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Article

Pipeline Corrosion and Its Preventions in the Oil and Gas Sector: A Review

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Abstract: The oil and gas sector is one of the major sources of revenue in the Nigeria Economy and its importance cannot be overemphasized. Transportation of petroleum product is one of the main activities in the petroleum industries and this is made easier and better with the use of pipelines produced mostly from iron, steel or related materials that are known to be corrosive especially on reaction with oxygen. Corrosion in pipelines is one of the major problems faced by the oil and gas sector in Nigeria today, the effect of corrosion in oil and gas pipelines has made corrosion control or prevention one of the factor to been considered in the oil and gas sector. In this review, different type of corrosion was discussed in details ranging from their formation to existence and there prevention was equally discussed which is basically the used of corrosion inhibitors, different corrosion inhibitors was discussed in details including their mode of existence and their application in pipeline so as to ensure that the effect of corrosion is minimized in the oil and gas sector.

Keywords: Corrosion, Oil, Gas

1. Introduction

Corrosion of oil and gas pipelines is indispensable neither can it be completely eliminated but can be minimized by taking preventive measures of various kinds depending on the causative agent of corrosion. The severe magnitudes of the deterioration progression have turn out to be problematic nationwide impact. Corrosion is the damaging attack of a metal by reacting with its surroundings (Roberge, 2000) and a regular prospective danger linked with oil and gas conveyance and production amenities (Kermani, 1997; Onen et al;. 2017; Etim et al., 2019). According to Champion Technologies, 2012, virtually any aqueous setting can encourage rust, which occurs beneath several compound circumstances in oil and gas manufacture, treating, and pipeline structures.

On 24th March of 1989, The Exxon Valdez oil leaked in Prince William Sound, lots of aquatic creatures were destroyed, and the ecosystem of local dwelling was broken up. It took over 30 ages for the resident societies to recover. Hence, noticing and observing the pipeline system is significantly important (Granham, 2003).

Crude oil and gas pipes might be aground, offshore or in wetland. The conveyance processes has continued to be a perplexing effort contrary to forces of natural surroundings. The prominence of the use of pipelines as the best and effectual means of product transportation from oil well head to the reservoir points, from the flow locations to the storing reservoirs in the depots and to the filling platforms far into the Atlantic cannot be exaggerated. For every ground revealed, the pipelines are further uncovered to the trial in the harshest surroundings Irrespective of the field site with all the location hostility, the pure carbon steel piping, remains the greatest path of product relocation from the holes to the reservoir due to its promising thermo-mechanical abilities. Crude oil and gas pipes in the cause of being used for transferring products are exposed to numerous surroundings principally the offshore fixings or installations. Additionally, the pipes could be submerged but in the long run this disclosure results in liability to numerous forms of peripheral and inner deterioration problems (Onusseit, 2010; Udosen et al., 2012; Nyborg, 2007; Lascaro, 1987; Asuquo et al., 2012).

As reported by Malik *et al*.,1999, Carbon based (organic) coating has been measured as most appropriate coatings that is not solitary good in corrosion opposition but also influenced to air, salinity and water resistance. Experimentally three types of organic varnish Polyurethane, Blended Merged epoxy and polyethylene to experiment it on steel to study the performance in aqueous surroundings. The outcome disclosed that polyethylene has worthy opposition to chloride and water permeation which can be measured as good form for exterior painting of steel pipes that is unprotected to air.

2. Types of Corrosion in Oil Pipelines

2.1. Galvanic Corrosion

Galvanic corrosion is the type of corrosion that occurs between two metals with different electrochemical potential are in interaction and are open to an electrolytic atmosphere. In such condition, the metal with fewer or the greatest negative potential converts the positive terminal and starts rusting (Martin, 1982; Nalli, 2010). The positive electrode loses metal ions to stabilize electron flow. Since metals are made up of minerals, numerous of such cells are fixed up, causing inter granulated corrosion. Difficulties are most severe when the proportion of the cathode-to-anode zone is enormous (Brondel *et al*., 1994).

2.2. Crevice Corrosion

Crack or crevice corrosion is usually a localized deterioration taking place in the thin consents or crevices in the metal and the liquid getting immobile in the crack. This is instigated by concentration variances of corrodes over a metal exterior part of metal (Roberge, 2000). Electro potential variances result in discriminatory crack or pitting deterioration attack. Oxygen dissolved in drilling mud sponsors gap and pitting attack of metal in the secure regions of drill cord and is the collective cause of catastrophes and mutilation under rubber conduit shields (Hudgins, 1969).

2.3. Erosion Corrosion

The mechanism in erosion corrosion escalate deteriorating reaction rate by nonstop eliminating of the passive layer of rust products from the wall of the pipeline. The passive layer is a tinny film of rust product that actually assists to calm the deterioration reaction and downcast it. Consequence of the instability and high shear strain in the pipeline, this inactive layer can be detached, triggering the erosion rate to escalation (Hassani *et al*., 2012). This type of corrosion is always noticed where there is great disorderly movement regime with considerably advanced rate of weathering (Sami *et al*., 2008) and is reliant on fluid movement rate and the thickness and morphology of solids existent in the liquid (Nalli, 2010). High rates and presence of coarse suspended solid and rusts in drills and produced fluids add to this damaging course. Erosion corrosion is often ignored or recognized as being caused by wear (Bertness, 1957).

2.4. Pressure (Stress) Corrosion Cracking

Pressure or stress corrosion cracking is a form of localized deterioration which produces cracks in metals by concurrent act of a rust and malleable stress. It spreads over array of rates is liable upon the blend of alloy and surroundings involved. Stress corrosion is the crack induced from combination influenced by flexible stress and eroding medium. The effect of pressure stress on a material appears to fall amongst dry crack and the exhaustion edge of that very material (Wilhelm *et al*., 1987).

2.5. Microorganism Instigated Corrosion

This type of rust is triggered by microbial activities. The microorganisms discharge waste material such as hydrogen sulfide and Carbon (iv) oxide and carboxylic acids that corrode the conduits by increasing the toxic nature of the fluid flowing in the pipe (Ossai, 2012). 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 (Nalli, 2010). Numerous reports of the presence of microbes in reservoirs had been published (Lazar *et al.*, 1985; Singer, 1985; Crawford, 1983). Lots bacteriological vegetation growing in oil ground, which included species of Escherichia, Pseudomonas, Bacillu. Micrococcus, Clostridium and Escherichia (Lazar *et al*.,1985; Itodo and Etim, 2015). It was reported by Gates, 1976 that Escherichia comprise of an enzyme called hydrogenase that maximizes molecular hydrogen and may be linked with cathodes hydrogen depolarization, triggering deterioration of steel sheaths and pipelines in the oil grounds.

2.6. Sour Corrosion

Sour deterioration of metal owing to interaction with hydrogen sulfide and dampness is called sour deterioration which is the most destructive to drill pipeline. Though Hydrogen sulfide is not destructive on its own, it turns out to be a rigorously destructive agent when it interacts with water (Ray *et al*., 1978), leading to pipeline corrosion (Nalli, 2010). When hydrogen sulfide dissolved in water a weak acid is produced and consequently, it is a basis of hydrogen ions and is destructive. The deterioration products are hydrogen and iron sulfide. Iron sulfide systems a balance that at low temperature can turn as a barrier to slow deterioration (Brondel *et al*., 1994) The methods of sour corrosion are constant, opposing, and stepwise erosion. The forms of sour rust are constant, opposing, and step by step cracking (Chilingar and Beeson, 1969)

2.7. Sweet Corrosion

Water and carbon (iv) oxide are crucial constituents for sweet corrosion to take place. The commonly compound found in oil ground environments is carbon (iv) oxide. Furthermore, it is also an erosive constituent found in natural gas, crude oil, and rain water. Carbon (iv) oxide is among the most soluble acidic gases in oil and gas transportation processes. Sweet deterioration process is due to the formation of trioxocarbonate (iv) acid. The acid is formed by dissolution of carbon (iv) oxide in the water. The presence of trioxocarbonate (iv) acid causes the drop in the value of pH of water, and a rise the deterioration likelihood of fluids inside pipes. Consequently, sweet corrosion occurs when acids interact with metals inside pipes (Bai *et al*., 2012).

3. Corrosion Prevention in Oil and Gas Production

Corrosion in oil and gas issues are none static occurrences. Fluid behavior changes with time, therefore systems become less responsive, as a result it limits rust mitigation process according to Champion Technologies, 2012. Within the circle of deterioration mitigation and inhibition in the oil and gas manufacturing, there are methodological alternatives such as anodic and cathodes protection, chemical quantity, material collection and the coating of the external and internal surface of the metal. It is extensively known in the oil and gas production that proficiently manages erosion and aid towards the conservation of asset reliability and accomplished optimization of preventing, observing and assessment costs, (Energy Institute, 2008).

To mitigate it is very important to begin by selecting alloys that are corrosion resistance, chemical treatment and interior lining. In degradation examination studies, oil wells, requires distinctive consideration should be positioned on temperature and pressure. Deterioration forecast models consist of the effects of pressure and temperature in the corrosion assessment while involving velocity, gas composition, the chemical content of the saline, and the mechanical dynamics (Obot *et al*., 2020). The slope of temperature along the broadcast path from the well depth to the wellhead has an unswerving effect on the phase solubility, density, and constancy of erosion products. However, the role of pressure is not the same; the overall pressure has no direct influence on deterioration. Nevertheless, it must be considered that the overall pressure is proportional to the individual pressure of Hydrogen sulfide and Carbon (iv) oxide which has a mega effect on deterioration (Richter *et al*., 2016).

3.1. Deterioration Inhibitors in Oil and Gas

Inhibitors are chemical substances that is added in minute quantity to an environment that is prone to corrosive attack which help prevent, sufficiently check and decreases metal degradation with respect to its environment (NACE, 1965). Amongst different alternatives for minimizing rust damage to wells during the production phase, the use of corrosion inhibitors is a more economical than Corrosion Resistance (Al-Shamari *et al*., 2011).

Degradation inhibitors are the chemicals substances inoculated into the well in numerous ways, so as to protect pipes against internal corrosion initiated by produced fluid. It is important to note that certain operators, by picking the suitable type and dosage of inhibitors to be injected into the wells, additional protect parts of the upstream amenities subsequently the well head. There exist several inhibitor formations to be added into the fluid produced; nevertheless, all listed inhibitors comprise of some degree number of base molecules. Oily acids and numerous nitrogenous compounds are the core element for the formation of these chemicals. Fatty imidazolines are the frequently used organic inhibitors, which are formulated from polyethylene amines and fatty acids. This type of imidazoline products are hydrocarbon soluble (Garverick, 1994). Imidazoline and heterocyclic annular configurations has been widely used as an efficient corrosion inhibitor in the oil and gas sector, and its

tolerant synergistic result with degree inhibitors has been evaluated, also a suitable mixing dose ratio has been attained (Gu *et al*., 2013). Quintanilla *et al*., 2009, reported that, nitrogenous functional group present in amino imidazole and imidazoline inhibitors have the ability to form film by sticking to the surface of the metal by dative or coordinate covalent bond. Repulsion of water resistance branch restricts the movement of the degradation particles near the surface.

3.2. Acidic Corrosion Inhibitors

One of the most commonly used well treatments is acidic method often used in to improve production yield in oil and gas. Acidizing improves the penetrability of formations and supports the movement of oil and gas into the reservoir (Ghommem *et al.*, 2015). Also used in analysis and preparing the wells, washing of the oil and gas pipes, and water pipelines to eradicate the salt deposits from the interior part of the metal (Shein and Denisova 2006).

Addition of hydrochloric acid solution is very crucial in order to have an increase in production and eradication of erosion damages (Frenier *et al.*, 1988). Priority is given to hydrochloric acid above other inorganic acids used in oil treatment processes because of the formation of metallic chloride which is insoluble in water. The main reason is that compounds of nitrate, phosphate and sulfate salts display lesser solubility compare to chloride salts (Jayaperumal *et al*, 2010). Often time chemical reaction takes place due to the reactivity of the acid used and other acid sensitive materials inside the well. If this is not stopped, the acid will be consumed before reaching an adequate level of the well. The rate of reaction of these different techniques which includes acid dissolution in none aqueous solvent or emulsion of aqueous acid in environs of oil rich (Singha and Quraishi, 2015). Upper part of the pipes are exposed to low temperate acids during acids treatment process while deep down the well pipes are susceptible to hot acids (Frenier *et al.*, 1988). Complication of erosion tends to occur as a result of acid treatment method; hence inhibitors are the most efficient means of minimizing deterioration during stimulating processes of a given well (Rostami and Nasr-El-Din, 2009). Corrosion intensification rate increases by an increase in temperature and concentration of the acid in a situation where corrosion inhibitors are absent. This can be resolved by dosing a required amount of corrosion inhibitors to preserve the materials used (metals) in the well (Barmatov *et al*., 2012). Usually, during oil and well stimulating processes a batch of erosion inhibitors is inoculated to the solution of acid. The most efficient and cost effective corrosion control method is the measurement of a single required dose of inhibitors into compartment containing corrosive acid. The cost of a well can be reduced through the use of appropriate inhibitor can enable the use of cheaper and easily accessible alloys which is more economical compare to use of Corrosion Resistance (Horsup *et al*., 2010).

3.3. Annulus Space Corrosion Inhibitors

In the modern days, a lot of information about the ruptures of degradation resistant alloys in space of annular has been manufactured. Therefore selection of completing liquids are chemically compactible with the alloy is necessary also management of the fluid is becoming alarming (McKennis *et al*., 2008). The effect of inhibitors in managing the havocs caused corrosion rate used in curtailing cracks from corrosion is discussed based of already existing occurrences (Galvele 1879; Zucchi *et al*., 2000).

According to Chesser, 1968), Sodium Lignosulfonate elevates the erosion resistance and avoiding stress through the formation of a protective film under functional (operating) process, also in the laboratory is usually related to magnetites. The influence of oxidizing agents, acidic gases such as hydrogen sulfide (H_2S) and Carbon (iv) oxide (CO_2), ions (CO_3^{2-} and HCO_3^-) and thiocyanate ions present in the packer fluid can distort this type of erosion (McKennis *et al*., 2009). During salt making process different salts are used individually or in combine form. The salts used include calcium chloride, zinc bromide, calcium bromide, potassium chloride and sodium chloride. The most frequently used corrosion inhibitor for this type of corrosion is organic compound (film forming amines) inhibitor which possesses low molecular weight (Hudson, 1986).

3.4. Green Inhibitors

Green inhibitors has been tested in different corrosive environment, the efficiency of Algerian flora has given the searcher the opportunity inhibitory potency of some plant compounds. The aqueous extract of the plant Asteraceae (Anacylus pyrethrum) stem and leave on slight steel corrosion, in sulphuric acid medium (0.5M). The end result indicated 87% inhibitory efficiency (Sheldon 2016). Adding Chamaerops Humilis can efficiently minimize strengthening of steel corrosion and increase the strength of the firm produced in alkaline solution and result to the formation of a better compact layer of protection on the surface (Ismail *et al.*, 2011).

The plant has such inhibitory efficiency due to the presence of phytochemical constituent which includes Catechol, Polyphenols, Gallic Tannins, Saponin, Flavonoids, Terpenoids, Cardiac glycosides and Anthacenosides (Odewunmi *et al*., 2015; Grassino, 2016; Li *et al.*, 2008).

The erosion inhibitory characteristics of vital oil of Mentha pulegium leaves have been examine as a green inhibitor of erosion of aluminum metal in phosphoric acid (2M) via electro-chemical impedance spectra study and potentiodynamic polarity and electrochemical impedance spectroscopy (Bereket and Yurt, 2011).

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