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Corrosion Types and Measures for Petrochemical Equipment

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Abstract: The corrosion problem of petrochemical equipment has always been one of the important factors restricting industrial development. Starting from the basic concept of corrosion, this article delves into various forms of corrosion in petrochemical equipment and their impact on equipment performance. Chemical corrosion, high-temperature corrosion, microbial corrosion, and stress corrosion are common forms of corrosion in petrochemical equipment, exacerbating equipment aging and wear. For different forms of corrosion, existing anti-corrosion measures include material selection, coating protection, electrochemical protection, etc. However, these measures also face certain limitations and challenges in practical applications. In summary, this article deeply analyzes the corrosion problem of petrochemical equipment, summarizes the limitations of existing anti-corrosion measures, and explores key measures to improve the anti-corrosion performance of petrochemical equipment. These research results are expected to provide useful references for equipment maintenance and safe operation in the petrochemical industry, and contribute to solving corrosion problems and improving equipment service life.

Keywords: Corrosion of Petrochemical Equipment; Corrosion Status; Corrosion Measures and Limitations.

1. Introduction

Petrochemical equipment is a key tool for converting raw materials such as crude oil into various valuable chemicals and energy. Petrochemical equipment plays a crucial role in multiple fields. They decompose crude oil into different fractions in refineries to meet transportation, industrial, and consumer needs. In addition, they are used to produce basic chemicals such as ethylene and propylene, which are key raw materials for manufacturing plastics, rubber, and synthetic fibers. The equipment is still playing a role in synthesizing agricultural fertilizers. Overall, petrochemical equipment extracts valuable products from raw materials, driving industrial and economic growth. However, environmental protection and sustainability also deserve attention, and measures need to be taken to reduce environmental impacts to ensure that industrial activities do not cause irreversible damage to the Earth.

Equipment anti-corrosion refers to the use of a series of measures to protect industrial equipment from corrosion, oxidation, and other damage. It emphasizes the following key points: extending the service life of equipment, avoiding damage to the surface and interior of equipment caused by corrosion and oxidation, reducing replacement frequency, and reducing production costs; Ensure production stability, prevent corrosion, ensure continuous and stable operation of equipment, and reduce the risk of production interruption; Improve product quality, take anti-corrosion measures to ensure that equipment does not introduce impurities or pollutants, and maintain high product quality; Ensuring safety and anti-corrosion can help reduce the risks of equipment leakage, explosion, and other hazards, and protect the safety and health of employees; Save maintenance costs, reduce maintenance and repair costs through anti-corrosion measures, and avoid high maintenance costs; Environmental protection and sustainability, anti-corrosion to reduce equipment damage and scrap, reduce resource waste, and comply with the principles of environmental protection and sustainability. In summary, equipment corrosion prevention is related to the long-term safety, stability, and efficient operation of industrial equipment. It needs to be considered in the design, manufacturing, and maintenance processes to ensure equipment lifespan, safe operation, improve production efficiency, and product quality. It is of great significance for the sustainable development of industry and economic prosperity.

2. Corrosion Forms and Effects of Petrochemical Equipment

2.1. Chemical Corrosion

Chemical corrosion of petrochemical equipment refers to the phenomenon of metal erosion and damage caused by the interaction between the equipment surface and chemical media during the petrochemical production process. This type of corrosion is caused by the interaction between specific chemical substances and equipment metals, leading to the release of metal ions, chemical reactions, or redox reactions, resulting in metal erosion on the surface of the equipment. In the petrochemical industry, equipment is widely used for the storage, transportation, and treatment of various chemical substances, including acidic, alkaline, oxidizing, reducing, and saline corrosive media. When these chemicals come into contact with the surface of the equipment, they may react with the metal surface, causing ion dissolution of the metal, reduction or oxidation of the chemicals, or forming corrosion products such as metal salts. These reactions can lead to corrosion and damage to the metal surface, thereby affecting the performance, safety, and service life of the equipment.

Chemical corrosion can usually be divided into two types in terms of manifestations: local corrosion: local corrosion refers to the occurrence of localized corrosion phenomena on the surface of equipment, such as pits, holes, or local depressions. These localized corrosion areas may lead to uneven corrosion on the surface of the equipment, increasing its vulnerability and potentially causing leakage and failure; Uniform corrosion: Uniform corrosion refers to the overall corrosion of the equipment surface, resulting in a reduction in

the thickness of the metal surface. Uniform corrosion may reduce the strength and durability of the equipment, causing it to lose its original performance. The formation of corrosion products is also a part of the chemical corrosion process. Sometimes, corrosion products form a protective film on the metal surface, which plays an anti-corrosion role. However, this layer of film may sometimes be unstable or incomplete, which can actually accelerate the occurrence of corrosion. The rate of chemical corrosion is influenced by various factors, including the properties of the chemical medium, temperature, pressure, metal materials, and composition. High temperature, high pressure, and corrosive media usually accelerate the corrosion rate. In order to prevent and manage chemical corrosion issues, petrochemical enterprises should take corrosion issues seriously and take appropriate prevention and management measures. The selection of corrosion-resistant materials, reasonable design of equipment to avoid dead corners of corrosive media accumulation, regular inspection and maintenance of equipment, and the application of effective anti-corrosion technologies such as anti-corrosion coatings are key measures to prevent and manage chemical corrosion, ensuring the safe operation and service life of equipment, reducing accident risks and losses caused by production interruptions.

2.2. High Temperature Corrosion

High temperature corrosion is a corrosion phenomenon caused by the action of medium in petrochemical equipment under high temperature conditions. In the petrochemical industry, many important process processes require high-temperature environments, such as cracking, reforming, hydrogenation, etc. These high-temperature processes play a crucial role in improving production efficiency and product quality. However, these high-temperature processes can also pose serious challenges to the surface of equipment, as metal materials are more prone to corrosion in high-temperature environments, leading to equipment damage and shortened lifespan.

High temperature corrosion can be classified into various types, including oxidation corrosion, sulfide corrosion, chloride corrosion, and alkaline corrosion. Under high temperature conditions, the metal surface reacts with oxygen to form an oxide layer. For example, steel reacts with oxygen at high temperatures to form iron oxide, forming oxide scales or scales, causing gradual corrosion of the equipment surface. In addition, there may be sulfides in some high-temperature petrochemical processes, such as hydrogen sulfide, which can react with metal surfaces and cause sulfide corrosion, becoming a common form of high-temperature corrosion. Chlorides may also participate in the corrosion process. Under certain high-temperature conditions, chlorides can accelerate the corrosion rate of metals and increase the risk of equipment corrosion. In addition, alkaline media, such as sodium hydroxide or potassium hydroxide, may be used in high-temperature petrochemical processes, and alkaline media may react with equipment surfaces to cause alkaline corrosion. The impact of high-temperature corrosion on petrochemical equipment is very serious, especially in high-temperature areas of equipment, such as furnace tubes, reactor walls, etc., which are often susceptible to corrosion erosion. The corrosion process may lead to thinning of equipment wall thickness, crack generation, and decreased metal strength, thereby increasing the risk of equipment failure. In order to effectively prevent and control high-temperature corrosion, petrochemical enterprises usually take a series of measures. Among them, selecting high-temperature resistant alloy materials and metal materials with good high-temperature corrosion resistance is a crucial step. In addition, the application of effective protective coatings is also an effective means. Coatings can form a protective layer on the metal surface, blocking the contact between the metal and corrosive media. In addition, controlling the content of corrosive substances in the medium and regularly inspecting and maintaining equipment are important measures to ensure long-term operation of equipment under high temperature conditions. In practice, petrochemical enterprises usually develop reasonable maintenance plans and anti-corrosion strategies by closely monitoring and evaluating the corrosion status of equipment in response to high-temperature corrosion issues. Only by comprehensively addressing the multifaceted challenges of high-temperature corrosion and ensuring the stable operation and safety of equipment under high-temperature conditions, can the sustainable development of the petrochemical industry and the improvement of production efficiency be guaranteed.

2.3. Microbial Corrosion

Microbial corrosion, also known as biological corrosion, refers to the corrosion phenomenon caused by the action of microorganisms (bacteria, fungi, etc.) in petrochemical equipment. These microorganisms can reproduce on the surface of equipment or in the medium, causing corrosion processes by producing metabolic products or acting on metal surfaces. Microbial corrosion usually occurs in humid environments or aqueous media, so water treatment and anti-corrosion measures are crucial in the petrochemical industry. Microbial production of acidic substances: Some microorganisms can produce acidic substances on the surface of equipment, such as sulfuric acid, hydrochloric acid, etc. These acidic substances can react chemically with metal surfaces, leading to corrosion. This type of microbial corrosion is common in some acidic environments, such as sulfuric acid bacteria and hydrochloric acid bacteria; Formation of biofilm: Microorganisms form viscous biofilms on the surface of equipment, which can adsorb water and maintain a humid environment, promoting redox reactions and metal corrosion. The formation of biofilms can accelerate the corrosion process and is difficult to remove with simple cleaning measures; Microbial production of oxides: Some microorganisms produce oxides, such as iron oxide (rust), which can cover the surface of equipment and further cause metal corrosion. This type of microbial corrosion typically occurs in oxygen-containing environments, such as iron bacteria.

Microbial corrosion is a complex and common problem that can lead to equipment damage, leakage, and failure in petrochemical equipment, thereby affecting production efficiency and safety. In order to prevent microbial corrosion, petrochemical enterprises usually adopt various prevention and control measures. Firstly, regular cleaning and disinfection of equipment can effectively reduce the proliferation of microorganisms and the formation of biofilms. Secondly, the use of antimicrobial agents can to some extent prevent the activity of microorganisms. In addition, maintaining appropriate water quality and environmental conditions is also crucial in controlling the occurrence of microbial corrosion. It is worth noting that microbial corrosion is a complex problem, as different combinations of

microorganisms and media can lead to different types of corrosion. Therefore, in petrochemical equipment, the prevention and control of microbial corrosion need to comprehensively consider multiple factors and adopt corresponding strategies. In order to ensure the safe operation of equipment and extend its service life, it is crucial to continuously monitor and study the mechanisms of microbial corrosion. Only through scientific prevention and control measures and continuous improvement can the petrochemical industry better cope with the challenges posed by microbial corrosion.

2.4. Stress Corrosion

Stress corrosion refers to the corrosion phenomenon on metal surfaces in petrochemical equipment caused by the presence of media and the stress acting on the equipment. This type of corrosion is different from environmental corrosion and chemical corrosion. It is a special form of corrosion caused by the stress interaction between chemicals in the medium and metals. There are mainly several types of stress corrosion: Stress Corrosion Cracking (SCC): Stress corrosion cracking refers to the occurrence of cracks on the metal surface under stress in the presence of a medium. This corrosion may manifest as intergranular cracks or cracks propagating along grain boundaries in materials. Stress corrosion cracking poses a serious threat to the structural integrity of equipment and may lead to equipment failure. This type of corrosion usually occurs when metal materials are in a tensile stress state and are more likely to occur when in contact with specific corrosive media; Environmentally Assisted Cracking (EAC): Environmental Assisted Cracking refers to the fracture of metal materials under specific environmental conditions under stress. This type of fracture may occur without significant corrosion, but its occurrence is closely related to environmental conditions. Environmental related fractures include stress corrosion cracking and hydrogen induced cracking, which are caused by the presence of specific corrosive substances and stress fields in the medium; Stress Corrosion Fatigue (SCF): Stress corrosion fatigue refers to the formation and propagation of fatigue cracks in metals subjected to stress in a medium and cyclic load (such as vibration or cyclic stress). This type of corrosion often occurs under high temperature and high-pressure conditions, affecting the durability and lifespan of equipment. Unlike pure fatigue failure, stress corrosion fatigue is caused by the presence of corrosive media.

The impact of stress corrosion on petrochemical equipment is very serious, as it is usually difficult to detect and predict, and may occur when the metal surface appears intact. Stress corrosion can quickly lead to equipment failure, posing a threat to the structural integrity and safety of equipment. In order to prevent and control stress corrosion, petrochemical enterprises usually take a series of measures.

Firstly, selecting stress corrosion resistant materials is a crucial step, as alloy materials with good stress corrosion resistance can reduce the corrosion risk of equipment. Secondly, reducing stress concentration is an important strategy. By optimizing design and processing techniques, reducing stress concentration areas can reduce the probability of stress corrosion. In addition, regular inspection and maintenance are also key measures to prevent stress corrosion. Timely detection and handling of potential problems can avoid equipment failure due to stress corrosion. When dealing with stress corrosion problems, it is necessary to comprehensively consider factors such as medium characteristics, equipment stress state, operating conditions, and material properties. Petrochemical enterprises should actively carry out research and monitoring of stress corrosion, continuously improve their understanding and prevention level of stress corrosion, to ensure the safe operation and reliability of equipment. Only through scientific prevention and control measures can the impact of stress corrosion on petrochemical equipment be effectively reduced, ensuring the sustainable development and safe production of the petrochemical industry.

3. Analysis of Existing Anti-Corrosion Measures

3.1. Overview of Existing Anti-Corrosion Measures for Different Forms of Corrosion

Water corrosion is a problem that requires special attention in petrochemical equipment. The solution includes: selecting corrosion-resistant materials, such as stainless steel and titanium alloy, to reduce the erosion of equipment caused by water corrosion; Using anti-corrosion coatings such as paint and polymer coatings to isolate moisture from metal surfaces and slow down corrosion; Conduct water quality control by reducing the content of corrosive substances such as oxygen and salt ions through water treatment, thereby reducing the rate of water corrosion. The problem of high-temperature corrosion requires targeted protective methods. Firstly, choose high-temperature resistant alloy materials that are suitable for high-temperature environments, such as nickel-based alloys and molybdenum alloys, to enhance the high-temperature corrosion resistance of the equipment. Secondly, by controlling the environment and reducing the oxygen and sulfide content in high-temperature environments, the occurrence of oxidative corrosion and sulfide corrosion can be reduced. Finally, high-temperature resistant coatings such as ceramic coatings and silicon carbide coatings are used to protect the equipment surface from high-temperature corrosion. These strategies help ensure the long-term stable operation of equipment in high-temperature environments. In terms of preventing microbial corrosion, the primary choice is to choose materials that are resistant to microbial corrosion, such as stainless steel and copper alloy, to reduce microbial erosion of equipment. In addition, by controlling the proliferation of microorganisms in water through water treatment and disinfection, antimicrobial agents can be added to disinfect the water to reduce the risk of microbial corrosion. In addition, regular cleaning and disinfection of equipment to remove microorganisms and biofilms can help prevent the occurrence of microbial corrosion. These measures help to protect equipment from microbial corrosion damage. The key measures to prevent stress corrosion include: firstly, stress relief through heat treatment and other means to reduce stress concentration of equipment, thereby reducing the possibility of stress corrosion. Secondly, reasonable methods should be adopted in structural design to avoid stress concentration and excessive stress, in order to reduce the risk of stress corrosion. Finally, priority should be given to selecting alloy materials that are resistant to stress corrosion to improve the corrosion resistance of the equipment. Integrating these strategies can help reduce the threat of stress corrosion.

The anti-corrosion measures for different forms of

corrosion usually require comprehensive consideration of multiple factors such as material properties, medium characteristics, environmental conditions, and equipment design. Regular equipment inspection and maintenance are also important measures for preventing and controlling corrosion, which can detect and address potential corrosion issues early, extend the service life of equipment, and ensure safe operation. Petrochemical enterprises should develop appropriate anti-corrosion strategies based on specific circumstances to ensure the long-term stable operation of equipment.

3.2. Evaluate the Effectiveness and Limitations of Existing Measures

There are some limiting factors in water corrosion prevention measures: firstly, the diversity of corrosive media results in significant differences in the types of corrosive substances and ions in different water quality. Therefore, when selecting corrosion-resistant materials and coatings, it is necessary to consider the influence of corrosive media. Secondly, the cost of corrosion-resistant materials and coatings is relatively high, especially for large-scale equipment or engineering projects, the adoption of these anti-corrosion measures may increase investment costs. These factors need to be carefully considered when formulating water corrosion protection strategies. High temperature corrosion protection measures have the following limitations: firstly, in the face of extremely high temperatures and strong corrosive media, even using high-temperature resistant alloy materials and coatings, it is difficult to completely avoid corrosion, which poses a challenge in extreme environments. Secondly, the selection of high-temperature resistant alloys is limited, as these materials often have limited applicability and cannot cope with all high-temperature corrosive environments. When facing these complex conditions, it is necessary to recognize the limitations of high-temperature corrosion protection. Microbial corrosion protection measures have the following limitations: firstly, microbial corrosion includes multiple types of microorganisms, which may cause different corrosion effects on different materials, making it difficult to find a universal anti-microbial corrosion strategy suitable for all situations. Secondly, some microorganisms have strong environmental adaptability and are difficult to completely eradicate, so anti-corrosion measures may be influenced by environmental conditions and microbial growth patterns. These factors require us to recognize the complexity of microbial corrosion protection. The protective measures for stress corrosion have the following limitations: firstly, the occurrence of stress corrosion is comprehensively affected by multiple stress effects, and it may be difficult to completely eliminate stress corrosion in response to complex stress fields. Secondly, the selection of stress corrosion resistant materials is limited, and the cost of using these materials is relatively high. When dealing with these issues, we need to recognize the complexity of stress corrosion protection.

The existing corrosion prevention measures have certain limitations when dealing with different forms of corrosion. Therefore, petrochemical enterprises need to comprehensively consider the impact of different forms of corrosion in equipment design and operation, adopt a strategy of combining multiple measures, regularly inspect and maintain equipment, to ensure long-term stable operation and extend service life of the equipment. In addition, for complex corrosive environments, scientific research and technological innovation remain important directions for improving anti-corrosion measures in the future.

4. Key Measures for Improving Corrosion Protection of Petrochemical Equipment

The key measures for anti-corrosion of petrochemical equipment include: firstly, in material selection and design, priority should be given to corrosion-resistant materials such as stainless steel and nickel-based alloys, and stress concentration and material corrosion tendency should be reduced by optimizing structural design. Secondly, corrosion-resistant coatings such as polymer and ceramic coatings are used to isolate metal from contact with corrosive media and delay the corrosion process. Environmental monitoring and control are key, and water quality monitoring and treatment can reduce the content of corrosive substances, while monitoring the properties of the medium and making corresponding adjustments. Regular inspection and maintenance are indispensable, and measures such as cleaning, repairing coatings, and eliminating stress concentration can detect and solve potential corrosion problems as soon as possible. Introduce new technologies such as nanocoating and electrochemical protection to continuously improve anti-corrosion performance. Employee training and awareness enhancement help them identify corrosion issues and take appropriate measures. Finally, environmental friendliness and sustainability should be considered in anti-corrosion measures to reduce their impact on the environment. These comprehensive measures will enhance the anti-corrosion ability of the equipment, ensure long-term stable operation of the equipment, reduce maintenance costs, and ensure the sustainability of production.

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