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Investigation of wax deposition prevention by using n-heptane for sustainable energy production from Fang oilfield

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Abstract. Waxy crude oils are normally found in petroleum reservoirs. Crude oil from wax formation is one of the crucial problems for flow assurance of pipeline transportation in oil and gas production. This issue can commonly cause wax deposition problem and it has made huge amount of economic losses such as production, time and maintenance cost. Therefore, it is a critical aspect to deal with wax deposition for crude oil flow assurance, especially in cold climate surface region. Nowadays, there are many methods that have been applied to reduce the wax deposition. In general, three methods are commonly utilized, mechanical, thermal and chemical ones. Among them, the usage of chemicals is commonly used in field because they can be applied easily rather than other techniques. In this study, n-heptane is selected to study the prevention of wax deposition because its property can reduce the pour point and wax deposit of crude oil. It is easily available as well. Therefore, the aim of this research is to investigate the effects of temperature and different chemical concentration on pour point and wax deposition of crude oil at three different temperatures ranging from 35 to 55 °C by applying cold finger method. Also, the pour point of crude oil is measured with different n-heptane concentrations by ASTM method. Moreover, the effect of different chemical concentrations on wax appearance temperature (WAT) is examined at temperatures between 80 °C to 40 °C with three different shear rates by viscometry method. From the results, it is reported that the total wax deposits from the cold finger depend on the amount of chemical concentration used. WAT with 20% n-heptane provides the highest performance for WAT reduction with 41 °C. Compared to 5%, 10% and 15% n-heptane concentration, WATs are reduced to 45 °C, 44 °C and 43 °C, respectively. For the pour point results, the higher amount of n-heptane concentration offers the higher reduction in pour point temperature and pour points are reduced significantly from original pour point at 36 °C to 34 °C, 30 °C, 26 °C and 22 °C with 5%, 10%, 15% and 20% n-heptane, respectively. It is also found that the amount of total wax deposits decreases when chemical concentrations increase. Moreover, the decline of temperature is found as one of the main factors to cause more wax deposition. There is a highest wax deposit reduction rate with 20% n-heptane at different temperatures compared to other concentrations. The wax deposition is reduced over 50% for each concentration. Therefore, this result is useful for the application of wax deposition, pour point and WAT studies in the crude oil production with less damaging environment for sustainable energy production.

1. Introduction

Waxy crude oils are widely found in the petroleum fluid reservoirs. Crude oil from wax formation is one of the crucial problems for flow assurance of transportation pipeline in oil and



gas production; thus making huge amount of economic losses [1]. In general, petroleum crude oil has different constituents comprising paraffinic, naphthenic, intermediate and asphaltenes. Both paraffinic and intermediate crude oil which has linear, branched and ring carbon structures are the origin of petroleum waxes [1]. Basically, crude oil contains paraffin hydrocarbons with the number of carbons from 18 to 36 (C18-C36) which are known as macrocrystalline wax and naphthenic hydrocarbon with the number of carbons from 30 to 60 (C30-C60) which are known as microcrystalline wax [1]. As the crude oil temperature decreases, the wax components start to precipitate out of the crude oil and this temperature is called wax appearance temperature (WAT) [2]. If the crude oil temperature is still dropped to pour point. The fluid cannot flow at this condition because the wax fragments will freeze. Therefore, these two points is critical for the crude oil properties [2].

The wax precipitation from crude oil throughout the production and transportation might create different kinds of issues. One of the issues discovered is solid wax deposition on well stream and pipeline. This problem is taken place when (1) the temperature of pipeline wall is decreased the wax appearance temperature of the crude oil, (2) a negative outspread temperature gradient exists in the fluid flow, (3) wax crystals can adhere in the wall because of high wall friction, (4) asphaltene from the crude oil has expanded after the contact with pipeline wall and bound together with wax crystals.

There are a lot of methods that have been applied to reduce the wax deposition. In general, three methods are commonly utilized, (a) mechanical (b) thermal and (c) chemical methods [3]. Among them, the usage of chemicals is commonly used in field because they can be applied easily rather than other techniques. In the process of bringing crude oil to the surface, the flow is too slow while waxy crude oil passes through low temperature zone. Therefore, the production engineers must plan to maintain fluid flow condition in the surface pipeline. Chemicals are frequently used for this problem to reduce the pour point of crude oil and to maintain the fluid flow condition.

In addition, the chemicals will be selected based on the dissolvability, harmfulness for environment, availability, economic feasibility on the project. First of all, the cost of the chemical has to be financially reasonable for the project. Moreover, the chemicals should be easily available anywhere and the harmful effect of chemical for environment has to be as low as possible. Additionally, another hazard issue is the flammability of the chemical solvent. The characteristics of fluid fuel is often described as flash point and this description is commonly used to avoid combustibility of the solvent [4]. Therefore, n-heptane chemical solvent is selected to study as one of the best solvents for reducing high viscosity of waxy crude oil and to increase paraffin wax solubility [4-5]. Consequently, the aim of the work is to reduce the pour point temperature, wax appearance temperature and the amount of wax deposition rate of crude oil with n-heptane. Furthermore, the different n-heptane ratios are designed to investigate the optimal conditions and the effects of different concentrations.

2. Materials and methods

2.1 Materials

Crude oil sample is obtained from Mae Soon oilfield, Northern Thailand. The original pour point of crude oil was 36 °C and wax appearance temperature of crude oil was 60 °C. N-heptane is purchased from Sigma-Aldrich.

2.2 Pour point test

The pour point measurement of crude oil is conducted by following the ASTM D 5853-11 procedure.

2.3 Wax appearance temperature measurement

The WAT is evaluated with viscometry method [5-7]. Brookfield viscometer with CP52 spindle is used to perform the test. The crude oil sample is heated at 80 °C above WAT of crude oil to confirm all wax

solid particles are totally dissolved before conducting the test and WAT measurement for crude oil with and without inhibitors is conducted the temperature range from 80 °C to 40 °C.

2.4 Wax deposition test for rod finger procedure

The rod finger method is used to determine the wax deposition rate of crude oil in the production flowline [8-10]. The wax deposition tests are conducted for 3 hours for each temperature at 35 °C, 45 °C and 55 °C with and without wax inhibitor. Four different n-heptane concentrations are varied for each experiment. The investigations are performed two times to provide correct data. At the final stage, wax deposit from rod finger is measured with four digits scale.

3. Results and discussion

3.1 Effect of n-heptane on pour point

The results of pour point measurement using different n-heptane concentration is illustrated in Figure 1. N-heptane is used as the solvents at varying concentrations. Pour point is reduced as a function of solvent concentrations. It is decreased as the concentration of n-heptane solvent is increased. The concentration of 5%, 10% and 15% can reduce the pour point to 34 °C, 30 °C and 26 °C, respectively. The optimal reduction is achieved at 22 °C with 20% of n-heptane concentration.

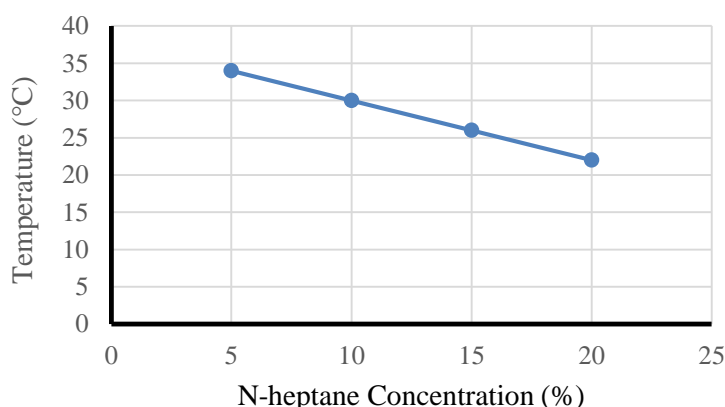


Figure 1. Effect of n-heptane on crude oil pour point

3.2 Effect of n-heptane on WAT

Theoretically, WAT can be obtained from the viscometry method by measuring the change of slope of temperature vs viscosity of oil. The point of slope change is the wax appearance temperature [5-7]. Wax crystal growth development will reach larger size at lower cooling rate because of extended time. In contrast, wax precipitation rate is faster with higher cooling rate. An increasing shear rate will decrease wax crystal size [11]. Moreover, the shear rate should not be accounted for using higher rate because crude oil which comes from reservoir to transport pipeline are generally shear-thinning. For this study, the measurement is conducted with constant cooling rate of 12 °C/hour and three different shear rates (6, 12 and 24 s⁻¹) are applied for this test. The wax appearance temperature of crude oil has been reduced by increasing n-heptane concentration from 5-20% by weight. At 24 s⁻¹ shear rate, WAT is decreased until 40 °C and 42 °C by adding 20% and 15% of n-heptane, respectively as shown in Figure 2 and 3. For other n-heptane concentrations, WAT can be reduced to 43 °C and 44 °C with 10% and 5% of n-heptane, respectively as presented in Figure 4 and 5. This can be explained that with an increasing concentration of n-heptane from 5% to 20%, wax appearance temperatures can be decreased.

Furthermore, WAT can be varied with shear rate as well. WAT can reduce with an increasing shear rate especially at 15% and 20% of n-heptane. Other n-heptane concentrations, WAT difference is not clear.

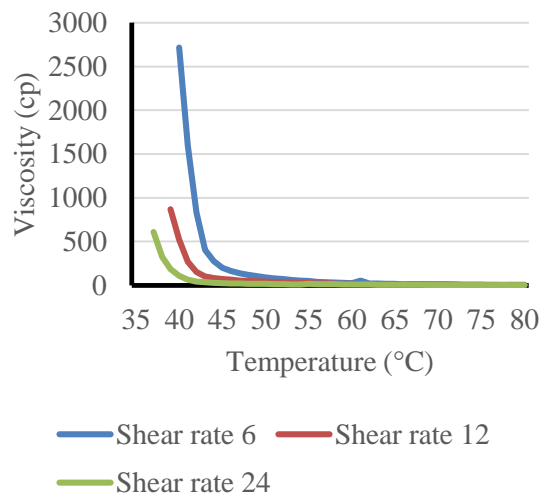


Figure 2. Effect of shear rate on wax appearance temperature of crude oil at 20% N-heptane.

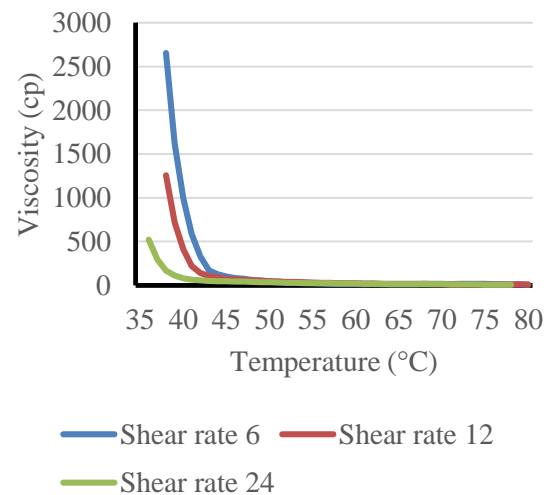


Figure 3. Effect of shear rate on wax appearance temperature of crude oil at 15% N-heptane.

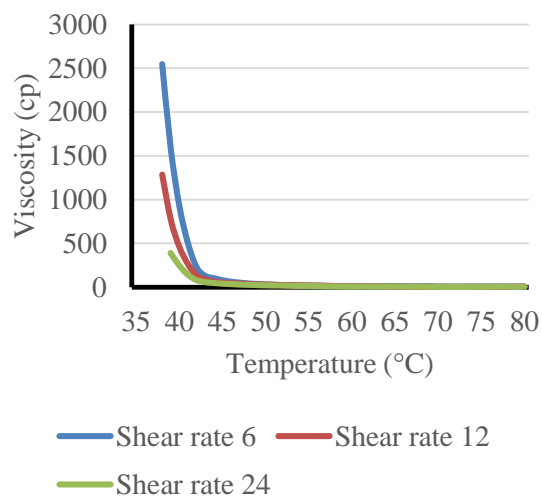


Figure 4. Effect of shear rate on wax appearance temperature of crude oil at 10% N-heptane.

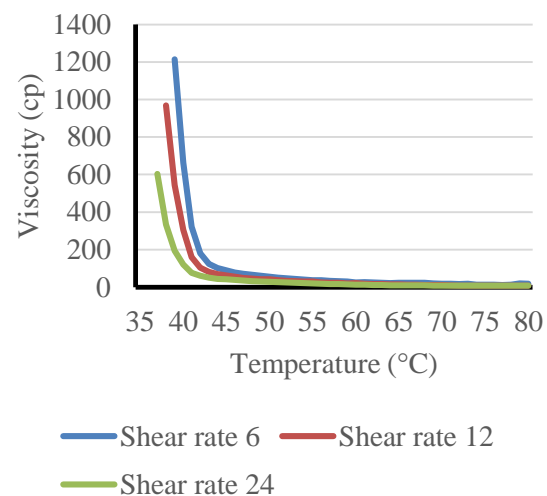


Figure 5. Effect of shear rate on wax appearance temperature of crude oil at 5% N-heptane.

3.3 Effect of n-heptane on wax deposition

One of the important factors in wax deposition is wax deposits duration. The wax deposits are gradually increased with the constant rate on the cold finger rod after 2-12 hours of test duration. Therefore, it is found that shorter test period results in less deposits and longer test period provides more deposits [12]. Therefore, in the present experiment with 2-hr period, the wax deposits of crude oil only are about 0.7 g at 55 °C and 1.2 g at 45 °C and the crude oil obtains enough waxy components. On the other hand, temperature is mentioned as a main factor for wax deposition and some researchers investigate wax

deposition by changing coolant rod temperature instead of bulk crude oil with cold finger method [12-13]. The variation of temperature of oil and the effect of different n-heptane concentration are emphasized in this experiment. The results, as presented in Figure 6 and 7, for wax deposition using different four concentrations are studied based on the efficiency to decrease the original amount of paraffin wax deposits. From Figure 6, the different line compares the reduction of wax deposits for each n-heptane concentration. Moreover, the effect of temperature on the crude oil with different concentration of n-heptane is compared as shown in Figure 7. According to the results, the amount of wax deposit is significantly reduced in each different temperature 55 °C, 45 °C and 35 °C. The effect of temperature of crude oil plays one of the important roles for decreasing wax components in oil because there is lots of wax components inside the crude oil. However, the high amount of solid wax is formed at 35 °C. From the results, only 20% and 15% of n-heptane provide the optimal conditions to apply even the temperature is at 35 °C.

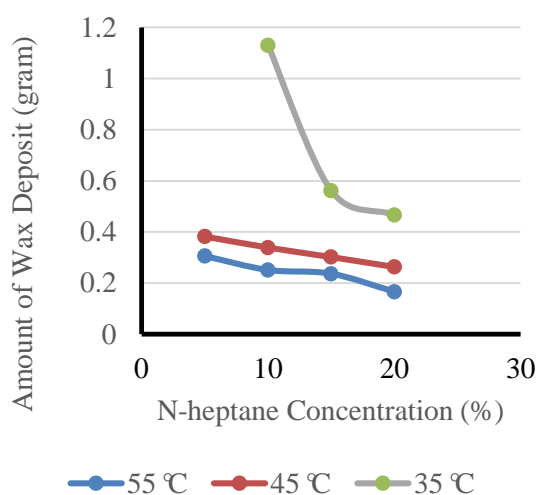


Figure 6. Effect of n-heptane concentration on amount of wax deposit .

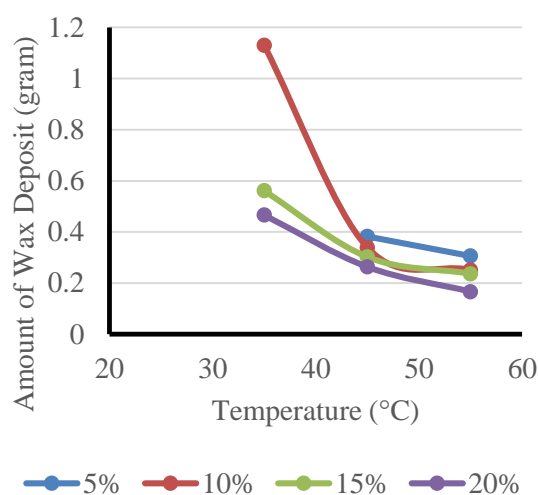


Figure 7. Effect of temperature on amount of wax deposit.

4. Conclusions

In conclusion, the effect of n-heptane concentration on pour point reduction, wax appearance temperature and the amount of wax deposition of crude oil has been studied with ASTM D 5853-11, viscometry and cold finger methods. For the pour point reduction, it is found that the only high concentrations would be maintain fluid state after declining temperature below 30 °C. On the other hand, the results of WAT are slightly different with the different n-heptane concentration. In addition, the variation of bulk oil temperature shows the increasing wax deposits. This study is successfully evaluated the suitable inhibitor concentration to reduce the wax deposit for crude oil from Fang oilfield. The detail of the understanding of inhibitor characteristics and the effect of different inhibitor concentration will provide the suitable condition and concentration to choose for effectively less chemical consumption and less amount of wax as a waste for sustainable production.

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