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To What Extent Could Methanol, Toluene and Gas Condensate Effect on Heavy Crude Oil Viscosity, Sheikhan Oil Field, Kurdistan, Iraq

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Abstract Sheikhan crude oil faces obstacles during transportation from production wellsite to processing facilities due to high viscosity. To enhance the flowability, reducing the sheikhan crude oil viscosity is a promising approach. For this purpose, a heavy crude oil sample from Sheikhan oilfield was blended with various rate of industrial polar solvents such as (Toluene, methanol) and gas condensate at different temperatures. This experimental study shows that mixing sheikhan heavy crude oil with toluene have a good reduction in the crude oil viscosity since this polar tends to interface between asphaltene sheets and dissociation of asphaltene aggregates. However, the impact of methanol on viscosity is less where this solvent tends to forming hydrogen bond between asphaltene sheets and methanol molecules. Finally, the gas condensate reduced the crude oil viscosity but its impact reduced at higher temperature.

Keywords Heavy Crude Oil, Viscous Crude Oil, Crude Oil Recovery, Chemical Solvents

1. Introduction

Heavy crude oil is a complex fluid with a viscosity and density higher than the conventional oil. Where the viscosity of this type of crude oil is greater than 100 c.p and the specific gravity is less than 20 API degree [10]. These two physical factors affect negatively on the crude oil mobility in both in-situ and surface conditions [2].

According to the Iraqi ministry of oil, heavy crude oil forms 55% of the total of oil in place (OIP) and most of which are on developing stages. The figure 1. The existence of viscous heavy crude oil in high amount in Sheikhan oil field attract the petroleum companies to extract and produce it. exhibit the heavy crude oil distribution in the north part of Iraq.

However, producing, transporting and refining the heavy crude oil are technically and economically challenging due to its reduced viscosity and mobility. Heavy crude oil contains high molar mass and highly polar traces called asphaltenes. It also contains several metals, particularly nickel, vanadium and iron [9]. These particles lead to increasing the crude oil viscosity which in turn reducing the mobility of crude oil through pipeline [14].

One of the major obstacles which face the production process of heavy crude is the high viscosity of this type of crude oil. Since the heavy crude oil is not easily flow or pumped from the production well head to the processing facilities [12].

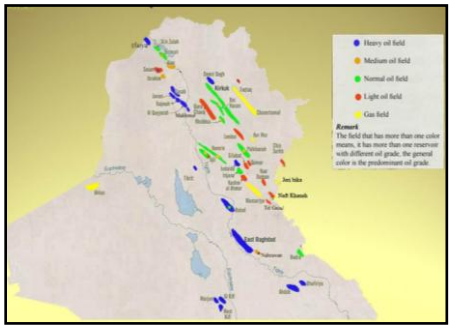

Figure 1. Heavy crude oil distribution according to the ministry of oil [1]

Besides, the transportation of high viscous heavy crude oil requires efficient and economical methods to transfer it. Therefore; the significant way to extract heavy crude oil from reservoir is to reduce its viscosity [1,3].

Practically, different applicable methods have been accomplished to reduce viscosity of heavy crude oil and improve their mobility through pipeline. Among these methods are a) thermal process by applying heat to production pipeline or crude oil itself oil b) viscosity dilution by adding chemical substances c) formation an emulsion of an oil-in-in water mixture [8].

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The main objective of this experimental study to find out the effect of adding different industrial or synthesized polar solvents like (Methanol, Toluene) and gas condensate at different concentration (5, 10, 15, 20 %) on the efficiency of the viscosity reduction of sheikhan heavy crude oil.

2. Crude Oil Viscosity Dilution Techniques

Several techniques have been utilized and examined to reduce the viscosity factor of heavy crude oil. However, dilution is one of the most common and widely used method. Since it allows increase the mobility of heavy and extra - heavy crude oil from a production site to processing units (P. Gateau, 2004). These techniques are:

a) Viscosity dilution by adding light hydrocarbon or alcohols
b) Crude oil viscosity reduction by applying heat
c) Chemical viscosity reduction additives.

2.1. Dilution with Light Liquid Hydrocarbons and Alcohol

This technique considers one of the effective and preferred option to reduce viscosity and increase the flow rate of heavy crude oil. Dilution with light liquid hydrocarbons fractions is widely used to facilitate pathway in the pipeline, and it involves adding light crude oil or condensate natural gas to heavy crude oil [5].

Although, the availability of transporting light hydrocarbon fractions or condensate from natural gas production, the large investment for pumping and pipeline are needed. The reason is increasing the volume of heavy crude oil carried and the need to separate the chemical solvents from the heavy crude oil at the same place [4].

This technique may face some challenges where any adjustment in the constitute of the crude oil impact on the required proportion of crude oil and solvents ratio [12].

It is also important to predetermine the viscosity and compatibility of crude oil solution. In addition, diluting the heavy crude oil with light fractions can change the stability of the asphaltene and cause them to flocculate and patriciate which in turn block pipelines [6].

2.2. Viscosity Dilution by Applying Source of Heat

The method is widely utilized to reduce the viscosity of heavy crude oil. The main principle of this technique lies in the fact that the viscosity factor decreases by increasing heat. The applied heat making the crude oil easier to be pumped through pipeline from the produced well to the production facilities. Therefore, it is necessary to maintain the temperature high at which the crude oil is extracted by isolated pipe [16].

Furthermore, an additional heat is required to be applied to the pipe which transports the crude oil due to the loss of the heat. This loss occurs as a result of a slow flow of crude oil through the pipeline. Therefore, the crude oil needs to be re-heating at the pump station [7].

However, the main limitation of this operation is the high operational cost especially for a long distance. Secondly, it is difficult to stable the temperature of the heavy crude oil in the pipeline when it transported underwater [15].

2.3. Viscosity Dilution by Chemical Substances

A series of studies have examined the chemical additives as a viscosity reducer in crude oil applications. However, these additives are extremely selective which means that some additives lack effectiveness for a specific type of crude oil [16].

In order to select the suitable chemical additives, it is essential to know rate of asphaltene in the crude oil whether it is low or high, the level of paraffin and the quantities of sulfur, nickel in the crude oil [13,17].

Based on the investigation performed by (Xie, et al., 2001) the oil based or the water based chemical additives are two important factors for crude oil viscosity dilution. The study shows that the oil-based additives a good crude oil viscosity reducer for low and medium crude oil. However, the water-based additives were excellent reducer for high viscosity. According to (Junaki, et al., 2012) mixing the heavy crude oil with chemical ionic additives, dilute the viscosity of heavy crude oil sample up to 65%.

3. Methodology

3.1. Material and Apparatus

A sample of heavy crude oil from sheikhan oil field/ Kurdistan / Iraq reservoir was collected in order to carry out this experimental study. The density of the sheikhan heavy oil sample is equal to 0.9594 gm/cc at the standard condition and the viscosity is 2221. 91C.st at the atmospheric pressure and temperature of T = 20℃. The table. 1 below summarizes the physical properties of the crude oil.

Table 1. Crude oil specification

Sample 250 ml	Sp.gr @ room temp	Sp.pr @ 15.56 C	API degree @60F	Total sulfur content (%)	Kinematic Viscosity (CSt) @20
Crude oil	17.6 API	0.9594	15.99	5.5866	2221.91

The solvents like Methanol, Toluene used for diluting heavy crude oil were purchased from the local store and the physical specification of these solvents presented in the table below.

Table 2. Properties of commercial solvents used for diluting heavy oils

Solvent	Molecular weight (gm\mole)	Density (gm/ml)	Melting point	Boiling point	Viscosity (cp)
Toluene	92.14	0.87	-95	111	0.55
Methanol	32.04	0.792	-97	65	0.545

In addition, a gas condensate sample with a specific gravity 0.6983 at 15.6 degree Celsius was obtained from a refinery unit located in Kurdistan/ Iraq. The properties of the gas condensate which used in this project is shown in the table below:

Table 3. Chemical and physical properties of gas condensate

Distillation ASTM D86	Degree centigrade
Initial Boiling point	31 Deg. Celsius
Final boiling Point	250 Deg. Celsius
Specific gravity at 15.6	0.6983
Total Sulphur content	520
Benzene	0.25
Aromatic	8.5
Olefins content	3.2
Saturated compound	87.3
Oxygen Content	0.35
Ethanol	0.89
Toluene	2.72
O-Xylene	0.25
P-Xylene	0.6
Ethylbenzene	0.82
Hemellitol	2.08

A Canon Fenske Opaque viscometer model 9721-B71 as shown in the figure 2 was utilized to measure the viscosity of the crude oil. This device is a modern version of traditional viscometer invented by Ostwald which enables measuring viscosity at various temperatures and atmospheric pressure.

Figure 2. Canon Fenske Viscometer

Figure 3. X -Ray sulfur meter

The figure 3 shown the X-Ray sulfur meter model RX-360SH which was employed to determine the total sulfur content in crude oil. The X-ray fluorescence (EDXRF) method, which is an accurate, non-destructive, economical and yet quick method prescribed in ISO 8754 and ASTM D4294-03.

3.2. Crude Oil Sample Preparation

The detailed experimental procedures for preparing the heavy crude oil sample for viscosity reduction are illustrated below.

Firstly, the density and the specific gravity of the crude oil sample were measured by ASTM D1298 method (Hydrometer glass) at room temperature. Then the kinematic viscosity and sulfur content for the heavy crude oil sample were measured at room temperature.

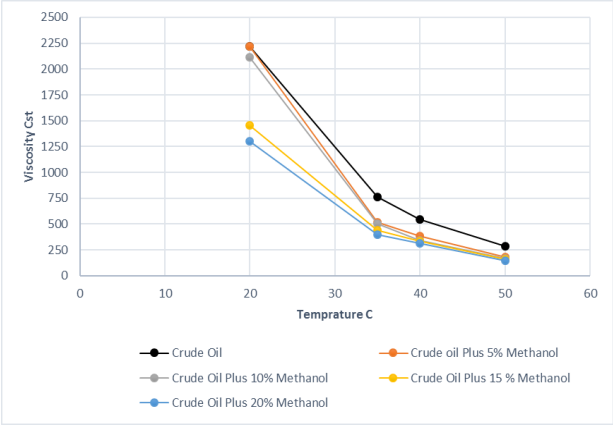
Secondly, 250 ml of heavy crude oil sample was mixed with methanol toluene and gas condensate of known concentrations (5, 10, 15, and 20 vol.%) in a closed beaker by stirrer device via magnet rotation. After appropriate mixing, Canon Fenske Opaque viscometer was utilized to measure kinematic viscosity at different temperatures (20, 35, 40 and 50 degree Celsius) and different solvents concentration.

Finally, the total sulfur content of heavy crude oil was measured by X - ray sulfur meter with the same condition above.

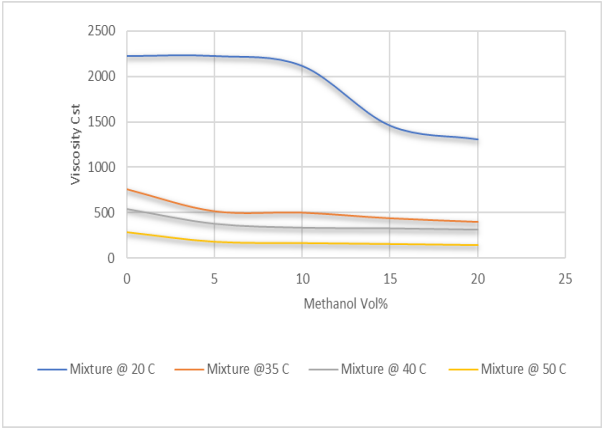
4. Result and Discussion

The two significant factors which reduce the viscosity of heavy crude oil are temperature and polar chemical solvents. In this study, the heavy crude oil sample with different solvents concentration at different temperature was examined to measure the effect of these factors on heavy crude oil.

The figures 4 (a &b) show that heavy crude oil viscosity reduction by using methanol solvent at different rate didn't contribute that much on viscosity reduction, or there is slight decrease in the viscosity of heavy crude oil.



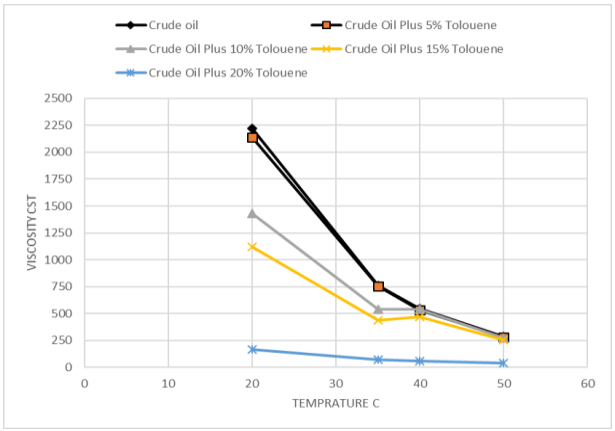
(a)



(b)

Figure 4. (a, b) Viscosity of heavy crude oil with different Methanol concentration at different temperature

There are two main reasons behind this low reduction of crude oil viscosity. Firstly, a solvent like methanol makes a hydrogen bond with its particles. Secondly, this solvent has a hydroxyl group (OH) on their molecules where an important interaction takes place with polar part of asphaltene. This interaction tends to promote separate asphaltene aggregates to smaller molecules in the solvent.



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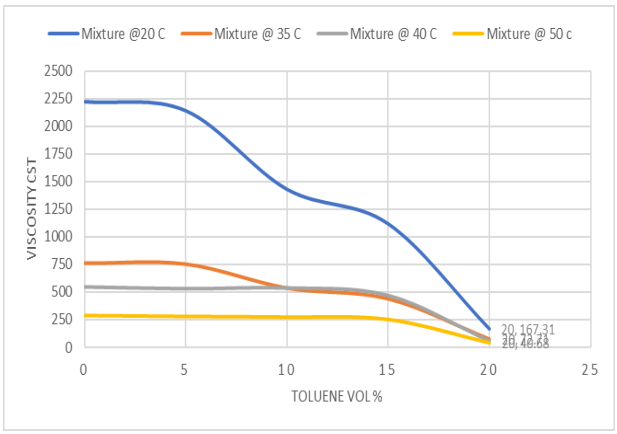
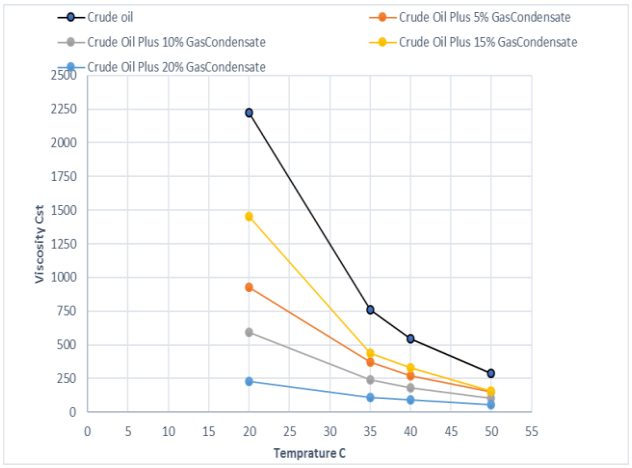


(b)

Figure 5. (a, b) Viscosity of heavy crude oil diluted by Toluene solvent at different rates and temperatures

Although the viscosity of toluene is higher than methanol at a similar temperature, the toluene solvent reduces the heavy crude oil viscosity more effectively than methanol. This is due to the aromatic characteristic of toluene solvent.

It is obvious that asphaltene content in heavy crude oil plays a significant role in the rheological properties of crude oil. Therefore, any adjustment in the component of asphaltene lead to a change in viscosity. The presence of aromatic molecules in toluene tend to locate between asphaltene sheets reducing overlap between large asphaltene macromolecules.



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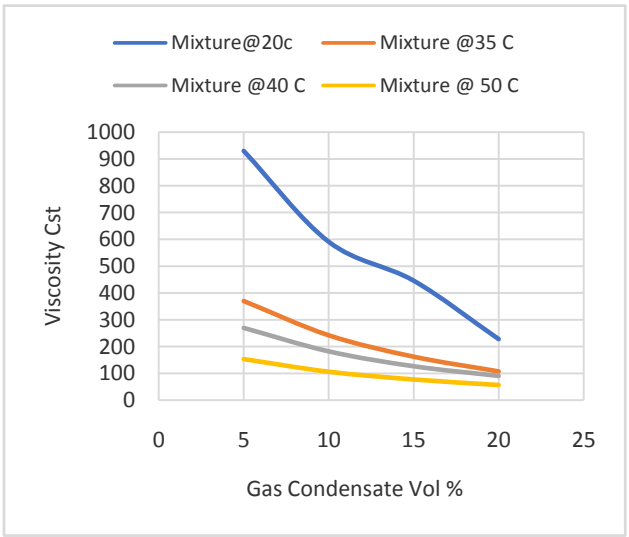

(b)

Figure 6. (a, b) Viscosity reduction by gas condensate at different concentration and temperatures

Due to the absence of polar components in gas condensate, it might be difficult to expect any contact between gas condensate structure and asphaltene particle in a such crude oil sample. From the figure above we can observe that the gas condensate has lowered the viscosity of heavy crude oil but the capability of reducing viscosity is lower than naphtha and toluene solvents.

5. Conclusions

Based on the experimental results which obtained from this research it can be concluded that, treating the sheikhan heavy crude oil sample with toluene solvent exhibits a high reduction in the crude oil viscosity. This is due to, the aromatic characteristic in this polar solvent. Where the aromatic molecules of toluene tend to settle between asphaltene molecules and increasing the breaking down of asphaltene agglomerates.

We also concluded that, the influence of methanol on heavy crude oil viscosity was less comparing with other polar solvents. Where methanol solvent creating hydrogen bond between methanol molecules and asphaltene.

Although the gas condensate diluted the viscosity of heavy crude oil, the situation was complex and it depends on the type of heavy crude oil. Since the gas condensate at high API showed lower viscosity reduction compared with, the lower one.

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