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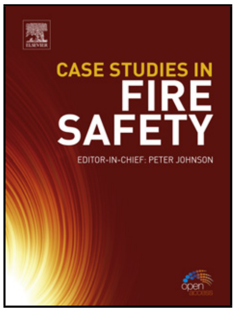

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Corrosion behavior of X65 pipeline steel: Comparison of wet–dry cycle and full immersion

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Highlights:

- The corrosion behavior of X65 steel under wet–dry cycle and full immersion was compared.
- Pitting corrosion occurred under wet–dry cyclic condition while general corrosion occurred under full immersion.
- Both of the pit depth, groove depth and diameter-to-depth ratios follow a lognormal distribution.
- The corrosion kinetics under both conditions follow empirical equation $d_t = \beta t^{\alpha}$.
- The peak intensity of γ-FeOOH fluctuates due to its reduction occurred during the wet–dry cycling process.

Abstract: The initial corrosion behavior of X65 pipeline steel subjected to wet–dry cyclic exposure and full immersion were investigated to determine the corrosion behavior of X65 pipeline steel in marine splash zone and below the waterline. The scanning electron microscope (SEM) test results indicated that pitting corrosion occurred under wet–dry cyclic condition whereas general corrosion occurred under full immersion. The statistical results of the measured pit depth and groove depth using 3D measuring laser microscope indicated that both of them follow a lognormal distribution rather than normal distribution. Moreover, the statistical distribution of diameter-to-depth ratio of pits also followed a lognormal distribution. The corrosion kinetics under both conditions followed the empirical equation $d_t = \beta t^{\alpha}$. The morphology of the corrosion surfaces and the cross-section of rust layer were examined using SEM and the compositions were analyzed using X-ray diffraction, which indicated that the sharp fluctuation of the peak intensity of γ-FeOOH was caused by its reduction during the wet–dry cycling process.

Keywords: Wet–dry cycle; Full immersion; Pitting corrosion; Statistical distribution

1. Introduction

Carbon steels are the most widely used pipeline materials in petroleum industry. The corrosion of pipelines will result in the leakage of crude oil and environmental pollution [1][2]. Marine structures, such as a riser and the legs of a platform, are exposed to cyclic wet–dry conditions in chloride solutions. The corrosion processes under such conditions are different from those occurring under full immersion. It has been shown that corrosion in the splash zone is much higher than that below the waterline and in the atmosphere. The mass loss increases quickly to peaks at approximately 250 mm above the water line and approximately 100–200 mm below the waterline [3]. The high-speed corrosion of splash zone is correlated to fluid scouring, salt deposition, wet–dry cycle, differential aeration, etc. [3].

In general, the humidity of marine atmospheric is high, which results in the formation of a layer of thin aqueous film on metal surfaces. Owing to the daily cyclic change of atmospheric humidity and temperature, the thickness of this thin electrolyte film increases and decreases alternately [4]. It had been observed that atmospheric corrosion of carbon or weathering steels begins at approximately 60% relative humidity (RH) at a very slow rate and increases sharply at 80% < RH < 100%. Electrolyte thickness of approximately 100 μm can be observed when 100% RH is reached [5]. Under atmospheric exposure conditions, the thickness and composition of electrolyte films is dependent on the salt loading density and RH [6]. Generally, maximum atmospheric corrosion rate occurs when the film thickness is within the range of 1–30 μm [7]-[10].

Many studies have identified the phenomenological distinctions between full immersion and thin-film atmospheric corrosion behavior [11]-[13]. While pitting corrosion is of utmost interest, it may result in the leakage of pipeline, stress corrosion cracking in loaded structures [14], and shortening of crack initiation life for a structure under cyclic loading [15]. The chloride ion is an important factor in pitting initiation. Many studies have identified the deleterious effect of the increase in chloride on the passive film stability, which is of critical importance to thin-film atmospheric exposure conditions [12][16]. Generally, pitting proceeds by the stochastic environment-induced rupture of a stable passive film [17]. This process often occurs proximate to the second-phase particles, such as magnesium sulfide inclusions [15]. The main role of chloride ions in pitting corrosion is to increase the chance of breakdown of passive films, rather than to inhibit the surface repassivation [18].