Technical Report

Studies on Inhibition of Microbial Induced Corrosion through Biocide Injection and Determination of Conditions for Assurance of Pipeline Integrity

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Abstract: Studies on the inhibition of microbial induced corrosion through biocide injection and determination of conditions for assurance of pipeline integrity have been carried out. The results of the investigation indicate that biocide requirement, biocide injection rate and pump stroke per minute increase with increase in both the water cut and gross fluid flow. It was found that (based on the convectional conditions Bpd/Br $\geq 17.857 \times 10^3$ and Br/SPM $\geq$ 0.28) pipeline integrity would be maintained at gross fluid flow range 123036-147857Bpd when the water cut is constant (2%) or at water cut range 1.8-2.0% when the gross fluid flow is constant (135000Bpd). It was also found that based on the formulated condition (Bpd/SPM $\geq$ 5000) in this work, pipeline integrity is assured at gross fluid flow range 123036-147857Bpd when the water cut is maintained constant at 2% or at water cut range 1.8-2.0% when the gross fluid flow is constant; at 135000Bpd. The short stroke pump was found to give more realistic and accurate biocide injection rate than the long stroke pump. [Report and Opinion. 2009;1(5):19-24]. (ISSN: 1553-9873).

Keywords: Effect, Biocide, Microbial Induced Corrosion, Oil Pipeline Integrity.

1. Introduction

Microbial corrosion, as the name implies, is a kind of corrosion caused or enhanced by micro-organisms, particularly sulphate reducing bacteria, although some other microbes are known to play a secondary role. There are two ways in which micro-organisms are involved in corrosion processes. Firstly, by virtue of their growth and metabolism they can introduce into an innocuous system, chemical entities such acids, alkali, sulphides, and other aggressive ions which will render the environment corrosive. Secondly, their presence could provide the structure with concentration cell, with some areas being anodic compared to the rest (Ijomah,1991).

Biofouling is the deposition onto a metal surface, of particles normally suspended in solution (Crook,1986). The colloidal matter could come from so many sources both internal and external. They could enter the process through make up water, especially the untreated surface water. It could be scrubbed from the air as in open recirculation systems and could also come from organic deterioration products. These particles tend to take up a charge opposite to that of the metal surface, and fouling results causing a decline in heat transfer (Crook,1986). Algae, i.e., chlorophyll-containing organisms that need light for growth, are usually present in industrial cooling towers. If allowed unchecked, they are capable of producing great masses of material whose weight could endanger the structure and whose mass impedes air and water flow. Even small growths could slough off and be carried into circulating stream as fouling matter.

Slimes normally contain fungi, yeast, bacteria and trapped quantities of organic and inorganic matter (Crook,1986). Slimes forming bacteria are usually encapsulated in this gelatinous mass. Alive, they attach themselves to steel surfaces and grow to restrict heat transfer. In extreme cases, they can also restrict water flow and the deposits also set up concentration cells, causing corrosion (Crook,1986).

Aerobic iron bacteria can oxidize ferrous ions in solution to the ferric state and thus effect the precipitation of ferric hydroxide (Loverell,1989). These organisms are common inhabitants of springs and may find their way into water pipes. Precipitated ferric hydroxides can build up on the internal surface of a pipe to form hard excrescences known as tubercles, which are firmly adherent to the metal surface (Booth,1985). The tubercle shields the surface of the pipe from contact with dissolved oxygen (Booth,1985). Hence, the metal at the base of the tubercle becomes anodic to those parts not covered by the deposit. The problem is often intensified by the fact that sulphate reducing bacteria takes advantage of the anaerobiosis created by the tubercles to make their input to the total corrosion.

Most instances of corrosion in the absence of oxygen have been attributed to the sulphate reducing bacteria (SRB), of genera; disulfovibrio and disulfotomaculum (Nwoye,2002). Typical examples of such an environment are natural water-logged soils and waters heavily polluted with organic matter. These microbes are obligate anaerobes, i.e, they will not grow in the presence of even traces of oxygen, but usually grow well at pH between 5 and 9 and temperatures between 25 and 44^0C, although some strains (disulfotomaculum nigrificans) are able to withstand higher temperatures (Crook,1986). They utilize hydrogen or some reducing substances for their life process. The corrosion is often localized and is generally characterized by a black corrosion product with a strong smell of hydrogen sulphide (H_2S) (Crook,1986). Sulphate reducing bacteria can cause serious damage in buried pipes, central heating installations, heat exchangers and cooling towers.

Mechanism of attack by sulphate reducing bacteria

Sulphate reducing bacteria have been found (Crook,1986) to utilize hydrogen for their metabolim. It then follows that for an iron or steel structure which has become polarized through the formation of hydrogen at the cathode and Fe^{2+} at the anode, the bacteria obtain their necessary hydrogen at the cathodic site, thus depolarizing the cathode. The S^{2-} ions arising from the sulphate reduction process then combines with Fe^{2+} ions to form ferrous sulphide (FeS). Hence, the anode reaction is also polarized, allowing the attack to proceed unhindered. Mathematically, the reaction is believed to follow the scheme (Crook,1986):

$$Fe = Fe^{2+} + 2e \quad \text{(anodic reaction)} \qquad (1)$$

$$2H^{+} + 2e = \quad \text{(cathodic reaction)} \qquad (2)$$

$$SO^{2-}_4 + 8H = S^{2-} + 4H_2O \qquad (3)$$
(cathode depolarization by SRB)

$$Fe^{2+} + S^{2-} = FeS \quad \text{(corrosion product)} \qquad (4)$$

$$FeS + 2H_2O = H_2S + Fe(OH)_2 \qquad (5)$$
(corrosion product)

It was found (Crook,1986) that when microbial growth occurs on a structure liable to corrosion such as pipeline, a differential aeration cell is usually set up between those parts of the structure where oxygen supply has been is depleted and those parts where micro-organisms are not active. The oxygen depleted regions will be anodic to the rest and will therefore become centre for active metal loss.

Prevention of microbial corrosion

The various measures which have been successfully applied to prevent or control microbial corrosion include: cathodic protection, aeration, removal of metabolite and use of inhibitors (Fontana and Greene,1967). Cathodic protection has been used successfully to control microbial corrosion since all the anodic areas are eliminated by making the entire structure the cathode of an electrochemical cell. The cheapest and most effective inhibitor for sulphate reducing bacteria is air or oxygen. Forced aeration of stagnant water has been used to control corrosion in tanks and incidentally, to banish offensive odours while the drainage of waterlogged soils to improve aeration has been used to control the corrosion of buried pipes. Sometimes, it is possible to control microbial action by removal of an essential metabolite from the system. For example, constructing cooling towers to exclude light is an effective means of control against algae. Inhibitors of microbial action are two types. These are biocides which actually kill the organisms and biostats which maintain the organisms in a state of inactivity or non-growth.

When biocides are used to inhibit the microbial actions of the sulphate reducing bacteria, some equations are vital for the control analysis (Okure,2000);

$$(Br) = 0.0028 \times WC \times Bpd \qquad (6)$$

$$(Bj) = Br/t \qquad (7)$$

Substituting the value of Br in equation (6) into equation (Okure,2000)

$$Bj = \frac{0.0028 \times WC \times Bpd}{t} \qquad (8)$$

Where

Br = Biocide requirement (US Galls.)
Bj = Biocide injection rate (US Galls./hr)
Bpd= Gross fluid flow
WC = Water cut (%)
t = Time elapse during the fluid flow (hr)
0.0028 = Flow constant

The aim of the present work is to study the inhibition of microbial induced corrosion through biocide injection and to determine conditions for assurance of pipeline integrity. In this work biocide was used to wipe the pipes conveying oil clean of these sulphate reducing bacteria so as to maintain high efficiency and uninterrupted flow of the fluid through the pipes. This way, it is expected that pipeline integrity would be maintained.

2. Materials and methods

Three major oil pipelines at offshore platforms in Akwa Ibom State, certified infested by sulphate reducing bacteria (following preliminary phynotipic examination carried out) were worked on during this study. Varied values of water cut (WC) and gross fluid flow (BPD) through the line to be treated were considered in order to evaluate the respective associated biocide requirements. The expected biocide requirement was based on 4 hrs fluid flow. Biocide injection rates were calculated and used to evaluate (by interpolation) the pump stroke per minute (both short and long stroke) using values obtained from the usage of Texsteam 5006 chemical injection pump. These values are presented in Table 1. Other results generated in the course of the research work are presented in Tables 2-5. Details of the stages of the experiments and techniques used are as stated in previous report (Nwoye,2000).

3. Results and discussion

Fig.1 shows that at constant gross fluid flow (135000Bpd), biocide requirement increases with increase in the water cut.

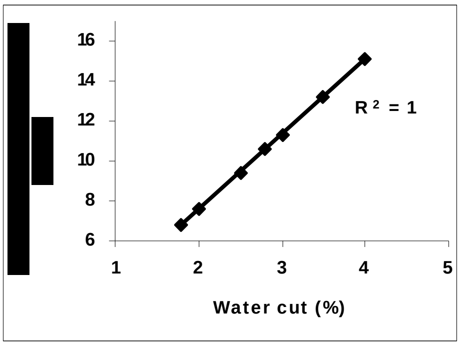

Fig. 1 Variation of water cut with biocide requirement at constant gross fluid flow

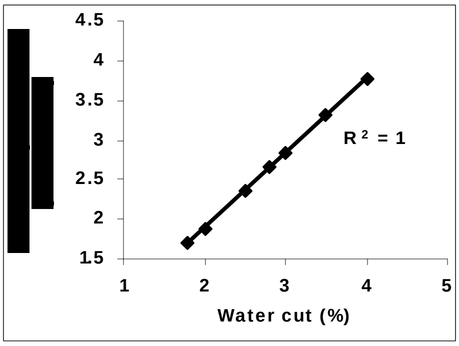

Fig. 2 Variation of water cut with biocide injection rate at constant gross fluid flow

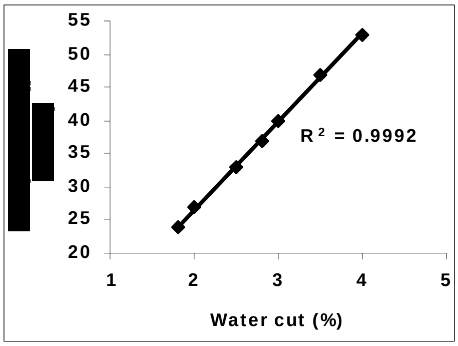

Fig. 3 Variation of water cut with pump stroke per minute obtained from short stroke

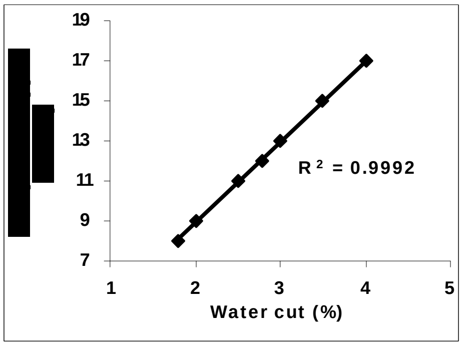

Fig. 4 Variation of water cut with pump stroke per minute obtained from long stroke

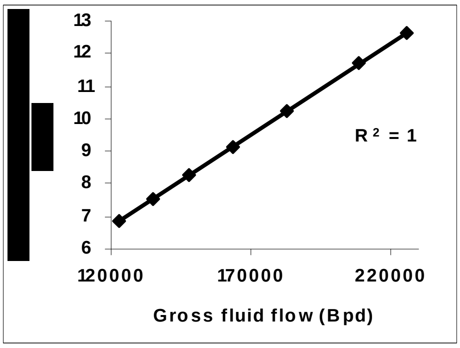

Fig. 5 Variation of gross fluid flow with biocide requirement at constant water cut

This was also the case with biocide injection rate in relation to the water cut (Fig. 2). The pump stroke per minute (SPM) calculated using the long and short pump strokes were also found to increase with increase in the water cut. This is shown in Figs. 3 and 4. Figs. 5 and 6 (at constant water cut of 2%) also indicate that both the biocide requirement and biocide injection rate increase respectively with corresponding increase in the gross fluid flow.

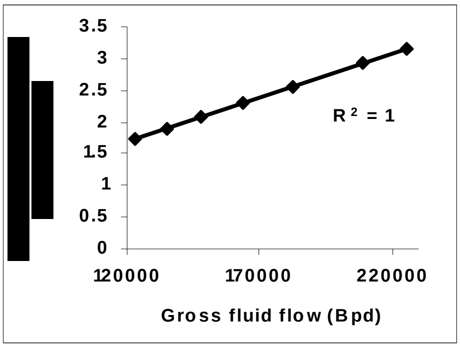

Fig. 6 Variation of gross fluid flow with biocide injection rate at constant water cut

Figs. 7 and 8 also show that the pump stroke per minute evaluated using short stroke and long stroke increase with increase in the gross fluid flow. Comparison of Figs. 3, 4, 7 and 8 shows that greater values and better relationship for pump stroke per minute is obtained as water cut varies and the gross fluid flow remain constant.

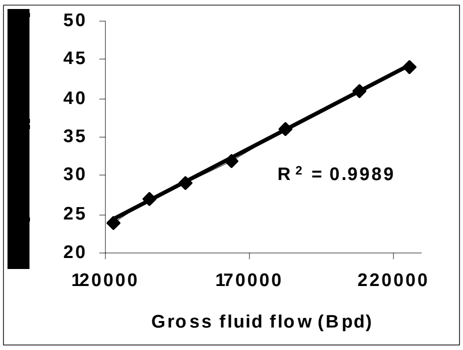

Fig. 7 Variation of gross fluid flow with pump stroke per minute obtained from short stroke

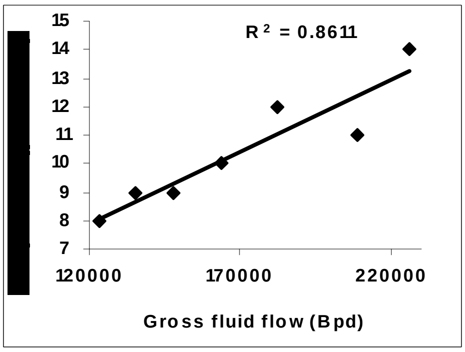

Fig. 8 Variation of gross fluid flow with pump stroke per minute obtained from long stroke

Table 1:Values obtained from Texsteam 5006 chemical injection pump used

SPM	Volume (US Galls./hr)	
	Long Stroke	Short Stroke
5	1.11	0.36
10	2.22	0.71
15	3.33	1.07
20	4.44	1.42
25	5.55	1.78
30	6.66	2.13
35	7.77	2.49
40	8.88	2.84
45	9.99	3.20
50	11.10	3.55
55	12.21	3.91

Table 2: Variation of Bpd/Br and Br/SPM with water cut at constant gross fluid flow

WC (%)	Bpd/Br (10^3)	Br/SPM
2.0	17.857	0.2800
2.5	14.286	0.2864
1.8	19.853	0.2833
3.0	11.905	0.2835
2.8	12.760	0.2859
3.5	10.204	0.2815
4.0	8.929	0.2853

Table 3: Variation of Bpd/Br and Br/SPM with gross fluid flow at constant water cut

Bpd	Bpd/Br (10^3)	Br/SPM
123036	17.857	0.2871
135000	14.286	0.2800
147857	19.853	0.2855
163571	11.905	0.2863
182500	12.760	0.2839
208571	10.204	0.2849
225714	8.929	0.2873

Table 4: Variation of Bpd/SPM with water cut at constant gross fluid flow (for the derived expression)

Bpd/SPM (10^3)	Bpd
5.1268	123036
4.0000	135000
5.6680	147857
3.4083	163571
3.6226	182500
2.9071	208571
2.5652	225714

Table 5: Variation of Bpd/SPM with gross fluid flow at constant water cut (for the derived expression)

Bpd/SPM (10^3)	WC (%)
5.1268	2.0
4.0000	2.5
5.6680	1.8
3.4083	3.0
3.6226	2.8
2.9071	3.5
2.5652	4.0

This is confirmed by the R^2 values from the respective figures which are 0.9992, 0.9992, 0.9989 and 0.8611 respectively. These R^2 values translate into the correlation coefficients R; 0.9996, 0.9996, 0.9994 and 0.9280 respectively following evaluation of the square root of R^2. Comparison of Fig. 7 and 8 shows (at constant water cut (2%)) a better relationship between pump stroke per minute and gross fluid flow as evaluated using short stroke than in the case of long stroke. Their respective correlation coefficients (0.9994 and 0.9280) confirm this. This is a clear indication that usage of short stroke pump gives more accurate biocide injection rate for treatment of SRB infested pipelines compared to long stroke pump.

Determination of conditions for Pipeline integrity

It has been found (Okure,2000) that pipeline maintains its integrity during flow of fluid when the expression;

$$\frac{Bpd}{Br} \geq 17.857 \times 10^3 \quad (US\ Galls.)^{-1} \qquad (9)$$

or

$$\frac{Br}{SPM} \geq 0.28 \qquad (10)$$

Where SPM is the pump stroke per minute.

Multiplying equations (9) by (10)

$$\frac{Bpd}{SPM} \geq 4999.96 \qquad (11)$$

Therefore, based on this derived expression (equation (11)), for pipeline to maintain its integrity,

$$\frac{Bpd}{SPM} \geq 5000 \quad \text{approximately)} \qquad (12)$$

Some results generated in the course of this work shows that at certain conditions, the derived expression (equation (12)) is valid for short stroke pump which has already been determined in this work (comparing Figs.7 and 8) to give more realistic and accurate biocide injection rate than the long stroke pump. Table 2 shows that at constant gross fluid flow, Bpd/Br & Br/SPM values are 19853 & 0.2833 at 1.8% water cut and 17857 & 0.28 at 2% water cut respectively. At constant water cut (2%), Table 3 indicates that Bpd/Br & Br/SPM values are 19853 & 0.2855 at gross fluid flow ; 147857Bpd and 17857 & 0.2871 at gross fluid flow;123036 Bpd respectively. Similarly, results shown in Table 4 indicate that at constant gross fluid flow, the evaluated values of Bpd/SPM = 5668 and 5126.8 at water cut values 1.8 and 2% respectively. Table 5 also shows that at constant water cut, Bpd/SPM values evaluated are 5668 and 5126.8 at gross fluid flow values 123036 and 147857 Bpd respectively.

Based on the foregoing, it is a clear indication that pipeline integrity would be maintained at gross fluid flow range 123036-147857Bpd when the water cut is constant (2%) or at water cut range 1.8-2.0% when the gross fluid flow is constant (135000Bpd). This analysis is based on the convectional conditions (Bpd/Br ≥17.857×10^3 and Br/SPM ≥ 0.28) for evaluating pipeline integrity. Based on the condition (Bpd/SPM ≥ 5000) formulated in this work, pipeline integrity is ensured at gross fluid flow range 123036-147857Bpd when the water cut is maintained constant at 2% or at water cut range 1.8-2.0% when the gross fluid flow is constant, maintained at 135000Bpd. This is confirmed in Tables 2-5.

4. Conclusion

Studies carried out on the inhibition of microbial induced corrosion through biocide injection indicate that biocide requirement, biocide injection rate and pump stroke per minute increase with increase in both the water cut and gross fluid flow. It was found that (based on the convectional conditions Bpd/Br ≥17.857×10^3 and Br/SPM ≥ 0.28) pipeline integrity would be maintained at gross fluid flow range 123036-147857Bpd when the water cut is constant (2%) or at water cut range 1.8-2.0% when the gross fluid flow is constant (135000Bpd). It was also found that based on the formulated condition (Bpd/SPM ≥ 5000) in this work, pipeline integrity is assured at gross fluid flow range 123036-147857Bpd when the water cut is maintained constant at 2% or at water cut range 1.8-2.0% when the gross fluid flow is constant, maintained at 135000Bpd. The short stroke pump was found to give more realistic and accurate biocide injection rate than the long stroke pump.

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