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STUDY OF THE CORROSION FACTORS IN OFFSHORE OIL PRODUCTION UNITS

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Abstract
Oil production in offshore fields is very important because of its operating conditions. The study of corrosion reasons in these facilities are different from onshore fields because of sea water utilization in desalters, compact equipments use and also high costs and risk in replacement of equipment parts.
This paper is going to specify important elements, which cause corrosion of process equipments in offshore oil fields, and also shows different ways for prevention of corrosion by reviewing a case study.
Key words: corrosion, offshore, oil production.

1. Introduction

In some of oil fields, produced oils are consisting of emulsion water, which has soluble salts such as $CaCl_2$, NaCl, and $MgCl_2$.

Oil production processes in oil fields includes demulsifying agents injection, oil temperature increase, use of electrical current.

If the salt content of the oil is high, in addition to dehydration, desalting stage will be necessary. In desalting stage, salt content of oil will be reduced by injection of fresh washing water.

Effective parameters in desalting process are: oil flow rate, temperature, type and flow rate of washing water, severity of mixing, type and amount of demulsifying agents, process pressure and desalter voltage.

In corrosion point of view, onshore and offshore production units are alike. The major differences between them are: supply of sea fresh water, cost of spare parts replacements and also high risk in material selection, platforms space limitation, use of compact equipment and necessary space for chemical injections.

In general, there are 3 parts in oil production facilities, which have high potential to encounter Corrosion:

a) **Well head and charismas tree**: corrosion of this part is erosion type. Produced acid gases from reservoir may increase corrosion rate. The best way to prevent corrosion of this part is proper selection of materials.
b) **Flow lines**: formed deposit in flow lines may cause corrosion and also pitting. Flowing water under oil may cause corrosion too. Corrosion can be prevented by optimum sizing of lines on basis of proper velocity and surface coating and also use of preventive chemical agents can help the prevention of corrosion.
c) **Process equipment**: as it is said, oil production process includes desalting and dehydrating stages, which are shown in fig.1. The main purpose of this paper is study of corrosion in this part of oil production establishments.

2. Description of process

In most of oil fields, oil production process are the same and are shown in fig 1.Crude oil passes through choke valves and then enters 3-phase separator. In this section gas and oil are separated. In order to desalting, crude oil is preheated by treated oil and then it will be heated in a steam heater to

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desalting temperature. Desalting system includes two stages. At the first stage crude oil is mixed with recycled water of the second stage and enters an electrical dehydrator. The emulsion of oil and water will be broken by use of residence time, electrical current and emulsifying agents. Separated water from first stage is sent to disposal water system and oil enters to second stage. In this part, at first oil is mixed with fresh water the same, as first stage and then oil and water emulsion will break in an electrical field. In offshore fields degasified disposed water is injected to disposal wells by booster pumps.

Effective parameters in corrosion of oil production equipments are:

- Conductivity and pH
- Dissolved gases like oxygen O_2, CO_2, H_2S.
- Microbial agents.
- Operating conditions such as: temperature, pressure, and fluid velocity.

Water is another important agent in corrosion of oil and gas equipments. Corrosion rate of emulsified water in oil is lower than separated water from oil, which it is very corrosive.

In general, effective parameters in water corrosion are: dissolved salts, dissolved oxygen, pH and fluid velocity.

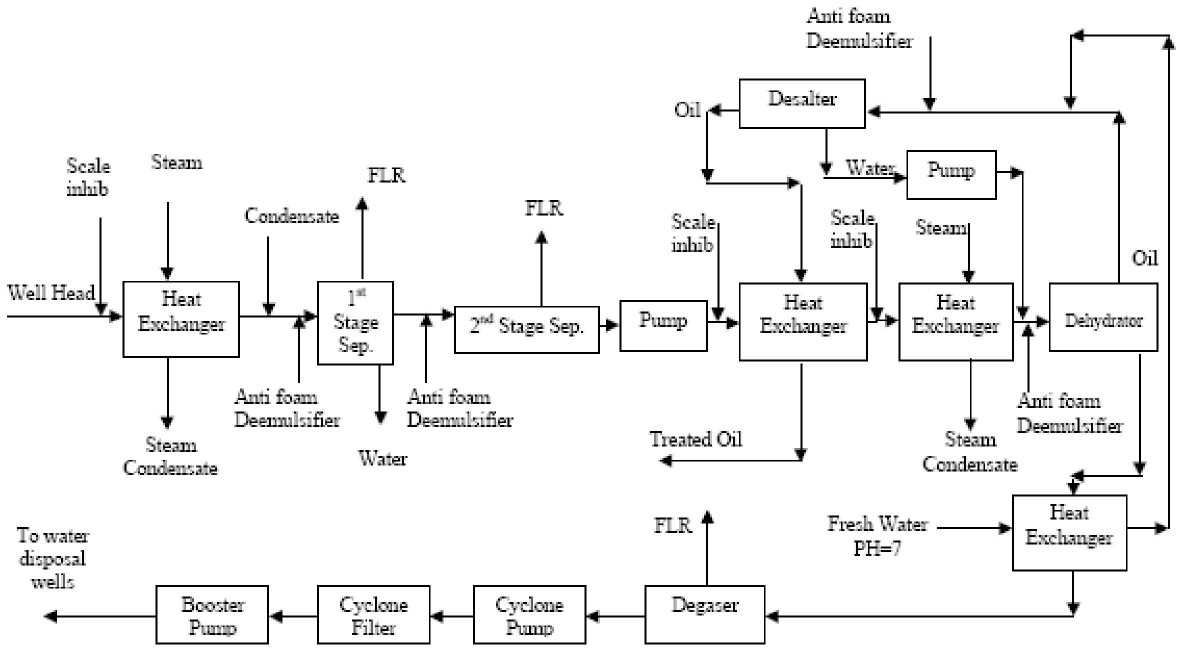

Figure 1- Offshore Oil Production Unit.

2.1 Conductivity and pH

If the surface of a metal is drenched by an electrical solution, there will be an electrical current between anode and cathode in corrosion cell. Corrosion rate will be increased if the conductivity of solution is high.

Distilled water has low conductivity; as a result, its corrosivity is low, in contrast salty water corrosivity is high because of its high conductivity. In oil production process, salt of oil is separated by water so it is one of the important sources of corrosion in desalters and water disposal flow lines.

As seawater is used as washing water in offshore fields, the process of seawater sweetening should be controlled precisely.

pH is another influential factor in water corrosion. Low pH is sign of acidic agents' existence, which increase corrosion rate. Corrosion intensity on basis of pH content is shown in fig.2[1].

2.2 Dissolved gases

Dissolved gases such as O_2, CO_2, H_2S increase water corrosion rate. If these gases escape from water with neutral PH, corrosion will be reduced. Dissolved oxygen as a strong oxidizer agent, has an important role in corrosion. Dissolved CO_2 and H_2S are ionized in water and as acidic factors decrease water pH. Among these gases, oxygen plays the most important role. This gas causes corrosion even in low concentration and its corrosion is usually in pitting form. Seawater is the main source of oxygen in offshore oil production process. Seawater sweetening process is as following:

At first seawater is filtered and then enters oxygen scavenger. In this tower its oxygen content will be decrease to zero by using ammonium sulfite.

In next stage, the salts of seawater are removed in reverse osmosis. Any problem in this process may increase salts and as a result increase in corrosion rate.

As it is said, desalter's water is supplied from sea, so control of the performance of oxygen scavenger in its operating conditions and the quality of oxygen removal agent is very important. A sample of corrosion caused by oxygen in offshore oil production units is shown in fig.3. Another dissolved gas in water is CO_2. When it is solved in water, its pH will decrease because of carbonic acid formation, so water corrosion will be increased. CO_2 corrosion is lower than oxygen but its corrosion is in pitting form (fig.4 [2])

The corrosion, which is caused by dissolved CO_2, is called "sweet corrosion" and the corrosion, which is caused by H_2S, is called "sour corrosion". H_2S of oil is dissolved in water and leads to decrease of pH.

The presence of H_2S even in low concentration causes metal cracking, which is called "sulfide stress cracking". A sample of pipe cracking caused by H_2S is shown in fig.5 [3].

In addition to CO_2 organic acids with low molecular weight such as acetic acid cause corrosion. In some system these acids play the main role in corrosion rate determination.

2.3 Microbial agents [4]

Microorganisms may cause H_2S formation. In oil production processes *Desulfovibrio desulfuricans* bacterium that is known as SRB, may cause H_2S formation too. SRB is anaerobes but it sometimes remains in oxygen water to find an appropriate environment. This bacterium can resist in low concentration of oxygen. The corrosion, which is made by SRB, is called "microbiological corrosion".

SRB converts sulphate ion into H_2S. Formed H_2S reacts with iron and produces FeS, which is cathode to steel and causes corrosion and also attracts more iron toward solution.

2.4 Operating conditions

Like the other chemical reactions, increase in temperature, accelerates reaction rate. According to a rule of Thumb, corrosion rate will be doubled per every 18^{o}F.

In oil production process, desalting usually performed in high temperature (between 90^{o}C to 120^{o}C related to oil API), so high temperature is an important factor in corrosion. Pressure also effects on chemical reactions but in oil production process its effect is more on dissolved gases value.

Fluid velocity is another important parameter in corrosion rate. Fluid with low velocity causes low corrosion rate.

Dead zone in piping and equipments is a proper site for bacteria, it is also a good place for accumulation of solid particles that lead to pitting corrosion.

High velocity of fluid increases rate of corrosion especially in presence of solid particles.

3. Case study

This part is going to clarify above-mentioned discussions. A failure case, which was related to an offshore oil production unit, is explained. Corrosion in this unit has happened in water disposal system equipments especially in connective pipes among desalter, dehydrator and water disposal wells (fig.1). Corrosion rate in this unit was so high that led to leakage in parts with high fluid velocity.

Corrosion reasons in this unit are:

a) **Corrosion caused by dissolved oxygen**: oxygen acts as an accelerator in cathodic reactions, by receiving electron in acidic and neutral environment is converted to water and in alkaline environment converts to hydroxyl ion. Lab tests show good performance of oxygen scavenger so oxygen has no role in corrosion.

b) **Corrosion caused by organic acids**:
According to reservoir conditions, type and contents of organic acids are different. These acids include aliphatic fatty acids, aromatic acids and naphthenic acids. Among these acids, those with 2 to 5 carbons (acetic acid, propionic acid, butyric acid, valeric acid) are soluble in water and other organic acids are insoluble. In this oil production unit, none of these acids were detected in water

disposal section, so low pH of water is not due to dissolving of organic acids.

c) **Corrosion caused by aerobic and anaerobic micro-organisms**: the presence of aerobic Microorganisms can lead to formation of inorganic acids such as: nitric or sulphuric acids. Anaerobic microorganisms can form hydrogen sulphate ions, which can increase water acidity.
According to lab results, no growth for microorganisms has been observed, so low pH of water is not because of microorganism's activity

d) **Corrosion caused by chloride ion**
Salts of crude oil include 85 % to 90 % sodium chloride and 10 to 15 % magnesium or calcium chloride. Heavy chloride salts ($MgCl_2$, $CaCl_2$) can be hydrolyzed with water in operating condition more than 105°C, which are explained as following:

$$MgCl_2 + 2H_2O \longrightarrow Mg(OH)_2 + 2HCl$$
$$CaCl_2 + 2H_2O \xrightarrow{\text{Heat}} Ca(OH)_2 + 2HCl$$

As $Mg(OH)_2$ and $Ca(OH)_2$ are weak alkynes agents and they also deposit, so formed HCl can increase water acidity.

Take it in to consideration that temperature more than 105°C accelerate hydrolysis of $CaCl_2$ and $MgCl_2$. In this unit desalting is performed in high temperature, so low pH of water is as a result of $MgCl_2$ and $CaCl_2$ hydrolysis. Water analysis results confirm this theory.

According to analysis of water, fresh water has low content of Ca^{2+} and Mg^{2+} ions but disposal water contains more mentioned ions in addition to high acidity. Calculations also show mole gram of Cl^- is too higher than mole gram of Na^+ in water, which shows HCl presence.

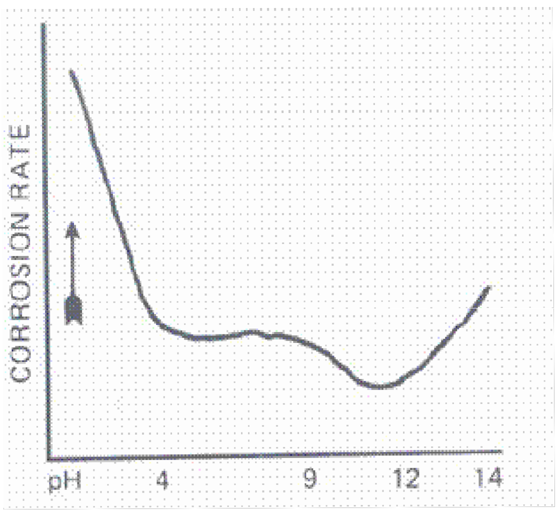

Figure 2-Steel Corrosion rate curve typical of variations related to hydrogen ion concentration in the electrolyte.

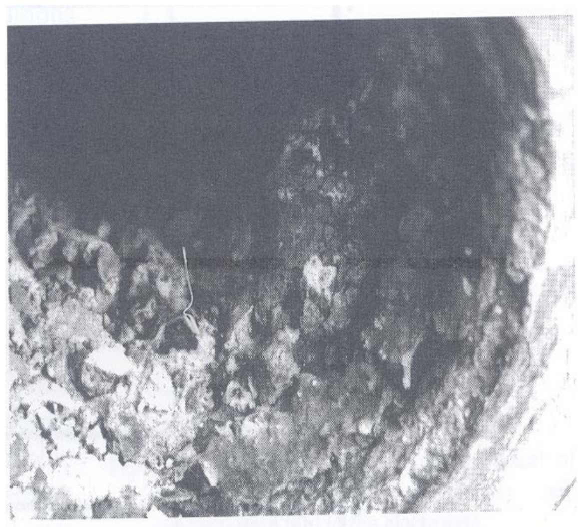
Figure 3-Oxygen corrosion tubercles-seawater supply line on offshore platform.

4. Conclusion

This paper reviewed the important corrosion factors in offshore oil production equipments. As it is mentioned, produced water has high potential to cause corrosion. The most effective parameters, which increase corrosion rate of water, are: electrical conductivity and pH, dissolved gases, microbial agents and process conditions. Results of a case study showed that hydrolysis of oil salts produce acid, which leads to corrosion.

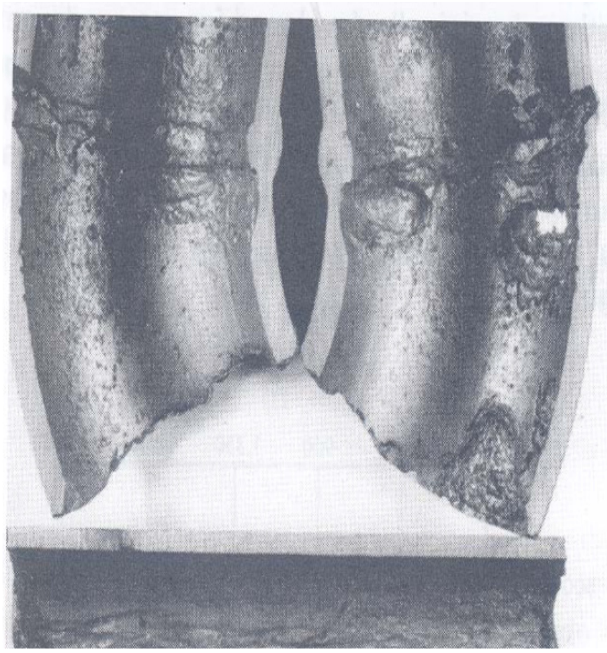

Figure 4-Typicall CO_2 corrosion in pipe

Figure 5-Pipe cracking caused by H_2S.

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