Development trend of protection technology for oil storage tank

DOU Ming-yuan1,2,3, LIAO Xiao-hua4, YANG Shen-jun4, QIN Ming-wei4, ZOU Shuai1,2,3 and HUANG Fu-chuan1,2,3*

1College of Mechanical Engineering, Guangxi University, Nanning, Guangxi, 530004, China
2Guangxi Key Laboratory of Petrochemical Resource Processing and Process Intensification Technology, Guangxi University, Nanning, Guangxi, 530004, China
3Guangxi Key Laboratory of Processing for Non-Ferrous Metals and Featured Materials, Guangxi University, Nanning, Guangxi, 530004, China
4South China branch of Sinopec Sales Co., Ltd
*Corresponding author’s e-mail: huangfuchuan@gxu.edu.cn
author’s e-mail: doumingyuan@foxmail.com

Abstract. Petroleum is the lifeline of the national economy and an important strategic resource for the survival and development of the country. Nowadays, the main way of storage of raw materials and products in the petroleum and petrochemical industry is tank storage, so the operation, maintenance and anti-corrosion of storage tanks play a vital role in the industrial safety of the entire industry. This paper summarizes the development of tank anti-corrosion technology in petrochemical industry at present, discusses the mechanism of tank inside and outside corrosion, various anti-corrosion measures, highlights the importance of tank anti-corrosion protection, and looks forward to the future development of tank anti-corrosion technology. Petroleum is the blood of modern industry and serves the national energy security. The anti-corrosion measures of storage tanks are of great significance to the key deployment of strategic oil reserves in China.

1. Introduction
Petroleum, known as the blood of industry, is an important resource guarantee for guaranteeing national energy security and social and economic sustainable development, an important strategic resource for national survival and development, and plays an extremely important role in national economic and social development as well as national defense construction and security. According to the data of the National Bureau of Statistics, China's oil output in 2018 was 189.1 million tons, and its oil import volume was 46.189.9 million tons, with an external dependence of 70.59%. According to the increase of China's oil demand, it is expected that China's total oil demand will exceed 700 million tons by 2020. At present, atmospheric pressure storage tank is the main method of oil storage.

Storage tank is an essential infrastructure in petroleum, chemical and other industries. According to the structure classification, it can be divided into dome type, floating roof type, internal floating roof type, horizontal type, ball type, etc. The vault tank, floating roof tank and horizontal tank are the most widely used and the most mature manufacturing and installation technologies in China. In actual
production, the corrosion of storage tanks directly affects the life of storage tanks and the operation of storage facilities, and ultimately affects the safe operation of storage and transportation systems. Crude oil contains a large amount of inorganic salts, water, and other corrosive media, which will cause corrosion to the tank inner wall. The geographic environment of the plant, such as the sea breeze in coastal areas, can cause corrosion damage to the outer wall of the tank. In recent years, with the increasing number of crude oil imported by enterprises, especially high-sulfur crude oil imported year by year, the corrosion of storage tanks has become more and more serious, and taking effective anti-corrosion measures is one of the most effective ways to prolong the service life of atmospheric pressure storage tanks.

Table 1. Petroleum related data of China in recent years.

| Year | Crude oil production (million tons) | Crude oil imports (million tons) |
|------|-----------------------------------|---------------------------------|
| 2019 | 19.10140                         | 50.572                          |
| 2018 | 18.91056                         | 46.189                          |

2. Corrosion mechanism of storage tank

The corrosion of oil tank is essentially chemical corrosion and electrochemical corrosion, which is mainly electrochemical corrosion, that is, metal oxidation and destruction caused by electrochemical action between metal surface and medium [1], and the electrochemical corrosion is related to the product concentration stored in the tank [2]. Due to the different environment in which corrosion occurs at the tank site, the mechanism of corrosion occurrence is also different. Corrosion can be divided into gas corrosion (mostly caused by corrosive gases volatilized from oil), liquid corrosion (corrosion of tank wall and floor by deposited water and inorganic salts in oil), soil corrosion and bacterial corrosion at tank bottom in contact with soil, etc. Only by correctly analyzing the types of storage tanks and different corrosion principles can we find ideal and economical anti-corrosion measures.

2.1. Corrosion of Crude Oil Tanks

Due to the water content of crude oil, a layer of oil precipitation will form at the bottom of the tank, which will cause serious corrosion relative to the bottom of the tank. Considering the overall situation of oil tank corrosion, the bottom of the tank often has the highest degree of corrosion, usually pitting corrosion is the main corrosion, and if serious, perforation at the bottom of the tank will be formed [3]. Wang Tao [4] analyzed the corrosion mechanism of the inner floor of crude oil tank in detail, analyzed the gas such as deposited water, hydrogen sulfide and carbon dioxide at the tank bottom, sulfate reducing bacteria, and gave the corresponding anti-corrosion methods. With the development of science and technology, more and more new technologies are applied to the tank floor detection. Hu Zhihai et al. [5] used acoustic emission detection technology to analyze the acoustic emission signal to judge the corrosion state of the floor, which has certain theoretical guidance for judging the corrosion state of the floor by the corrosion rate. Liu Qihua [6] and others used acoustic emission technology to obtain the acoustic emission information of the bottom plate of the tank, combined with the parameters of the tank itself, and established a model to evaluate the corrosion of the tank by combining genetic algorithm (GA) and neural network, which has a certain reference value for the evaluation of the corrosion of the bottom plate of atmospheric pressure tanks in China. Zhao Junwei [7] and others discussed and analyzed the far-field eddy current detection technology applied in the tank floor detection process, which provided support for the tank floor corrosion detection work. Yawei Lu et al. [8] analyzed the influence of deposited liquid on the corrosion of tank floor from a microscopic point of view, which plays a certain role in preventing the corrosion of tank caused by coal liquefaction.

The tank roof seldom contacts with the storage medium directly, so chemical corrosion is the main cause of corrosion in the gas phase part of the tank [9]. Water entering the tank through the breathing valve combines with corrosive gases such as $O_2$, $CO_2$ and $SO_2$ volatilized from the crude oil to
condense into acidic solution on the inner surface of the tank, resulting in corrosion. Atmospheric corrosion is one of the main causes of corrosion on the outer wall of tank roof. A large amount of water vapor, oxygen, carbon dioxide and other gases exist in the atmosphere, which together with the accumulated water on the tank roof, form a weak acidic solution to cause corrosion on the outer wall of tank roof. In addition, defects in the welds and insufficient sealing of the insulation layer may cause corrosion on the top of the tank [10]. He Mei et al. [11] analyzed the causes of floating roof corrosion of large floating roof crude oil storage tanks and proposed corresponding solutions. Zhang Yongxian et al. [12] made corresponding preventive study on the corrosion mechanism of aluminum floating roof of methanol tank.

The bottom edge plate of the tank is connected with the tank foundation. Due to the change of tank load and ambient temperature, a large gap will be formed between the bottom edge plate and the tank foundation. Rainwater and other corrosive media deposit around the edge plate, causing serious electrochemical corrosion, thus reducing the life of the tank [13]. Therefore, the edge plate of the tank is also one of the main anti-corrosion parts [14]. In addition, due to the temperature effect, the corrosion of the heated tank is more serious than that of the normal temperature tank. No matter which construction technology, material, method and structure are used for the edge plate corrosion protection of storage tank, it has a great relationship with geographical area, climate, worker, etc.

The inner wall corrosion of the tank body is mainly liquid corrosion, mainly from the oil itself. This liquid corrosion will not be too serious when the gas-liquid interface changes little. In general, the corrosion degree of the outer wall of the tank body is lighter, and the corrosion of the outer wall of the oil tank belongs to atmospheric corrosion. The climate conditions and the degree of atmospheric pollution in various regions have different effects on the corrosion degree of the outer wall of the oil tank, and the corrosion situation has a certain correlation with the environment of the tank. Generally, coastal cities and cities with higher industrialization have the most serious corrosion [3], because the atmospheres of coastal cities or cities with higher industrialization contain more salt particles and chlorides, which will form a water film on the metal surface so that oxygen can reach the metal surface more easily, thus accelerating the corrosion of the metal.

2.2. Corrosion of refined oil tank

The corrosion of refined oil tank is mainly affected by water, air, sulfide, chloride and other substances, which often occurs on the tank roof, wall and bottom inside the tank. The main characteristics of tank roof corrosion are gas phase space corrosion, accompanied by uneven pitting corrosion, and usually comprehensive corrosion. When the temperature is higher, the water vapor on the tank roof is more and the corrosion is more serious. The corrosion characteristics of tank wall are mainly pitting corrosion with uniform distribution. Corrosion points mainly occur at the oil-gas interface and water-oil interface, about four fifths of the tank wall height. The corrosion degree is related to the type of refined oil, water content, temperature, etc. The corrosion of the tank bottom of the refined oil tank is the most serious, and it is also the most difficult to find out the corrosion. It is mainly ulcerated pitting corrosion, especially at the weld and depression of the tank bottom. Whether the corrosion is serious or not is related to the water content of the refined oil, and sulfur, chlorine and other elements in the refined oil will accelerate the corrosion of the tank bottom.

3. Anti-corrosion measures for storage tanks

There are many kinds of anti-corrosion measures for storage tanks. Corresponding anti-corrosion measures can be selected according to different corrosion sites and different corrosion mechanisms. In recent years, most of the anti-corrosion of oil tanks have used coating protection, cathode protection and biological anti-corrosion, operation and maintenance technology to alleviate the corrosion of oil tanks. Among these anti-corrosion measures, coating anti-corrosion is one of the main means of oil tank anti-corrosion. In recent years, relevant experts have improved and standardized the corrosion protection of coatings, and further clarified the corrosion protection measures of storage tanks [15].
3.1. Coating Protection of Tanks
The coating anticorrosion protection for storage tanks is the most common, effective, economical and practical anticorrosion protection measure to delay tank wall corrosion [16]. When choosing the internal anti-corrosion coatings, the following conditions should be met: (1) the chemical properties are stable, and the coatings need to have good acid and alkali resistance; (2) good waterproof performance; (3) high temperature resistance; (4) good compression and wear resistance; (5) good insulation performance. In the selection of anti-corrosion coating for storage tanks, epoxy coating has become the first choice for anti-corrosion in oil storage tanks at home and abroad due to its stable chemical properties, good compression resistance, good wear resistance and good electrical insulation performance, and it is more common in the application of anti-corrosion for the inner wall of oil storage tanks. In recent years, more new technologies and new anticorrosive coatings have been applied, especially vinyl ester resin, which has a relatively mature preparation process [17,18], owing to its better high temperature resistance, corrosion resistance and other properties, so it has a good development prospect. Fluorocarbon coatings are also widely used in the anti-corrosion of crude oil tanks, which is a new type of film-forming base material fluorocarbon resin. At present, fluorocarbon coatings have a very wide application prospect in the anti-corrosion work of crude oil tanks. Dong Zhanfen [19] and Hongliu [20] introduced vinyl ester resin and fluorocarbon coating in detail, and prospected the future development. Marcella Grosso et al. [21] applied eddy current detection technology to the detection of tank coating, which provided a new idea for the field anti-corrosion construction. Zhang Yongji [22] introduced the analysis of intelligent detection technology of anticorrosive coating thickness for large storage tanks, which plays an important role in the later operation and maintenance of anticorrosive coating.

3.2. Surface Treatment of Tanks
Before painting the anticorrosive material, the outer wall of the tank will be surface treated. Ultra-high water jet is generally used to completely remove the oil pollution, rust and other adhesives on the surface of the tank. Surface treatment of storage tanks not only effectively avoids secondary metal pollution caused by sand blasting and shot blasting, but also avoids static electricity and has high operation safety, which has an impact on whether the anticorrosive materials applied to oil tanks can achieve the desired effect [3]. The surface antiseptic treatment of the tank can make it achieve the designed antiseptic effect, prolong the service life of the tank, and meet the technical requirements of oil storage and transportation [23]. When surface treatment is carried out, anticorrosive construction is not carried out until the outer surface of the tank presents a uniform metallic color and the rust removal grade needs to reach Sa2.5 or Sa3.0 [24]. Jorge Felipe Ramos Pontes et al. [25] studied the effect of corrosion inhibitors used in surface treatment on the anti-corrosion performance of epoxy coating system, and finally concluded that brine solution with borax content of 1% had the best inhibitory effect on the surface of carbon steel and zinc, which had a certain reference effect on the surface treatment work in practical engineering. C.I Elsnel et al. [26] evaluated the effect of surface treatment on the anticorrosive performance of the coating system, and concluded that the surface treatment of steel materials can improve the anticorrosive performance of the material well and make the steel better protected by the coating. Therefore, the surface treatment of the tank is an important measure to improve the anti-corrosion effect of the tank.

3.3. Cathode Protection of Tanks
The principle of cathode protection is cathode polarization of the metal at the bottom of the crude oil tank to reduce the probability of corrosion of the metal at the bottom of the crude oil tank. Cathode protection is generally divided into two types: sacrificial anode and current protection. The anticorrosive coating of crude oil storage tank plays a certain isolation role in anticorrosion to avoid the corrosion current generated by cathode and anode in corrosive battery. However, corrosion, aging and other problems often occur in the anti-corrosion coatings. Sometimes there are defects and pinholes in the construction, which seriously affect the protection effect of the anti-corrosion coatings.
Therefore, it is not ideal to use the anti-corrosion coatings alone. However, the use of cathode protection measures alone will result in an increase in power consumption and thus increase costs. Therefore, joint protection measures are generally adopted, i.e., cathode protection is applied in the places where the corrosion layer is most damaged, such as the bottom plate of the tank [27], which has the best effect and reasonable cost. Jia Shengwei et al. [28] evaluated the cathode protection project of steel storage tanks in the Third Oil Production Plant of Dagang Oilfield, and proved the feasibility of cathode protection measures in anticorrosion protection. Zhang Shihu et al. [29] evaluated the operation of the cathode protection system of the storage tank in Sulige gas field. The combined protection mode of "anticorrosion layer + cathode protection" was adopted for the storage tank and pipeline, which could protect the storage tank and pipeline and prolong the service life. In order to effectively solve the problems of large-scale sewage tank inner wall sacrificial anode cathode protection, such as large consumption of anode itself, short service life and difficult on-line monitoring, Li Junlong et al. [30] used the method of forced current cathode protection to protect the sewage tank from corrosion, and achieved good results. Khalil M Abed et al. [31] studied the effect of volatile corrosion inhibitors on cathode protection, which is very helpful for the selection of preservatives in practical engineering. W. J. Santos et al. [32] combined cathode protection system with boundary element method to propose a new anti-corrosion technology for storage tanks, which provides a new idea for anti-corrosion methods.

3.4. Biological Desulfurization Technology

Sulfur element in storage medium (e.g. crude oil) in storage tank is one of the important reasons for tank corrosion. Therefore, microbial strains can be used to reduce sulfur content in storage medium in order to reduce tank corrosion. Biological desulfurization, also known as biocatalytic desulfurization (BDS), is a new technology for removing bound sulfur from sulfur-containing heterocyclic compounds in storage media (crude oil) by using aerobic and anaerobic bacteria at normal temperature and pressure. Compared with the traditional hydrodesulphurization process, the biological desulfurization technology has the advantages of small investment, low energy consumption and low operation cost. Therefore, domestic and foreign experts have carried out a large number of studies on it [33, 34, 35, 36, 37], which is the current research focus.

3.5. Operation and maintenance of storage tanks

The operation and maintenance of storage tanks are also an indispensable part of anti-corrosion work. The corrosion of tank bottom is mostly related to the accumulation of water at the tank bottom, which will accelerate the corrosion of the tank. Therefore, during the operation of the tank, attention should be paid to the water accumulation at the bottom of the tank and timely treatment should be carried out. Storage tanks are threatened by various types of corrosion for a long time in operation. In order to reduce the economic losses caused by corrosion, precise and reliable corrosion monitoring technology [38] should be adopted for storage tanks, so that the corrosion situation of storage tanks can be known in time and corresponding adjustments can be made. Zhang Yongji [22] made a detailed analysis of the intelligent detection technology for the thickness of the anticorrosive coating of large storage tanks, which is of great help to the operation and maintenance of the coating of storage tanks. Li Jingyan et al. [40] made an in-depth analysis on the management problems of fire and explosion prevention, poisoning and asphyxia prevention, temporary power consumption, etc. in the construction of internal anti-corrosion engineering to ensure the safety of anti-corrosion construction in storage tanks.

4. Conclusion and Prospect

(1) Coating protection is one of the main anti-corrosion measures for storage tanks, which has the advantages of small investment and easy operation. Therefore, the later operation and maintenance of the tank coating plays a vital role in the anti-corrosion of the tank, and is the focus direction of the field staff.
(2) Multidisciplinary crossover is the direction of current discipline development. Therefore, the combination of biotechnology and antiseptic technology is a hot topic of current research, and the purpose of antisepsis can be achieved by some green, environmentally friendly and low energy consumption means.

(3) Later operation and maintenance of Tank Anticorrosion work is an essential part of the whole anticorrosion work, so it has higher requirements for practitioners. Therefore, all practitioners and universities should strengthen the training of relevant professionals, transport talents for relevant fields, and do a good job in the future of tank corrosion protection.

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