Technical Report

Effect of Velocity of Cleaning Pigs on the Efficiency of Fluid Delivery in the Pigged Pipeline System

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Abstract: Studies have been carried out to investigate the effect of velocity of cleaning Pigs on the efficiency of fluid delivery in pigged pipeline system. The results of the investigation indicate that increase in the velocity of the Pig increases the acceleration of the Pig leading to increase in the force exerted on the wall of the pipe. This invariably results to increased dislodgment and removal of corrosion products, films, particles, wax and other unwanted debris accumulated within the pipeline. It was observed that the efficiency of fluid flow through pigged pipelines is dependent on the velocity of fluid flow (after pigging) which in turn depends on the velocity with which the Pig ran during the cleaning process. [Report and Opinion. 2009;1(5):14-18]. (ISSN: 1553-9873).

Keywords: Keywords: Velocity, Cleaning Pigs, Efficiency, Fluid Delivery, Pipeline System.

1. Introduction

Deposition onto a metal surface, of particles normally suspended in solution has been reported (Ijomah,1991) as biofouling. 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 (Ijomah,1991). 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 (Ijomal,1991). 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 (Ijomah,1991).

Aerobic iron bacteria can oxidize ferrous ions in solution to the ferric state and thus effect the precipitation of ferric hydroxide (Crook,1986). These organisms are common inhabitants of springs and may find their way into water, oil and gas 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 and resist fluid flow (Loverell,1989). The tubercle shields the surface of the pipe from contact with dissolved oxygen (Loverell,1989). 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 (Booth,1985). 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^{0}C, although some strains (disulfotomaculum nigrificans) are able to withstand higher temperatures (Ijomah,1991). 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) (Ijomah,1991). 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 (Ijomah,1991) to utilize hydrogen for their metabolism. 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 (Ijomah,1991):

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

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

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

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

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

It was found (Ijomah,1991) 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.

Observations show that pigging in pipelines is inevitable in order to achieve very high level of pipeline integrity by elimination of various kinds of corrosion products, films, particles and wax that accumulate in the pipes. It was also observed that the efficiency of fluid delivery depends mainly on the level of cleanliness achievable within the internal area of the pipelines, which in turn depends on the effectiveness of the pigging process.

The present work is aimed at investigating the effect of velocity of cleaning pigs on the efficiency of fluid delivery in the pigged pipeline system. In this work, pigs were used to clean the pipes of various kinds of corrosion products, films, particles and wax accumulated by the activities of sulphate reducing bacteria and environmental influences so as to maintain high efficiency of fluid flow through the pipes.

2. Materials and methods

In this study, work was carried out on three major oil pipelines; PPL 1, PPL 2, and PPL 3 at offshore platforms in Akwa Ibom State, having been certified infested with sulphate reducing bacteria (following preliminary phynotipic examination carried out) and observed to contain deposits of wax and particles. Varied velocities of Pig were recorded by varying the volume fluid flow and the pressure within the internal area of the pipe. The mass of the debris dislodged from the pipe during the pigging process was determined for each velocity of Pig considered. The time elapse (in seconds) during which the pigging process occurred was recorded. Details of the stages of the experiments and techniques used are as stated in previous report (Nwoye,2002).

3. Results and discussion

As Pig moves at increased velocity V, it exerts increased force called Force of Erasure on the wall of the pipe in accordance with the equation (Okeke,1987);

$$F = ma \qquad (6)$$

Where

$$a = \left(\frac{V - U}{t}\right) \text{(Okeke,1987)} \qquad (7)$$

Therefore, substituting equation (7) into equation (6), it reduces to;

$$F = m\left(\frac{V - U}{t}\right) \qquad (8)$$

Where

F = Force (N)
m = Mass of Pig (53.8 Kg)
a = Acceleration of the Pig (m/s^2)
V = Final velocity of Pig (m/s)
U = Initial velocity of Pig at time t = 0 (m/s)
T = Time elapse between the beginning and end of the pigging process

The increased force was observed to cause increased dislodgment and removal of the corrosion products, films, particles and wax accumulated on the pipeline. Equation (7) shows that when the velocity of the Pig increases, the acceleration of the Pig increases. Equation (8) shows that this results to increase in the force exerted on the wall of the pipe since the mass of the Pig is constant. Similarly, increase in velocity has been reported to increase momentum (Okeke,1987). It has also been reported (Okeke,1987) that when the momentum of a moving object is increased, the force called into play also increases.

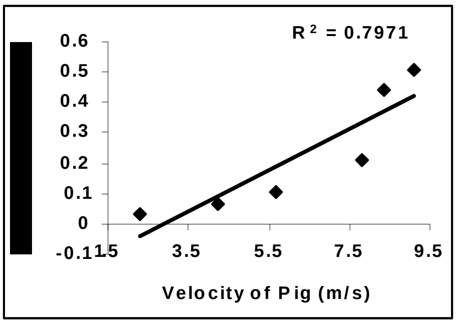

Fig. 1 Effect of velocity on Force of Erasure

The results generated in this field work as shown in Figs. 1 & 2 for PPL 1, Figs. 3 & 4 for PPL 2 and Figs. 5 and 6 for PPL 3 respectively indicate that as the velocity of running Pig is increased during cleaning of pipelines, the force exerted by the moving Pig during this cleaning process also increases resulting in the increased dislodgment and removal of unwanted debris within the pipeline. This invariably enhances the efficiency of fluid flow through such pigged pipelines.

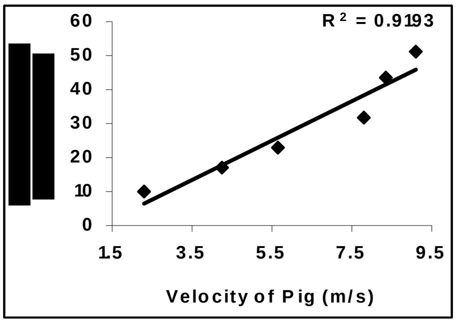

Fig. 2 Effect of velocity on the mass of debris removed

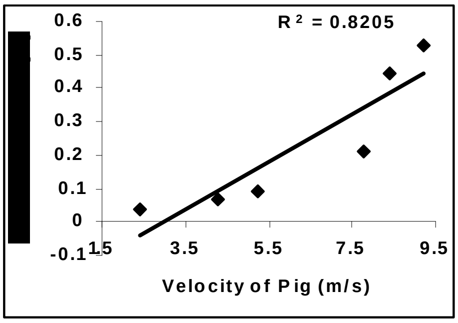

Fig. 3 Effect of velocity on Force of Erasure

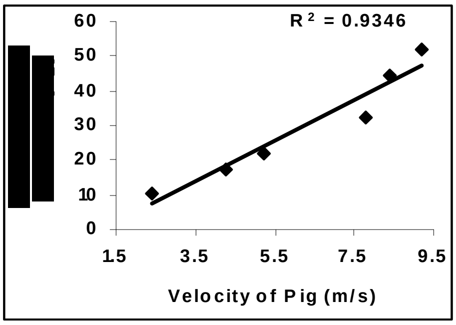

Fig. 4 Effect of velocity on the mass of debris removed

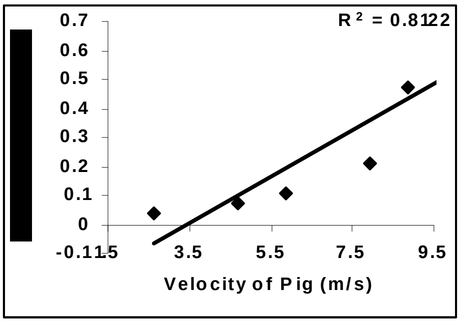

Fig. 5 Effect of velocity on Force of Erasure

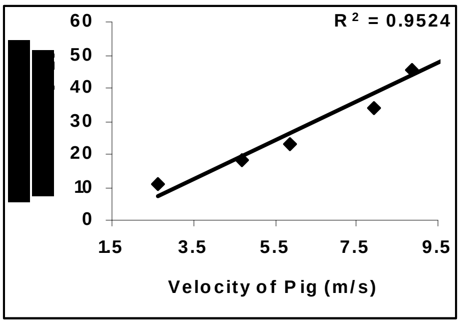

Fig. 6 Effect of velocity on the mass of debris removed

Table 1: Time elapse (seconds) during the pigging process in pipelines

PPL 1	PPL 2	PPL 3
3580	3541	3498
3431	3428	3396
2998	3001	2989
1996	2006	1996
1023	1016	1003
967	942	842

Effect of pigging on the efficiency of fluid delivery through pipeline system

The primary purpose of any pipeline maintenance programme is to maximize flow ability and prolong the life of the pipeline system. To calculate the efficiency of fluid delivery through pipeline system;

Let

α_i = Installed mass flow rate of fluid through the pipeline (i.e when pipeline is devoid of obstacles) (kg/s)

α_o = Obstructed mass flow rate of fluid through the pipeline (kg/s)

In both cases, (installed and obstructed mass flow rates), the mass of fluid flowing through the pipeline is the same. The difference in their flow rates stems on their velocities of flow. The velocity of flow of fluid through the pipelines of obstructed internal diameter was observed to be lower than that obtained for clean and newly installed pipelines functioning at its installed capacity.

Mass flow rate is given by;

$$\alpha = \text{Mass} \times \text{Velocity} \quad (9)$$

Based on the foregoing,

$$\alpha_i > \alpha_o \quad (10)$$

Considering equation (9) and substituting in equation (10)

$$MV_i > MV_o \quad (11)$$

Where

V_i = Installed velocity of fluid flow through the pipeline (m/s)
V_o = Obstructed velocity of fluid flow through the pipeline due to obstacle (m/s)

Generally,

$$\text{Efficiency} = \left(\frac{\text{output}}{\text{input}}\right) \times 100 \quad (12)$$

Therefore, the efficiency of fluid flow through pipeline of known installed capacity is given by;

$$E = \left(\frac{\alpha_o}{\alpha_i}\right) \times 100 \quad (13)$$

Where

α_o = output
α_i = input

Substituting equation (11) from equation (10) into equation (13)

$$E = \left(\frac{MV_o}{MV_i}\right) \times 100 \quad (14)$$

Since the mass of fluid flowing through the pipeline is constant,

$$E = \left(\frac{V_o}{V_i}\right) \times 100 \quad (15)$$

Since $V_i = V_o$, effective pigging and cleaning of the pipeline would have the effect of increasing the efficiency of flow in equation (10) since the value of V_o increases. High efficiency of fluid flow is achieved when the inner part of the pipe is so effectively cleaned that there is very little or no obstacle in form of dirt, corrosion products, wax and particles inside the pipes. In this situation, the value of V_o increases greatly and become very close to V_i, hence making efficiency E very close to 100%. Therefore, pigging pipelines with achievable high degree of cleanliness within the internal diameter, and along the entire length of the pipeline gives very high value of V_o and evaluation of E in this case gives a very high value. Based on this, it clear that when pigging of oil field pipelines are carried out obtaining high degree of cleanliness inside the pipeline, there is high efficiency of fluid delivery to predetermined destination, all other factors being constant.

4. Conclusion

Studies carried out to investigate the effect of velocity of cleaning Pigs on the efficiency of fluid delivery in pigged pipeline system shows that increase in the velocity of the Pig increases the acceleration of the Pig leading to increase in the force exerted on the wall of the pipe. This resulted to increased dislodgment and removal of corrosion products, films, particles, wax and other unwanted debris accumulated within the pipeline. The efficiency of fluid flow through pigged pipelines is dependent on the velocity of fluid flow (after pigging) which in turn depends on the velocity with which the Pig ran during the cleaning process.

Acknowledgement

The authors thank the staff of SynchroWell Services for their technical assistance during this work.

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Table 2: Effect of velocity of fluid on its flow efficiency

	PPL 1		PPL 2		PPL 3	
	Bp	Ap	Bp	Ap	Bp	Ap
Velocity (V_o) (m/s)	1.96	2.78	2.01	2.76	1.98	2.75
Efficiency (E) (%)	70	99.29	71.79	98.57	70.71	98.21

Installed velocity (V_i) of fluid flow through the pipeline: 2.8 m/s

Where

Bp = Before pigging
Ap = After pigging