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Development and Application of Corrosion Monitoring and Management System for Chemical Equipment

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The purpose of this study is to analyze and study the development and application of corrosion monitoring and management systems for chemical equipment. The design and optimization of chemical equipment corrosion management system were carried out through the experimental analysis of the corrosion, corrosion curves and preservatives at the outlet of the oil pump on the second side line of the vacuum distillation tower. The results show that mechanism changing laws and corrosion rate are important considerations for the design of chemical anti-corrosion equipment. It is concluded that by adjusting the preservatives and improving the electrical desalination, the corrosion rate can be reduced, and corrosion indicators can be consistent with the production requirements.

1. Introduction

At the present stage, corrosion is a common problem in the operation of chemical equipment. Improving the corrosion monitoring and management systems for processing equipment is an effective measure to increase the economic efficiency of chemical plants. Although most enterprises have taken some measures to improve anti-corrosion technologies of chemical equipment and optimize the corrosion monitoring and management systems, the current anti-corrosion situation of chemical equipment is not optimistic. This paper analyzes the corrosion, corrosion curves and corrosion inhibitors at the openings of oil pumps on the second side lines of vacuum distillation towers as well as the proportioning of preservatives as a reference for optimizing the current monitoring and management systems of chemical equipment.

2. Literature review

Metal corrosion is ubiquitous. Corrosion of chemical equipment is most common due to corrosion of chemical mediators. Metal corrosion not only wastes resources, but also causes production accidents and casualties. Material corrosion refers to the destruction, metamorphism or deterioration of materials and material properties under the chemical, electrochemical and physical effects of the surrounding medium. Metal corrosion is usually defined as destruction or deterioration caused by chemical or electrochemical interaction between metal and surrounding environment (or medium). Thermodynamically, in addition to a few precious metals (such as gold and platinum), all kinds of metals have a tendency to change into ions. Therefore, metal corrosion is a spontaneous reverse process of metallurgy. The vast majority of metals are subjected to varying degrees of corrosion in the use environment. Corrosion has brought huge economic losses and social harm to human beings. According to statistics, the annual scrap metal equipment and materials due to corrosion are equivalent to 1/3 of the annual output of metal, of which about 1/3 metal materials cannot be recycled because of rusting. The problems of economic loss and casualties caused by corrosion are becoming more and more prominent. Online corrosion monitoring is developing rapidly as the technology of continuous measurement of corrosion rate and some parameters related to corrosion rate. In the domestic petrochemical enterprises, the research and application of the technology become an important topic.
Q345R has excellent mechanical properties and is one of the most commonly used materials for chemical equipment. Due to the corrosion of the actual chemical production medium, the corrosion problem of Q345R

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equipment still exists, and some scholars have done research on it. Bibi et al. studied the stress corrosion cracking (SCC) sensitivity of Q345R in H_2S medium by uniform design method and slow strain rate tensile (SSRT) test. It was found that the concentration of SCC sensitive H_2S was between 100-280ppm in the case of acidic pH in the solution. At the same time, the effect of pH on the SCC sensitivity of Q345R was studied by the slow strain rate tensile test and the uniform design method. It was considered that the pH of the solution was the key factor affecting Q345RSCC (Bibi et al., 2017). Grey and Tarascon used the experimental method of wedge open loading constant displacement pre-crack to study the effect of pure carbonate on the occurrence of SCC in Q345R. It was found that Q345R would have SCC only when the pH corresponding potential of sodium carbonate concentration is in the SCC sensitive potential zone (Grey and Tarascon, 2017). Jjunju and others studied the SCC sensitivity of Q345R in carbonate and hydrogen sulfide medium by means of SSRT. It was considered that with the increase of sodium carbonate concentration, the pH of the solution increased, the SCC sensitivity of Q345R decreased, and the SCC sensitivity caused by H2S was very low when pH was between 9-10. At the same time, it is found that the effect of temperature increase on the uniform corrosion rate of Q345R is greater than that of SCC sensitivity by the experimental method of preloading crack with wedge open loading (Jjunju et al., 2016). Kamali et al. used the wedge open loading constant displacement pre-crack specimen to study the SCC caused by nitrate. It was found that the sensitivity of SCC was related to the concentration of nitrate, temperature, pH and O_2; the temperature increased and the sensitivity increased; the sensitivity of pH was unchanged in 3~7, it was more than 7, and the sensitivity of SCC decreased. O_2 content increased, $NO3^{2-}$ concentration was reduced, and SCC sensitivity decreased (Kamali et al., 2016). Leveson firstly used the SSRT test method to study the sensitivity of SCC in the refining medium of Q345R, and analyzed the individual action and interaction action of H_2S concentration, chlorine ion content, temperature and pH value to SCC sensitivity. It was found that the concentration of H_2S has the greatest influence on the sensitivity of SCC, and there was no significant relationship between Cl^- content and SCC sensitivity. For SCC sensitivity, there is interaction between temperature and H_2S concentration. Then, the SCC of Q345R in anhydrous ammonia medium was studied by the method of constant strain pre-crack sample. The effect of environmental factors and stress on the SCC of Q345R in anhydrous ammonia medium was analyzed. It was found that the crack of Q345R in anhydrous ammonia medium was almost no expansion, and the threshold value of stress intensity factor was larger than 90Mpa (Leveson, 2015).

In summary, SCC sensitivity of Q345R is positively correlated with H_2S concentration, temperature and $NO3^{2-}$ concentration, and negatively correlated with $CO3^{2-}$ concentration and O_2 content. H_2S and $CO3^{2-}$ play their role by changing pH of the solution, the concentration of H_2S increases, pH decreases, and the sensitivity of SCC increases; the concentration of $CO3^{2-}$ increases, pH increases, and the SCC sensitivity decreases.

In view of the galvanic corrosion behavior of Q345R, Liu et al. applied the method of full immersion test weightlessness and the steady-state polarization curve of the CHI660B electrochemical tester. It was found that in the 10% concentration of hydrochloric acid, the galvanic corrosion occurred in the Q345R and hash C-276 alloy, the corrosion rate of C-276 alloy decreased, and the corrosion rate of Q345R increased. The corrosion rate was related to time, cathode and anode area ratio, temperature, and velocity. The corrosion rate decreased with time and tended to be stable, and increased with the increase of the area ratio, temperature and velocity of cathode and anode area (Liu et al., 2016). Rezvanizaniani et al. adopted the linear polarization and alternating current impedance spectroscopy of PARSTAT2273 to study the effect of strain on the corrosion rate of Q345R. It was found that the strain increased in the CO_2 saturated solution and the corrosion rate of Q345R increased (Rezvanizaniani et al., 2014). The corrosion inhibition caused by $NaNO_2$ sodium nitrite and bentonite was studied by the method of soaking corrosion experiments by Selcuk. It was found that the corrosion inhibition efficiency was proportional to the concentration after the critical concentration of $NaNO_2$ was reached (Selcuk, 2017).

To sum up, the above research work is mainly on the chemical equipment corrosion. The equipment and materials of Q345 are mainly explored, but it lacks the research of corrosion monitoring management system. Therefore, based on the above research status, the development and application of corrosion monitoring and management system for chemical equipment are focused on. The corrosion analysis of the second side oil pump outlet, the on-line corrosion / etching thickness measurement technology, the selection and application of the anticorrosion material and antiseptic additive are studied in detail. The corrosion monitoring and management system of chemical equipment is also of very important application value.

3. Experiment principles and methods

The key issue affecting on-line electrochemical technology at industrial sites is the delivery of noises to the metal electrodes and circuitry to be tested through conducting media, which results noises hundreds of times that of useful signals that may cause fatal effect on the accuracy of measurement. Therefore, effective processing of noises is the key to the success of on-line electrochemical monitoring technology. The Institute of Metal

Research, Chinese Academy of Sciences has successfully developed the on-line electrochemical monitoring technology through years of efforts. The advantages of this technology mainly include real-time collection of corrosion data, real-time view of data in the control room terminal, free distribution of monitoring points within the scope of 1000m and regulated data management. In order to reduce the damages to the tested electrode, the monitoring systems are chosen according to the application environments and the polarization resistance ranges of the measurement systems for weak polarization measurement and the linear polarization measurement. If the polarization resistance is low (that is, the corrosion rate is high), the linear polarization measurement will be chosen, and it is required to determine whether to adopt AC impedance technology to eliminate the impact of dielectric resistance according to the impact of the dielectric resistance on the measurement results.

4. Experiment analysis and results

4.1 Corrosion monitoring curves and analysis

Figure 1 shows the trend curve of the inlet corrosion depth of the atmospheric tower top heat exchanger, which was increased by 32μm from October 18 to October 27, 2014, and the average corrosion rate was l.29mm/a; after sampling of the sewage on the atmospheric tower top, the corrosion rate was measured to be 1.05mm/a with a CMB-510B electrochemical instantaneous corrosion rate meter and 0.85mm/a with a portable inductive probe. The results of the three methods are close and the data are thus reliable. The measurement results show that the corrosion rate is high, and it required to remind the production workshops to take measures for process improvement.

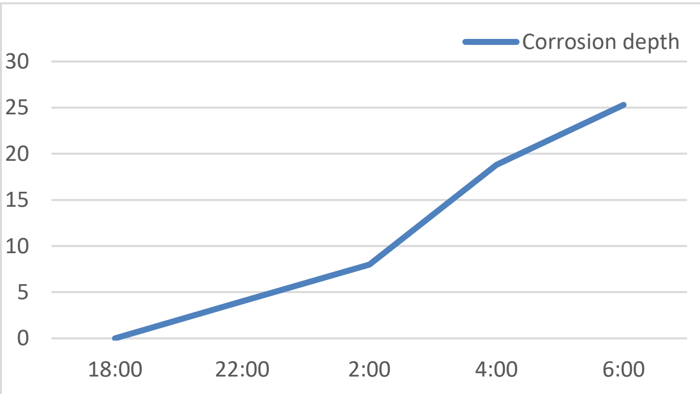

Figure 1: the trend curve of the inlet corrosion depth of the atmospheric tower top heat exchanger

The corrosion depth curve is divided into three sections, a-b, b-c and c-d, to calculate the corrosion rate, as shown in Table 1. The corrosion rates of the three sections were 0.99 mm/a, 1.73 mm/a and 0.17 mm/a, respectively. Since the preservative adjustment and electrical desalination improvement started on October 27, 2014, the corrosion rate has been greatly reduced and the corrosion indicators have reached the production requirements. The combination of the application of on-line corrosion monitoring technology with the tower top sampling, especially the routine analysis in the initial application stage, is indispensable. As shown in Figure 4, the ferric ion concentration and chloride ion concentration during October 22, 2014 -23 were too high, and the pH values were too low, so it can be judged that the corrosion was increased during this period. The results of on-line monitoring for tower top sampling are consistent.

Table 1: stage corrosion rate calculation list

Time segment	Corrosion depth added value	cycle	Corrosion rate
a-b (18:00-6:00)	9.5	84	0.99
b-c (6:00-10:00)	24.5	124	1.73
c-d (10:00-18:00)	2.0	104	0.17

4.2 Analysis on the corrosion at the outlet of oil pump on the second side line of the vacuum distillation tower of the refinery

The application of resistance probe technology to on-site monitoring of the reaction speed (i.e., test sensitivity) has been suspected, and a set of monitoring results with the corrosion rates of less than 0.lmm/a were analyzed. The probe was installed at the outlet of oil pump on the second side line of the vacuum distillation tower, where the temperature was 305°C and the pressure was 0.2 MPa. The corrosion depth was firstly measured, and its increment was adopted for the calculation of the corrosion rate.

The total corrosion depth measured from May 1, 2015 to July 14, 2015 was 7 μm and the corrosion rate was 0.035 mm/a. The corrosion at the outlet of oil pump on the second side line of the vacuum distillation tower was slight, so no further adjustment to the anticorrosion measures was required. In addition, although the corrosion loss of the probe is very low, the data obtained by the monitoring system under harsh industrial environment is very stable, indicating that the monitoring sensitivity and stability of the resistance probe are relatively high and can be used for the monitoring of weak corrosion environments and the observation of the effect of preservative filling on the tower top.

The high-temperature resistance probe has been developed to solve the problem of serious corrosion at high-temperature parts in domestic refineries when refining high-sulfur and high-acid crude oil while lacking monitoring means. Advanced sealing technology and unique production process are adopted to ensure the probe to work stably and reliably in the temperature of 0 ~ 540 ℃ and the pressure of O ~ 2MPa. The successful application of this technology symbolizes that refineries may monitor the corrosion in any process at atmospheric and vacuum pressures.

4.3 On-line corrosion/etching thickness measurement technology

Corrosion monitoring, originally a mixture of such technologies as corrosion test and non-destructive field testing equipment, functions to carry out regular on-line or off-line testing on the corrosion of the equipment with corrosion tests and non-destructive testing technology so as to obtain related data as corrosion rate and ion concentration. The continuous updating of the monitoring technology reflects the development of corrosion monitoring technology. For example, the application of new technologies such as high-temperature resistance and inductive probes has expanded the scope of corrosion monitoring to a certain extent and improved the monitoring accuracy. With the development and application of modern computer technology and programs, the corrosion management system is constantly evolving. At present, the system structure mainly includes two server systems, browser and a client, with enhanced features of software development and improved data processing and analyzing capabilities, thus facilitating quickly search and management of the data.

Table 2: Comparison of ultrasonic technology

Compare	Conventional ultrasonic technology	New Ultrasound (MIST) Technology
Corrosion measurement	Yes	Yes
Corrosion rate detection accuracy	10--25mpy	l-3mpy
The time required	A long time	At least 30 times faster
Online wireless technology	No	Yes
Database support	No	Yes
Dynamic corrosion monitoring	No	Yes

The field application of online corrosion/etching thickness measurement technology is as follows: new ultrasonic sensors are bond onto the surface of the pipe to be tested for transfer of dynamic data to a computer in the central control room (see Figure 2) on a regular basis. This system, adopting the MIST technology, is advantageous over conventional ultrasonic technology in high accuracy and fast response, etc. Due to the use of the online monitoring mode, the monitoring efficiency is improved. Table 2 shows the comparison between the new on-line ultrasonic thickness measurement technology and the conventional ultrasonic thickness measurement technology.

Figure 2: German ultrasonic sensor

The online corrosion monitoring technology is further expanded to the monitoring based on the corporate network, in which the data can be viewed and downloaded over the LAN. Adopting the S / C (SERVER / CLNET) technology, the terminal computers of the corrosion monitoring system can become front-end collectors in the corporate network for data exchange with several online monitors at the site via the front-end collectors of 485 communication line, and the acquired data are stored in the local machines. The clients run a different version of the program from that of the front-end collectors, namely, the "client program". In the corporate network, each terminal is assigned a unique IP address. By entering the IP address of the front-end collector on the client, the user can obtain the field data and preset system information.
The corrosion monitoring corporate LAN allows the users to browse data of other terminals in the network, but not to process the data from other terminals or sending the processed data back to the original collector for storage, in addition, remote management of data and sharing of data in other related industries are also urgent, so such features cannot be realized without the support of the Internet. To develop the Internet platform for corrosion monitoring, it is required to pay attention to the data security and prevention of virus attacks, other concerns include facilitating the site management and services of developers; and due to the high requirements for the initiation of the development, it is required to consider that the future development target is a national online corrosion monitoring network and the Internet-based development of corrosion monitoring will be a new milestone for the development of corrosion monitoring.

4.4 Selection and application of anti-corrosion materials and anti-corrosion additives

The content in the reprinted Manual on Corrosion and Protection of Petrochemical Installations and Equipment will not be repeated here. The use of anti-corrosion additives has a history of more than 120 years, and the oil refining and petrochemical industries are major users of them. According to the statistics of the Japan Corrosion Cost Survey Board, in 1997, the expenses in Japan for anti-corrosion additives against metal corrosion was 49.9 billion Yen, accounting for 1.1% of the total cost of anti-corrosion. This figure is almost three times that of the previous (1975) survey, an increase of 0.5 percentage points. This indicates that the use of anti-corrosion additives is increasing year by year. The largest users of anti-corrosion additives are water treatment systems, with such costs accounting for 50.4% of their total costs; and boiler water treatment systems go next with the proportion of 44.0%; the figures of petrochemical process systems and water supply systems are respectively 2.5% and 3.3%.
The development of anti-corrosion additives has undergone three stages. Taking anti-corrosion additives for cooling water as an example, anti-corrosion additives started to extend to clean chemicals after the 1980s (see Table 3). Organic compounds were basically used to meet the environmental requirements, to which domestic practitioners of anti-corrosion additives should pay special attention when developing and choosing anti-corrosion additives.

Table 3: development of anti-corrosion additives for cooling water

purpose	period	Anti-corrosion additives
Anticorrosion effect	1960 years ago	Chromate, phosphate, nitrite, borate, silicate, zinc salt
Effect, economy	In 1960-1980	Cationic, polyphosphate, vanadate, aluminate, sulfonate, polyacrylate, colloidal salt, interfacial active ao mixture
Effect, environmental protection	1980-now	Tannic acid, natural compound, surfactant, acid derivative, natural polymer, ozone

In order to ensure long-term operation of the equipment, it is important to monitor the equipment around the clock in addition to stabilizing operating parameters, improving equipment materials and proper use of anti-corrosion additives.

Predecessors have summarized various corrosion phenomena in the operation and proposed corresponding detection methods. However, these methods have certain scopes of application, furthermore, the detection accuracy is also far from satisfaction, and some of them have not yet been put to industrial applications, so careful selection is required. For example, for stress corrosion cracking of stainless steel, it is very difficult to accurately measure the depth of the crack, and sometimes you can only wait until the leak was detected to shut down for maintenance. Another example is the determination of ultrasonic testing thickness, in such case you also need to wait until shutdown to verify the accuracy of its determination. Faults are often caused by the interaction of chemical phenomena such as corrosion and material deterioration with mechanical phenomena (fatigue and damage) that need comprehensive consideration.

5. Conclusion

Mechanism changing laws and corrosion rate are important considerations for the design of chemical anti-corrosion equipment. According to the experiment, by adjusting the preservative and improving the electrical desalination in October 2014, the corrosion rate can be reduced, and corrosion indicators can be consistent with the production requirements. At the same time, stabilizing operating parameters, improving equipment materials, proper use of anti-corrosion additives and all-weather detection are important contents for the development and application of corrosion monitoring and management systems for chemical equipment of enterprises.

Scientific anticorrosive methods and strict supervision system are the development trends for the development of corrosion monitoring and management systems for chemical equipment of enterprises. Understanding the corrosion of equipment through corrosion detection systems will help enterprises to reduce economic losses, ensure the daily operation of equipment and improve the economic benefits.

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