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15/ENG07/008

CHEMICAL ENGINEERING

CHE 582: CORROSION ENGINEERING

ASSIGNMENT

1. What is Corrosion?

Corrosion is a natural process that converts a refined metal into a more chemically stable form such as oxide, hydroxide, or sulfide. It is the gradual destruction of materials (usually a metal) by chemical and/or electrochemical reaction with their environment. (Wikipedia, 2020)

In the most common use of the word, this means electrochemical oxidation of metal in reaction with an oxidant such as oxygen or sulfates. Rusting, the formation of iron oxides, is a well-known example of electrochemical corrosion. This type of damage typically produces oxide(s) or salt(s) of the original metal and results in a distinctive orange coloration. Corrosion can also occur in materials other than metals, such as ceramics or polymers, although in this context, the term "degradation" is more common. Corrosion degrades the useful properties of materials and structures including strength, appearance and permeability to liquids and gases.

b. With the aid of Chemical reactions, briefly describe corrosion mechanisms.

- **Sweet Corrosion (CO_2 Corrosion)**

  CO_2 is one of the main corroding agents in the oil and gas production systems. The
  Dry CO2 gas is not itself corrosive at the temperatures encountered within oil and gas production systems but is so when dissolved in an aqueous phase through which it can promote an electrochemical reaction between steel and the contacting aqueous phase.
  CO2 will mix with the water, forming carbonic acid making the fluid acidic. CO2 corrosion is influenced by temperature, increase in pH value, composition of the aqueous stream, presence of non-aqueous phases, flow condition, and metal characteristics and is by far the most prevalent form of attack encountered in oil and gas production.
  At elevated temperatures, iron carbide scale is formed on the oil and gas pipe as a protective scale, and the metal starts to corrode under these conditions.

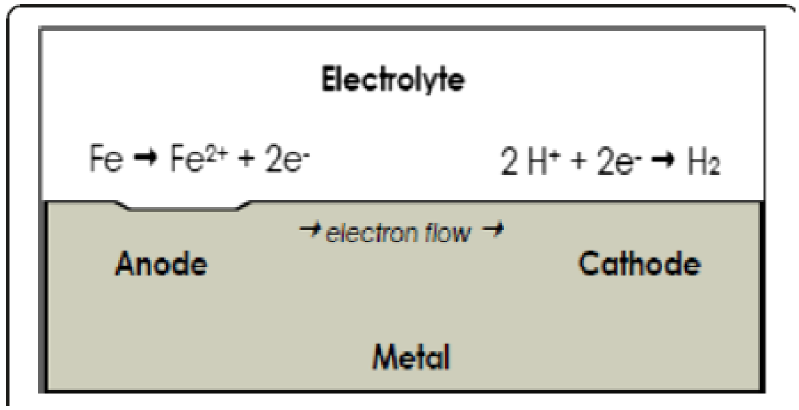

Figure 1: Corrosion Process

CO2 corrosion can appear in two principal forms: pitting (localized attack that results in rapid penetration and removal of metal at a small discrete area) and mesa attack (a form of localized CO2 corrosion under medium-flow conditions). Various mechanisms have been postulated for the CO2 corrosion process but all involve either carbonic acid or the bicarbonate ion formed on dissolution of CO2 in water.

The best-known mechanism is given as;

$$H_2CO_3 + e^- \rightarrow H + HCO_3^-$$

$$2H \rightarrow H_2$$

With the acid steel reacting

$$Fe + Fe^{2+} \rightarrow 2e^-$$

And overall

$$CO_2 + H_2O + Fe \rightarrow FeCO_3(Iron\ carbonate) + H_2$$

- **Sour Corrosion (H2S Corrosion)**

The deterioration of metal due to contact with hydrogen sulfide (H2S) and moisture is called sour corrosion which is the most damaging to drill pipe. Although H2S is not corrosive by itself, it becomes a severely corrosive agent in the presence of water, leading to pipeline embrittlement. Hydrogen sulfide when dissolved in water is a weak acid, and therefore, it is a source of hydrogen ions and is corrosive. The corrosion products are iron sulfides (FeS) and hydrogen. Iron sulfide forms a scale that at low temperature can act as a barrier to slow corrosion. The forms of sour corrosion are uniform, pitting, and stepwise cracking.

The general equation of sour corrosion can be expressed as follows;

$$H_2S + H_2O + Fe \rightarrow FeS_x + 2H + H_20$$

- **Galvanic Corrosion**

This type of corrosion occurs when two metallic materials with different nobilities (electrochemical potential) are in contact and are exposed to an electrolytic environment. In such situation, the metal with less or the most negative potential becomes the anode and starts corroding. The anode loses metal ions to balance electron flow. Because metals are made up of crystals, many of such cells are set up, causing intergranular corrosion.

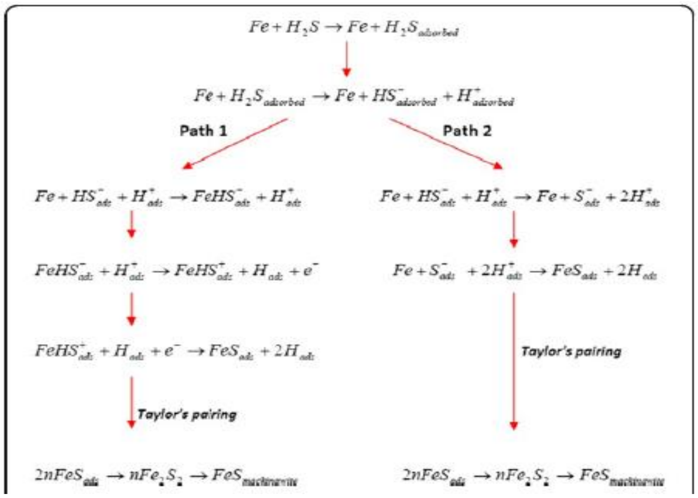

Figure 2 : Diagrammatic representation of the galvanic corrosion (Lekan, et al., 2013)

- **Crevice Corrosion**

  Crevice corrosion is normally a localized corrosion taking place in the narrow clearances or crevices in the metal and the fluid getting stagnant in the gap. This is caused by concentration differences of corrodents over a metal surface. Electrochemical potential differences result in selective crevice or pitting corrosion attack. Oxygen dissolved in drilling fluid promotes crevice and pitting attack of metal in the shielded areas of drill string and is the common cause of washouts and destruction under rubber pipe protectors.

- **Erosion Corrosion**

  The erosion corrosion mechanism increases corrosion reaction rate by continuously removing the passive layer of corrosion products from the wall of the pipe. The passive layer is a thin film of corrosion product that actually serves to stabilize the corrosion reaction and slow it down. As a result of the turbulence and high shear stress in the line, this passive layer can be removed causing the corrosion rate to increase. The erosion corrosion is always experienced where there is high turbulence flow regime with significantly higher rate of corrosion and is dependent on fluid flow rate and the density and morphology of solids present in the fluid. High velocities and presence of abrasive suspended material and the corrodents in drilling and produced fluids contribute to this destructive process. This form of corrosion is often overlooked or recognized as being caused by wear.

- **Microbial Induced Corrosion**

  This type of corrosion is caused by bacterial activities. The bacteria produce waste products like CO_2, H_2S, and organic acids that corrode the pipes by increasing the toxicity of the flowing fluid in the pipeline. The microbes tend to form colonies in a hospitable environment and allow enhanced corrosion under the colony. The formation of these colonies is promoted by neutral water especially when stagnant. Numerous reports of the presence of microbes in reservoirs had been published. It was found that found abundant microbial flora indigenous in oil field formation waters, which included species of Bacillus, Pseudomonas, Micrococcus, Mycobacterium, Clostridium, and Escherichia. Escherichia is reported to contain hydrogenase, an enzyme that utilizes molecular hydrogen and may be associated with cathodic hydrogen depolarization, causing corrosion of steel casings and pipes in the oil field. Microbiologically induced corrosion (MIC) is recognized by the appearance of a black slimy waste material or nodules on the pipe surface as well as pitting of the pipe wall underneath these deposits.

- **Stress Corrosion Cracking**

  Stress corrosion cracking (SCC) is a form of localized corrosion which produces cracks in metals by simultaneous action of a corrodent and tensile stress. It propagates over a range of velocities from 10^{-3} to 10 mm/h depending upon the combination of alloy and environment involved. SCC is the cracking induced from the combined influence of tensile stress and a corrosive medium. The impact of SCC on a material seems to fall between dry cracking and the fatigue threshold of that material. SCC in pipeline is a type of environmentally associated cracking. This is because the crack is caused by various factors combined with the environment surrounding the pipe. The most obvious identifying characteristic of SCC in a pipeline is high pH of the surrounding environment, appearance of patches, or colonies of parallel cracks on the external of the pipe.

2. Give three catastrophic incidences that had been recorded historically as a result of corrosion failure.

- On 28 April 1988, a 19-year-old Boeing 737 aircraft, operated by Aloha, lost a major portion of the upper fuselage near the front of the plane due to corrosion damage, in full flight at 24,000 ft.
- Statue of Liberty which was officially inaugurated on 28 October 1866, on Bedloe's Island, in the New York harbor had undergone severe galvanic corrosion after which remedial measures were taken.
- sewer explosion that killed over 200 people in Guadalajara, Mexico in April 1992. Besides the fatalities, the series of blasts damaged 1,600 buildings and injured 1,500 people. Damage costs were estimated at 75 million US dollars

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