

*Full Length Research Paper*

# An assessment of inhibitor performance on corrosion rate of low carbon steel under flow condition

Akintola B. J\*, O. K Otari and Mohammed F. I

Department of Mechanical Engineering, Ahmadu Bello University Zaria, Nigeria.

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The effect of flow velocity on the performance of neem seed oil on corrosion rate of low carbon steel was investigated using the weight loss method. The coupons were flush mounted in inhibited and uninhibited corrosive media for 96 h. The flow velocity was varied for Reynolds numbers of 3705, 3054, 2220 and 734. The result showed that the inhibitor performed very well with time under flow conditions with better performance at laminar flow.

**Key words:** carbon steel, inhibitor performance, corrosion rate.

## INTRODUCTION

Many subjects are studied for their inherent interest and not because they have any direct industrial or social application. Corrosion, however, has same interest and in addition, affects progress negatively, particularly in engineering in a very vital way. Some scholars have really worked on this aspect for years. Wen et al. (2007) investigated the effects of fluid flow on SRB biofilms. Various studies have indicated that sessile bacteria in biofilms, not planktonic bacteria suspended in liquids, are directly responsible for pitting attack on metal surfaces in microbiologically influenced corrosion (MIC), which has been detected not only in static fluid systems, but also in flow systems. Fluid flow directly impacts mass transfer and biofilm formation. A sufficiently high linear flow velocity can prevent biofilm establishment or even dislodge an established biofilm. Boris et al. (2009) conducted research on several types of corrosion inhibitors. Active ingredients of those inhibitors included long chain amines, fatty amides, imidazolines, fatty acids and their salts. The results, which include the corrosion and electrochemical testing data, show that generally tested corrosion inhibitors are effective in studied range

of flow rates and compatible with flow modifiers (Glenn et al., 2003; Sharma et al., 2010).

Corrosion can be in many forms but this research focuses on the internal corrosion of pipelines (erosion corrosion). Internal pipeline corrosion in oil production and transportation is always associated with the presence of water, and the likelihood of corrosion generally increases with the volume fraction of water. The simultaneous flow of oil and water in crude oil production and transportation pipelines is a common occurrence, seen anywhere from the well perforations to the final stages of separation. Corrosion gases such as CO<sub>2</sub> and H<sub>2</sub>S are also commonly present in these systems. Typically at low water cuts, this is not an issue as all the water is entrained by the flowing oil. As the water cut increases, water "breakout" may occur, leading to segregated flow of separate layers of water and oil phases. Therefore, the possibility of corrosion is high where the water phase wets the pipe wall typically at the bottom (www.key-to-steel.com, 2005; Ailor, 1971).

## Velocity corrosion

High velocity fluid may cause erosion of a metal surface. These high velocity gases are often found at the wellhead of high pressure gas wells. The high velocity gas may

\*Corresponding author. E-mail: [akintola993@abu.edu.ng](mailto:akintola993@abu.edu.ng).

prevent corrosion inhibitors from adhering to metal surfaces and strip protective scales from the metal (Mora-Mendoza et al., 2002; Qasim et al., 2008).

Low velocity may cause another type of corrosion. Low velocity areas may serve as incubation sites for sulfate reducing bacteria. These sites may also tend to hold water at low points in a flow line. Sites with excess water accumulation are more corrosive (Silverman, 2004; Stupnisek-Lisac et al., 2000).

### Fluid flow effects on corrosion

Fluid flow affects the corrosion inhibition of materials. The fluid flow may be either viscous (laminar or streamline) or turbulent, the type of flow depends on the value of the Reynolds number (Re). When Re is less than the critical value, 2100 flow will be viscous; at 2100 there is a transitional region, and for higher values of Re, the flow will always be turbulent. Hence it is a challenge for corrosion engineers to determine more precisely the flow conditions leading to entrainment of the free water layer by the flowing oil phase (Douglas, 1976; Gyngell, 1951; Yu et al., 2002).

### EXPERIMENTAL PROCEDURE

The set up consists of a reservoir tank, a centrifugal pump, a flow meter and a valve to control the flow rate. A rubber tube was used to convey the crude oil from the tank through pump to the flow meter down to the test chamber and then back to the tank. The test chamber consists of four low carbon steel coupons of 1 cm in diameter and 2 cm in length. The coupons were degreased with acetone ( $\text{CH}_3\text{COCH}_3$ ), air dried prior to exposure after each experiment. The test chamber was disassembled and the coupons were washed with distilled water, rinsed with acetone, and cleansed with emery cloth and air dried. The experiment was carried out at room temperature and was run for 96 h based on the fact that it was set for laboratory test. The overall fluid velocity was regulated by the valve connected to the flow meter inlet. Reynolds's numbers of 734 to 3705 were used in this experiment to observe the corrosion rate from laminar to turbulent flows. Neem seed oil (NSO) was used as corrosion inhibitor at room temperature. Perez-Heranz et al (2001)

### Corrosion rate

The principal factors that determine the rate of corrosion of steel are:

- (i) The type and amount of pollution, sulphur dioxide, chlorides, dust,
- (ii) The 'time of wetness', that is, the proportion of total time during which the surface is wet due to rainfall, condensation, flow velocity, etc,
- (iii) The temperature.

The rate of corrosion can be determined by the relation (Callister, 1997):

$$\text{CPR} = \frac{87.6 \times \text{Weight Loss}}{T \times A \times \rho} \quad (\text{mm/yr}), \quad (1)$$

where:

= Weight Loss

T = Exposure Time (h)

$\rho$  = density of steel = 7.87 g/cm<sup>3</sup>

$$A = \text{Surface Area} = 2 \times \pi r^2 + 2 \pi r h \quad (\text{cylindrical coupon}) = 7.8571 \text{ cm}^2$$

Where:

r = radius of coupon

h = height of coupon

The Reynolds number of the flow was calculated using the relationship in equation (2) below (Massey, 1976):

$$\text{Re} = \frac{\rho v d}{\mu} \quad (2)$$

where, v = flow velocity

$\mu$  = Coefficient of dynamic viscosity = 24.4 Cp (measured from chemical engineering Lab, Ahmadu Bello University Zaria)

$\nu$  = Kinematic viscosity =  $2.84 \times 10^{-5} \text{ m}^2/\text{s}$

$\rho$  = Density of crude oil = 860 kg/m<sup>3</sup>

d = Pipe diameter = 47.4mm

The flow velocities were found using the Toricelli's formula:

$$v = \sqrt{2gH} \quad (3)$$

where

H = velocity head

g = acceleration due to gravity = 9.81m/s<sup>2</sup>

Since

$$\text{Re} = \frac{\rho v d}{\mu} \quad (4)$$

### RESULTS

Figure 1 showed that corrosion rate for uninhibited solution is higher than the inhibited solution. The rate of corrosion increased in both cases which indicated that the protective layer formed at the surface of the inhibited coupons does not prevent it from corrosion under flow condition, where it is seen that hydrodynamic conditions can also affect the inhibition of metal corrosion. Flow can increase mass transport of inhibitor molecules that cause more inhibitor presence at the metal surface. This effect can improve the inhibition performance. Nevertheless, hydrodynamic conditions can increase mass transport of metal ions ( $\text{Fe}^{2+}$ ) produced during metal dissolution, from

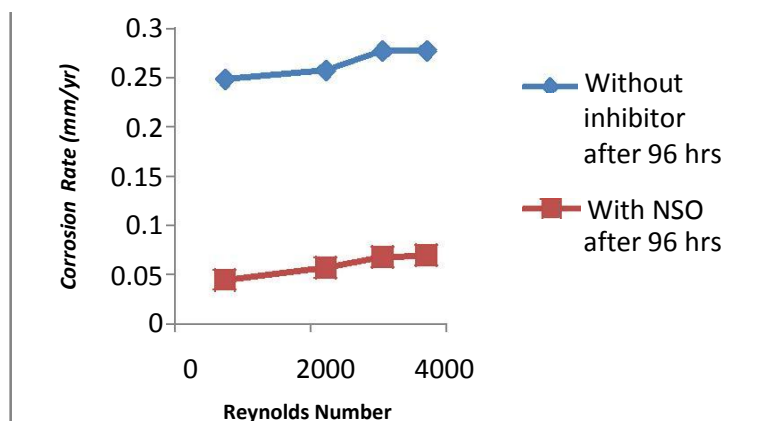


Figure 1. Corrosion rate against Reynolds numbers after 96 h.

electrode surface to the bulk of solution and hence lead to less  $[\text{Fe-Inh}]^{2+}$  complex presence on electrode; this is a harmful effect for inhibition performance. In addition, the high shear stress resulted from high flow velocity can also separate inhibitor layer or adsorbed  $[\text{Fe-Inh}]^{2+}$  complex and cause more desorption from metal surface which acts as a negative factor on inhibition efficiency as studied by Silverman (2004) and Yu et al. (2002).

## Conclusions

The effect of flow velocity of the activated crude oil on corrosion rate of low carbon steel was investigated using the weight loss method. The coupons were immersed in inhibited and uninhibited solution for 96 h. The flow velocity was varied for Reynolds numbers of 3705, 3054, 2220 and 734 at average temperature of 29°C.

It was observed that the scale formed at the surface can be removed due to erosion–corrosion which results in further corrosion attack. When inhibitors are added to the corrosive media it forms a layer and also reduce the initial rate of attack. The result showed the importance of inhibitor, which reduced corrosion rate with time under flow conditions with better performance at laminar flow.

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