A Corrosion Model for Oil and Gas Mild Steel Production Tubing

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ABSTRACT

The Institute for Corrosion and Multiphase Technology's (ICMT) FREECORP model was used as a basis for a production tubing corrosion model, here called WELLCORP. The original FREECORP model was modified to account for nonidealities in the gas and liquid phases. Additionally, improved solubility models for carbon dioxide (CO_2) and hydrogen sulfide (H_2S) were added. Results showed that the new model provides better corrosion predictions than the base model.

KEY WORDS: carbon dioxide, corrosion prediction, hydrogen sulfide, model

INTRODUCTION

Carbon dioxide (CO_2) and hydrogen sulfide (H_2S) corrosion is a significant problem in oil and gas production and transportation (transmission and distribution) systems.[1] Corrosion of the production systems has received significant attention because of the high CO_2 and H_2S content in the oil and gas production fluids that can cause substantial damage to the downhole components. Modeling has contributed a great deal in understanding and mitigating the corrosion problem.[2] There are many corrosion models available.[3] However, these models were designed for internal pipeline corrosion and are not meant for use in production tubing applications. Therefore, there is a need to develop better prediction tools—if possible, a mechanistic model, like what has been done for transport pipeline conditions with the Institute for Corrosion and Multiphase Technology's (ICMT, Ohio State University, Athens, Ohio) FREECORP.[4]

The objective of this research was to extend the current mechanistic model, FREECORP, to better predict general corrosion rates at conditions found in oil and gas wells by adapting the current FREECORP point model to create WELLCORP. Corrosion prediction in WELLCORP will be improved by adding more accurate model physics to better simulate conditions found in gas well production tubing and by predicting corrosion product layers using a thermodynamic calculation to determine the most stable product. The long-term goal is to create a line model using WELLCORP and to compare the results with field measurements to quantify the accuracy of the model. This work, however, focuses on improving the underlying point model and comparing with experimental data.

RESULTS AND DISCUSSION

Changing the CO_2 solubility model was the first improvement made. The base model, FREECORP, utilized a correlation for Henry's law; but at the conditions in gas wells, it can overestimate the CO_2 concentration. The WELLCORP model implements the Duan CO_2 solubility model and Duan H_2S solubility model.[5-6] In addition to the solubility model changes, the Pitzer

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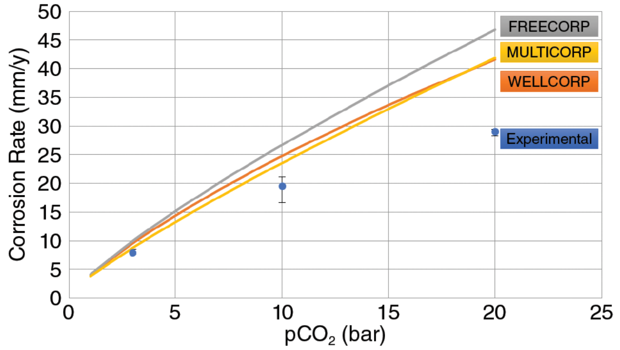

FIGURE 1. *Comparison between corrosion models and experimental data, at 60°C, pH 5.0, 1 m/s, 1 wt% sodium chloride (NaCl), C1018 steel. Experimental data taken from Wang, et al.*[9]

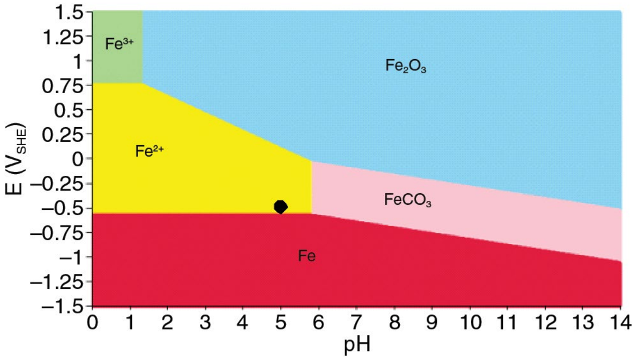

FIGURE 2. *Example Pourbaix diagram for an Fe-H_2O-CO_2 system with a system pH of 5.0 and a corrosion potential of –0.5 V.*

activity model has been added to account for non-idealities in the aqueous phase, which are present in the brines produced by oil and gas wells.[7-8] WELLCORP is intended for use with mild steels, so the model was compared with experimental corrosion rates carried out on C1018 (UNS G10180)[(1)] steel, FREECORP-calculated corrosion rates, and the MULTICORP (ICMT's transient mechanistic model)-calculated corrosion rates (Figure 1).

Corrosion rate results suggest that the improved model provides more accurate results than the FREECORP and provides similar results to MULTICORP in the range of conditions tested. The model also predicts the most stable corrosion product using a single-point Pourbaix diagram calculation (Figure 2). The calculated corrosion potential and pH are used as inputs for this calculation. The model was verified with the results of Tanupabrungson, et al., and Ning, et al.[10-11]

CONCLUSIONS

❖ This work has demonstrated that the original model, FREECORP, has been improved with new physics and solubility models. WELLCORP compared well with laboratory data taken on mild steel and showed an improvement over the base model FREECORP. Several new features were added, including a thermodynamic calculation to determine which corrosion product will be present, an activity coefficient model to correct for non-idealities in the aqueous phase, and a real gas equation-of-state to model non-idealities in the gas phase. An improved version of the FREECORP point model was used to create a line model, which can be used to model oil and gas production data and predict production tubing wall loss in systems using mild steels.

[(1)] UNS numbers are listed in *Metals and Alloys in the Unified Numbering System*, published by the Society of Automotive Engineers (SAE International) and cosponsored by ASTM International.

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REFERENCES

1. M.B. Kermani, A. Morshed, *Corrosion* 59, 8 (2003): p. 659-683.
2. S. Nešić, *Corros. Sci.* 49, 12 (2007): p. 4308-4338.
3. R. Nyborg, "Field Data Collection, Evaluation and Use for Corrosivity Prediction and Validation of Models—Part II: Evaluation of Field Data and Comparison of Prediction Models," CORROSION 2006, paper no. 06118 (Houston, TX: NACE International, 2006), p. 1-15.
4. S. Nešić, H. Li, D. Sormaz, J. Huang, "A Free Open Source Mechanistic Model for Prediction of Mild Steel Corrosion," Presented at 17th Int. Corrosion Cong., paper no. 2659 (Houston, TX: NACE International, 2008).
5. Z. Duan, R. Sun, *Chem. Geol.* 193, 3-4 (2003): p. 257-271.
6. Z. Duan, R. Sun, R. Liu, C. Zhu, *Energy Fuels* 13 (2007): p. 2056-2065.
7. K.S. Pitzer, *J. Phys. Chem.* 7242, 6 (1972): p. 268-277.
8. K.S. Pitzer, G. Mayorga, *J. Phys. Chem.* 77, 19 (1973): p. 2300-2308.
9. S. Wang, K. George, S. Nešić, "High Pressure CO_2 Corrosion Electrochemistry and the Effect of Acetic Acid," CORROSION 2004, paper no. 04375 (Houston, TX: NACE, 2004), p. 1-17.
10. T. Tanupabrungsun, D. Young, B. Brown, S. Nešić, "Construction and Verification of Pourbaix Diagrams for CO_2 Corrosion of Mild Steel Valid up to 250°C," CORROSION 2012, paper no. 01418 (Houston, TX: NACE, 2012).
11. J. Ning, Y. Zheng, D. Young, B. Brown, S. Nešić, *Corrosion* 70, 4 (2014): p. 375-389.