Corrosion and Protection of Metal in the Seawater Desalination

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Abstract. Seawater desalination develops rapid for it can solve water scarcity efficiently. However, corrosion problem in the seawater desalination system is more serious than that in normal water. So, it is important to pay attention to the corrosion and protection of metal in seawater desalination. The corrosion characteristics and corrosion types of metal in the seawater desalination system are introduced in this paper; In addition, corrosion protect methods and main influencing factors are stated, the latest new technologies about anti-corrosion with quantum energy assisted and magnetic inhibitor are presented.

1. Introduction
Metal corrosion brings huge economic loss and social harm in our daily life and production. According to the statistics, about 1/3 annual production of metal scrap in the world, ascribed to the corrosion of metal materials and equipments. The direct economic lose even account for 2% to 4% of each country’s gross domestic product (GDP). And this loss is six times of sum lost, which caused by earthquakes, floods, typhoons and other natural disasters. The sea water desalination, seawater cooling and seawater comprehensive utilization is an efficient way to realize water increment and solve the problem of fresh water lake. However, most metals and alloys in marine operations inevitably eroded, because the sea is rich in natural electrolytes and highly corrosive. Therefore, in order to use marine resources efficiently and respond to sustainable development actively, investigate corrosion behavior in seawater desalination, and take appropriate anti-corrosion measures are very necessary.

2. Corrosion types and damages
Corrosion of metals in seawater desalination system includes both general and localized corrosion. Both corrosions will bring great harm to the service life of seawater desalination equipment and safe operation of the system. Corrosion in the seawater leads significant economic losses, such as loss of production, loss of product, loss of efficiency and product contamination. Even more serious, corrosion in the seawater leads catastrophic major accidents, such as leakage of toxic substances, causing environmental pollution, endangering people's health, et al.

3. Corrosion Characteristics of Metal in Seawater Desalination
As metal physical properties and chemical properties are not uniform, the potential is different on different parts of metal surface, and local corrosion cell or micro cell is formed in the seawater. The
main behaviors of corrosion in seawater are shown as four corrosion characteristics, according to the seawater characteristics and metal corrosion law.

(1) When dissimilar metals contact, anode metal may cause significant galvanic corrosion damage, which ascribed to the seawater has good conductivity and small corrosion resistance.

(2) Since seawater has vast amount chlorine, passive metals prone to suffer the localized corrosion in seawater, such as pitting corrosion, crevice corrosion and stress corrosion, and prone to suffer erosion corrosion in the high velocity seawater.

(3) Any factor of increasing limiting diffusion current density could aggravate metal corrosion. This because the corrosion of carbon steel in seawater is oxygen absorb corrosion, which controlled by oxygen distribution, and the anodic polarization energy is very small.

(4) According to the contact style of metal and seawater, the sea could be categorized into five zones: atmospheric zone, splash zone, tidal zone, immersion zone and sea area. The metal corrosion in these areas is quite different, and the most serious corrosion appears in splash zone.

4. The main Influencing Factors of metal corrosion in seawater medium

4.1. Salinity
The salt content of seawater is higher than that of fresh water. The salt content in water directly affects the conductivity and oxygen content of water. With the increase of salt content in water, the electrical conductivity of water increases but the oxygen content decreases. Salinity in seawater is not consistent with the behavior of NaCl, which is due to the calcium and magnesium ions contained in the metal surface precipitation of calcium carbonate and magnesium hydroxide precipitation, the metal has a certain protective effect. In the estuary area, the salinity of seawater is lower than that in the sea, the content of calcium and magnesium is small, and the corrosiveness of metal increases. Chloride in seawater can destroy the oxide film on the surface of metal and form a complex with metal ions, which produce hydrogen ions during hydrolysis, so that the acidity of seawater increases, and the local corrosion of the metal is strengthened.

4.2. Conductivity
Seawater not only high salt content, and almost all of which are in the ionization state of the salt, which makes the sea water as a good conductivity of the electrolyte. This determines the process of seawater corrosion, not only micro-battery corrosion activity, while the macro battery activity is also large. The results show that with the increase of conductivity, microcrystalline corrosion and macroscopic cell corrosion will accelerate.

4.3. Dissolved oxygen
The more the dissolved oxygen content of the sea, the higher the electrode potential of the metal in the sea, the faster the corrosion rate of the metal. But for aluminum and stainless steel a class of metal, when it is oxidized, the surface to form a thin layer of oxide film to protect the metal is no longer corroded, that is, to maintain a passive state. In addition, in the absence of dissolved oxygen in the sea, copper and iron almost no corrosion.

4.4. pH
In general, the pH of the sea water is conducive to the inhibition of seawater corrosion of steel. However, the pH of the seawater is far from the effect of oxygen content on the corrosion. Although the surface seawater pH is higher than that of the deep seawater, the corrosion of the surface seawater is far higher due to the photosynthesis of the seawater in the surface Stronger than deep seawater, which is consistent with the actual experimental conclusion.
4.5. Physical factors
Such as flow rate, tide, temperature and so on. the dissolved oxygen diffuses faster toward the cathode, increasing the corrosion rate of the metal, When the relative velocity of the sea increases with respect to the metal, In the atmosphere near the sea, there is a lot of water and salt, and there is sufficient oxygen and corrosion to the metal Relatively strong, therefore, in the average high tide line above the water spray splash to the place (splash zone), the metal surface is often in the case of wet and oxygen, the most serious corrosion; water temperature, will accelerate the corrosion. But the temperature increases, the solubility of oxygen in seawater is reduced and the corrosion is reduced.

5. Methods and Developments of Corrosion Protection in Seawater Desalination

5.1. Selection of the proper materials
In order to ensure long-term safe operation of equipment, reasonable selection of material is the most important aspect. It is necessary to consider the process conditions, but also consider the materials structure, properties and the changes during use process.

5.2. Surface Treatment and Coating
Surface treatment and coating technologies are focus on the interface of metal materials and corrosive medium. We can achieve the purpose of corrosion protection by the treatment of metal plating and non-metallic coating.

5.3. Cathodic Protection
Cathodic Protection is an electrochemical method to reduce corrosion. This method protect metal by provide a certain amount of electron current (or current) for cathodic polarization, make the potential of the metal to be negative, and make it in the thermodynamic stable region. According to the way of providing current, the cathode protection can be classified as sacrificial anode cathodic protection method and impressed current cathodic protection method. [1].

The electrochemical reactions of these processes are as follows:

a. Electrochemical corrosion process, Anodic reaction:

\[ \text{Fe} \rightarrow \text{Fe}^{2+} + 2e^- \]

Cathodic reaction:

\[ \text{O}_2 + 4e^- + 2\text{H}_2\text{O} \rightarrow 4\text{OH}^- \]

b. Sacrificial anode cathodic protection, Anodic reaction:

\[ \text{Me} \rightarrow \text{Me}^{2+} + 2e^- \]

Cathodic reaction:

\[ \text{O}_2 + 4e^- + 2\text{H}_2\text{O} \rightarrow 4\text{OH}^- \]

c. Impressed current cathode protection, Anodic reaction:

\[ 2\text{H}_2\text{O} \rightarrow \text{O}_2 + 4\text{H}^+ + 4e^- \]
\[ 2\text{Cl}^- \rightarrow \text{Cl}_2 + 2e^- \]

Cathodic reaction:
5.4. **Corrosion Inhibitor**

The corrosion inhibition is a method of adding small chemicals to the corrosive media, and through physical, chemical or physical/chemical reactions to block (or slow down) the rate of corrosion of metal, while maintaining the original physical, chemical and mechanical properties of metallic materials. This method is a convenient, quick and low-cost method [2,3].

6. **Novel Protect Methods of Magnetic Corrosion Inhibitor and Quantum Technology**

6.1. **Magnetic Corrosion Inhibitor**

The magnetic organic corrosion inhibitor expects to overcome organic corrosion inhibitor’s defect of weak binding force and improve its inhibition efficiency, by the introduction of magnetic. It is could form film by organic lipophilic group on the surface on the carbon steel, and enhance the binding force by its magnetic force.

6.2. **Quantum Technology and its Application in Seawater Decalination**

This method based on the quantum information theory and biological information technology. Water itself solves the rust and scale problems. The activity of water is greatly enhanced, the nature of water is changed and the ability of dissolving and containing ions is enhanced, under the action of vibration wave. At the same time, the physical characteristics of calcium, iron, magnesium and other related substances in the seawater are changed, leading to the preventing corrosion and fouling.

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