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The Research of Oil and Gas Pipeline Corrosion and Protection Technology

LIU Xu[a]; WANG Xiaoyu[b],*

[a] Daqing Oilfield Company, the Fifth Oil Production Plant, Daqing, China.
[b] Machinery Institute of Science and Engineering, Northeast Petroleum University, Daqing, China.
*Corresponding author.

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Abstract
Corrosion of the oil and gas pipelines not only reduces the service life of the pipelines, serious still can cause major catastrophic incidents. Therefore, research on the corrosion mechanism of oil and gas pipelines and improved protection technology is crucial. This paper introduces the corrosion mechanism of oil and gas pipelines, and the current technology of corrosion were analyzed in details.

Key words: Service life; Corrosion mechanism; Protection technology

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INTRODUCTION
As one of the five major transportations, pipelines, compared with others, have the following advantages: (a) low cost; (b) high efficiency; (c) short construction period; (d) safe and environmentally friendly; (e) suitable for all kinds of areas. Hence, they're generally considered as cheaper, safer and more effective. With the global oil and gas industry developing rapidly, the pipelines for the transport of oil and gas are mainly made of steel and usually burried underground, where, however, the pipelines can get seriously corroded. Once corrosion happens, it shortens the pipelines' lifespan and contaminates the oil within, what's worse, it might lead to inccidents like catching on fire. As a result, having a complete and thorough understanding of corrosion mechanism and its related anti-corrosion technology is crutial.

1. CORROSION MECHANISM IN OIL AND GAS PIPELINES
There are althoger two kinds of corrosions, which are inner corrosion and outer corrosion based on where the corrosions take place. The following paragraphs are the detailed descriptions to these two corrosions.

1.1 Corrosion Mechanism on the Inner Side of the Pipelines
The corrosion on the inner side of pipelines is caused by a series of chemical or electrochemical reactions. These reactions mainly come from the contact between the inner side of the pipelines and the chemicals in the oil and gas during the transport. Besides, erosion is another contributer to the pipeline corrosion.

1.1.1 The Erosive Action of Multiphase Flows in the Pipelines
During the transport, the gravel and detritus produced in exacting oil erode the inner side of pipelines in the oil-gas flow. It generally happens in a corroded environment and is called erosive corrosion due to its combined effect with corrosion. With such effect, the corrosions on the surface of the pipelines fall off and leave it vulnerable to the corrosion.

1.1.2 H_2S Corrossion
H_2S easily ionizes in water which causes corrosion and hydrogen embrittl ement:

$H_2S \rightarrow H^+ + HS^-$, $HS^- \rightarrow H^+ + S^{2-}$, $2H^+ + Fe \rightarrow Fe^{2+} + H_2\uparrow$

H_2S chemically reacts with metal in an aerobic environment:

$2Fe + 2H_2S + O_2 \rightarrow 2FeS + 2H_2O$

$4Fe + 6H_2S + 3O_2 \rightarrow 2Fe_2S_2 + 6H_2O$

$H_2S + 2O_2 \rightarrow H_2SO_4$, $Fe + H_2SO_4 \rightarrow FeSO_4 + H_2O$

H_2SO_4, in H_2S's reaction product, contributes to chemical and possibly electrochemical corrosion.

1.1.3 CO_2 Corrosion

CO_2 tends to cause general corrosion and local corrosion, which happens more often. Local corrosion's chemical corrosion reaction formula is:

$CO_2 + H_2O \rightarrow H_2CO_3$, $H_2CO_3 \rightarrow H^+ + HCO_3^-$

$HCO_3^- \rightarrow H^+ + CO_3^{2-}$

H_2CO_3 contributes to hydrogen polarized reaction of pipelines:

$Fe + H_2CO_3 \rightarrow Fe\,CO_3 + H_2\uparrow$

1.1.4 SO_2 Corrosion

SO_2 reacts with Fe and produces $FeSO_4$ in an aerobic environment, further more, the $FeSO_4$ hydrolyzes into oxide and free acid. Then the free acid accelerates Fe's corrosion and produces fresh $FeSO_4$ which goes into hydrolysis again. With such cycle, the corrosion in the pipelines accelerates.

1.2 Corrosion Mechanism on the Outer Side of the Pipelines

The medium in the surrounding reacts with the outer side of metal pipelines within chemically, electrochemically and physically and causes it certain damages. And these damages are called outer corrosion of pipelines. The soil is complex three-phased system, which makes it a conductor to the metal pipelines. Plus, the oxygen concentration cell caused by the oxygen concentration difference accelerates the pipeline corrosion.

2. ANTI-CORROSION TECHNOLOGY APPLIED TO OIL PIPELINES

2.1 Coating Protection Technology

Applying an anti-corrosion coating to the pipelines' surface helps separate it from the corrosive surrounding and bring down the corrosion rate.

2.1.1 Organic Coating

Organics are known for their relatively better acid and corrosion resistance and are widely used. In recent years, coatings like 3-layered polyethylene（3PE）coating, epoxy coating（FBE）and coal tar coating have been manufactured. Their advantages and disadvantages have been listed in the table below.

Table 1
Advantages and Disadvantages of Organic Coating

	Advantages	Disadvantages
Petroleum and asphalt coating	It has good acid and alkali resistance, high insulativity, water resistance and adhension as well as the ability to prevent the surface from peeling. Besides, materials used to make the coating are abundant and easy to be found; And finally it is cheap with high efficiency	It has low mechanical properties and a thermal stability; It is easy to be damaged by the plants roots and bacteria; It ages fast
Coal tar coating	It has good insulativity and doesn't easily get eroded by the bacteria; It has a low absorption rate and strong adhension with a long lifespan	It has a low mechanical strength and thermal stability; It's highly toxic and vulnerable to soil stress; It requires harsh construction conditions
Epoxy coating	It is compact and has a fine adhension; It is salt and alkali resistant; It has a smooth surface	It has a high water absorption rate and is highly crisp
Three-layered polyethylene coating	It has a fine adhension, penetration-resistance, mechanical properties and soil stress resistance; It's also environmentally friendly	It's expensive and complex to be manufactured; its thickness isn't the same everywhere; its temperature is hard to control; Pores and bubbles are easy to form
Epoxy coal and asphalt coating	It has a fine insulativity and is water-proof; Its surface is smooth; It's heat, wear and discrete current resistant; Its life span is long	It has a long curing period and hard to apply to the surface; It has a low stability
Rubber anti-corrosion coating	It has a fine insulation and is salt resistant; It's firm; It doesn't cost much or pollute the environment as much	It's soft and easy to get damaged; Its field joint coating is difficult to conduct

As shown in the table above, organic coatings all have disadvantages, no matter how well they may function in anti-corrosion. But, some of those disadvantages are not as serious as they seem. Currently, epoxy coating is internationally recognized as one of the best technologies of anti-corrosion and widely used throughout the world.

2.1.2 Inorganic Coating

It's well known that inorganic non-metallic materials are outstanding in resisting corrosion, wear and heat. As a result, using inorganic materials in the manufacture of anti-corrosion coatings has drawn more and more attention for the time being. A few products have been manufactured at home and abroad and recieved great feedbacks.

(a) Cement Mortar Coating

Cement mortar is rich in alkali which produces a passive film on the inside of pipelines and prevents it from getting corroded. It's non-toxic, safe, easy to apply and cheap.

(b) Enamel Coating

Enamel is currently considered as best material with a perfect overall anti-corrosion performance. Except for hydrofluoric acid，it is capable of resisting all kinds of acid and salt and takes its anti-corrosion performance to a new level, besides, it has a fair price. With all these advantages, enamel coating has been generally and widely accepted in the anti-corrosion industry.

(c) Ceramic Coating

Ceramic coating is outstanding in resisting corrosion, oxidizability as well as high temperature and has brought itself so much attention.

(d) Thermal Spraying Glass-Glaze Coating

Mix the technologies of thermal spray and enamel, we get a highly compact and corrosion-resistant coating, that is thermal spraying glass-gaze coating. Its surface is smooth with little resistance.

The latter three coatings are not widely in use, because they are relatively more complex to manufacture. They are more energy consuming and expensive. In addition, they all have low binding strength and are highly crisp, which makes them easy to fall off from the surface.

2.1.3 Composite Coating

Glass-flake coating and epoxy zinc rich primer coating are currently the two better known types of composite coatings. The glass flakes of the coating are parallel to each other and overlap inside the coated film, which forms a compact impervious layer. The layer then forces the medium to take a roundabout into the surrounding and stops the pipelines from getting corroded. Glass-flake coating stands out beacuse of its long life spand and better performance in resisting chemical corrosion, seepage, coldness and heat. As for epoxy zinc rich primer coating, the organic inside resists corrosion. It sacrifices its anode to protect the pipelines from the corrosive surrounding. Epoxy zinc rich primer coating has a fine impermeability and corrosion resistance.

2.2 Technology of Corrosion Inhibitor

The technology of corrosion inhibitor is mainly applied to the inner side of pipelines. By using corrosion inhibitor, it changes the surface of corroded metal or alloy and alternates the reactions between anode and cathode, which decreases the reaction rate and slows the corrosion. Even better, with just a small amount of the inhibitor, the pipelines' life span would be expanded.

2.3 Electrochemical Anti-Corrosion Technology

Electrochemical anti-corrosion technolog, as a spare means, it evidentally increases the efficiency in corrosion resistance.

2.3.1 Impressed Current Protection

Impressed current protection adds negative current to the outside of the pipelines and restrains the corrosion by polarizing its cathode. It is suitable for bad corrosive environment with high resistance because of its flexible control on its anode. But, impressed current protection is expensive and provides electromagnetic interference to surrounding metallic facilities.

2.3.2 Sacrificial Anode Protection

Sacrificial anode protection, against the flaws of impressed current protection, aims to sacrifice the anode to protect pipelines from corrosion. It polarizes the pipelines and brings down the corrosion rate by connecting with some metal, which provides protection current. Sacrificial anode protection is suitable regions with no power supply for it's easy to be conducted and fixed.

CONCLUSION

The corrosion in oil pipelines is unavoidable, that's why it's urgent to study the technologies of corrosion resistance. However, even though China's most materials of corrosion resistance have been localized, our products are still not as good as those of foreign countries due to the lack of technologies. Thus, it's important to improve the manufacture of our anti-corrosion coatings so that more new technologies could be applied to making more oil and gas pipelines with batter performance, lower cost and longer life span.

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