Modelling Based Detection of Early Stage Corrosion Degradation of Pipeline Steels

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Main Objective

This project was awarded to Iowa State University to develop experimental protocols to detect early stage degradation associated with stress corrosion cracking (SCC) in pipeline steels in high-pH bicarbonate solution, based on a combined modeling – experimental approach.

Project Approach/Scope

- Develop predictive model for early intergranular corrosion damage (IGC) preceding SCC. Model is based on our experimental findings:
  - Layer of reduced hardness near corroded GBs suggests nonequilibrium vacancies
  - Preferential Si oxidation at GBs can explain vacancy formation.
  - Triangular corrosion product wedges indicate uniform steel dissolution rate \( V_s \) on grain faces, slightly higher GB dissolution rate \( V_{gb} \)

Results to Date

- The vacancy diffusion-based mechanism was implemented in a finite element simulation of intergranular corrosion.
- Experimentally measured GB corrosion rates and wedge angles are quantitatively consistent with the independently determined vacancy diffusivity \( D_v \) in steel of \( \approx 10^{-12} \text{ m}^2/\text{s} \).
- Model predicts formation of sharp wedges during long corrosion exposures leading to low corrosion rates (prediction currently being tested by SEM). Narrow-angle wedges can concentrate external stresses and act as precursors for SCC.
- Inhibition of SCC may be possible by reducing the Si content of steel. Electrochemical impedance spectroscopy is being developed to detect corrosion crevices and cracks.

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References


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