UNIVERSITI TEKNOLOGI MARA

CORROSION MECHANISM IN MARGINAL SOUR (CO_2/H_2S) ENVIRONMENT WITH CORRELATION OF H_2S IN AQUEOUS STATE

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ABSTRACT

Marginal sour environments, where H_2S concentrations less than 100 ppm coexist with CO_2, present unique corrosion challenges in oil and gas transportation. Unlike fully sweet or sour environment this condition is poorly understood and studied. Existing standards like NACE MR0175 rely on gas-phase concentration at 25 °C, which may not reflect aqueous-phase corrosion where gas solubility is temperature-dependent. This study investigates the corrosion behavior of API 5L X65 carbon steel at 1 bar and varying temperatures using gas mixtures containing 0, 30, 60, and 100 ppm H_2S balanced with CO_2. Uniform corrosion rates were determined by ASTM G1-03, pitting corrosion by ASTM G46-21, and surface morphology by SEM/EDX. Findings revealed at a constant temperature of 50 °C, the uniform corrosion rate decreased with increasing H_2S concentration, from 3.36 mm/yr at 0 ppm to 0.40 mm/yr at 100 ppm, due to the formation of protective FeS layers. This trend was consistent across all tested temperatures. However, at constant H_2S concentration, the uniform corrosion rate increased with temperature. At 100 ppm H_2S, the corrosion rate increased from 0.22 mm/yr at 30 °C to 0.71 mm/yr at 70 °C. SEM analysis revealed a distinct local breakdown of the corrosion product layer at 30 ppm H_2S for both 50 °C and 70 °C. Localized corrosion was most severe at 30 ppm H_2S and 50 °C, where the highest pitting rate of 8.44 mm/yr was recorded, indicating the formation of an unstable and non-protective scale. A threshold of aqueous H_2S concentration (2.78×10^{-6} M) was identified, when exceed this threshold the pitting rates remained below 2.00 mm/yr. This study highlights low H_2S levels drive severe localized corrosion, while $H_2S(aq)$ serves as a key predictor of FeS protectiveness for improved risk mitigation in marginal sour environment.

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TABLE OF CONTENTS

CHAPTER 1

INTRODUCTION

1.1 Research Background

Corrosion in oil and gas pipelines presents a significant challenge, not only threatening asset integrity but also leading to considerable economic losses and increases safety risks. Pipeline corrosion is broadly categorized into internal and external type[1]. Internal corrosion occurs due to the flow of corrosive fluids within the pipeline, while external corrosion impacts the outer surface, which is exposed to environmental factors[1], [2], [3], [4], [5]. These two forms develop independently, necessitating distinct mitigation strategies. For instance, cathodic protection, effective for external corrosion is entirely unsuitable for internal corrosion. Among these, internal corrosion is the most dominant reasons for leaks and failures for wet gas pipelines, sour gas pipelines and crude oil pipelines. This type of corrosion can manifest in various ways, including microbiologically influenced corrosion (MIC)[6], [7], erosion corrosion[8], under-deposit corrosion[9], pitting corrosion[10], [11], [12], bottom-of-line corrosion and top-of-the-line corrosion[13], [14]. Each of these forms presents unique challenges to pipeline sustainability.

Corrosion environments are typically classified into sweet or sour categories based on their chemical composition. Sweet corrosion is primarily associated with carbon dioxide (CO_2), while sour corrosion involves hydrogen sulfide (H_2S)[15]. Understanding the distinctions between these environments is critical for developing effective corrosion management strategies. While the classification of corrosion environments as sweet or sour helps guides material selection and mitigation strategies, identifying marginal sour corrosion where both CO_2 and H_2S are present remains a challenge. The current reference for defining a marginally sour environment aligned with NACE MR0175[16], a P_{CO_2}/P_{H_2S} ratio of 500, is only valid at 25 °C in the gas phase. However, this rating does not account for temperature variations, which affect the solubility of both gases. Thus, this rating usually underrated in predicting the exact environment and leading to inaccurate guide in material selection and mitigation strategies.

Corrosion fundamentally occurs in the aqueous phase[17], where CO_2 and/or