CAAP Quarterly Report

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

Contract Number: 693JK32250008CAAP

Project Title: Performance Evaluation and Risk Assessment of Excessive Cathodic Protection on Vintage Pipeline Coatings

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For quarterly period ending: 12/31/2022

Business and Activity Section

(a) Contract Activity

No materials were purchased during this quarterly period.

(b) Status Update of Past Quarter Activities

The kick-off meeting of this project was performed on Nov. 14, 2022, with project managers, PIs, and graduate students.

(c) Cost Share Activity

No cost share activity during this quarterly period.

(d) Technical Approach

The goal of this proposed study is to evaluate the performance of vintage pipeline coatings under excessive cathodic protection (CP) levels through experimental testing, numerical analysis, and probabilistic modeling. The experimental testing and numerical analysis will be used to investigate coating disbondment under CP, which will help identify key influencing factors and understand the mechanism on cathodic disbondment. The obtained coating performance profile will be then used for the probabilistic degradation model development, which is crucial for evaluating time-dependent pipeline reliability and developing recoating strategy. Knowing how the influencing factors and excessive CP impacts the coating and pipeline performance, the critical section of the pipeline and the recoating time can be determined. Specific technical objectives are proposed as follows:

- Identify types of coating used on vintage pipelines that have issues with excessive CP;
- Systematically evaluate coating performance of coating cathodic disbondment and underneath

corrosion through global and local measurements;

- Identify critical influencing factors/conditions the pipeline coatings can be damaged by excessive amounts of CP;
- Better understand coating cathodic disbondment mechanism;
- Probabilistically model degradation evolution of coated vintage pipeline performance;
- Assess pipeline coating performance and determine recoating time based on the time-dependent reliability;
- Generate guidance for effective CP levels to ensure the corrosion protection while minimize coating's cathodic disbondment.

To achieve the proposed research objectives, six tasks are developed.

- Task 1. Identification of vintage pipeline coatings and influencing factors in coating cathodic disbondment (University of Akron and Marquette University)
- Task 2. Evaluation of coating cathodic disbondment considering key influencing factors through laboratory testing (University of Akron)

  Task 2a. Pipeline coating samples

  Task 2b. Experimental design considering key influencing factors

  Task 2c. Characterization of coating cathodic disbondment under CP
- Task 3. Numerical simulation of pipeline coating disbondment behavior and CP system (Rutgers University)
- Task 4. Probabilistic degradation model of coated pipe wall due to excessive CP (Marquette University)
- Task 5. Determination of recoating time using reliability-based approach (Marquette University)
- Task 6. Industrial collaborations (University of Akron, Marquette University, Rutgers University)

1. Task 1. Identification of vintage pipeline coatings and influencing factors in coating cathodic disbondment

1.1 Background and Objectives in the 1st Quarter

Buried pipelines are protected from corrosion attack by coating and cathodic protection (CP). However, excessive CP could cause serious damage on many types of vintage pipeline coatings, and consequently pipeline integrity.

There are three objectives in this Task. The first objective is to classify pipeline coatings based on the CP compatibility, that is, to understand which type of the coating belongs to CP-shielding coating and which belongs to CP-compatible coating, and the interaction of each coating with CP (the ability to withstand the alkaline environment created by the CP). The second objective is to answer the following questions: (1) which types of coating have been used in vintage pipelines? (2) did the vintage coating experience cathodic disbondment; if so, under what conditions? (3) what are the major properties of the identified coating? The third objective is to understand the key influencing factors on the cathodic disbondment of the identified coating type.

The first and second objectives of this task is addressed in the 1st quarter through a literature review.

1.2 Research Progress in the 1st Quarter

The coatings used in pipeline include coal tar coatings (coal tar enamel and coal tar epoxy coating), asphalt based coatings (asphalt mastic and asphalt enamel), polyethylene (PE) coatings (PE tape, dual-layer PE, three-layer PE, multi-component PE), fusion-bonded epoxy (FBE) coatings (single-layer FBE, dual-layer FBE, three-layer FBE), three or multi-layer polyolefin polyethylene or polypropylene coatings, high-performance composite coatings (HPCC), etc. [Guermazi et al., 2009; Howell & Cheng, 2007; Xu et al., 2020].

Pipeline coatings are divided into plant-applied coatings and field-applied coatings. The primary plant-applied coatings include coal tar, asphalt, PE, liquid epoxy, FBE, and HPCC. The field-applied coatings include tape coatings, shrink sleeve, wax, mastics, and others [Cheng, 2016]. A brief history for the usage of these coatings is presented in Figure. 1 [Papavinasam & Revie, 2005], although different references may have different beginning and ending years for some coatings [Xu et al., 2020]. Early pipeline coatings like coal tar and asphalt are no longer used to coat newly constructed pipelines due to generally poor field experiences and health hazards. Solid film-backed PE tape is also declining in use because of its poor adhesion, soil stress issues, and external corrosion occurrence. On the other hand, FBE coating is presently the dominant anti-corrosion coating that has been applied to most pipelines in North America [Cheng, 2016; Xu et al., 2020].

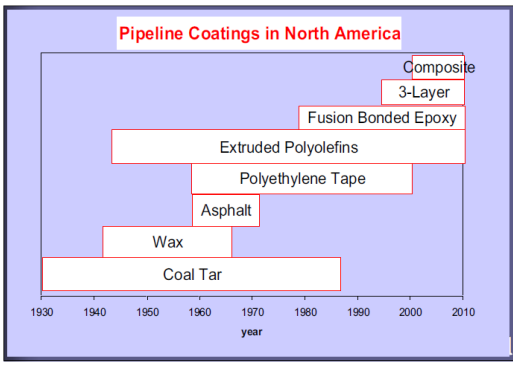

Figure. 1. Pipeline coatings used in North America [Papavinasam & Revie, 2005].

The CP shielding coatings include PE coating, polyolefin coatings, and solid film bakes tape coatings. The CP compatible coatings include FBE, viscous elastic coatings, asphalt enamel coatings, and meshed baked tape coatings.

1.3 Conclusions

The pipeline coatings can be classified as plant-applied coatings and field-applied coatings. They can also be classified as CP shielding coatings and CP compatible coatings.

1.4 Future Work (next quarter)

More literatures will be reviewed to better achieve the three objectives of this task.

2. Task 2: Evaluation of coating cathodic disbondment considering key influencing factors through laboratory testing

This task will start on the 3rd quarter of this project.

3. Task 3: Numerical simulation of pipeline coating disbondment behavior and CP system

This task will start on the 5th quarter of this project.

4. Task 4: Probabilistic degradation model of coated pipe wall due to excessive CP

This task will start on the 5th quarter of this project.

5. Task 5: Determination of recoating time using reliability-based approach

This task will start on the 9th quarter of this project.

6. Task 6: Industrial collaborations

This task will be updated once the collaborations are established.

Reference

Cheng, Y. F. (2016). *Pipeline Coatings*: NACE International.

Guermazi, N., Elleuch, K., & Ayedi, H. F. (2009). The effect of time and aging temperature on structural and mechanical properties of pipeline coating. *Materials & Design, 30*(6), 2006-2010.

Howell, G. R., & Cheng, Y. F. (2007). Characterization of high performance composite coating for the northern pipeline application. *Progress in Organic Coatings, 60*(2), 148-152.

Papavinasam, S., & Revie, R. W. (2005). *Standards for pipeline coatings*. Paper presented at the Workshop on Advanced Coatings R&D for Pipelines and Related Facilities, Gaithersburg, MD, USA.

Xu, M., Lam, C. N. C., Wong, D., & Asselin, E. (2020). Evaluation of the cathodic disbondment resistance of pipeline coatings – A review. *Progress in Organic Coatings, 146*, 105728.