CAAP Quarterly Report

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Prepared for: *U.S. DOT Pipeline and Hazardous Materials Safety Administration*

Project Title: Development of New Multifunctional Composite Coatings for Preventing and Mitigating Internal Pipeline Corrosion

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For quarterly period ending: *Dec. 31th, 2019*

Business and Activity Section

(a) Generated Commitments

Top journal paper published: a journal paper, entitled "*Enhanced Protective Coatings Based on Nanoparticle fullerene C60 for Oil & Gas Pipeline Corrosion Mitigation*" was published in a top Journal - Nanomaterials (Impact factor=4.034). PhD student Xingyu Wang who mainly takes charge of this research was the first author.

Invited keynote speech: Dr. Lin was invited to give a keynote speech, "*Machine learning, data analytics and information fusion for structural health monitoring*", on the internal conference of 2019

International Conference on Artificial Intelligence, Information Processing, and Cloud Computing (AIIPCC 2019) hold in Dec. 19-21, Sanya, China.

Conference presentation in post sections: Dr. Lin attended and presented their work on national conference 2019 Defense TechConnect Innovation Summit, Oct. 8-10, National Harbor, Washington D.C., USA.

Invited talk: Dr. Lin was invited to give a talk at Civil Engineering department in University of North Dakota, "*Data-Driven Structural Diagnosis and Conditional Assessment*" in Nov. 6th, 2019, Grand Forks, ND.

Conference paper accepted in the international conference, 10TH International Conference on Bridge Maintenance, Safety and Management 2020, June 28-July 2, Sapporo, Hokkaido, Japan. Xingyu Wang, and Zi Zhang were the first author of these two papers.

(b) Status Update of Past Quarter Activities

The research activities in the 13rd quarter included: (i) Characterizing new composite coatings; (ii) Characterizing new carbon-based nanofiller nanocomposite coatings; (iii) Flow durability test for modified field performance, as summarized below.

Tasks 5-7: Summary of Characterization of the new coating systems and performance assessment

13.1 Objectives in the 13rd Quarter

i. To characterize the durability of the proposed multifunctional coating, duration from 500 to 1000 hours. The corrosion resistance and hydrophobicity were evaluated after exposure.
ii. The modified field reliability test with a liquid flow instrument was kept running to examine the selected coatings.

13.2 Results and Discussion

13.2.1 Durability evaluation of the proposed high-performance multifunctional coating

To further evaluate the durability and reliability, the proposed multifunctional high-performance protective coating was continuously exposed to the salt fog spray in this report. The exposure time has increased up to 1000 hours.

The Bode plots that obtained from the EIS measurement confirmed the proposed coating has extraordinary anti-corrosion performance and durability; hence, the coating behaved as an intact protective layer and remained in model A after 1000 hours of exposure.

The results from the water adhesion showed a strong agreement with the contact angle test. As the exposure time elapsed, no significant increase in water adhesion was observed, indicating the surface remained undamaged under the severe environment.

13.2.2 The carbon nanofiller reinforced coating

This section was to demonstrate the effectiveness of the carbon-based nanofillers for enhanced high-performance coating. The corrosion resistance of the nanofiller reinforced epoxy coating was obtained by EIS measurement, which includes Bode plots before and after salt fog spray exposure.

Before exposure: Excellent corrosion resistance reinforcement was observed. All the groups exhibited high impedance value at the low-frequency region, and the phase angle remained close to 90 degrees in all the tested frequency, which suggests that the protective coatings behaved as an intact layer and have excellent barrier performance to protect the substrates.

After exposure: The EIS data were collected after 100, 200, and 500 hours of salt spray exposure. All the groups have shown their excellent anti-corrosion performance after 200 hours of exposure, as no degradation was observed in neither impedance nor phase angle plots.

However, after 500 hours of exposure, the groups have shown much stronger enhancement compared with controlling groups.

The tensile properties of the nanocomposites were evaluated by measuring maximum tensile stress, strain at failure, and Young's modulus during the test. The overall results suggested that the addition of nanofillers would dramatically increase the strength and strain of the epoxy resin.

13.2.3 Modified field reliability test with liquid flow instrument

To further investigate the corrosion resistance performance of the coatings under dynamic liquid flow, illustrated in Fig. 1, the flow test was continued, and the exposure duration was increased up to 1000 hours.

Figure 1. Setup for long-term durability tests

As expected, the neat epoxy has the weakest corrosion under the liquid flow condition, and severe coating degradation was observed when the exposure time elapsed, which both the impedance and phase angle were decreased in Bode plots.

Improved corrosion resistance was observed in the specimen that reinforced by nanofillers. In the first 500 hours, no significant reduction was observed in the impedance curve, indicating the coating behaved as an intact layer to prevent the corrosion attacks. However, the phase angle was slightly decreased when the exposure time elapsed, indicating the coating degradation was initiated after the exposure.

13.3 Summary & Conclusion

In this report, we presented the test results from the experiments study that proposed from last report, which includes:

1) Evaluation of the long-term performance for the proposed multifunctional coating with longer exposure duration.
2) Study the coating performance under dynamic liquid flow condition with longer exposure duration.
3) Characterization of the carbon-based nanofiller reinforcement in nanocomposite coatings.

The detailed results were presented in the previous section, and the findings were summarized and discussed below:

- The proposed multifunctional coating has maintained its protective properties after 1000 hours of salt spray exposure. Based on the EIS results, the coating film was still intact after salt spray as no degradation was observed.
- The EIS measurement from a liquid flow test was performed to evaluate several developed coatings. After exposure, the obtained results indicated that the addition of nanofiller could improve the corrosion resistance of epoxy resin; however, material degradation was still observed after 1000 hours.
- The carbon nanofillers showed strong reinforcement on corrosion resistance, abrasion resistance, mechanical strength, which indicated this nanofiller system has a high potential for pipeline corrosion control and mitigation.

(e) Description of any Problems/Challenges

No problems are experienced during this report period

(f) Planned Activities for the Next Quarter

The planned activities for next quarter are listed below:

- To continue efforts in characterizing the proposed multifunctional coating.
- To characterize the performance of the other developed coatings under the predetermined liquid flow condition.