Effect of Intermittent Wetting on Corrosion Inhibition in Oil/Water Systems

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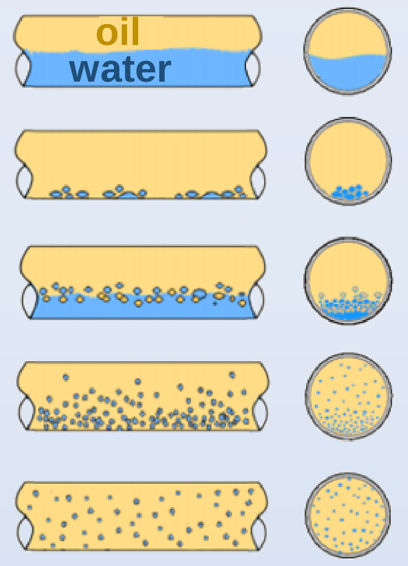
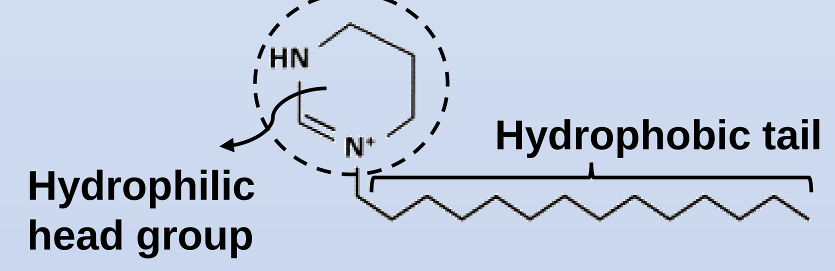
Introduction

- Oil and gas production involves the flow of multiphase mixture of hydrocarbons, water and gas.
- Consequently, pipeline internal surfaces can be alternately wetted by oil (oil-wet) and water (water-wet), leading to a phenomenon termed intermittent wetting.



Schematics of observed horizontal oil-water flow patterns[1]

- The use of corrosion inhibitors (CIs) is common practice to protect pipelines. The CI model compound in this work is a pyrimidinium-type inhibitor which is found in particular commercial CI formulations and is water soluble.



Structure of 1-Tetradecyl-1,4,5,6-tetrahydropyrimidinium (THP-C14)[2,3]

Motivation

- Most published inhibition studies only consider the aqueous phase (no oil added).
- Adding hydrocarbon complicates experimental methodologies and can lead to spurious results if not done consistently.
- Effects of an oil phase and oil/water wetting should be included in laboratory studies of CIs.

Objective

Develop experimental procedures utilizing electrochemical methods and contact angle measurements to study how intermittent wetting, simulating multiphase flow phenomena, impacts corrosion inhibition.

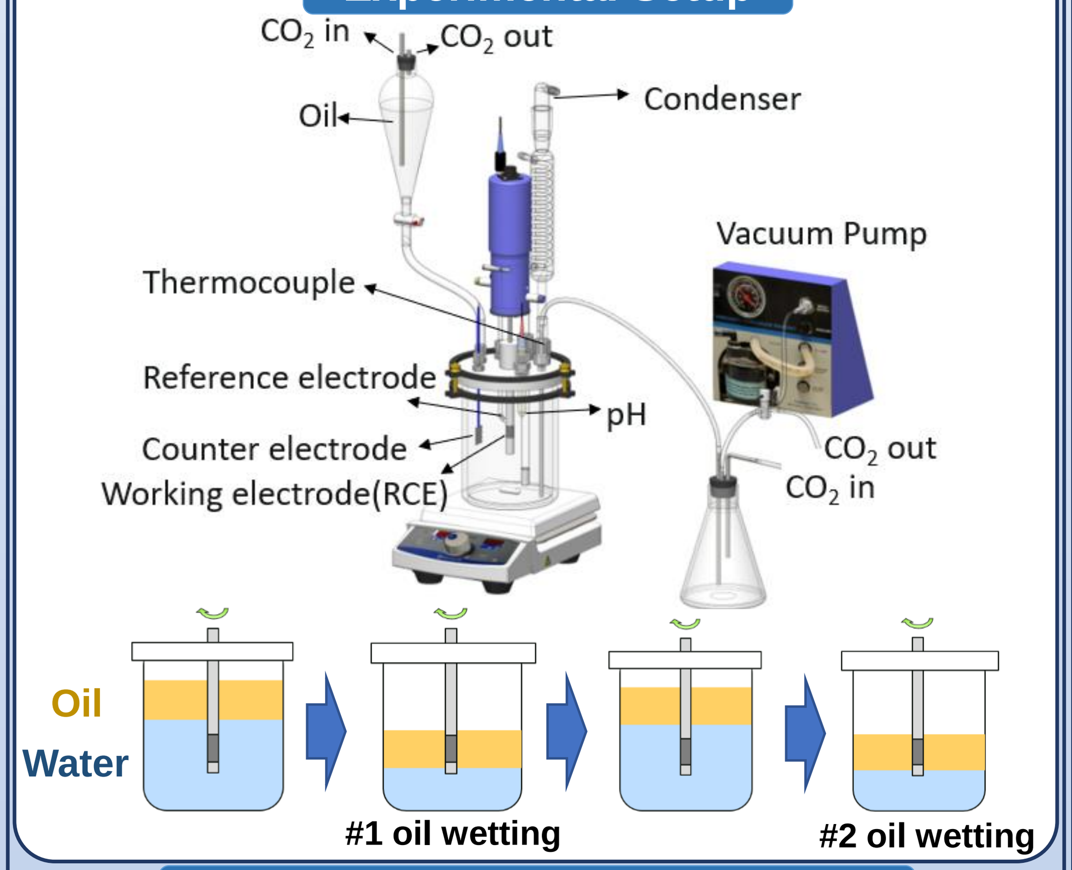
Methodology

Electrochemical Measurements

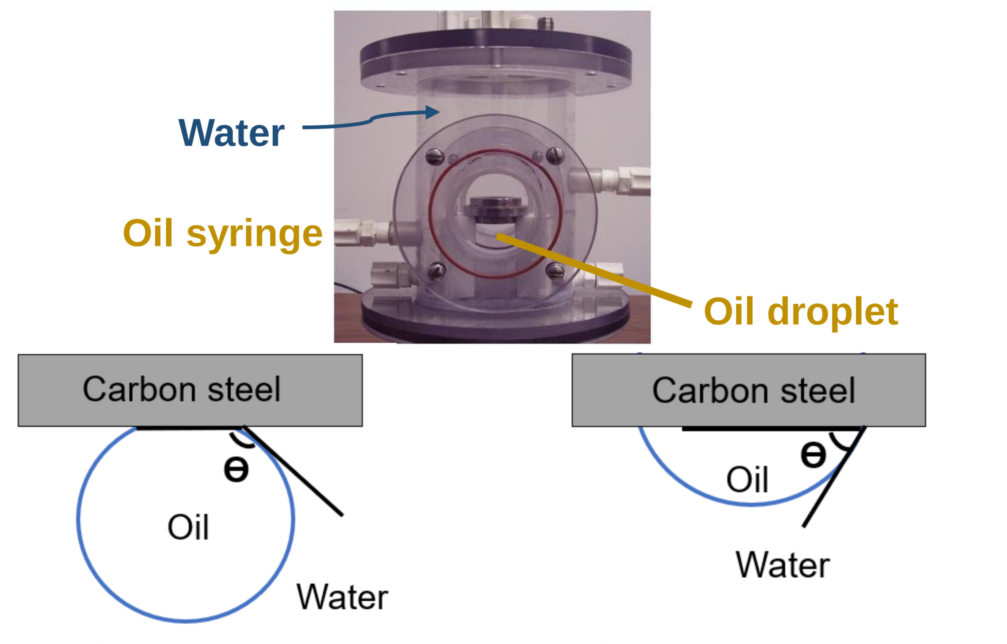
Experimental Matrix

Description	Parameters
Working electrolyte	50 g/L NaCl
Material	Carbon steel UNS G10180 (C1018)
Sparge gas	CO_2
RCE velocity	1000 rpm
Temperature	25°C
Corrosion inhibitor (CI) model compound	1-tetradecyl-1,4,5,6-tetrahydropyrimidinium bromide (THP-C14)
pH	4.50 ± 0.05
Oil type	LVT 200 model oil
Specimen exposure	Pure water wetting; oil/water intermittent wetting
Measurement techniques	Electrochemistry (LPR, EIS, potentiodynamic polarization)

Experimental Setup

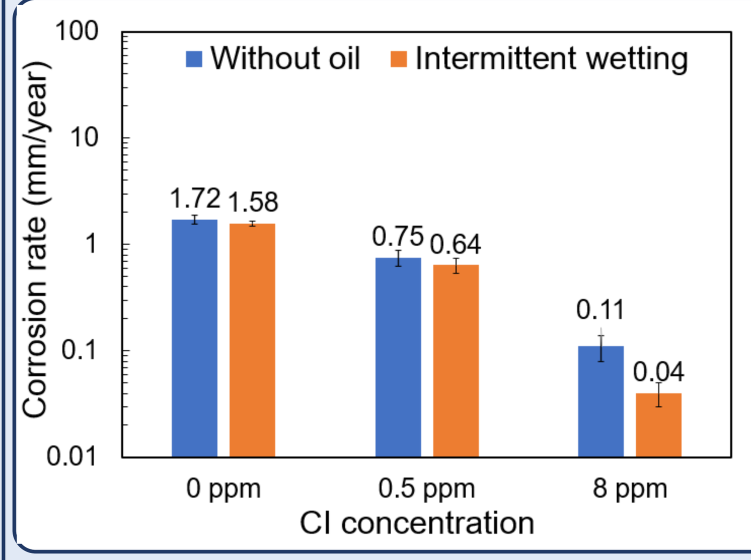


Contact Angle Measurements



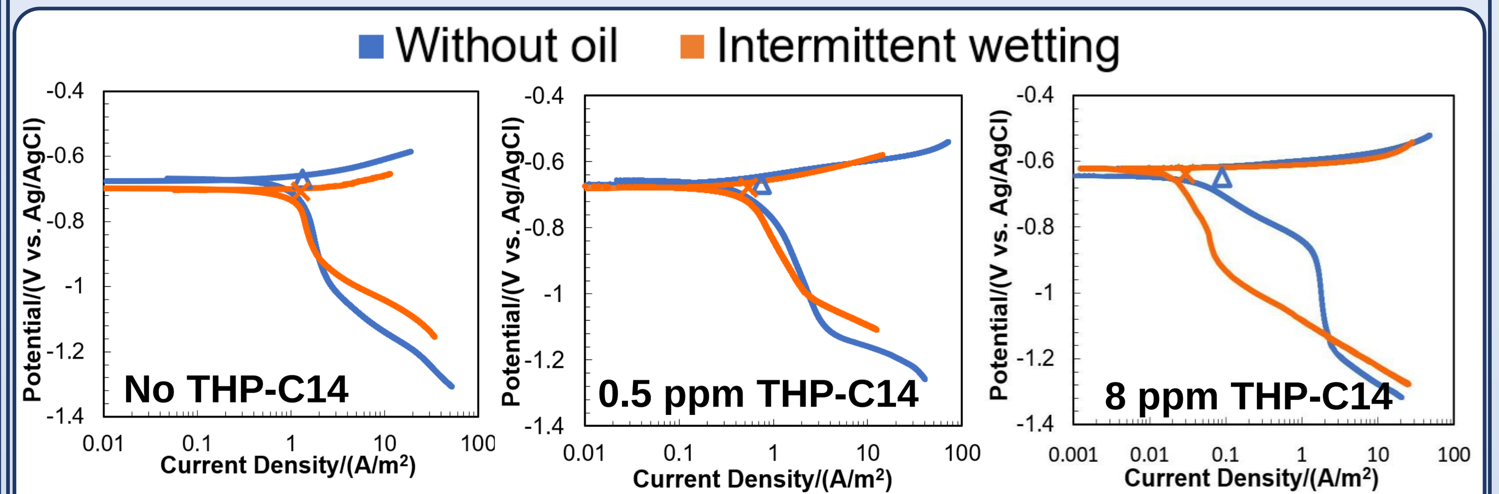
Results and Discussion

Corrosion Rate



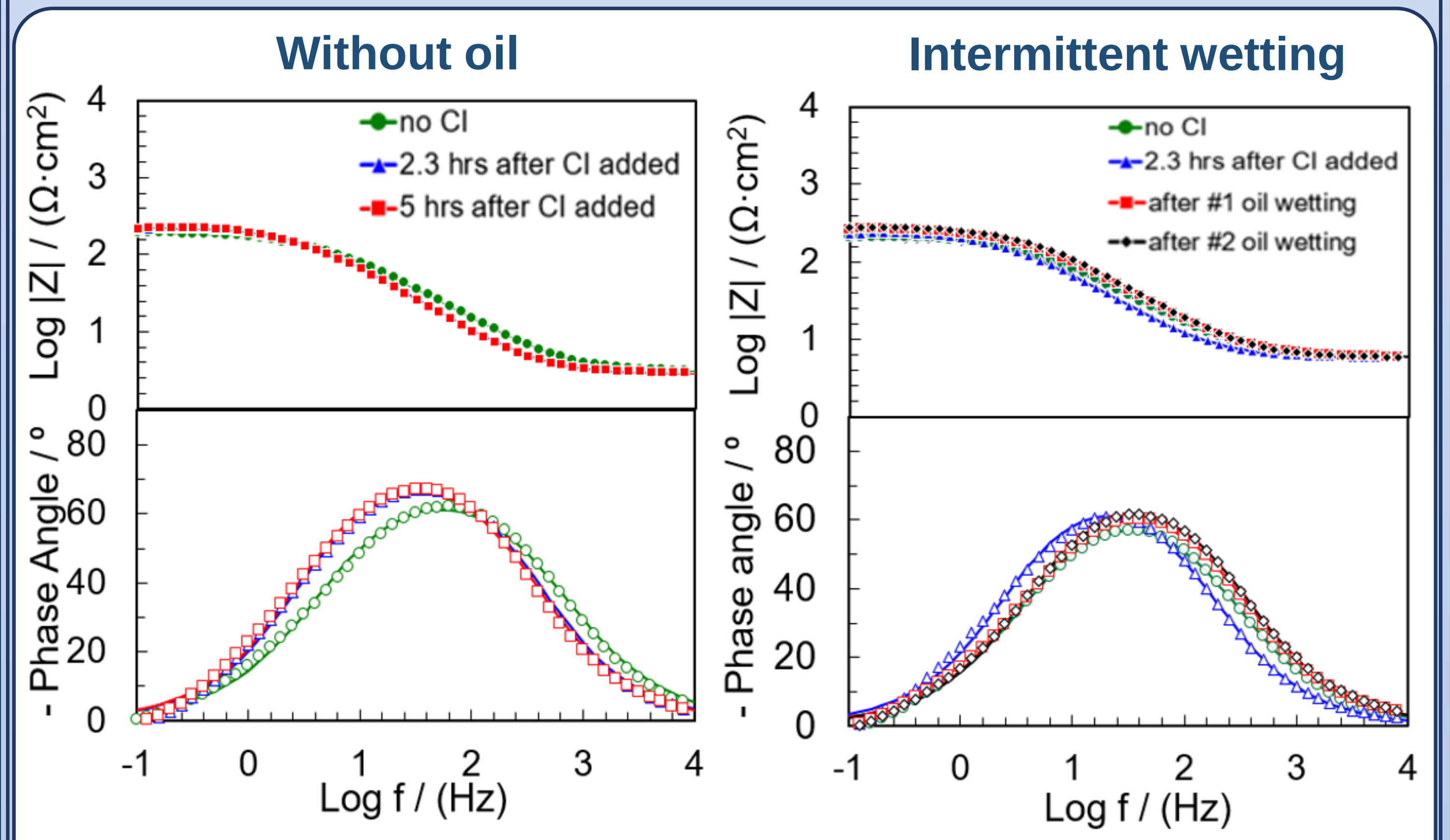
- LVT 200 model oil did not influence the corrosion behavior of carbon steel without corrosion inhibitor in the intermittent wetting experiments.
- As THP-C14 concentration increased, the presence of oil significantly promoted corrosion inhibition for intermittent wetting.

Potentiodynamic Sweeps



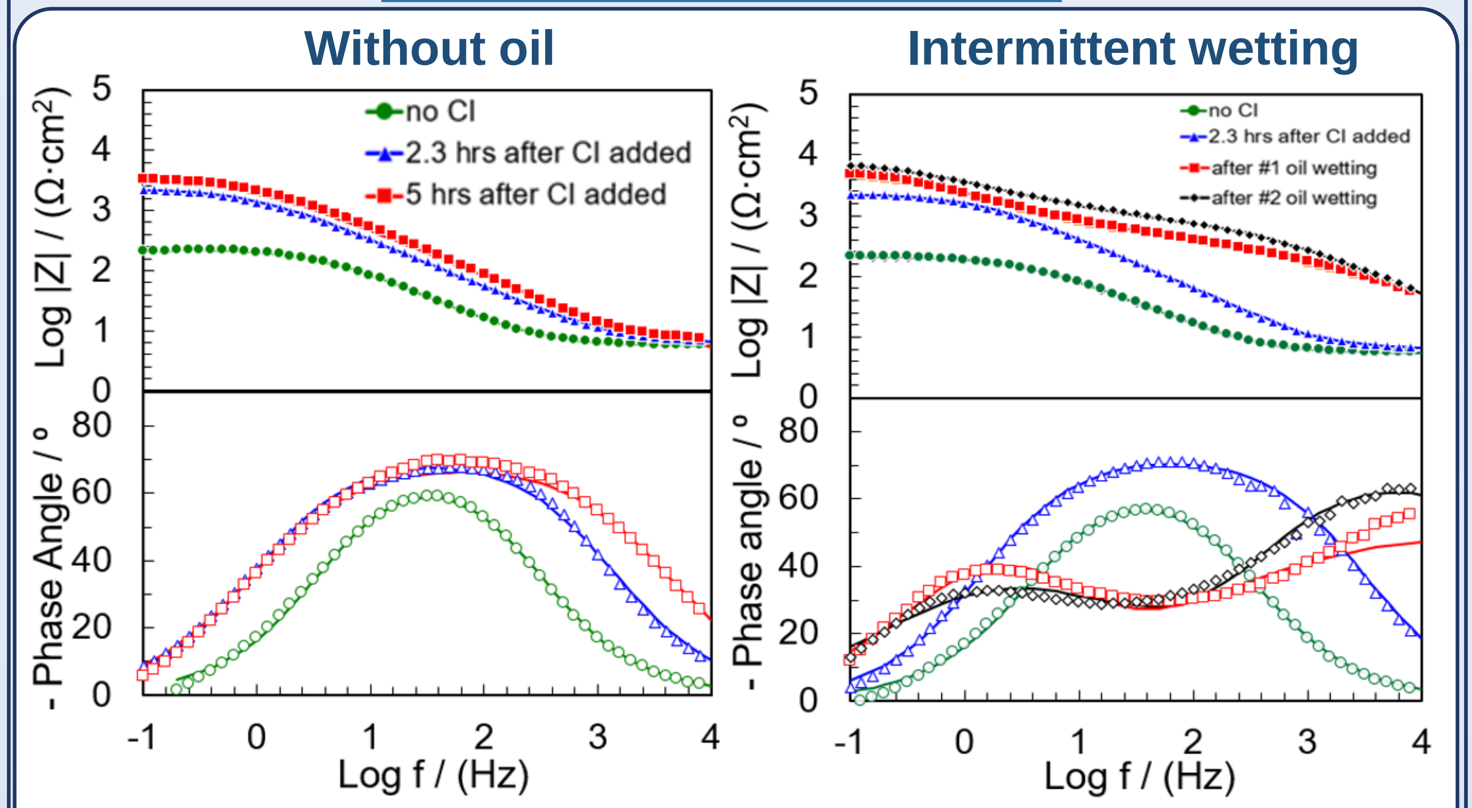
With 8 ppm THP-C14, potentiodynamic sweeps for the intermittent wetting case showed a shift for the limiting current of the hydrogen evolution reaction compared with the experiment without any oil.

EIS for 0.5 ppm THP-C14



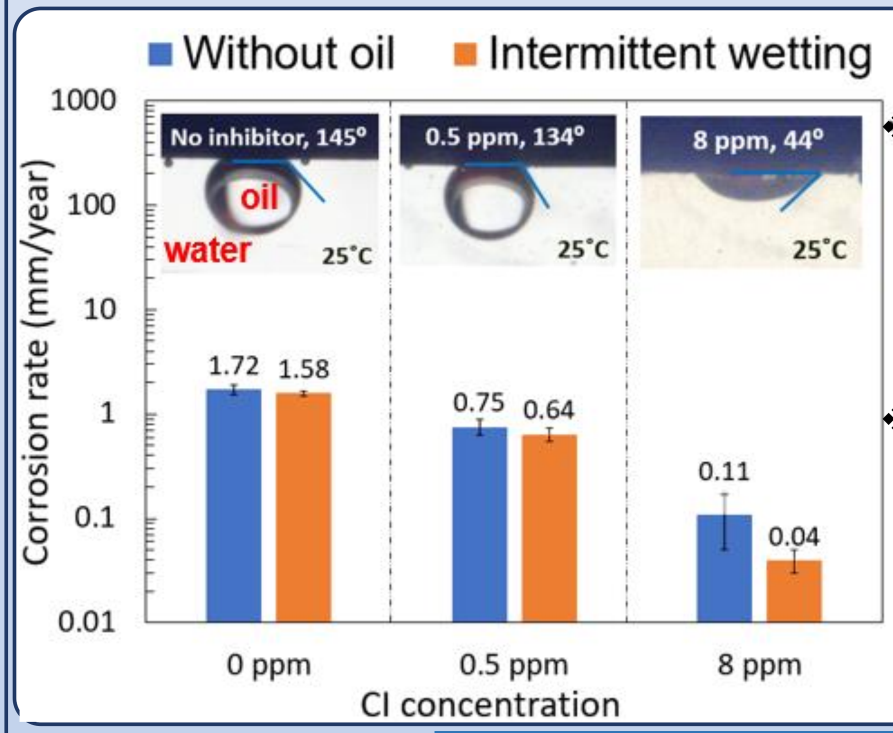
Only one time constant was detected during the test with and without oil. The inhibitor layer characteristics did not change significantly under an effect of hydrocarbon.

EIS for 8 ppm THP-C14



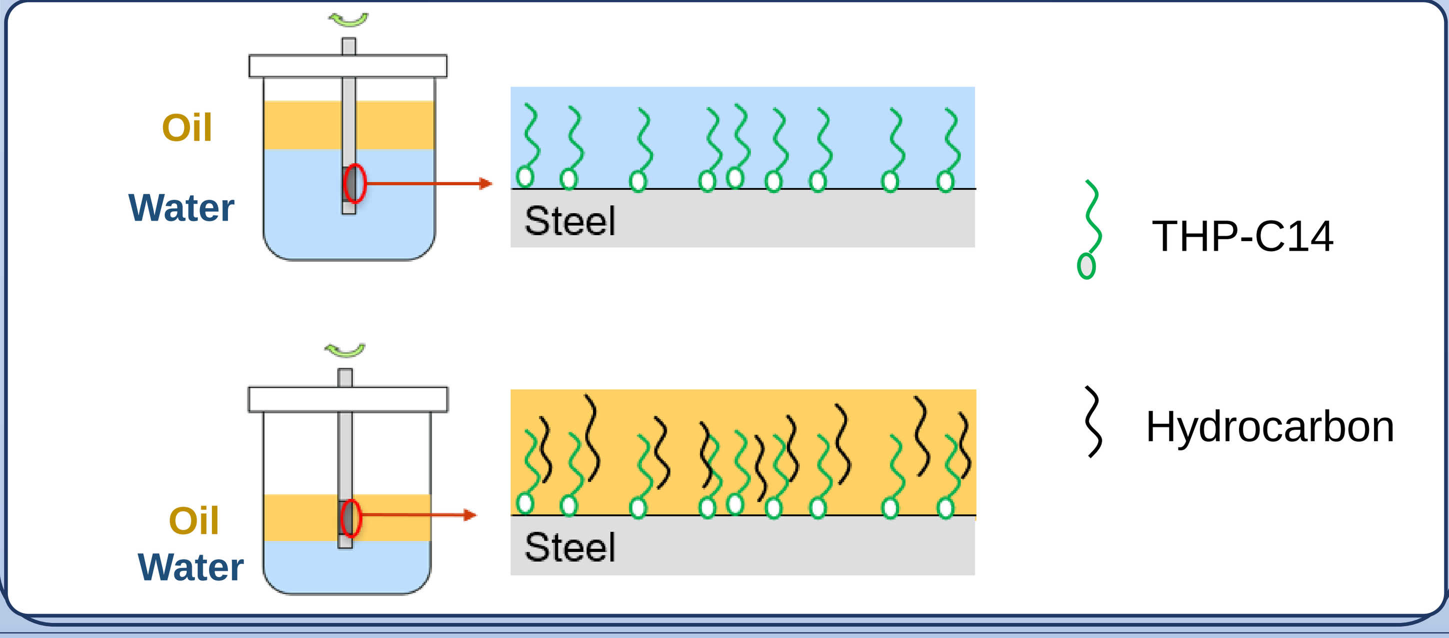
- Only one time constant was detected during the test. The inhibitor film may not be packed or thick enough to show a different time constant.
- The formed inhibitor film incorporated with hydrocarbon changed the electrode-electrolyte interfacial structure and resulted in the extra time constant.

Correlations of Surface Wettability and Corrosion Rate



- The wettability of the carbon steel surface changes from hydrophilic to hydrophobic with increased inhibitor concentration.
- When the metal surface was hydrophobic, the corrosion rate can be further decreased.

Proposed Mechanism



Conclusions

- LVT 200 model oil did not influence the corrosion behavior of carbon steel without the addition of THP-C14 inhibitor.
- Addition of 0.5 ppm THP-C14 only reduced corrosion rate by a factor of 2 in the aqueous solution w/o hydrocarbon. Further intermittent wetting with hydrocarbon did not change significantly corrosion rate.
- With 8 ppm THP-C14, corrosion rate was reduced by an order of magnitude w/o hydrocarbon. However, during intermittent wetting, the formed inhibitor film incorporated hydrocarbon and changed the electrode-electrolyte interface, retarding the mass transfer of corrosive species to the metal surface and promoting its inhibition.
- The enhanced inhibition with direct exposure to hydrocarbon (intermittent wetting) could be related to a wettability change of the steel surface due to the formation of a hydrophobic inhibitor film that allowed the attachment of the oil.

Future Work

- Understand the relationship between corrosion rate and wettability using different types of inhibitors, as well as over a wide temperature range at different conditions for oil/water intermittent wetting.
- Using this as a foundation, develop models to predict both corrosion and mitigation for oil/water systems.

References

[1] Kee, K. E. "A Study of Flow Patterns and Surface Wetting in Gas-Oil-Water Flow", PhD Dissertation, Ohio University, 2014.
[2] Y. He, *et al.*, "Micellization and Inhibition Efficiency," in NACE - International Corrosion Conference Series, no. 16872, 2021.
[3] S. Ren, *et al.*, "Methodology for Corrosion Inhibitor Characterization Applied to Phosphate Ester and Tetrahydropyrimidnium Model Compounds", in NACE - International Corrosion Conference Series, no. 16443, 2021.

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