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Cathodic Protection Systems: Safeguarding Steel against Corrosion

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Abstract

Corrosion is a pervasive and costly problem that affects various industries worldwide, causing significant damage to structures and infrastructure made of steel. The degradation of steel due to corrosion not only leads to financial losses but also compromises the safety and reliability of critical assets. To combat this destructive force, engineers and researchers have developed cathodic protection systems, a powerful defense mechanism that safeguards steel against corrosion. Galvanic cathodic protection systems are an effective and widely used method for safeguarding steel structures against corrosion. This corrosion control technique, also known as sacrificial anode cathodic protection, relies on the principle of creating a galvanic cell to prevent the corrosion of steel.

Keywords: Corrosion • Cathodic protection • Galvanic cell

Introduction

Corrosion is an electrochemical process that occurs when metals, such as steel, react with their environment. When steel is exposed to moisture, oxygen and other corrosive substances, it undergoes oxidation, resulting in the formation of iron oxide, commonly known as rust. This process weakens the structural integrity of steel, leading to degradation and potential failure over time. Cathodic protection is a corrosion control technique widely used in industries such as oil and gas, marine, transportation and infrastructure. It works on the principle of electrochemistry, where a metal is protected by making it the cathode of an electrochemical cell [1]. By providing a more easily corroded metal (an anode) or an external source of direct current, the cathodic protection system redirects the corrosion process, effectively protecting the steel from degradation.

Galvanic cathodic protection systems utilize a more active metal, such as zinc or magnesium, as sacrificial anodes. These anodes are connected to the steel structure and corrode sacrificially, preventing the steel from corroding. The anode material is selected based on its electrochemical properties and the expected corrosion environment. When the anode corrodes, it releases electrons that flow through the electrolyte (soil or water) and onto the steel structure, forming a protective layer of electrons on its surface. This negative charge suppresses the oxidation process and inhibits corrosion. Galvanic cathodic protection systems utilize a more reactive metal, known as a sacrificial anode, to protect the steel structure [2]. The sacrificial anode typically made of zinc, aluminum, or magnesium, is connected to the steel structure and electrically bonded. When the anode and steel are immersed in an electrolyte, such as soil or water, a galvanic cell is formed.

Literature Review

The anode material chosen for the system is more easily corroded than the steel structure it is protecting. As a result, it sacrifices itself by undergoing corrosion, while the steel structure remains protected. The anode releases electrons during the corrosion process and these electrons flow through the electrolyte and onto the steel structure, creating a protective layer of negative charge on its surface. This layer suppresses the oxidation process and effectively inhibits corrosion. Galvanic cathodic protection systems are relatively simple and easy to install, making them suitable for a wide range of applications. They require minimal maintenance and can be implemented in both buried and submerged structures. Compared to other corrosion control methods, galvanic cathodic protection systems are often more cost-effective [3]. The sacrificial anodes are inexpensive and readily available, reducing the overall installation and maintenance costs.

Galvanic cathodic protection systems do not require an external power source or rectifier, as the corrosion of the sacrificial anode generates the necessary electrical current. This self-powered nature simplifies the system design and reduces energy consumption. Galvanic cathodic protection systems are environmentally friendly, as they do not require the use of chemicals or power sources that may have environmental impacts. The sacrificial anodes can be easily replaced or recycled once depleted. Buried pipelines, such as those used for oil, gas, or water transportation, are susceptible to corrosion. Galvanic cathodic protection systems help prevent corrosion damage and extend the lifespan of these pipelines. Steel structures exposed to seawater, such as piers, docks and offshore platforms, are highly vulnerable to corrosion [4]. Galvanic cathodic protection systems offer effective protection in these aggressive environments.

Discussion

Above-ground storage tanks, especially those containing corrosive substances, can benefit from galvanic cathodic protection systems to mitigate corrosion risks and maintain their structural integrity. Galvanic cathodic protection can also be used to protect the steel reinforcement in concrete structures, such as bridges and parking garages, from corrosion caused by chloride ingress or carbonation. Impressed current cathodic protection systems involve the use of an external power source, such as a rectifier, to generate a direct current [5]. This current is then impressed onto the steel structure through anodes made of materials like graphite, mixed metal oxide, or platinum-coated titanium. The impressed current system allows for precise control of the protection potential, making it suitable for larger structures or those exposed to more severe corrosion conditions. The rectifier adjusts the current output to ensure the steel structure maintains a desired level of cathodic protection.

By inhibiting corrosion, cathodic protection systems extend the lifespan of steel structures, reducing the need for frequent repairs or replacements. Implementing cathodic protection systems can be cost-effective in the long run compared to the expenses associated with repairing or replacing corroded structures [6]. Cathodic protection can be applied to various structures, including

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pipelines, storage tanks, offshore platforms, bridges, piers and reinforced concrete structures. Cathodic protection systems are environmentally friendly as they minimize the need for chemical inhibitors and reduce the potential for leaks or spills caused by corroded structures. In many industries, cathodic protection systems are mandated by regulations and codes to ensure the integrity and safety of structures.

Conclusion

Corrosion poses a significant threat to steel structures across industries. However, with the implementation of cathodic protection systems, engineers and asset owners can effectively combat this destructive force. Whether through galvanic (sacrificial anode) or impressed current systems, cathodic protection provides a reliable and cost-effective solution for safeguarding steel against corrosion. By incorporating this corrosion control technique into infrastructure design and maintenance practices, we can ensure the longevity, safety and reliability of vital assets for generations to come. Galvanic cathodic protection systems provide a reliable and cost-effective solution for protecting steel structures against corrosion. By utilizing sacrificial anodes that corrode sacrificially, these systems prevent the steel from corroding and extend the lifespan of critical assets. By implementing these systems, engineers and asset owners can ensure the integrity and durability of steel structures, leading to increased safety and reduced maintenance costs in the long run.

Acknowledgement

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Conflict of Interest

None.

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