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Impacts of Viscosity, Density and Pour Point to the Wax Deposition

[1]Andhy Arya Ekaputra, [1]Khalik M. Sabil, [2]Arya Hosseinipour and [1]Ismail Bin Saaid
[1]Department of Petroleum Engineering,
[2]Department of Chemical Engineering, Universiti Teknologi PETRONAS,
Bandar Seri Iskandar, Tronoh, 31750, Perak, Malaysia

Abstract: In order to overcome wax deposition problem, the better understanding of the physical characterization of crude oil is necessary. Viscosity, density and pour point are properties that ascertain handling characteristics of crude oils. In this study, crude oils from Malaysian oil fields are studied to determine their wax formation tendency for flow assurance purposes. For this study, density, viscosity and pour point of all crude oils is measured by digital den-sity meter (DMA 4500 M), advanced AR-G2 rheometer and D-97 ASTM methods, respectively. Result showed that there is linear trend between density and temperature. In general, wax precipitation and deposition has direct relationship with wax content of crude oil. Moreover, the shear rate has considerable effect on viscosity reduction. Temperature reduction causes viscosity to increase. However, it is against shear rate that tends to lower it.

Key words: Wax deposition, density, viscosity, pour point, shear rate

INTRODUCTION

Wax deposition is one of the serious problem in oil industry. It has got a crucial attention to overcome this issue in more hostile environment in new oil fields exploration especially in deep water. Waxes, that are known as mostly heavy saturated paraffins, tend to precipitate when the temperature and pressure of oil fields drop during the production and transportation. Wax Appearance Temperature (WAT) determines the deposition of the wax on the reservoir or pipelines when the temperature of the reservoir or production line falls below the WAT. WAT is regularly used to measure the tendency of a crude oil to produce wax in relation with pressure and temperature reduction. In simple words, WAT is the temperature at which the first wax crystal appears. Wax deposition will be complex and costly. It will cause a lot of difficulties in blocking of transport equipments and pipelines. If not treated, well can eventually decrease or in worst condition block the flow in production line or even in well (Sanjay *et al*., 1995; Merino-Garcia and Correra, 2008; Al-Yaari, 2011; Taraneh *et al*., 2008; Alghanduri *et al*., 2010; Zhu *et al*., 2008; Elsharkawy *et al*., 2000; Aiyejina *et al*., 2011).

One of the preliminary diagnostic tests in petrolem industry to conceive problems related to wax precipitation and deposition is to determine density/API gravity. This property of crude oil has been used to estimate the quality of a crude and has direct insight into capability of the oil to inhibit the precipited wax particles. This suspension of the wax particles is due to the difference between gravities of the wax crystals and the oil.

Another important property is viscosity that determines the flowabilty of crude oils. It is a very intense function of wax deposition rate and cause wax pericipitation. It will be determined at different temperatures to ascertain handling characteristics (Zhu *et al*., 2008).

Practically, there are different compositional and physicochemical analyses to characterize oils and theirs waxes. These are American Petroleum Institute (API) gravity and viscosity, wax content, WAT and pour point. In addition, various instruments have been used to characterize waxes (Coutinho and Daridon, 2005; Musser and Kilpatrick, 1998). All these techniques will give us lot information to clarify the causes of wax precipitation and lead us to better comprehend, prevent and predict it in every part of production, transportation and storage of petroleum (Alghanduri *et al*., 2010).

The purpose of this study is to evaluate the characteristics of three different Malaysian crude oils to comprehend problems related to wax deposition. These fields are located approximately in a water depth of 60-70 m (Kechut *et al*., 2001; Agil *et al*., 2008; Abd Karim *et al*., 2006). The average seabed temperature for these fields is around 25°C at depth of 61 m whereas, the surface temperature is at 34°C (Agil *et al*., 2008; Mohammad and Maung, 2000; Kadir *et al*., 1997).

Corresponding Author: Andhy Arya Ekaputra, Department of Petroleum Engineering, Universiti Teknologi PETRONAS, Bandar Seri Iskandar, Tronoh, 31750, Perak, Malaysia

Technical reports from crude oil operators in these fields showed that these crude oils produced wax during transportation based on the characteristics of these crude oils, their production histories and the seabed and surface temperatures.

MATERIALS AND METHODS

Data collection: Three Malaysian waxy crude oils were used in this study. Samples were taken from exploration fields of Penara, Angsi and Dulang. The main characteristics of these samples, including density, pour point, WAT and wax content were reported by Kelechukwu (2011).

Experimental apparatus and method: In this study, density of all crude oilsis measured by digital density meter (DMA 4500 M) equipped with automatic gas bubble detector. The measurement was conducted according to ASTM D2501, ASTM D4052 and ASTM D5002 standards at 60°C. Then, the density at different temperaturesis calculated by using correlation equation (Brown, 1996). Accuracy of digital density meter measurement for density and temperature was 0.00005 g cm^{-3} and 0.03°C, respectively.

Viscosity was measured by using advanced AR-G2 rheometer (TA Instruments, USA) equipped with zero gap geometry and measurement was conducted according to the ASTM D-445 standard. Based on the medium to high viscosity range, 40 mm geometry was more versatile to be used for majority of medium viscosity materials. Therefore, the medium 40 mm parallel plate diameter with gap setting of 300 μm was used.

Pour point was measured by using manual method based on ASTM D-97. The sample was cooled inside a cooling bath to allow the formation of paraffin wax crystals. At about 9°C above the expected pour point and for every subsequent 3°C, the test jar was removed and tilted to check for surface movement. When the specimen does not flow when tilted, the jar was held horizontally for 5 sec. If it does not flow, 3°C is added to the corresponding tem-perature and the result is the pour point temperature.

Prior to any measurement, crude oil samples were heated to a temperature of 70°C for 20 min in a water bath shaker to ensure that all wax crystals have been dissolved. Then, 1 mL oil was transferred to density meter by syringe to fill the oscillation U-tube to measure the density of the crude oils. For the measurement of the viscosity, a volume of approximately 0.35 mL was put over the geometry plate. A small amount of sample was placed in solvent trap geometry to avoid errors caused through evaporation and minimize weathering effects. Viscosity was measured at different shear rates in the range of 50, 100 and 500 sec^{-1} at different temperature from 5-50°C. For this purpose, a continuous ramp experiment was used to apply an increasing shear stress on the sample with data collected under equilibrium conditions. The temperature of the sample was adjusted using the peltier plate prior to each test. An equilibrium time of 3 min was set to reduce any structure effects and temperature gradients within the loaded sample.

RESULTS AND DISCUSSION

Relationship between viscosity and shear rate at different temperatures: Viscosity is a kind of physical property of crude oil that determines the flowability. It is influenced by wax precipitation and plays a significant role on the wax deposition rate. Results Fig. 1-3 shown that the

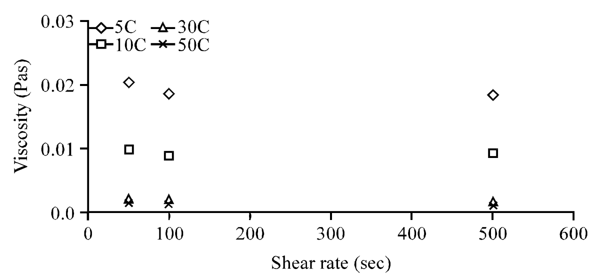

Fig. 1: Viscosity of Penara crude oil vs. shear rate at different temperatures

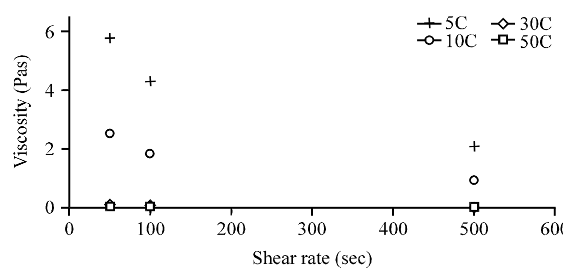

Fig. 2: Viscosity of Angsi crude oil vs. shear rate at different temperatures

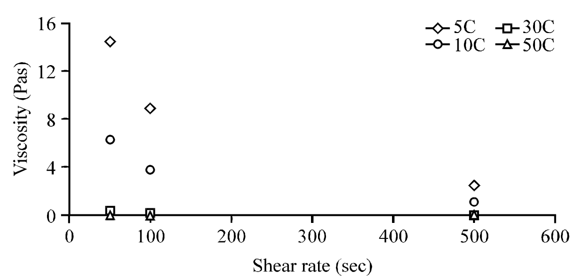

Fig. 3: Viscosity of Dulang crude oil vs. shear rate at different temperatures

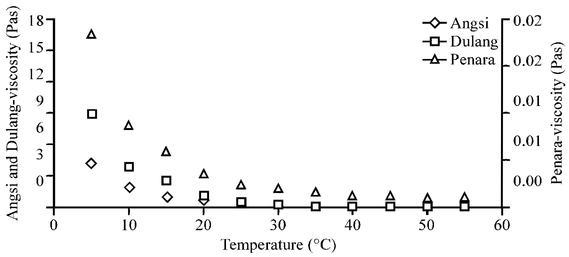

Fig. 4: Viscosity of Malaysian crude oils at different temperatures at shear rate of 100 (sec^{-1})

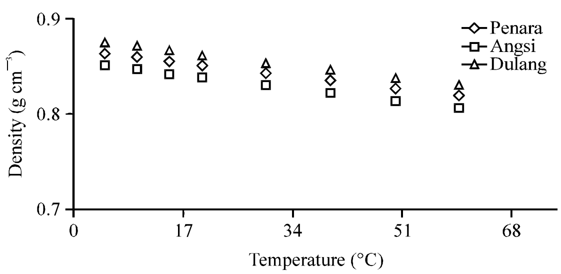

Fig. 5: Density of crude oils versus different temperature

Table 1: Density of the crude oils in this study

Temperature (°C)	[1]Density (g cm^{-3}) Penara	Angsi	Dulang
5	0.86405	0.8510	0.8746
10	0.85981	0.8467	0.8703
15	0.85563	0.8424	0.866
20	0.85149	0.8382	0.8618
30	0.84336	0.8299	0.8535
40	0.83541	0.8218	0.8454
50	0.82766	0.8139	0.8375
60	0.82007	0.8062	0.8298
70	0.81268	0.7987	0.82220

[1]Density uncertainty is 0.0001 (g cm^{-3})

shear rate has considerable effect on viscosity reduction. It could be seen from these figures that temperature reduction caused viscosity to increase. However, it is against shear rate that tends to lower it. In Fig. 4, viscosity is increased as temperature decreased and this is caused formation of a gel network. This might cause the risk of wax precipitation is getting higher based on the geographical locations and the depths of these fields. Therefore, the implication of wax inhibitors is inevitable to avoid wax deposition and pipeline clogging especially for Penara.

Relationship between density/API gravity and temperature: The density of crude oils was measured at 60°C. Then the density was calculated at different temperatures by using a correlation equation (Brown, 1996). These values are tabulated in Table 1.

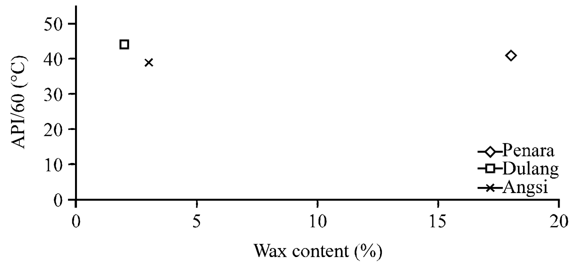

Fig. 6: API gravity versus wax content of different crude oil

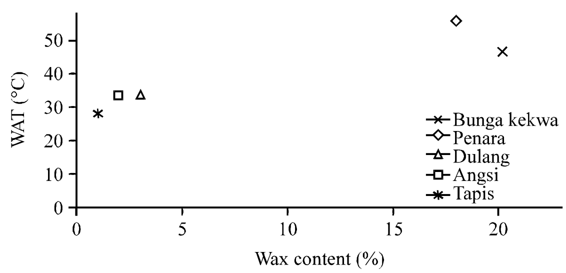

Fig. 7: WAT versus wax content of different crude oil (Kelechukwu, 2011)

API gravity plays an important role in petroleum industry. The crude can be categorized as a lightoil if it has high API. This is due to presence of the high light hydrocarbon fractions. It means, this high API gravity shows that crude oil has low density and can freely flows at room temperature. Furthermore, it will affect crude oil to have low specific gravity, viscosity and generally low wax content. Commonly, the higher wax content of a crude oil the more paraffinic it is and the lower wax content, the more aromatic it is. There are numerous exceptions to this rule-of-thumb and other data must be used to verify a crude oil's cha-racter. Probably, the most widely used index is the characterization or K Factor (Watson *et al*., 1935).

As it can be seen from Fig. 1, there is linear trend between density and temperature. The same trend for crude oils is reported by Modesty (Kelechukwu, 2011). There is an inverse relationship between API gravity and density. As mentioned earlier, as API gravity being higher, the crude oil will be defined as light crude with lower density and wax content. This can be proved and seen in Fig. 5. Figure 6 shows that wax precipitation and deposition has direct relationship with wax content of crude oil.

As shown in Fig. 7, all the crude oils have WAT values higher than 25°C. Based on the geographical locations and the depths of these fields, the average seabed temperature for these fields is around 25°C at a

Table 2: Pour point of crude oil

Crude oil	Pour point (°C)
Angsi	28
Tapis	15
Dulang	31

depth of 61 m and the surface temperature of 34°C which are well below or almost the same as the WAT of Angsi, Dulang and Penara crude oils (Kelechukwu, 2011). The implication of these results is these crude oils have the risk of producing wax in the transportation pipeline especially from Penara field and utilization of wax inhibitor is necessary to avoid pipeline plugging.

Relationship between experimental pour point and wax content: The knowledge of the pour point of a fluid is especially at fluid transportation of big importance. A solidifying fluid can plug pipelines and so pumps can be damaged by over-stressing or the feed rate is strongly decreasing (PSL Systemtechnik, 2011). The experimental result of pour point of crude oil is illustrated on Table 2. In crude oil, a high pour point is generally associated with a high paraffin content, typically found in crude deriving from a larger proportion of plant material (ASTM Standard D5949, 2003).

According to the Table 2, the highest pour point is Dulang and the lowest pour point is tapis. It means Dulang contains high wax. So, the Dulang crude needs a crucial attention for minimizing its wax.

CONCLUSION

In this study, density and viscosity for 3 different Malaysian crude oils in the different conditions have been measured. Experimental results show that there is linear trend between density and temperature. Also, wax precipitation and deposition has direct relationship with wax content of crude oil. The shear rate has considerable effect on viscosity reduction. Temperature reduction caused viscosity to increase. However, it is against shear rate that tends to lower it.

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