Research Paper

Crude Characterisation on Rheometer for Flow Assurance

Technology

KEYWORDS : Flow Assurance, Rheometer, Wax Appearance Temperature (WAT), Crude Oil, Inhibition Mechanism

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ABSTRACT

Flow assurance basically involves ensuring the fluid flow as intended in a pipe or a well. Wax deposits begin to form when the temperature in the wellbore falls below wax appearance temperature (WAT). This condition leads to reduced production rates and larger pressure drops. Wax problems in production wells are very costly due to production down time for removal of wax. To improve the efficiency of the transportation and the crude oil quality, prevent blockage, preventing and removing wax is very important. In order to develop a solution to wax deposition, it is essential to characterize the crude oil and study phase behavior properties. This paper summarizes the results of the various experiments conducted using crudes of different wells. The experiments conducted during this study include measurement of viscosity as a function of time at different shear rate. It also shows the effect of pre-treatment on crude oil. The paper also discuss about the comparison between use of xylene and pour point depressants (PPD) at different concentration on crude oil.

INTRODUCTION

One of the major problems confronting the petroleum industry is the untimely blockage of oil arteries due to deposition of heavy organics (asphaltene, resin, paraffin wax) present in the oil. The continued deposition of heavy organics results in reduced area which may lead to plugging of pipe cross section. This can result in huge economic loss. The phenomena may also take place in the formation near the wellbore. (Adesina F., et al., 2010)

Flow Assurance addresses the issues of deposition of heavy organics during entire petroleum extraction process from the reservoir to surface process facilities and beyond. The precipitation of waxes from petroleum mixtures at low temperatures may cause different problems during production, transport in pipelines, or storage. Such problems are well-known within the petroleum industry and the best way to deal with such problems is to predict its occurrence and act preventively.

WAX

Waxes are defined as the relatively high molecular weight C_{18}-C_{60} alkanes, which are deposited as solids when there is a change in thermodynamic equilibrium, such as the temperature falls below the cloud point. Wax mainly consists of n-alkanes and iso-alkanes. This can be classified into two type macro crystalline and micro crystalline. Macro crystalline waxes (Paraffinic waxes) are iso-paraffins and naphthenes within the range of C18 to C36. Micro crystalline waxes are mainly n-alkanes within the range C30 to C60. (Adesina F., et al., 2010) The critical point in the rheology of waxy crudes is cloud point. Above the cloud point, flow is Newtonian and when the temperature of the crude oil drops below the cloud point the solubility of wax fractions is significantly reduced to cause wax precipitation which changes the flow behaviour to non-Newtonian. When the rheology of the fluid changes, it is observed that there is ten-fold or more increase in viscosity. This results in additional pressure drop and decreases pipeline efficiency because of potential plugging. (Elsharkawy, A. M., et al., 1999)

Figure 1: Wax plug in wellbore on platform in North Sea. (Labes-Carrier, C., et al., 2002)

The viscosity is one of the most important physical properties affecting the flow behaviour of crude oil. Investments of millions of dollars are committed to the transport of crude oil in pipelines designed. The return on the investment may disappear if the flow rate in a given pipeline is not as high as anticipated due to lack of understanding of the factors affecting the oil's viscosity. Figure 1 shows the wax plugging in wellbore. The presence of wax crystals leads to a wide range of non-Newtonian characteristics including yield stress, pseudo plasticity (shear thinning) and time dependency. The industrial cost involved in preventing wax deposition is high, and the petroleum industry is always looking for a cheap and effective additive to control the problem. (Wardhaugh, L. T., and Boger, D. V., 1988) Figure 2 shows the severity of wax deposition resulting in clogging of pipeline.

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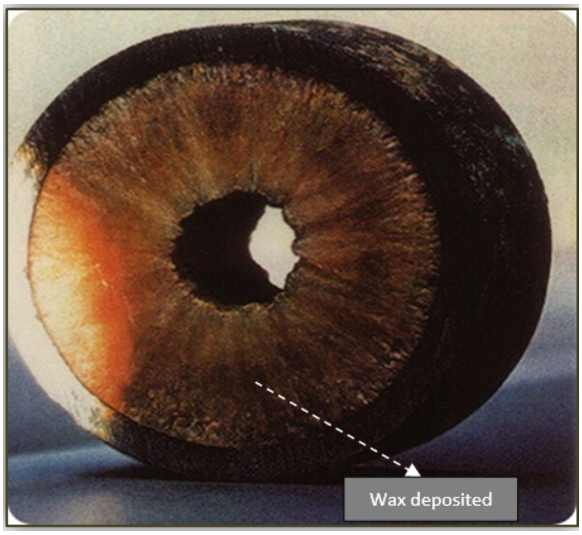

Figure 2: Severity of wax deposition-Decrease in pipeline thickness due to wax deposition (Oseghale, C. L., and Akpabio, E. J, 2012)

RHEOMETER

Rheology is the study of the flow of matter, primarily in liquid state. The term Rheometer comes from the Greek word rheo, meaning flow, and Rheometer is a device for 'measuring flow'. A Rheometer is a laboratory device used to measure the way in which a liquid, suspension or slurry flows in response to applied forces. It is used for those fluids which cannot be defined by a single value of viscosity and therefore require more parameters to be set and measured than is the case for a viscometer. It measures the rheology of the fluid. Viscosity is a measure of the resistance of a fluid which is being deformed by the shear stress. Stress is the measure of internal force applied to an object. Shear stress is the stress which is applied parallel to the face of an object or material. In every day terms, viscosity is "thickness or internal friction".

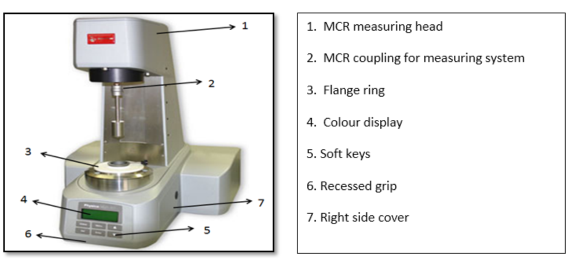

Figure 3: Schematic of a Rheometer Instrument (https://www.oelcheck.de/uploads/pics/rheometer_01.jpg)

EXPERIMENT

Experiments were conducted using Rheometer (ANTON PAAR CORPORATION) to understand how viscosity of crude oil of X fields changes as a function of time. Two different kind of waxy crude oils were used as test specimens. The properties of crude oil used are listed below in Table 1. The experiments were conducted at constant shear rate at given temperature. The experiments also include the comparison of effect of xylene and PPD on crude. The crudes were tested with 1% and 2% xylene and PPD at different shear rate.

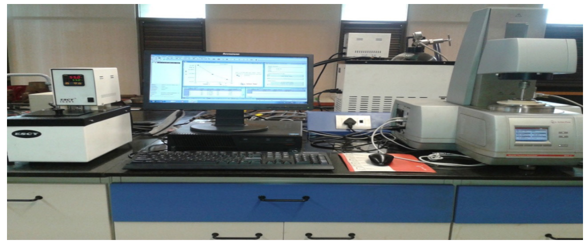

Figure 4: Rheometer (Pandit Deendayal Petroleum University Laboratory)

PRE-TREATMENT OF OIL SAMPLE

The oil specimens were pre-treated to eliminate the past history effect. The oil specimens in sealed bottles were heated to 65°C in water bath for 40 minutes to make it homogeneous. The oil specimens were then held at room temperature and mixed thoroughly before they were loaded to the Rheometer cup.

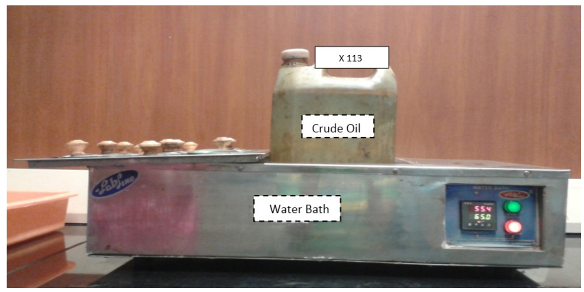

Figure 5:Pre-treatment of crude sample (Pandit Deendayal Petroleum University Laboratory)

CHARACTERISTICS OF CRUDE OIL OF X FIELD

The following are the properties of the crude samples which are used in the study.

Table 1: Characteristics of Crude Oil of X Field

WELL NO	PAY ZONE	POUR POINT	WAX %	ASPHALTENE%	RESIN %
X#A	K-VI+VII	36	14.35	2.79	22.26
X#60	K-X	45	37.34	2.20	8.39
X#113	K-V	33	22.45	0.19	6.20
X#46	K-V+VI	39	39.38	0.57	12.08

RESULTS

In the first set of experiments we have considered the variation of viscosity with time at different shear rate without pre-treating and after pre-treating the crude sample of X #A. The results are as shown in Figure 6(a) and 6(b). As shown in the graph viscosity at 30 sec^{-1} is higher than the viscosity at shear rate of 50sec^{-1}. Similarly it can be seen from the result that as the shear rate is increased at constant temperature viscosity is decreased. The graphical result also shows that the viscosity is decreased after pre-treatment of crude sample as compared to sample without pre-treatment. Comparing the result of after pre-treatment and before pre-treatment, it is seen that after pre-treatment the peaks are reduced comparatively.

In the second set of experiments, three different crude samples having different wax percentage are tested. X#46 has the highest wax content and highest viscosity while X#113 has the lowest wax content and lowest viscosity and X#60 has the moderate viscosity and wax content. The results are shown in Figure 7 (a), (b), (c) shows the reduction in viscosity with increasing shear rate. Also the viscosity is decreased as the wax percentage is reduced.

Figure 8 (a), (b), (c) shows the effect of 1%xylene on crude. It can be seen from the graph that xylene reduces the viscosity of crude oil. Figure 9 (a), (b), (c) shows the effect of 2% xylene on crude. The results indicate that there is greater reduction in viscosity with 2% xylene compared to 1% xylene.

Figure 10 (a), (b), (c) shows the effect of 1% PPD on crude. It can be seen from the graph that PPD reduces the viscosity of crude oil. Figure 11 (a), (b), (c) shows the effect of 2% PPD on crude. The results indicate that there is greater reduction in viscosity with 2% PPD compared to 1% PPD.

INHIBITION MECHANISM OF XYLENE

The wax deposition-inhibiting action of the xylene-based inhibitor is attributed to its interaction with the forming wax aggregates. The xylene-based inhibitor has structures with segments that interact with the forming wax crystal and prevent wax crystal growth. (Bello, O., et al., 2005)

The waxes in crude oils are paraffinic and vary in amount and molecular weight distribution. When waxy crudes are cooled down, the paraffinic wax starts to crystallize in the form of thin plates, needles, or micro crystals. As wax components come out of solution, the needles compact into a three-dimensional network. Plates curl on their edges, forming hollow needles that can then network. In the present investigation, the xylene exhibited good performance as wax deposition inhibitor and flow improver. In addition to this it also facilitates greater adsorption of the inhibitor molecules onto the wax crystal networks and prevents the interlocking of the three-dimensional wax networks. The ability to form a stable suspension in the crude oil makes the inhibitor effective at concentration in the parts-per-million range, compared to the concentration of the wax crystals. (Bello, O., et al., 2005)

INHIBITION MECHANISM OF PPD

Pre-treatment of crude oils with PPD is an attractive alternative to solve wax deposition problems during transport of crude oils along pipelines. Wax crystal modifiers are chemicals capable of growing into wax crystals and to alter their growth and surface properties. These chemicals reduce the affinity of crystals to interlock and form three-dimensional networks, thereby lowering the pour point and the viscosity. For that, they are commonly named as pour point depressants (PPD). (Coto, B., et al., 2014)

CONCLUSION

The viscosity of a crude oil is one of its most important physical properties in flow assurance study. We can use the rheological measurements to give estimation about Flow Assurance.

Crude oils and the mixtures of different fields were characterized using Rheometer. The study shows that viscosity decreases as the shear rate is increased. The samples are analysed in both without pre-treatment and after pre-treatment. The peaks obtained in the graphs without pre-treatment is due to the non-homogenous nature of crude oil. Peaks are obtained when the crystal particles present in the crude sample strike the Rheometer. By pre-treating the crude oil the peaks obtained are reduced.

The samples were also analysed using xylene and PPD. The use of xylene and PPD showed a decrease in viscosity at constant shear rate. The decrement in viscosity is higher with 2% xylene as compared to 1% xylene. Also the decrement in viscosity with 2% PPD is higher than with 1%PPD. By comparing the results obtained for xylene and PPD at different concentration and shear rate, we can see that reduction in viscosity with xylene is higher as compared to PPD.

The wax deposition-inhibiting action of the xylene-based inhibitor is attributed to its interaction with the forming wax aggregates. The xylene-based inhibitor has structures with segments that interact with the forming wax crystal and prevent wax crystal growth. In the present study, the xylene exhibited good performance as wax deposition inhibitor and flow improver. The ability of xylene to form stable solution in the crude oil makes the inhibitor effective. The formulation has a good wax-deposition inhibiting, pour-point depressing, and viscosity-reducing effect for the tested crude oils.

ACKNOWLEDGEMENT:

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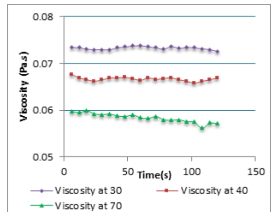
VISCOSITY VS TIME PLOT OF DIFFERENT CRUDE of X 108 WITHOUT AND WITH PRE-TREATMENT



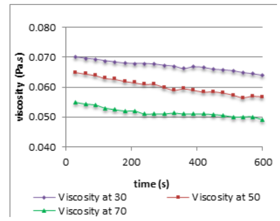
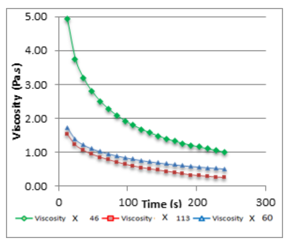


Figure 6(a): Without pre=treatment (X A)
Figure 6 (b): With pre-treatment (X A)

VISCOSITY VS TIME PLOT OF DIFFERENT CRUDE (X 60, X 113, X 46)



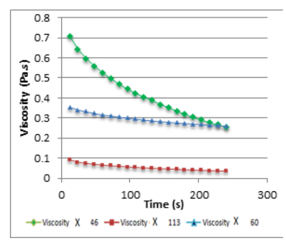


Figure 7 (a): At constant shear rate of 30 (1/s)
Figure 7 (b): At constant shear rate of 50 (1/s)

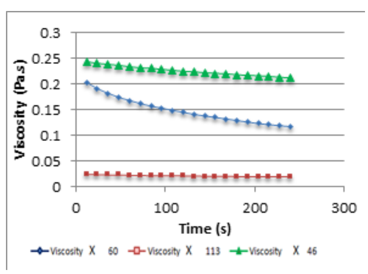
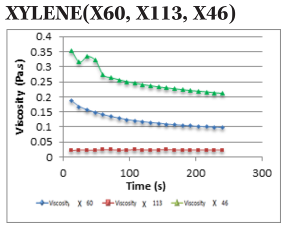


Figure 7 (c): At constant shear rate of 70 (1/s)

VISCOSITY VS TIME PLOT OF DIFFERENT CRUDE WITH 1% XYLENE(X60, X113, X46)



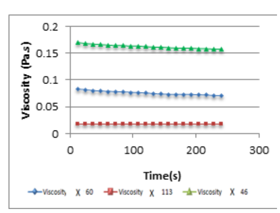


Figure 8(a): At constant shear rate of 30(1/s)
Figure 8 (b) : At constant shear rate of 50(1/s)

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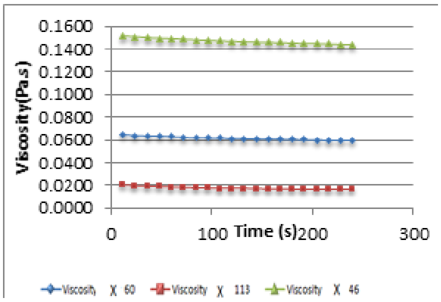

Figure 8 (c): At constant shear rate of 70(1/s)

VISCOSITY VS TIME PLOT OF DIFFERENT CRUDE WITH 2% XYLENE(X60, X113, X46)

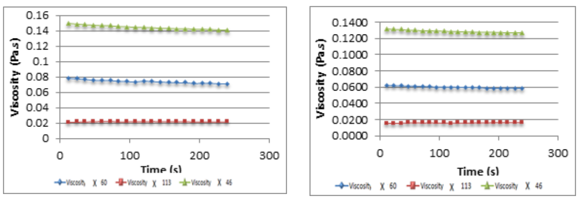

Figure 9 (a): At constant shear rate of 30(1/s)
Figure 9 (b): At constant shear rate of 50(1/s)

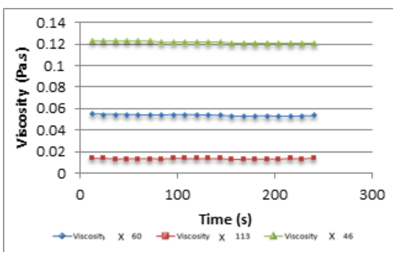

Figure 9 (c): At constant shear rate of 70(1/s)

VISCOSITY VS TIME PLOT OF DIFFERENT CRUDE WITH 1% PPD(X60, X113, X46)

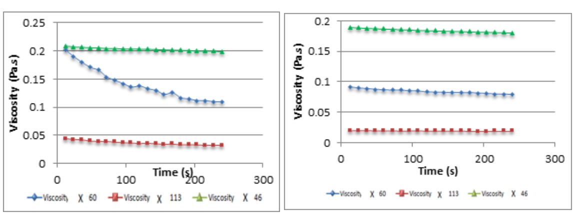

Figure 10 (a): At constant shear rate of 30(1/s)
Figure 10 (b): At constant shear rate of 50(1/s)

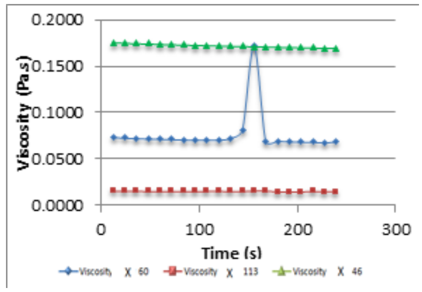

Figure 10 (c): At constant shear rate of 70(1/s)

VISCOSITY VS TIME PLOT OF DIFFERENT CRUDE WITH 2% PPD(X60, X113, X46)

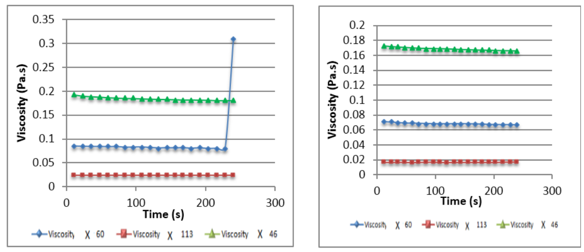

Figure 11(a): At constant shear rate of 30(1/s)
Figure 11 (b): At constant shear rate of 50(1/s)

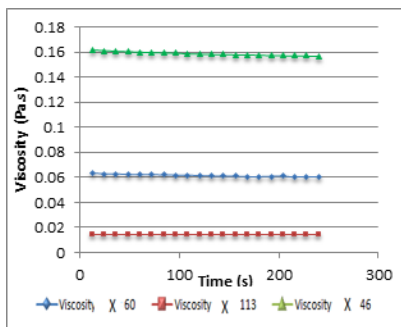

Figure 11(c): At constant shear rate of 70(1/s)

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