Chapter 7

Molecular Interaction of Lactams With Mild Steel in Hydrochloric Acid Environment:

Corrosion Inhibition Efficiency and Surface Adsorption Mechanisms

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ABSTRACT

The inhibition effect of some lactams (Pyrrolidin-2-one, δ-valerolactam, and ε-caprolactam) on the corrosion behaviour of mild steel in 1M Hydrochloric acid solution was studied by weight loss and electrochemical techniques. The results demonstrated that both δ-valerolactam, and ε-caprolactam significantly inhibit corrosion. Specifically, δ-valerolactam achieved an inhibition efficiency of 85.2%, while ε-caprolactam exhibited a higher inhibition efficiency of 91.5%. The thermodynamic parameters governing the adsorption process such as adsorption heat, adsorption entropy, and adsorption free energy were determined and discussed. The adsorption of lactam compounds on the mild steel surface in 1M HCl follows the Langmuir adsorption isotherm model.

1. INTRODUCTION

The extensive utilization of mild steel in the industry is attributed to several factors, including its affordability, making it an economically viable choice (Fayomi et al., 2021), excellent mechanical properties, easy availability, cold working ability (Kaya et al., 2023), and the capacity to be hot worked

DOI: 10.4018/979-8-3693-7505-1.ch007

without compromising mechanical properties (Sedik et al., 2020; Oyekunle et al., 2019). mild steel is a common option for a container that holds aggressive solutions (Yadav et al., 2016), acids, bases, salts, reactions reagents, and tanks for handling corrosive liquids (Hussain et al., 2023; Matad et al., 2014). Acidic solutions play a vital role in processes, such as descaling, cleaning, and various petrochemical processes (Al-Moubaraki et al., 2021; Kuren et al., 2023). Acids including sulfuric, acetic, nitric, and hydrochloric acids are frequently used in pickling (Ding et al., 2016). Moreover, these acids are widely employed for drilling fracturing and acid simulations during various stages in oil exploration (Abd-El-Nabey et al., 2024), production, and descaling operations, as well as in numerous other industrial applications (Askari et al., 2021).

Building on this basis, Park et al. studied the long-term corrosion performance of three tested steels in an acidic environment. Their research underscored the remarkable features of mild steel, including its cost-effectiveness, widespread availability, and high tensile strength, which makes it a preferred choice in industries dealing with corrosive substances. The authors reiterated the critical role of acids in various applications including drilling and oil exploration, further supporting the notion that mild steel remains a vital material in aggressive environments (Park et al., 2022).

Most recently, (Alharbi et al., 2024) focused on low-carbon steel (AISI 1010), and its corrosion behavior was influenced by grain size. This study provides insights into the microstructural aspects that affect corrosion resistance, and demonstrates that variations in grain size can significantly affect the mechanical properties and performance of low-carbon steel. The findings indicated that a finer grain structure, achieved through heat treatment, enhances corrosion resistance, which is essential for materials used in industrial processing equipment. This study adds a nuanced understanding of how microstructural characteristics can be optimized to improve the longevity and reliability of mild steel in corrosive environments. Collectively, these studies illustrate the critical relationship between the material properties, corrosion behavior, and industrial applications of mild steel. They highlighted the ongoing need for research to enhance the performance of mild steel in aggressive environments, thereby ensuring its continued relevance in various industrial sectors.

Corrosion is a natural and electrochemical phenomenon that results in the degradation of materials through their interactions with the surrounding environment (Fernandes et al., 2014; Rinky et al., 2023). In acidic solutions, H^+ ions and dissolved oxygen serve as inherent catalyst for corrosion. It is a continuous process that cannot be entirely halted, but can be decelerated. Corrosion inhibitors represent the most efficacious method for slowing down the reaction and protect metals in various industries and fields (Amin et al., 2006). Corrosion inhibitors are among the most recognized and effective methods for preventing the degradation or destruction of metal surfaces in industrial applications. Due to its low cost and practicality, this method has become popular (Pokhmurs'kyi et al., 2004; Sivakumar et al., 2021).

The classification of inhibitors based on their chemical functionality can be categorized into two primary types. Inorganic and organic inhibitors (Oyekunle et al., 2019; Sanaei et al., 2017). Inorganic inhibitors are characterized by their capacity to facilitate the oxidation of metals, thereby forming a passive layer on the metal surface that provides protection against corrosion. The efficacy of these inhibitors is primarily attributed to the negative anions present in the crystalline salts, such as calcium metasilicate, sodium chromate, phosphate, molybdate, and zinc oxide, which play a significant role in mitigating metal corrosion (Sanaei et al., 2017).

Conversely, organic inhibitors are typically composed of complex structures that include π-bonds and possess active centers or functional groups (Aslam et al., 2021; Goyal et al., 2018). These inhibitors can be subdivided into two categories: (i) organic anionic inhibitors, which include mercaptobenzotriazole,

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