# Corrosion Inhibition For Wax Deposition Effect Of Flow Rate On Crude Oil Pipeline

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***Abstract*—The aim of the study is to examine the corrosion inhibition for wax deposition effect of flow rate on crude oil pipeline. The paraffin wax on the surface provides excellent corrosion protection, while others provided only moderate or negligible protection in the crude oil pipeline, but most of the corrosion protection has been lost due to the long chain paraffin layer being physically removed from the surface during the periods of increased temperature or increased flow rates. An experimental flow loop was constructed for the crude oil pipeline for the flow effect of wax deposition on $CO_2$ corrosion. The linear polarization resistance method was used to measure the corrosion rate in mils per year (mpy) against time (minutes) using MS1000 Corrosion Meter. MATLAB software was used for simulation with the experimental results and the input parameter from the wax physical properties and operating conditions. Based on the analysis, it was observed that at time 18 minutes, the experimental and the model results predicted a significant reduction of corrosion rates while others gave only moderate or negligible protection to the crude oil pipeline. From the profile plot, the values of the corrosion rate (mpy) against time (min) of the experimental and model results are 3 (0.83 mpy, 0.9337 mpy), 6 (0.69 mpy, 0.8167 mpy), 9 (0.94 mpy, 0.6997 mpy), 12 (0.76 mpy, 0.5827 mpy), 15 (0.42 mpy, 0.4657 mpy), 18 (0.21 mpy, 0.3487 mpy). But the variation of the experimental and model results in terms of deviation is (0.07%) indicating that both results are insignificant in variation, showing positive agreement between the experimental and model results. It has been found that as the deposition of the paraffin wax increases the corrosion rate decrease. This proves that paraffin wax deposition on the steel pipe act as a protective layer to inhibit corrosion.**

***Keywords—corrosion, inhibition, pipeline, wax, deposition***

## I. INTRODUCTION

Flow assurance, in this sense, seeks to forecast the behavior of fluids as they pass through pipelines and processes in order to identify concerns that may jeopardize safety, integrity, production capacity, and product availability. Flow assurance is primarily concerned with avoiding deposits from forming inside the pipe (Callister, 2017). Wax deposition, which is the obstruction of flow lines due to the deposition of heavy organic compounds contained in the oil, is the most common of these (Callister, 2017). Wax precipitation and deposition can significantly influence the economy for a field, because operational and remedial costs are increased in addition to decreasing production (Fasano et al., 2014). This emphasizes that accurate wax deposition modeling is of high importance, and high reliability is required for these models. Untreated wax deposition leads to a reduced flow area, and in worst case the deposit may even block the pipe. In order to handle the deposition problem, it is important to know where wax will form, how much wax that will form, how fast the wax will form and how deposition wax can be prevented. To accomplish this, wax deposition models are used. These models predict the wax deposition effects profile along the pipeline defines potential wax problems and estimates the pigging frequency before production starts up. However, for an operating pipe, the pigging frequency can be determined by Pressure Pulse profiling of deposits combined with tracer injection, and this way the location and extent of the deposit is measured. In a field pipeline, underestimation by a wax deposition model increases the potential risk of a stuck pig during a pigging operation. On the other hand, over estimation results in too high pigging frequency, and thus unnecessary operational costs (Gjermundsen, 2018). Accurate wax predictions may lead to suitable pigging programs for pipelines, and less wax inhibitors can be used. From an economic point of view correct predictions may reduce the pigging frequency, and thereby reduce the expenses. From an environmental point less use of chemicals is favourable. The solid form of paraffin is usually called “paraffin wax” or just “wax”. Paraffins are one of the most common components in crude oil. In chemistry, paraffin is the common name for alkane hydrocarbons with the general formula CnH2n+2. Wax deposition is a long-standing issue in the oil sector, with the industry losing hundreds of millions of dollars each year to deal with it (Gjermundsen, 2018)

Wax deposition is a complex process that is one of the primary unsolved difficulties in Flow Assurance in pipelines and manufacturing equipment. Petrobras created the word "flow assurance" in the early 1990s to denote "flow assurance" (Gjermundsen, 2018). It covers all strategies for ensuring that hydrocarbons are delivered efficiently from wells to collection facilities. It entails safely and efficiently transferring hydrocarbons from deposits to sale locations. It works with hydrates, wax, corrosion, scale, and sand among other solid deposits. During the movement of fluids through pipelines and processes, flow assurance encompasses the examination of thermal, hydraulic, and production chemistry issues.

## II. MATERIALS AND METHODS

The following material were used in this study, they are flow-loop build with steel pipe, 0.5hp pump, flow meter, MS1000 Corrosion Meter, waxy crude oil was used in this study.

### A. EXPERIMENTAL PROCEDURE

To study the effect of flow rate on wax deposit on corrosion of crude oil pipeline, the crude oil sample is pumped into the flow-loop set up under different operating conditions. The range of the inlet temperature of the waxy crude oil was (10-40$^{o}$C). The experiment was conducted 5 times, at time interval of 3-18 minutes, temperature was varied between 15-35$^{o}$C and flow rate were also varied between 10.21-50.70 L/min. The experiment was carried out at varying temperature with time while flow rate is kept constant. At temperature of 15, 20, 25, 30 and 35$^{o}$C and time at 3, 6, 9, 12, 15 and 18 min while keeping flow rate constant for each experimental run at 10.21, 20.37 30.45, 40.28, 50.70 L/min to determine the corrosion rate against time. After testing the corrosion rate of the waxy crude oil to ascertain the effect of flow rate at varying temperature and time of the paraffin wax deposited on the crude oil pipeline. The results were recorded, the graph of corrosion rate (mpy) against time (min) was plotted and the result were analyzed.

### B. Simulating Model

A computer program was developed to solve the governing equations of the formulated models using the parameters from wax operating conditions and the experimental data from the effect of wax concentration on corrosion against time in minutes. The model was simulated using MATLAB software. Based on the model developed, F= F_o λ t is the flow rate model used for simulation to determine the effect of flow rate on wax deposit on corrosion rate (mpy) against time (min) in crude oil pipeline. The simulation results of the model were recorded, graph plotted and analyzed to compare the experimental and model data on wax deposition

## III. Results and Discussion

Experimental Result for the Effect of Flow Rate at 50.70 L/min on Corrosion rate (mpy) against Time (min) for Wax Deposition during corrosion inhibition.

| Time (min) | Corrosion Rate (mpy) @15$^{o}$C | Corrosion Rate (mpy) @ 20$^{o}$C | Corrosion Rate (mpy) @ 25$^{o}$C | Corrosion Rate (mpy) @ 30$^{o}$C | Corrosion Rate (mpy) @ 35$^{o}$C |
|---|---|---|---|---|---|
| 3 | 0.83 | 0.92 | 0.73 | 0.76 | 0.69 |
| 6 | 0.69 | 0.75 | 0.58 | 0.88 | 0.95 |
| 9 | 0.94 | 0.66 | 0.81 | 0.79 | 0.74 |
| 12 | 0.76 | 0.87 | 0.69 | 0.57 | 0.67 |
| 15 | 0.42 | 0.91 | 0.88 | 0.82 | 0.56 |
| 18 | 0.21 | 0.47 | 0.54 | 0.38 | 0.62 |

Table 1a: Experimental Result of the Effect of Flow Rate on Wax Deposit on Corrosion Rate (mpy) versus Time (min) at constant Flow Rate of 50.70 L/min while adjusting Temperature (15, 20, 25, 30 and 35$^{o}$C)

Table 1b: MAT LAB Simulation Result of the Effect of Flow Rate on Wax Deposit on Corrosion Rate (mpy) versus Time (min) at constant Flow Rate of 50.70 L/min while adjusting Temperature (15, 20, 25, 30 and 35$^{o}$C)

| Time (min) | Corrosion Rate @ 15$^{o}$C | Corrosion Rate @ 20$^{o}$C | Corrosion Rate @ 25$^{o}$C | Corrosion Rate @ 30$^{o}$C | Corrosion Rate @ 35$^{o}$C |
|---|---|---|---|---|---|
| 0 | 1.0507 | 1.0507 | 0.9193 | 0.722 | 0.93 |
| 1 | 1.0117 | 1.0117 | 0.9044 | 0.7204 | 0.9081 |
| 2 | 0.9727 | 0.9727 | 0.8895 | 0.7188 | 0.8862 |

| | | | | | |
|---|---|---|---|---|---|
| **3** | 0.9337 | 0.9337 | 0.8746 | 0.7172 | 0.8643 |
| **4** | 0.8947 | 0.8947 | 0.8597 | 0.7156 | 0.8424 |
| **5** | 0.8557 | 0.8557 | 0.8448 | 0.714 | 0.8205 |
| **6** | 0.8167 | 0.8167 | 0.8299 | 0.7124 | 0.7986 |
| **7** | 0.7777 | 0.7777 | 0.815 | 0.7108 | 0.7767 |
| **8** | 0.7387 | 0.7387 | 0.8001 | 0.7092 | 0.7548 |
| **9** | 0.6997 | 0.6997 | 0.7852 | 0.7076 | 0.7329 |
| **10** | 0.6607 | 0.6607 | 0.7703 | 0.706 | 0.711 |
| **11** | 0.6217 | 0.6217 | 0.7554 | 0.7044 | 0.6891 |
| **12** | 0.5827 | 0.5827 | 0.7405 | 0.7028 | 0.6672 |
| **13** | 0.5437 | 0.5437 | 0.7256 | 0.7012 | 0.6453 |
| **14** | 0.5047 | 0.5047 | 0.7107 | 0.6996 | 0.6234 |
| **15** | 0.4657 | 0.4657 | 0.6958 | 0.698 | 0.6015 |
| **16** | 0.4267 | 0.4267 | 0.6809 | 0.6964 | 0.5796 |
| **17** | 0.3877 | 0.3877 | 0.666 | 0.6948 | 0.5577 |
| **18** | 0.3487 | 0.3487 | 0.6511 | 0.6932 | 0.5358 |

Table 2: Comparison of Experiment and Model Results of the Effect of Flow Rate on Wax Deposit on Corrosion Rate (mpy) against Time (min) at Flow Rate of 50.70 L/min and Temperature at 15$^{o}$C

| **Time (min)** | **CR Exp (mpy)** | **CR Model (mpy)** | **Error** |
|---|---|---|---|
| **3** | 0.83 | 0.9337 | -0.1037 |
| **6** | 0.69 | 0.8167 | -0.1267 |
| **9** | 0.94 | 0.6997 | 0.2403 |
| **12** | 0.76 | 0.5827 | 0.1773 |
| **15** | 0.42 | 0.4657 | -0.0457 |
| **18** | 0.21 | 0.3487 | -0.1387 |

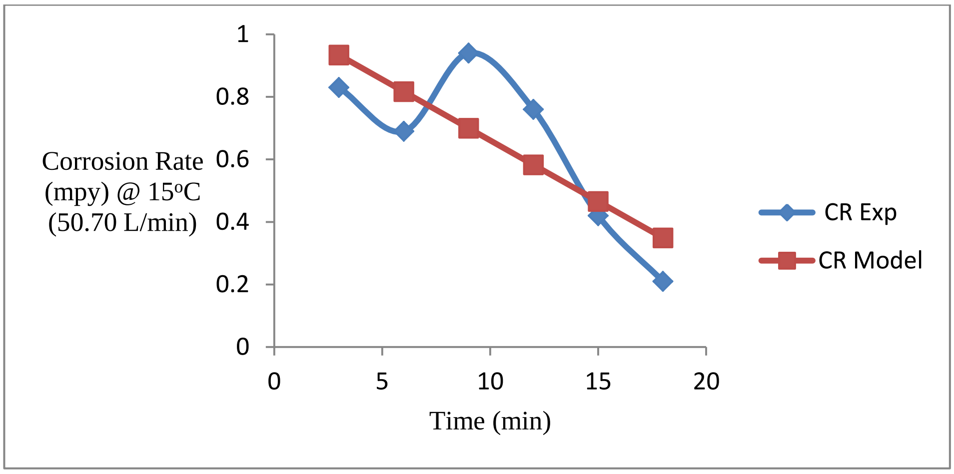


Fig. 2: Comparison of Experimental and Model Results of the Effect of Flow Rate on Wax Deposit on Corrosion Rate (mpy) against Time (min) at Flow Rate of 50.70 L/min and Temperature at 15$^{o}$C

Fig. 2: shows the variation profile plot of experimental and model results of the effect of flow rate on wax deposit on corrosion rate (mpy) against time (min) at flow rate of 50.70 L/min and temperature at 15$^{o}$C L/min during the corrosion inhibition.

At time 18 minutes, the experimental and the model results predicted a significant reduction of corrosion rates while others gave only moderate or negligible protection to the crude oil pipeline.

From the profile plot, the values of the corrosion rate (mpy) against time (min) of the experimental and model results are 3 (0.83 mpy, 0.9337 mpy), 6 (0.69 mpy, 0.8167 mpy), 9 (0.94 mpy, 0.6997 mpy), 12 (0.76 mpy, 0.5827 mpy), 15 (0.42 mpy, 0.4657 mpy), 18 (0.21 mpy, 0.3487 mpy). But the variation of the experimental and model results in terms of deviation is (0.07%) indicating that both results are insignificant in variation, showing positive agreement between the experimental and model results.

Table 3: Comparison of Experimental and Model Results of the Effect of Flow Rate on Wax Deposit on Corrosion Rate (mpy) against Time (min) at Flow Rate of 50.70 L/min and Temperature at 20$^{o}$C

| Time (min) | CR Exp (mpy) | CR Model (mpy) | Error |
|---|---|---|---|
| **3** | 0.92 | 0.8746 | 0.0454 |
| **6** | 0.75 | 0.8299 | -0.0799 |
| **9** | 0.66 | 0.7852 | -0.1252 |
| **12** | 0.87 | 0.7405 | 0.1295 |
| **15** | 0.91 | 0.6958 | 0.2142 |
| **18** | 0.47 | 0.6511 | -0.1811 |

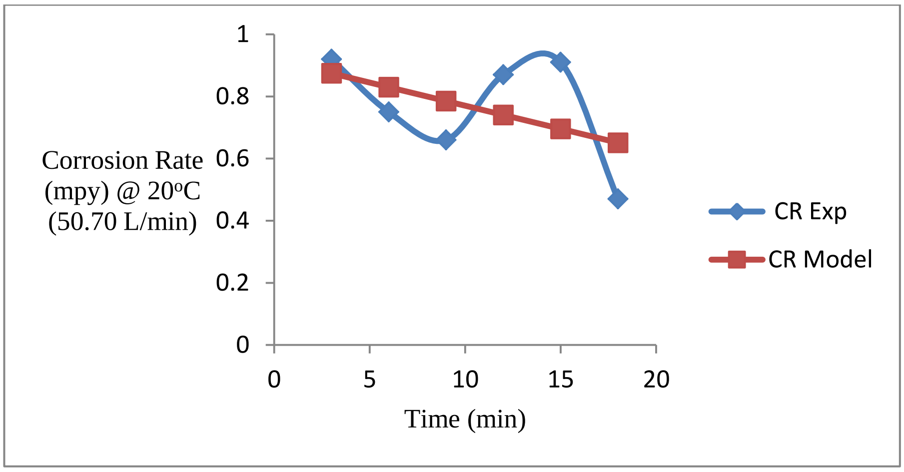


Fig. 3: Comparison of Experimental and Model Results of the Effect of Flow Rate on Wax Deposit on Corrosion Rate (mpy) against Time (min) at Flow Rate of 50.70 L/min and Temperature at 20°C.

Fig. 3: shows the variation profile plot of experimental and model results of the effect of flow rate on wax deposit on corrosion rate (mpy) against time (min) at flow rate of 50.70 L/min and temperature at 20°C L/min during the corrosion inhibition.

At time 18 minutes, the experimental and the model results predicted a significant reduction of corrosion rates while others gave only moderate or negligible protection to the crude oil pipeline.

From the profile plot, the values of the corrosion rate (mpy) against time (min) of the experimental and model results are 3 (0.92 mpy, 0.8746 mpy), 6 (0.75 mpy, 0.8299 mpy), 9 (0.66 mpy, 0.7852 mpy), 12 (0.87 mpy, 0.7405 mpy), 15 (0.91 mpy, 0.6958 mpy), 18 (0.47 mpy, 0.6511 mpy). But the variation of the experimental and model results in terms of deviation is (0.06%) indicating that both results are insignificant in variation, showing positive agreement between the experimental and model results.

Table 4: Comparison of Experimental and Model Results of the Effect of Flow Rate on Wax Deposit on Corrosion Rate (mpy) against Time (min) at Flow Rate of 50.70 L/min and Temperature at 25°C

| Time (min) | CR Exp (mpy) | CR Model (mpy) | Error |
|---|---|---|---|
| **3** | 0.73 | 0.7172 | 0.0128 |
| **6** | 0.58 | 0.7124 | -0.1324 |
| **9** | 0.81 | 0.7076 | 0.1024 |
| **12** | 0.69 | 0.7028 | -0.0128 |
| **15** | 0.88 | 0.698 | 0.182 |
| **18** | 0.54 | 0.6932 | -0.1532 |

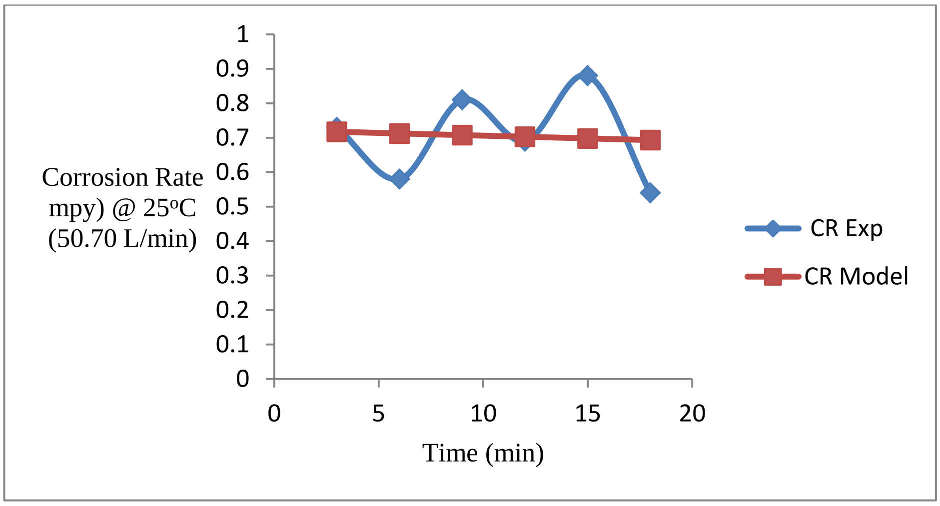


Fig. 4: Comparison of Experimental and Model Results of the Effect of Flow Rate on Wax Deposit on Corrosion Rate (mpy) against Time (min) at Flow Rate of 50.70 L/min and Temperature at 25°C

Fig. 4: shows the variation profile plot of experimental and model results of the effect of flow rate on wax deposit on corrosion rate (mpy) against time (min) at flow rate of 50.70 L/min and temperature at 25°C L/min during the corrosion inhibition.

At time 18 minutes, the experimental and the model results predicted a significant reduction of corrosion rates while others gave only moderate or negligible protection to the crude oil pipeline.

From the profile plot, the values of the corrosion rate (mpy) against time (min) of the experimental and model results are 3 (0.73 mpy, 0.7172 mpy), 6 (0.58 mpy, 0.7124 mpy), 9 (0.81 mpy, 0.7076 mpy), 12 (0.69 mpy, 0.7028 mpy), 15 (0.88 mpy, 0.698 mpy), 18 (0.54 mpy, 0.6932 mpy). But the variation of the experimental and model results in terms of deviation is (0.03%) indicating that both results are insignificant in variation, showing positive agreement between the experimental and model results.

Table 5: Comparison of Experimental and Model Results of the Effect of Flow Rate on Wax Deposit on Corrosion Rate (mpy) against Time (min) at Flow Rate of 50.70 L/min and Temperature at 30°C

| Time (min) | CR Exp (mpy) | CR Model (mpy) | Error |
|---|---|---|---|
| **3** | 0.76 | 0.8643 | -0.1043 |
| **6** | 0.88 | 0.7986 | 0.0814 |
| **9** | 0.79 | 0.7329 | 0.0571 |
| **12** | 0.57 | 0.6672 | -0.0972 |
| **15** | 0.82 | 0.6015 | 0.2185 |
| **18** | 0.38 | 0.5358 | -0.1558 |

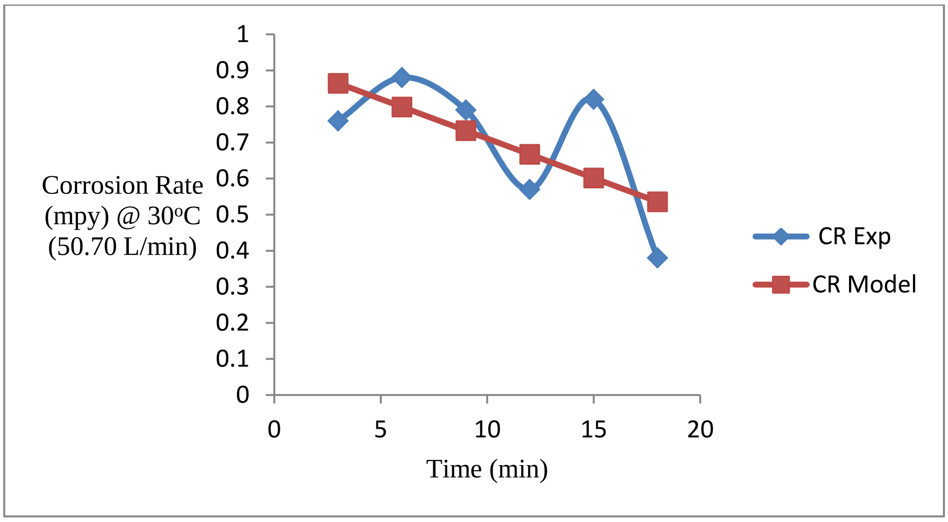


Fig. 5: Comparison of Experimental and Model Results of the Effect of Flow Rate on Wax Deposit on Corrosion Rate (mpy) against Time (min) at Flow Rate of 50.70 L/min and Temperature at 30$^{o}$C.

Fig. 5: shows the variation profile plot of experimental and model results of the effect of flow rate on wax deposit on corrosion rate (mpy) against time (min) at flow rate of 50.70 L/min and temperature at 30$^{o}$C L/min during the corrosion inhibition.

At time 18 minutes, the experimental and the model results predicted a significant reduction of corrosion rates while others gave only moderate or negligible protection to the crude oil pipeline.

From the profile plot, the values of the corrosion rate (mpy) against time (min) of the experimental and model results are 3 (0.76 mpy, 0.8643 mpy), 6 (0.88 mpy, 0.7986 mpy), 9 (0.79 mpy, 0.7329 mpy), 12 (0.57 mpy, 0.6672 mpy), 15 (0.82 mpy, 0.6015 mpy), 18 (0.38 mpy, 0.5358 mpy). But the variation of the experimental and model results in terms of deviation is (0.07%) indicating that both results are insignificant in variation, showing positive agreement between the experimental and model results.

Table 6: Comparison of Experimental and Model Results of the Effect of Flow Rate on Wax Deposit on Corrosion Rate (mpy) against Time (min) at Flow Rate of 50.70 L/min and Temperature at 35$^{o}$C

| **Time (min)** | **CR Exp (mpy)** | **CR Model (mpy)** | **Error** |
|---|---|---|---|
| **3** | 0.69 | 0.8187 | -0.1287 |
| **6** | 0.95 | 0.7734 | 0.1766 |
| **9** | 0.74 | 0.7281 | 0.0119 |
| **12** | 0.67 | 0.6828 | -0.0128 |
| **15** | 0.56 | 0.6375 | -0.0775 |
| **18** | 0.62 | 0.5922 | 0.0278 |

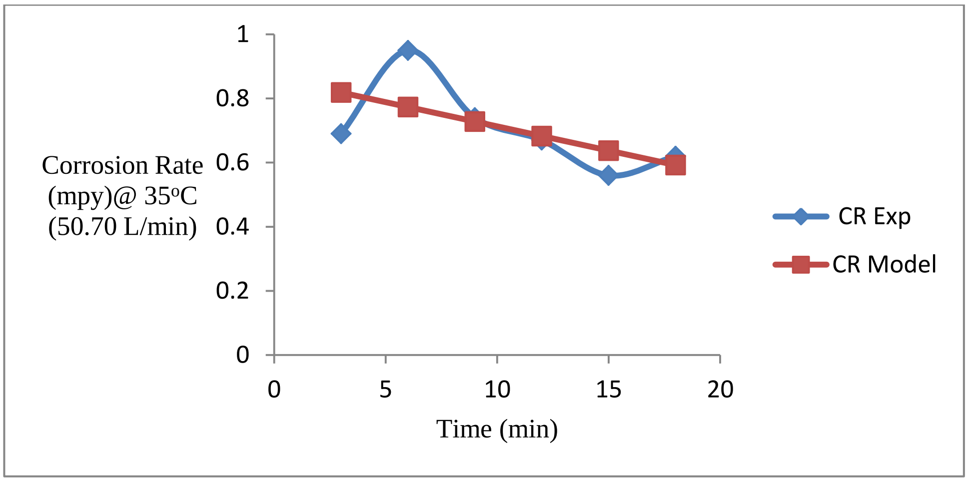


Fig. 6: Comparison of Experimental and Model Results of the Effect of Flow Rate on Wax Deposit on Corrosion Rate (mpy) against Time (min) at Flow Rate of 50.70 L/min and Temperature at 35$^{o}$C

Fig. 6: illustrate the variation profile plot of experimental and model results of the effect of flow rate on wax deposit on corrosion rate (mpy) against time (min) at flow rate of 50.70 L/min and temperature at 35$^{o}$C L/min during the corrosion inhibition.

At time 15 and 18 minutes, the experimental and model results predicted a significant reduction of corrosion rates while others gave only moderate or negligible protection to the crude oil pipeline.

From the profile plot, the values of the corrosion rate (mpy) against time (min) of the model experimental and model results are 3 (0.69 mpy, 0.8187 mpy), 6 (0.95 mpy, 0.7734 mpy), 9 (0.74 mpy, 0.7281 mpy), 12 (0.67 mpy, 0.6828 mpy), 15 (0.56 mpy, 0.6375 mpy), 18 (0.62 mpy, 0.5922 mpy). But the variation of the experimental and model results in terms of deviation is (0.06%) indicating that both results are insignificant in variation, showing positive agreement between the experimental and model results.

## V. Conclusion

The presence of a paraffin wax film on the surface reduces general corrosion rates significantly, yet localized corrosion has been detected due to the paraffin layer's loss of integrity. This demonstrates that the deposition of paraffin wax on the steel pipe acts as a protective coating that prevents corrosion. As a result, temperatures, flow rates, and concentrations below the wax appearance temperature must be researched in order to evaluate the influence of wax deposition on crude oil pipeline corrosion. When a wax layer is applied to a steel surface, it slows corrosion by preventing corrosive species from diffusing to the surface. By coating the inner wall of the pipeline with paraffin wax, it works as a corrosion inhibitor while also restricting flow. The paraffin wax on the surface of the crude oil pipeline provides good corrosion protection, whilst others only give poor or no protection. However, due to the long chain paraffin layer being physically removed from the surface during periods of elevated temperature or flow rates, the majority of the corrosion protection has been lost. The protection provided by paraffin is assumed to be due to physisorption, which is caused by weak intermolecular interactions such as van der Waals forces. Despite the lack of surface chemical activity, paraffin can form on the pipe surface at low temperatures, below the so-called wax appearance temperature. When the wax layer covers the steel surface, it can slow down corrosion by preventing corrosive species from diffusing to the surface.

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