

Discussions of General Methods for Measurement and Monitoring of Corrosion in the Oil & Gas Industry

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Abstract

With a rapid consumption of oil energy, valuing the amount of hydrocarbon is a significantly noteworthy topic in the world. According to the result of studies, the leakage of oil transportation pipelines is one of the central reasons that lead to the waste of oil energy. Although hydrocarbon is a widely used energy, there is another reason makes people have to pay attention to it, which is the serious influences created by the accidents of oil leakages. Furthermore, based on the studies, there are many reasons could result the failures of pipeline systems. However, the prominent reason causes the leakage accident of oil pipeline systems is the corrosion issue of pipelines, pipeline corrosion can reduce the strength and integrity of pipelines' structure. Therefore, engineers have realized that predicating the corrosion of pipelines can make contributions to avoid the failures of transportation systems. As a result, lots of technologies have been developed to detect the corrosion of pipelines, which could be classified into five categories, Electrical Resistance Monitoring, Electrochemical Methods, Hydrogen Monitoring, Weight Loss Coupons, and Non-Destructive Testing Technology. The main purpose of this essay is going to give a brief introduction and detailed analysis about those technologies.

Key words: Pipeline corrosion; Detection methods; Transportation systems

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INTRODUCTION

Pipeline system takes an important part in oil production. After oil is discovered from underground, it is a significant process to transport products to the exports safely and successfully. Due to pipelines are usually buried underground or exposed to the atmosphere, when leakages happens during the transport system, it could cause lots of damage to the surroundings and losses to the oil company. Because oil is a non-renewable resource, it is really a precious possession for human's social life. Furthermore, the lamentable loss for the oil company is the economical losses. According to one report, it costs \$300 billion to solve the corrosion problem every year^[1]. However, the worst thing is the serious results to the local environment. There is a famous example to show how badly the leaked oil will influence the environment. On 24 March of 1989, The Exxon Valdez oil spilled in Prince William Sound, thousands of marine creatures were killed, and the economical system of local residence was broke up. It took over 30 years for the local society to recover. Therefore, detecting and monitoring the pipeline system is significantly important^[2].

1. CAUSES OF PIPELINE FAILURE

Understanding what kind of reasons can lead to the failure of pipe system is significantly important to achieve successful oil and gas transportation. As far as known, pipes are usually buried under ground or over ground at the atmosphere. Due to the environment of underground and over ground continually changing, some natural causes could influence the normal working or even result in injuries to pipelines. Damage caused by earth movement, heavy rains, flood, high winds, changes of temperature and other weather changes cannot be avoided. Besides these natural effects, humans make some accidents happen as well. For example, pipelines are broken by excavation by

operator or struck by vehicles. Furthermore, failed materials and equipment also could weaken petroleum transfer structure. However, the vital reason leads to numerous accidents is corrosion issues. According to the US Department of Transportation's Research and

Special Programs Administration, the main reason of transmission accidents is tube corrosion in the year between 2002 and 2003. The figure 1 below shows the accidents percentage of each kind failure happened in one year with various reasons^[3].

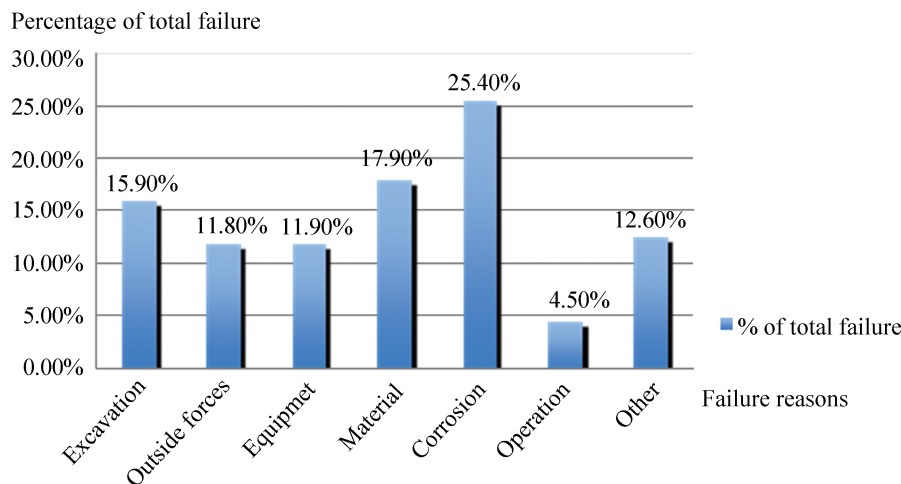


Figure 1
Pipeline Accidents Summary by Causes

1.1 Main Causes of Pipeline Corrosion

Due to pipeline corrosion, the wall thickness, strength and integrity of pipelines are reducing. Furthermore, leakages and degradation of pipelines may happen during the oil and gas transportation. The pipeline corrosion can be definite like this, which is pipeline corrosion is a deterioration of tubing metals, and this phenomenon is because of electrochemical or chemical reactions between the metal and its environment. Corrosion cannot be recognized obviously until degradation is well advanced. Basically, there are two main parts of pipeline corrosion, which are internal corrosion and external corrosion.

External corrosion means deterioration happens outside pipelines. Those transmission pipelines are exposed to the ground or atmosphere, and the changeable components of surrounding result in the corrosion of outside tubing. Compared to external corrosion, internal corrosion is harder to control. There are two types of corrosion always occur inside pipelines, which are sweet corrosion and sour corrosion. The existence of CO₂ and H₂S leads to sweet and sour corrosion happens in the hydrocarbon flows.

1.1.1 Sweet Corrosion

Carbon dioxide and water are essential substances for sweet corrosion to occur. CO₂ is a common compound of environments in the oil field. Moreover, it is also an erosive component found in crude oil, natural gas, compensated and produced water. Carbon dioxide is one of the highest soluble acid gases in oil and gas transport system. The sweet corrosion phenomenon is due to the formation of carbonic acid. H₂CO₃ is produced after carbon dioxide solute in the water. The existence of carbonic acid leads to the decrease in the pH value of

water, and increase the corrosion possibility of fluids inside tubing. Therefore, sweet corrosion happens when acids contact with metals inside pipelines^[4].

1.1.2 Sour Corrosion

Hydrogen sulphide is a poisonous gas, which often could be found in oil field where is located at shale or sandstone, and there are 40% of wells have hydrogen sulphide. Measuring the partial pressure of corrosive gases could be helpful to determine if the fluid is soured or sweet in the pipelines. The fluid is soured and corrosive, when the partial pressure of hydrogen sulfide is over 0.05. However, the main substance lead to sour corrosion is not hydrogen sulphide, but is sulfuric acid. Due to H₂SO₄ is a corrosive component and also is the product of the reaction between water and H₂S, the source of hydrogen ions is provided by sulfuric acid which will result in corrosion inside pipelines.

1.2 Types of Pipeline Corrosion

1.2.1 Galvanic Corrosion

The potential differences of metals are due to the various activities of pipeline metals. A more active metal and a less active metal are contact in an electrolyte. Because of the electrochemical action, one metal to be the cathode and the other one will be the anode, and the more active metal is going to dissolve in the liquid medium. This kind of corrosion is called galvanic corrosion.

1.2.2 Intragranular Corrosion

Typically, intragranular corrosion occurs in the pipe wall and at the grain boundaries of a metal, and the boundaries are anodic to the surround grain materials. The diversity in purity levels and the misaligned strain energy of atoms in the grain boundaries cause this corrosion.

1.2.3 Localized Corrosion

Pitting, stress-corrosion cracking, crevice corrosion and filiform corrosion are belonging to localized corrosion. Usually, localized corrosion exists at special area of pipe surface. Pitting occurs at small areas of the pipeline surface, and results in deep, narrow attack. High operating temperatures and tensile stress lead to the high stresses which restrict pipelines, consequently, corrosion happens in tubing and cracks exist could result in leakage of flowing. When screwed fitting are joined with pipes, crevice corrosion will exist at the junction surfaces and result cracking of pipelines.

1.2.4 General Attack Corrosion

General attack corrosion occurs in a similar way with localized corrosion, the main corrosion mechanism is the electrochemical process. As a result, the pipelines trend to be thinning uniformly.

1.2.5 Fretting Corrosion

Usually, repetitive slip takes place at the connected areas of two surfaces, and it leads to the decrease of protected film. Therefore, metal deterioration results from the slip, which means fretting corrosion happens.

2. GENERAL DETECTING AND MONITORING METHODS FOR PIPELINE CORROSION

The report of oil spill accident at Arabian Gulf states that, it is estimated about 144,000 metric tons of oil polluted the area of Arabian Gulf in 1979, and 43% of those accidents are the result pipeline failure^[5]. However, the worst results of those failures are damage to the marine environment and its economical sources, which also could break down human life. This accident shows the serious consequence of oil pollution. Hence, the results of oil spill incidents are not only the loss of the oil company, but also the significant damage to the environment.

It is well known that corrosion is not only occurs in pipeline, but also happens in other facilities. So, control of corrosion is important in oil engineering. Since corrosion exists, a basic control theory has been developed to monitor corrosion issues. The theory of corrosion control has four basic aspects.

(a) The correct and detailed information of oil field can make great contributes to the engineer design. For example, choosing suitable pipeline material and transportation route are depended on the accurately information of the oil field surrounding. Furthermore, choosing suitable pipeline material also can minimize the possibility of corrosion occurs.

(b) To meet the requirement of environmental conditions, choosing an appropriate material of pipeline is essential.

(c) Coating is indispensable to separate the metal materials with environments. Corrosion can be decreased through coating as well.

(d) Monitoring the environment of oil system can prevent the formation of corrosion. And modifying the process environment can reduce the possibility of corrosion occurrence.

But corrosion control process can be successful and leakages can be avoided due to the completely corrosion measurement, which means corrosion detection is much more important. The goal of corrosion monitoring is to give a detailed and correct indicator of the corrosion damage happening potential^[6]. The indicator can make great contributes to prevent significant corrosion damage occurring. Because of the variation and changeable of tubing surroundings are hard to predict, which means the outstanding reasons are hard to predict, and the best method to solve this problem is detecting and monitoring the internal pipeline corrosion issues thoroughly.

As previously mentioned, there are kinds of different corrosion could occur in pipelines, therefore, only one inspection method or tool cannot monitor all kinds of corrosion. Varied methods detect and monitor corrosion issues with different corrosion types. But there is a summary of the most important and basic corrosion related parameters, which can be used for corrosion measurement.

- (a) Fluid flow
- (b) Presence of a water phase
- (c) Carbon dioxide fugacity
- (d) PH level of fluid
- (e) Temperature of fluid
- (f) Pressure inside pipelines

Since the development of corrosion monitoring, lots of detecting methods have been developed to monitoring the corrosion and corrosion degree of pipelines. It is well known that some methods are used for surface inspection. For example, visual examination, acid pickling and etching, magnetic particle, liquid penetrant and eddy current. Those methods are measuring the external corrosion at the surface of pipelines, and are usually very easy to operate. Compare to the external inspection, internal inspection is much more complicated. Based on a summary of corrosion detection methods, those inspecting technologies could be classified into five categories.

- (a) Electrical Resistance Monitoring
- (b) Electrochemical Methods
- (c) Hydrogen Monitoring
- (d) Weight Loss Coupons
- (e) Non-Destructive Testing Technology
- (f) Optical methods of monitoring pipeline corrosion

Each kind of measuring methods has different working principle, and varied advantages. Some methods will be introduced in next part. But according to the practical applications, the most common and widely technology used for detecting corrosion is the electrical resistance technique^[7].

2.1 Electrical Resistance Monitoring

The basic working principle of electrical resistance measuring technique is monitoring the changes in resistance of a metal element. Because a change in resistance is proportional to a growth of corrosion, monitoring the differences of resistance number can inspect the degree of corrosion. The detail calculation process of electrical resistance monitoring is showed in

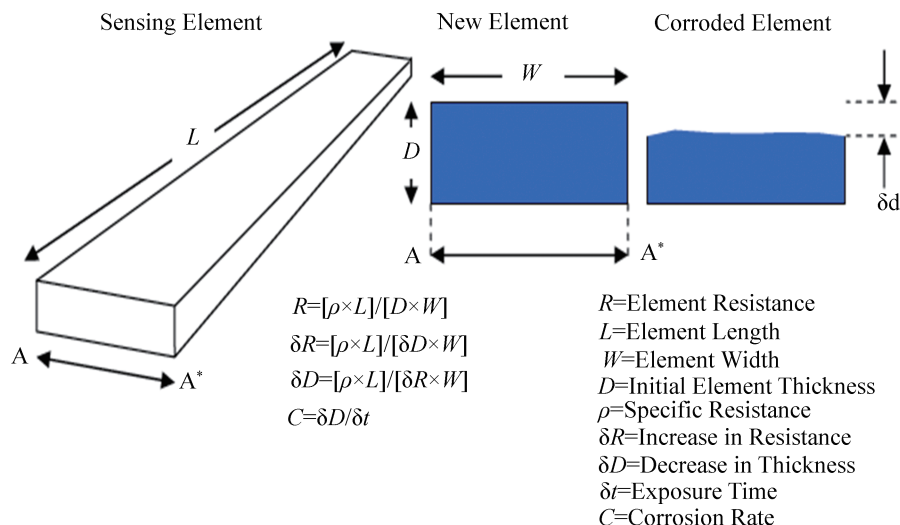


Figure 2
Basic Theory of Electrical Resistance Monitoring

2.2 Electrochemical Methods

Because the underlying phenomenon of corrosion is a combination of electrical and chemical processes, lots of detecting methods are developed based on electrochemical monitoring. The basic working theory of electrochemical monitoring is detecting the electrochemical change by electron transfer. Commonly, the most widely used technique to detect corrosion in oilfield is linear polarization resistance^[8].

In linear polarization resistance, some key factors take important places. They are a resistance between the corroding interface and the reference electrode, and the polarization resistance, which is the most important factor used to calculate the corrosion rate. According to the study of linear polarization resistance technique, the Stern-Geary equation is needed in this technique, which was discovered by Stern and Geary in 1957. The Equation (1) is showed below.

$$I_{\text{corr}} = \frac{\beta}{R_p} \quad (1)$$

Where, the I_{corr} is the corrosion current. β is the Stern-Geary constant. R_p is the polarization resistance.

Beside linear polarization resistance, there are another three techniques used widely in oilfield, which are wide potential scans, alternating current impedance and electrochemical noise.

2.3 Hydrogen Probes

When the PH level is lower than 7, it means corrosion reactions could happen, and hydrogen gas is generated

inside the pipeline. Therefore, hydrogen probes can be used to detect corrosion in pipelines. The successful development of hydrogen probes is depended on the investigation, which measures the flux of hydrogen passing through the steel. The flowing build up a pressure within the probe, and correlates this pressure with the causticity of the system. Hence, the corrosion damages related with hydrogen can be measured.

Figure 2. Basing on the electrical resistance monitoring theory, electrical resistance probes have been developed. The function of electrical resistance probe is converting the data of resistance to the corrosion engineering's office, and the engineers will go further analyze. Beside the electrical resistance probe, some other traditional methods are measuring the surface resistivity or conductivity of tubing, which are based on direct current electrochemical methods.

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2.4 Weight Loss Coupons

Weight loss coupon is an old accessing to corrosion measurement. The working principle of this tool is that the occurrence of pipeline corrosion could lead to the changes of the pipeline weight. It means the corrosion rate could be proportioned to the weight loss of pipelines. Therefore, weight loss coupon is used to measuring the related weight loss of pipelines, and coupon provides the data of integrated corrosion loss. Figure 3 shows some examples of weight loss coupons.

2.5 Non-Destructive Testing Method

None-destructive testing method means when using techniques to test a subject without effects and damages to the piece itself. This testing method has been utilized to detect pipeline corrosion for a long time. Totally, this method can be used to detect the surface corrosion of pipeline and the internal corrosion of pipeline. Here is a list of some common used techniques, which are non-destructive testing method.

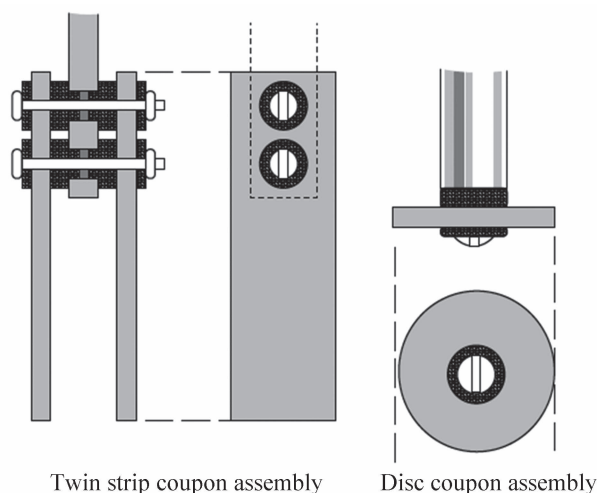


Figure 3
Examples of Weight Loss Coupons

- i. Surface inspection
 - (a) Visual examination
 - (b) Acid pickling and etching
 - (c) Magnetic particles
 - (d) Liquid penetrant
 - (e) Penetrant testing
- ii. Internal inspection
 - (a) Radiography
 - (b) Ultrasonic
 - (c) Pressure and leak testing
 - (d) Eddy current

However, radiography is the most adaptable non-destructive inspection technique in oilfield. X or gamma rays are energy sources of this technique to detect the corrosion inside pipelines, and the result of detection can be showed by the creation of images on film or digital media. A simple working process of radiography is showed in Figure 4. The basic theory of radiography is that it can measure the thickness of pipelines.

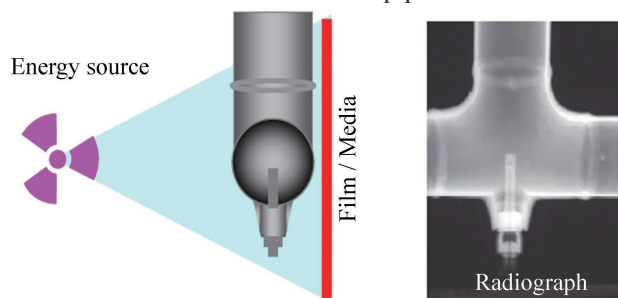


Figure 4
The Process of Radiography

2.6 Optical Methods of Monitoring Pipeline Corrosion

Lots of techniques are mentioned previously, it shows the diversity of techniques used for pipeline corrosion. However, the exploration of new inspection technologies cannot be stopped. Although lots of method can be used to measure the corroded hydrocarbon pipelines, there are drawbacks of each methods^[9]. Such as for electrical

resistance probes, the biggest drawback is that probes have to be inserted into the fluid, which could influence the obtained data when it stays in fluid for a long time. Furthermore, all the electrochemical techniques only can be used in an environment, when the iron sulphide deposits form at a sour condition. The fidelity of electrical resistance probes will be affected in sour systems and the accuracy of direct current electrochemical methods also could be affected by the heating in process. Moreover, hydrogen probes only can provide a general indication about the corrosion inside pipelines. Additionally, in the operation of radiograph, due to X ray and gamma ray are dangerous energy, safety risk exists. Beside this, isotopes are unsafe and also need to be processed and stored securely. Therefore, much more adaptable technologies still need to be explored.

Based on the analysis of pipeline corrosion occurrence, it is clearly known that the significant factor to obstruct the corrosion inspection is the environment of setting pipelines. Commonly, the locations of constructing oil pipelines are underground and undersea. Hence, the poor visibility is a disadvantageous condition to monitor pipeline corrosion. Based on visual disadvantage, new technologies have been developed to overcome this problem.

Reasonably, the requirement for better corrosion detection technologies is an essential to overcome poor visibility in detecting process, and it leads to the exploration of new type technique to inspect pipeline corrosion. Since optic was discovered in 700BC, lots of scientists have kept on studying it and developing techniques based on it. Therefore, with the improvement in optic field, scientists have figured out more information about optical technologies. According to the investigations of optics, optical methods could be recognized one kind of technology with a high sensitive in visibility. Due to the advantages of optical methods in visual characteristic, lots of new substances have been found out, for example, polarization and laser. Furthermore, there is a numeral growth of optical applications, which have been developed and used in varied industrial field. Consequently, engineers have tried to investigate the advanced visibility of optical methods to solve the poor visibility issue in oil field as well. Until now, holography technique and laser induced breakdown spectroscopy are two famous optical technologies, which have a big potential to detect and measure corrosion of oil pipelines. Based on those two theories, some optical equipment was developed experimentally to detect corrosion issue. Such as optical corrosion meter, which is based on holography interferometry, has a potential to be used in oilfield to inspect pipeline corrosion. Evidences will be shown to prove the possibilities of using holography and LIBS techniques for pipeline corrosion in next chapter, and detailed analysis of those two methods is going to be illustrated in next part as well.

CONCLUSION

Hydrocarbon energy has been widely applied in lots of different industries, and plays an important role in human beings life, especially in transportation systems. Therefore, it is really necessary to reduce the potential of wasting this energy during the exploration procedure. Based on the outcome of US Department of Transportation's Research and Special Programs Administration, corrosion of pipelines is a main factor leads to oil spill accidents. Solving corrosion issues of oil pipelines can reduce the possibility of occurrence of oil leakages, there is a rapidly development of detection methods, non-destructive technology could be recognized as a commonly used method to inspect corrosion of pipelines. Using those non-destructive technologies can detect the corrosion of pipelines and help reduce the potential of incidences of pipeline leakages effectively. It is well known that more progressive methods would be developed to control pipeline corrosion in the future.

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