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Surfactant as Corrosion Inhibitors: A Review

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Abstract: ***Corrosion is a pervasive issue with substantial impacts on infrastructure, the economy, safety, and the environment. This study explores the mechanisms of corrosion and highlights the importance of preventive measures, particularly focusing on the use of surfactants as corrosion inhibitors. Surfactants, known for their ability to adsorb onto metal surfaces and form protective barriers, have emerged as a promising solution to prevent metal degradation. Their effectiveness is influenced by factors such as molecular structure, concentration, and environmental conditions. Surfactants offer several advantages over traditional inhibitors, including versatility, ease of application, and environmental friendliness, being often biodegradable and less toxic. These qualities make them suitable for use across various industries, such as oil and gas, water treatment, and manufacturing. The research emphasizes the potential of surfactants to provide sustainable and effective corrosion protection, contributing to the longevity and safety of metal infrastructure.***

Keywords: Corrosion Inhibition, Surfactants, Metal Protection, Environmental Friendliness, Infrastructure Durability

1. Introduction

The effects of corrosion on the environment and human life are significant, influencing infrastructure, the economy, and overall safety [1]. Understanding the mechanisms behind corrosion and exploring protective strategies can help reducing these harmful impacts. Corrosion is also the process by which refined metals convert into more stable compounds such as metal oxides, sulfides, or hydroxides. Similarly, the rusting of iron involves the formation of iron oxides due to the interaction with water and oxygen in the atmosphere. On a deeper level, corrosion is an irreversible and spontaneous reaction where metals transform into more stable chemical forms like oxides, sulfides, or hydroxides. Corrosion affects our daily lives in numerous ways, often unnoticed. For example, the corrosion of steel rebar in concrete can lead to the failure of highways, the collapse of electrical towers, and structural damage to buildings, parking garages, and bridges, all of which carry high repair costs and pose risks to public safety. Preventing corrosion is essential to ensuring a safer future for upcoming generations. Research, innovation, and raising public awareness will be crucial in mitigating the widespread yet often overlooked effects of corrosion.

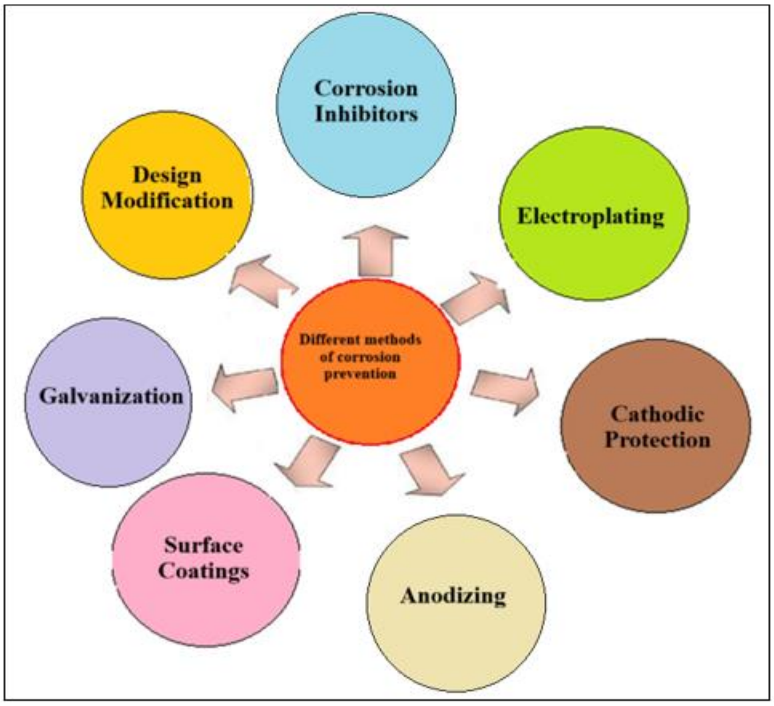

Figure 1: Picture showing different methods of corrosion prevention

Different methods are used to prevent corrosion, galvanization, surface coating, anodizing, cathodic protection, electroplating, use of corrosion inhibitors etc. [2, 3]. Corrosion inhibitors are chemical substances used to prevent or slow down the corrosion of metals by forming a protective barrier on the metal surface. They are widely employed in various industries, such as oil and gas, water treatment, and manufacturing, to enhance the longevity and reliability of metal equipment and infrastructure. The primary function of corrosion inhibitors is to interfere with the electrochemical reactions that cause corrosion, thereby reducing the rate at which metal degradation occurs. The effectiveness of a corrosion inhibitor depends on several factors, including the type of metal, the corrosive environment, and the concentration of the inhibitor. For instance, in the oil and gas industry, specific inhibitors are chosen to protect pipelines from corrosion caused by hydrogen sulfide or carbon dioxide in the presence of moisture. In water treatment plants, inhibitors are used to protect the internal surfaces of pipes and tanks from corrosion caused by chlorides and other aggressive ions. The effectiveness of surfactants as corrosion inhibitors depends on several factors, including their molecular structure, concentration, and the nature of the corrosive environment. Ionic surfactants, such as cationic, anionic, and amphoteric surfactants, are particularly effective in aqueous environments, where they can interact with both the metal surface and corrosive ions to form stable, protective layers. Non - ionic surfactants, on the other hand, can be effective in both aqueous and non - aqueous environments and are often used in combination with other types of inhibitors to enhance corrosion protection. Surfactants are advantageous as corrosion inhibitors due to their versatility, ease of application, and environmental friendliness. They can be easily added to corrosive media, such as cooling water systems or oil pipelines, and provide effective protection at relatively low concentrations. Additionally, many surfactants are biodegradable and less toxic than traditional inorganic inhibitors, making them an attractive option for industries seeking to reduce their environmental impact. Overall, surfactants represent a promising and versatile approach to corrosion prevention, offering effective and sustainable solutions for protecting metal surfaces from degradation.

2. Surfactants

The term “surfactant” represents a material which shows some interfacial activity. In other words, a surfactant shows tendency to adsorb at surfaces and interfaces. The term interface denotes a boundary between any two immiscible phases while surface denotes a boundary between a liquid and a gas phase. The term surfactant was first registered as a trademark for selected surface operational products [4], and later it was allowed to use for public domain [5]. Surfactant molecules consist 2 (or more) portions of different chemical substances, one portion being cooperative with H_2O molecules and the other part not being compatible with them. The physical characteristics of tensiomeric substance differ from those of smaller or non - amphipathic molecules in one major aspect, namely the sudden change in their properties above a certain concentration known as critical micelle concentration (CMC) [6 - 15]. At low concentrations, most properties are similar to those of a normal electrolyte. One notable exception is the surface tension, which decreases rapidly with increasing surfactant concentration. However, all the characteristics (interfacial and bulk) show a sudden change at a particular amount, which is consistent with the fact that at and above this concentration, surface tensiomeric ions or molecules in solution form larger units. These units are called micelles (self assembled structures) and the first formed aggregates are generally approximately spherical.

3. Classification of surfactant

Table representing types of surfactants and their uses:

Types of surfactants	Uses
Anionic Surfactants	Laundering, dishwashing liquids and shampoos [16].
Cationic Surfactants	Anti - corrosive agent for steel, flotation collectors for mineral ores [17, 18].
Non - ionic Surfactants	Household cleaners and hand dishwashing liquids.
Zwitterionic Surfactants	Personal care and household cleaning products.

4. Use of surfactant in corrosion inhibition

Surfactants have gained significant attention as potential corrosion inhibitors in recent years. Their ability to associate at interfaces and in solutions, forming aggregates, is well - documented [19]. The adsorption of surfactants on metal surfaces plays a critical role in corrosion inhibition, as the primary function of the surfactant's functional group is to adsorb onto the metal. This adsorption process is key to preventing corrosion and is generally linked to the surfactant’s capacity to form micelles [20 - 24]. Therefore, a deeper understanding of how surfactants adsorb onto metal surfaces and contribute to corrosion inhibition is crucial for both theoretical and practical applications. Surfactant inhibitors can function as either anodic or cathodic inhibitors. They create a physical barrier on metal surfaces by adsorbing onto them, thereby reducing corrosion. As a result, surfactants are often categorized as barrier - type inhibitors. These inhibitors typically contain nitrogen or sulfur atoms in their functional groups, with nitrogen frequently being part of a hydrocarbon ring. The unpaired electrons of the nitrogen atom often form bonds with metal substrates, while the π electrons in resonating hydrocarbon ring structures also interact with metal surfaces to form bonds. This bonding is often classified as chemisorption, making it difficult for these molecules to be displaced by reactants or for the metal surface to be exposed to the environment at the adsorption site. Effective corrosion inhibition by surfactants depends on their adsorption, which is influenced by factors such as solution composition, adsorbate concentration, the interaction between the adsorbate and the surface, the properties of both the surface and the adsorbate, and the electrochemical potential of the surface.

5. Conclusion

Corrosion poses a significant threat to infrastructure, safety, and the economy, making its prevention vital for the durability of metal structures. Among the various methods to combat corrosion, surfactants have shown great promise as inhibitors. These compounds adsorb onto metal surfaces, forming protective barriers that prevent degradation. Their effectiveness depends on factors like molecular structure and environmental conditions. Surfactants are versatile, easy to apply, and environmentally friendly, often being biodegradable and less toxic than traditional inhibitors. Their ability to function in both aqueous and non - aqueous environments makes them valuable across industries, including oil and gas, water treatment, and manufacturing. In summary, surfactants offer a sustainable and effective solution for corrosion prevention, playing a crucial role in protecting metal surfaces and contributing to a safer, more sustainable future.

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