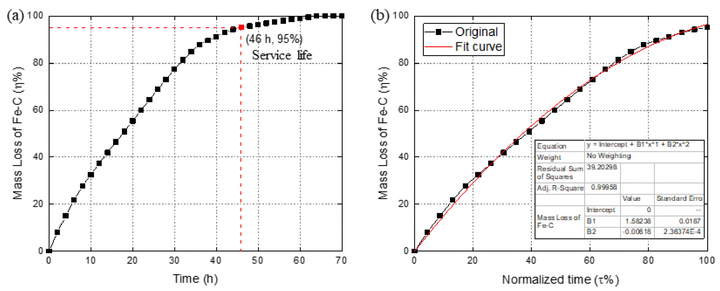

Figure 4. The Fe-C coated LPFG sensors in 3.5 wt.% NaCl solution (a) mass loss of Fe-C coating over time, and (b) mass loss of Fe-C coating over normalized time.

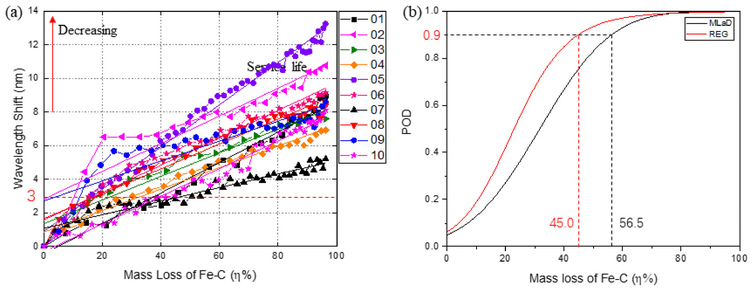

Figure 5. (a) The wavelength shift with mass loss of Fe-C coating, and (b) POD curves of two statistical methods

CONCLUSIONS

1. Selecting polynomial fit for the corrosion characteristic curve was reasonable since the R-square of the fit curve is 0.99958, which is very close to 1.
2. The wavelength shift of Fe-C coated LPFG sensors were different, but 60% was within 6~9 nm, which could be regarded as a common case for future research.
3. The REG method was more robust than the MLaD method since it considered the difference between each data set. Therefore, the REG method would be recommended for corrosion monitoring in applications.

REFERENCE

1. C.R. Guo, L. Fan, C.L. Wu, G.D. Chen, and W. Li, Ultrasensitive LPFG Corrosion Sensor with Fe-C Coating Electroplated on a Gr/AgNW Film, Sensors and Actuators: B. Chemical, 283: 334-342 (2018).
2. D. Roach and T. Rice, Addressing Technical and Regulatory Requirements to Deploy Structural Health Monitoring Systems on Commercial Aircraft, Proceedings of the World Congress on Aeronautical Science (2018).
3. W.Q. Meeker, D. Roach, and S.S. Kessler, Statistical Methods for Probability of Detectinon in Structural Helth Moiniioubg, Proceedings of the 12th International Conference on Structural Health Monitoring of Intelligent Infratraucture, St. Louis, MO (2019).
4. G.R. Guo, Long Period Fiber Grating, Thin Coating of Graphene and Silver Nanowires, and Corrosion Sensing for Life-Cycle Assessment of Steel Structures, Ph.D. Dissertation submitted to the Graduate Faculty of Missouri University of Science and Technology (2019).

ACKNOWLEDGEMENTS

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