Probabilistic Performance Evaluation of Cathodically Protected Pipeline Considering AC Corrosion

PHMSA Pipeline and Hazardous Materials Safety Administration

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Main Objectives

1. Determine critical influencing factors on AC corrosion
2. Better understand AC corrosion mechanism with systematical consideration of different combinations of influencing factors
3. Probabilistically model time evolution of AC corrosion profile
4. Assess pipeline performance under CP and AC corrosion based on probability of failure
5. Optimize CP design under different combinations of influencing factors
6. Investigate the impact of various physical quantities and uncertainty sources on pipeline reliability

Project Approach/Scope

Task 1: Identify key influencing factors in AC corrosion.	
Methodology	1.A comprehensive literature review 2.Collect testing data from research publication or technical report
Task 2: Generate realistic AC corrosion profile	
Methodology	1.Investigate AC corrosion by real-time electrochemical measurements 2.Investigate AC corrosion by 3-day weight loss measurements
Task 3: Numerical simulation of AC corrosion behavior and CP system	
Methodology	Multi-physics simulation using COMSOL
Task 4: Probabilistic prediction model of AC-induced corrosion and reliability assessment	
Methodology	Risk Criteria using Probability of Failure (Reliability)

Methodology for reliability assessment

The AC corrosion rate, r, can be model through influencing factors, $\mathbf{x}$:

$$r(\mathbf{x}) = \hat{r}(\mathbf{x}) + \sigma\varepsilon$$

where $\hat{r}$ = predicted corrosion rate, $\sigma\varepsilon$ = model error. Therefore, corrosion depth, d, can be obtained by

$$d(\mathbf{x}) = \sum_{i=1}^{n} r_i(\mathbf{x})\Delta t_i$$

where i is the number of intervals for a year. The probability of burst failure, P_f, of a pipeline can calculated by utilizing the *First Order Reliability Method (FORM)* as below:

$$P_f = P\left[C_p(\mathbf{x}) - D_P \le 0\right]$$

where $C_p(\mathbf{x})$ = burst pressure capacity; D_P = operating pressure

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Results to Date

Experiment setup

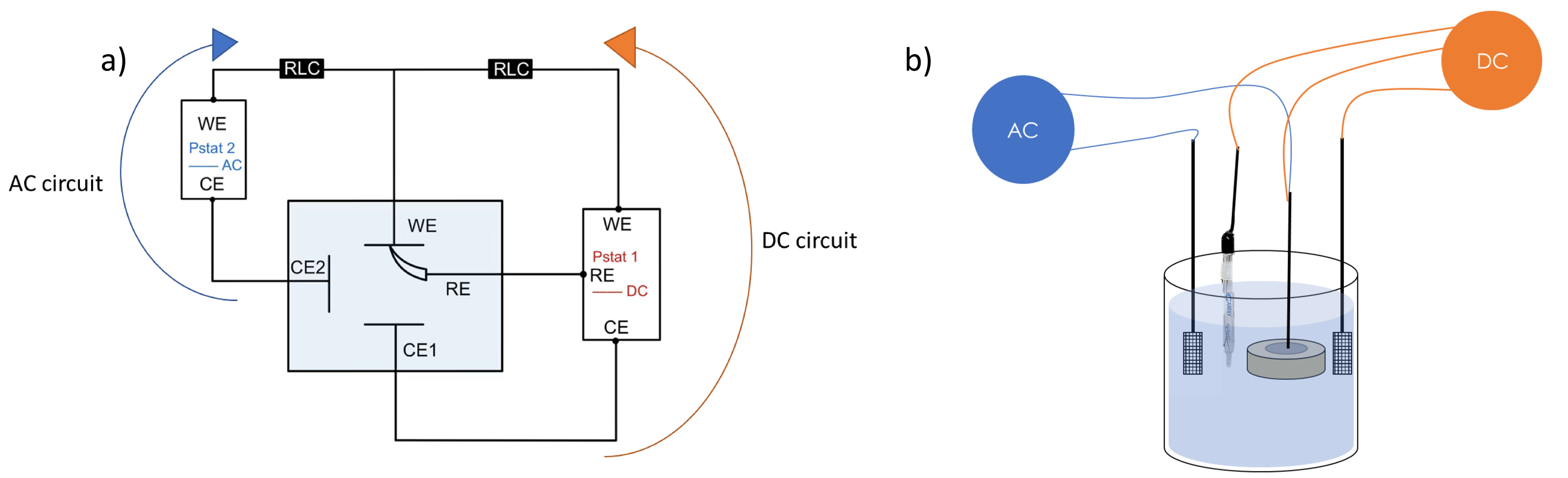

Figure 1. a) Electrochemical equivalent circuit for experiment; b) Schematic diagram for lab testing.

Corrosion rate results

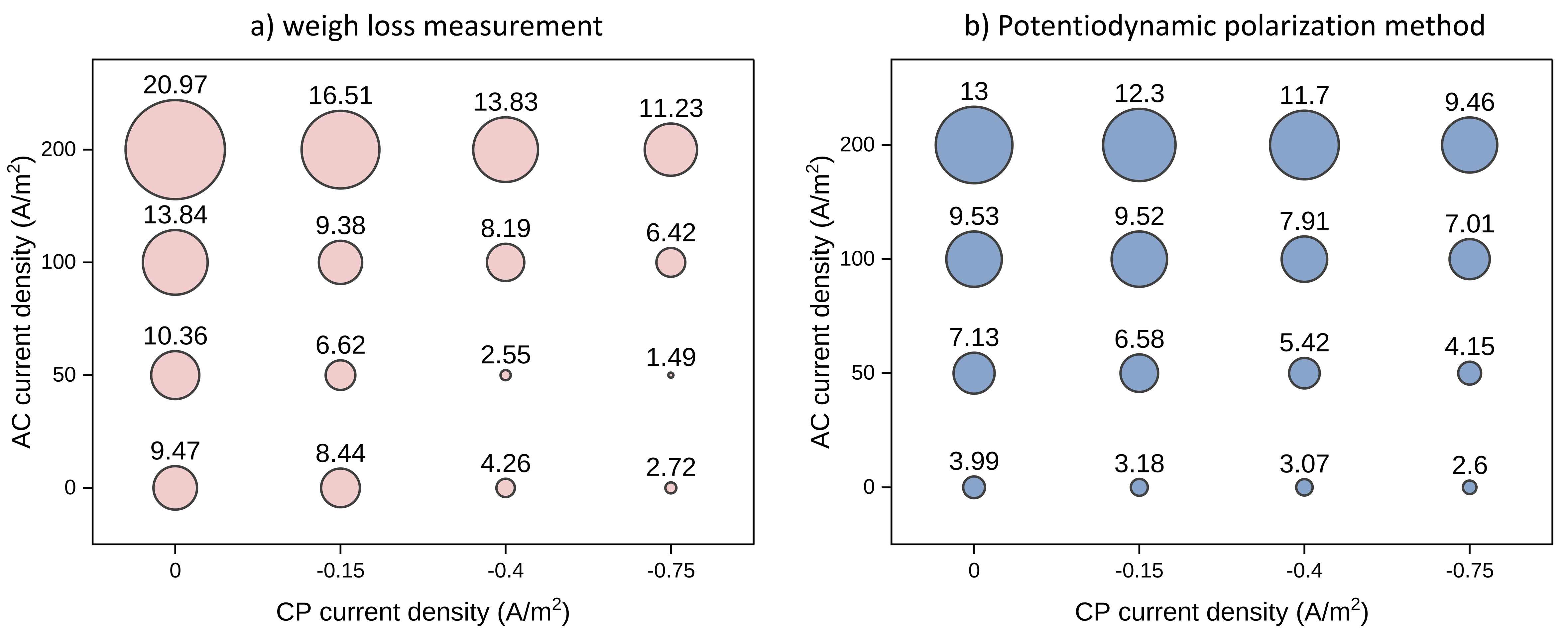

Figure 2. a) Corrosion rate (mpy) of C1018 steel under different AC and CP current density by 3-day weight-loss testing; b) Corrosion rate (mpy) of C1018 steel under different AC and CP current density by potentiodynamic polarization method.

Simulation results

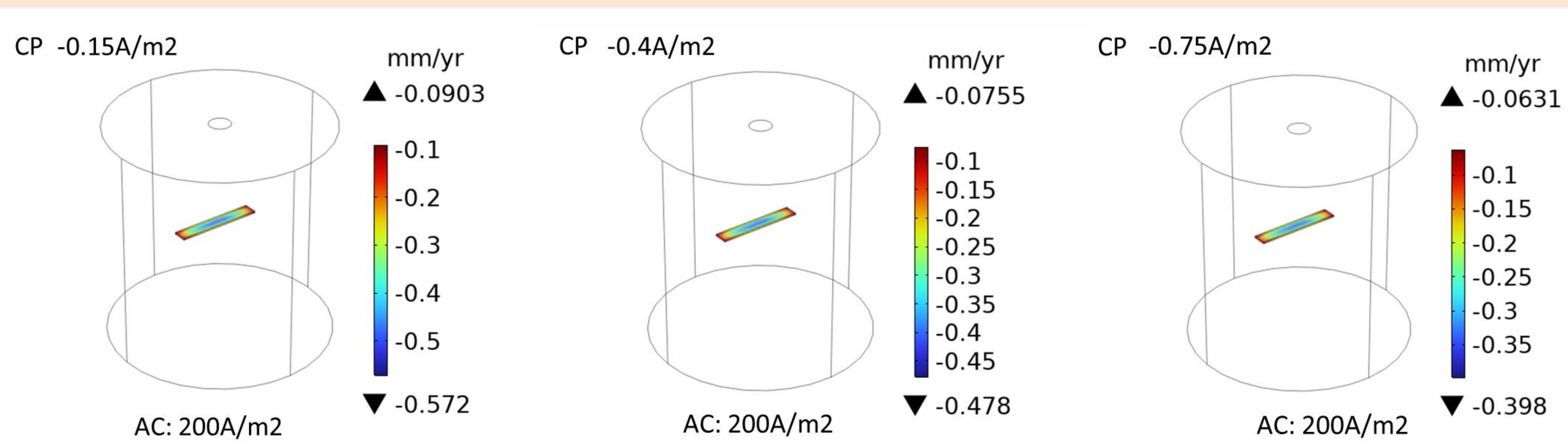

Figure 3. Corrosion rate of C1018 steel under different AC and CP conditions obtained from multi-physics simulation.