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Estimation of the Restarting Pressure for Abu-Attifel Crude Oil

Fathi I. Ashour[1,*], Mohamed A. El-Meshragi[2], Ezeddine E. Zorgani[3]
[1]Department of Chemical, Polymer and Petroleum Engineering, Higher Institute for Comprehensive Professions, Algaraboli, Libya
[2]Chemical and Petroleum Engineering Department, Al-Mergib University, Alkhoms, Libya
[3]Libyan Petroleum Institute, Tripoli, Libya
[*]Corresponding Author: fathi_ashor@hotmail.com

Abstract

Many pipelines around the world are now transporting wax-containing crude oils. Transporting such oils poses serious handling problems that is tragically have been very expensive to overcome. Wax containing crude oil has high pour point. Wax crystallizes as temperature is reduced. These results in gelled crude when the temperature is getting lower than pour point during shut down periods. Waxy crude oils contain a large amount of wax, possess a high pour points and exhibit non-Newtonian viscosity behavior. As the waxy oil cools, crystallization of the paraffin causes part of crude oil mass to gel. Actually congealing of the oil may start at temperatures considerably above the pour point. When this cooling takes place in a pipe a certain pressure is required to initiate the flow of the waxy crude. Also an important for pipeline design is the definition of pressure required to start up the pipeline after shutdown. In addition, the laboratory tests of the fluid to be transported is also important to characterize its exact rheological behavior by means of a full scale test loop. An experimental study of the flow behavior (restarting pressures, RSP) for Abu-Attifel crude oil was the major objective of the study. The obtained results have been used to test a mathematical model, which simulates the oil pipeline. OPAL (OPAL limited, UK, and Aberdeen) Pipeline Restart Pressure Apparatus was used to study re-start pressure of desired crude oil. Result of RSP for Abu-Attifel crude oil samples (1 m, 2 m and 5 m) long, at constant diameter ($3/8in$), is measured. In addition, RSP for samples (1/4 in and 3/8 in) diameter, at constant length (1 m), is also measured. The major effect on the yield stress is the temperatures only, but diameter and length of the pipeline have minor effect. The RSP begun at 35 $°C$ or above for Abu-Attifel field.

Keywords: Abu-Attifel; crude oil analysis; pipeline; restarting pressure; RSP.

1. Introduction

Waxy crude are distinguished, as far as pipelines are concerned, by the fact that they exhibit Newtonian viscosity behavior at temperatures above the pour point, at the lower temperature the more observed is the deviation from a Newtonian fluid to non-Newtonian fluid.

Many pipelines around the world are now transporting crude oil containing wax. Transporting such oils poses many problems, and handlings topically have been very expensive to overcome. Heating, diluting with other crude oils, or transporting by trucks or rails have been costly means of handling. Crude oil containing wax has high pour point. Such wax crystallizes at low temperature. The waxy crude oil crystallizes when the crude oil cools and causes part of crude oil mass to gel. Actually congealing of the oil may start at temperatures considerably above the pour point. When this cooling takes place in a pipe, a certain pressure is required to initiate the flow of the waxy crude. Waxy crude oils are be-

Table 1.1: specification of ABU-ATTIFEL Crude oil

specification	Unit	
Density @ 60 0F	g/ml	0.8246
Sp-Gr		08251
API		40.0
Wax content	% wt.	36
Pour point	0C	39
Asphaltenes	% wt.	0.09

coming more important since often have low sulfur contents, making them desirable from an environmental view point.

The pour point is not completely indicates a crude oil's flow properties; however viscosity and gel strength should also be considered. An important of understanding the flow properties of crude oils, viscosity, gel strength (yield value) and pour point are all considered together. Many pipelines still specify pour point as the sole criterion for determining acceptability of a crude oil. This often is an unrealistic and unnecessary constraint because viscosity and gel strength indeed may be more important. Also an important for pipeline design is the definition of pressure required to start up the pipeline after shutdown and of pressure losses under steady stat conditions. The restarting pressure (RSP) to break the gel and RS the flow may exceed sometimes the bursting pressure of the pipeline, this consideration must be taken into account while simulating the pipeline.

In addition the laboratory tests of the fluid to be transported is also important to characterize its exact rheological behavior by means of a full scale test loop. Once the exact characteristics of the fluid have been determined, several methods are available to solve pipeline transportation problems.

The objective of this study to determine the flow properties RSP of ABU-ATTIFEL crude oil at selected condition. Therefore an experimental system has been used to measure restarting pressure of crude oil samples. Correlation will be used to predict the restarting pressure for major pipeline using results from laboratory.

ABU-ATTIFEL field is one of the major oil productions fields in Libya. All crude oils which produced from the reservoirs are characterized by high wax contents and high pour point. The specifications of ABU-ATTIFEL Crude oil are listed in table 1.1.

The oil samples have been taken from storage tank (i.e. dead crude which is pumped from ABU-ATTFEL field to 103 field through pipeline 132km, 30").

2. Material and Methods

The principle is that a there is a linear relationship between the force required to RSP a model pipeline and the energy needed to restart a full scale pipeline. Therefore under strict temperature conditions the pressure increase measured before oil starts to flow from the model pipeline is proportional to the pressure required to get oil flowing from a full scale pipeline at the same temperature. The cooling rate and the length of the time held at the static temperature. If crude oil in a full pipeline settles at an ambient temperature below the pour point the oil in the pipeline will gel. An additional force above the energy required to maintain flow is required to restart the pipeline. OPAL Equipment will be used to measure RSP at different conditions.

OPAL Pipeline RSP Equipment was designed by OPAL limited (UK, Aberdeen) specifically to study re-start pressure. The System includes: Water bath, Model pipelines, Coolant/Heating unit, Pump and pressure gages. Fig 2.1 shows the complete Pipeline Re-start Equipment with a close-up of a section of a 4-pipeline unit (model pipe).

3. Experimental Procedure

The scope of the experimental work is to obtain a relationship between RSP and the length of the sample in the pipe at different temperatures. The experiments were run at Libyan Petroleum Institute (LPI).

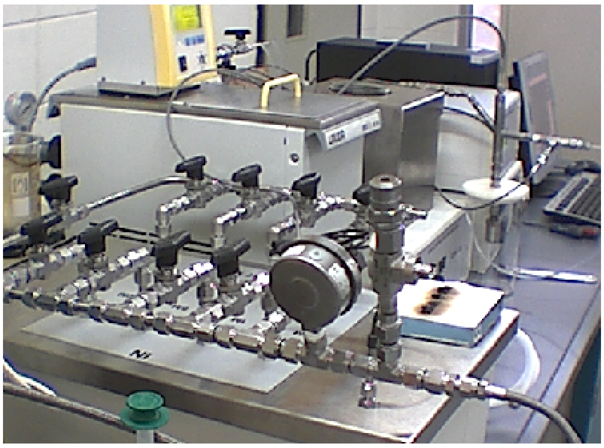
A sample of crude oil is heated to 20 $^{\circ}C$ above pour point or to the process temperature before the crude enters the low ambient temperature environment and circulated through the model pipeline.

The oil is circulated through the model pipeline in a coolant-bath at the same temperature as the oil. A minimum of 5 volumes of oil are passed through the model pipeline.

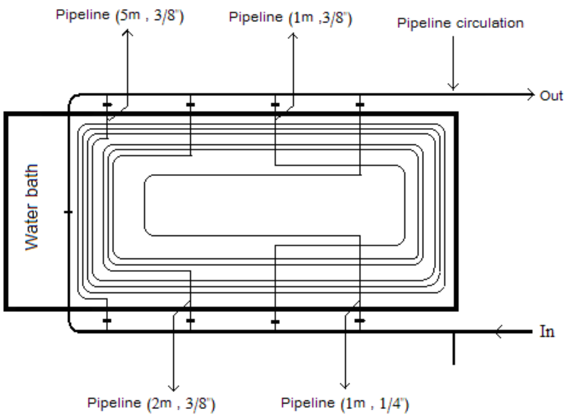
The pipeline is placed in a coolant, usually water, bath and the water cooled under controlled conditions using a programmable cooler. Once the minimum ambient temperature has been achieved the shut in periods are measured. After each period has elapsed the pipelines can be isolated and restarted

Figure 2.1: Restart Pressure Measurement Equipment

(a)



(b)



individually by pumping hot oil through the line. As the length, diameter and cross section of the pipeline are known the yield stress for the oil in the pipeline can be calculated and is used to calculate the maximum pressure increase required to restart a pipeline of known diameter and length.

4. Results and Discussion

The main goals of this study to determine the RSP of the pipeline transporting waxy crude oil (ABU - ATTIFEL crude oil) at temperature ranged from 5 °C to 40 °C with increasing gradient by 5 each run. The results collected using pipe loops of limited length of few meters (1m, 2m, and 5m) .This data mimic for major pipelines.

Figure 4.1 and figure 4.2 present plots of RSP versus the temperature for different sample's lengths and diameter ,The highest value of RSP is measured at 5 °C , RSP increases as temperature decreases, because the temperature decreases had effect on the wax formation in the waxy crude oil. Sharp decrease of RSP in temperature range of 15 °C to 35 °C because the wax crystals began melt is observed in this range, and the effect of temperature change on RSP can be negligible before 10 °C as well as when the temperature exceed 35 °C because are the wax crystals in crude can be considered completely formatted below 10 °C and above 35 °C the wax crystals in the crude are melted.

Figure 4.1: Relationship between RSP and temperature for (1m, 2m & 5m) at constant diameter (3/8").

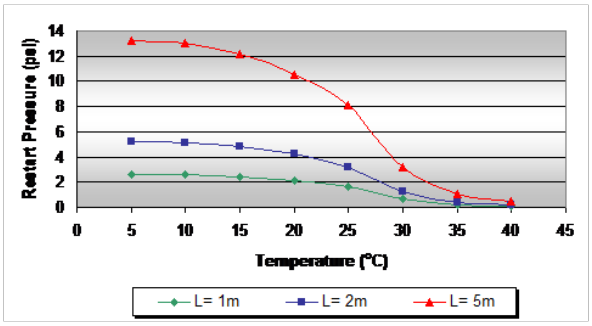


Figure 4.2: Relationship between RSP and temperature for samples diameter are (1/4" & 3/8") at constant length (1m).

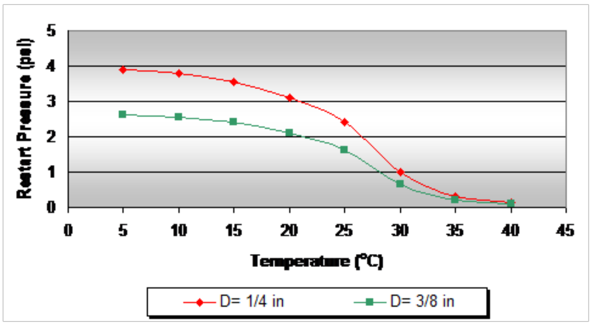


Figure 4.3: Relationship between temperature and RSP for full scale pipeline.

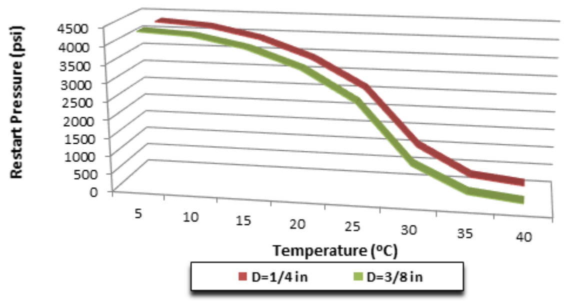
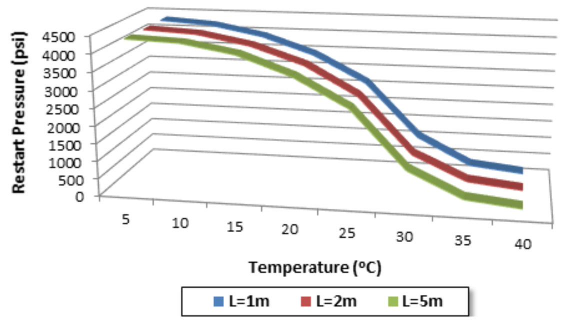


Figure 4.4: Relationship between temperature and RSP for full scale pipeline.



The Experimental results will be introduced and used for calculation of RSP for full pipeline. This method depending on uses of yield stress measurements results:
The method adopted is based on the assumptions:

- The applied pressure uniformly all over the pipe length.
- The yield stress of crude oil is the same all over the pipe.

RSP is calculated for the full scale pipeline by the equation:
[Ajienka J. A. & IKoku C. U. (1995)]

$$RSP = \frac{(4\,L * \tau_y)\,/D}{6891.2} \tag{4.1}$$

The yield stress is calculated for the model pipeline by the equation: [Ajienka J. A. & IKoku C. U. (1995)]

$$\tau_y = \frac{RP\,*\,D}{4\,L} \tag{4.2}$$

Figure 4.3 and figure 4.4 presents the RSP of full scale pipeline versus the temperature, according to experimental work results. figure 4.3 calculated at constant length and different diameters. figure 4.4 calculated at different lengths and constant diameter. The full scale pipeline follow the same behaviour for samples, this means that the RSP is independent on the length and diameter of pipeline and only is dependent on temperature.

The bursting pressure of a pipeline is estimated from the following equation: [Max S. P. & Klans D. T. (1980)]

$$P_b = \frac{2\,*\,S_t\,*\,t_m}{D_m} \tag{4.3}$$

Where:
P_b= Bursting pressure, (psi).
S_t= Tensile strength, (psi).
t_m= Minimum wall thickness, (in).
D= Mean diameter, (in).
For the pipeline $(132km)$, the diameter of the pipe is 30" by using the above equation is $400psi$.

5. Conclusion

1. Restarting pressure for different sample model length and different diameter has the same behavior.
2. The main pipeline from ABU-ATTIFEL field to 103 fields, the restarting pressure should be begun at 95 $(35\ ^{\circ}C)$ or above.
3. The major effect on the yield stress is the temperatures only, but diameter and length of the pipeline have minor effect.
4. Fixed the outlet temperature of the crude oil in pipeline near the pour point is more suitable and change inlet temperature at different flow rate.
5. The pour point does not completely indicate a crude oils flow properties, viscosity and gel strength should also be considered.

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