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Density Prediction of Asphaltenic Synthetic Oil and Comparison with Crude Oil at Different Operating Conditions

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Abstract

The measurement and prediction of density is required for accurate assessment of the production rate of oil. In the present study, the impact of synergetic parameters (pressure, temperature, and fluid composition) on the density of asphaltenic synthetic oils and crude oil is investigated. Furthermore, within the range of operating condition for 546 experimental data of asphaltenic synthetic oils, a correlation is proposed for synthetic oil including toluene, normal heptane and asphaltene extracted from various crude oils. The comparison between the experimental data and the predicted densities showed that the proposed model accurately predicted the experimental data with correlation coefficients (R^2) of more than 0.97. The results also confirmed that the propensity of densities by changing various parameters are as follows. At a given temperature as pressure increases, density increased for crude and synthetic oils. Furthermore, for both types of attempted oils, at different pressures, an increase in temperature caused the reduction of the density. The impact of temperature was dominant in the range of 50 to 80 °C. In addition, for asphaltenic synthetic oils, an increase in the concentration of asphaltene in the synthetic oils, especially from 5 to 10 wt. %, resulted in a significant increase in the oil density.

Keywords: Density, Crude Oil, Asphaltenic Synthetic Oil, Modelling, Experimental Data, Asphaltene.

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Introduction

Density is one of the main properties of oil from reservoir conditions to downstream processes [1]. For instance, interfacial tension (IFT) between fluids depends on different factors such as fluids composition and so does the oil density [2]. So far, many studies have been conducted to predict the density of oil and its derivatives with different methods [3-7]. In this study, the density of different synthetic and crude oils are predicted under different operating conditions. In addition, a comprehensive empirical correlation is proposed for measuring the synthetic oils density.

Methodology

The investigated asphaltene was extracted from one of the oil fields in southern Iran (with a molecular weight of 174.8) and its compositions are provided in Table 1.

The extraction of asphaltene from the investigated crude oil was closely followed by the ASTM (D80-2007) procedure. In doing so, n-heptane was firstly added to the crude oil by a ratio of 40 to 1 before shaking the mixture for two days and every day for 4 hours by magnetic stirrer. After making the mixture of crude oil and n-heptane homogeneous, then the precipitated asphaltene was separated from the mixture using a filter paper. To obtain a purer sample, asphaltene was again dissolved in toluene, then was precipitated again by n-heptane with reflux action in a Soxhlet extractor. This process was repeated to the point that the solution in the Soxhelt tank became clear.

Synthetic oil solutions used in this study were prepared in two steps. In the first step, the synthetic solution containing 60% toluene and 40% n-heptane. Next synthetic oil compositions with 10 vol% increase to toluene concentration (10 vol% reduction of heptane normal) prepared and this process continues to 100 volumes of toluene (0% volume of toluene). In the second step, 5 ,2.5 ,1 and 10 wt% asphaltene was added to the first solution (containing toluene and n-heptane). Asphaltene dissolution in the oil solution was accomplished by using a magnet stirrer (at rotation per minute (rpm) of 600 for 5 hour) and shaker (at a speed of 150 rpm for 24 hours). The density of synthetic solutions and crude oil at desired temperature and pressure was measured by using a density meter (DMA HPM Anton-Paar).

Results and Discussion

Figure 1 shows the trend of crude and synthetic oils density at different pressures and temperatures.

Table 1. Composition of crude oil from which asphaltene was extracted.

Component	N_2	CO_2	C_1	C_2	C_3	iC_4	nC_4	iC_5	nC_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}^+
Mole Percent	0.293	0.902	18.46	5.707	4.159	0.74	2.326	1.402	1.811	3.189	3.393	4.027	4.196	3.701	2.453	43.241

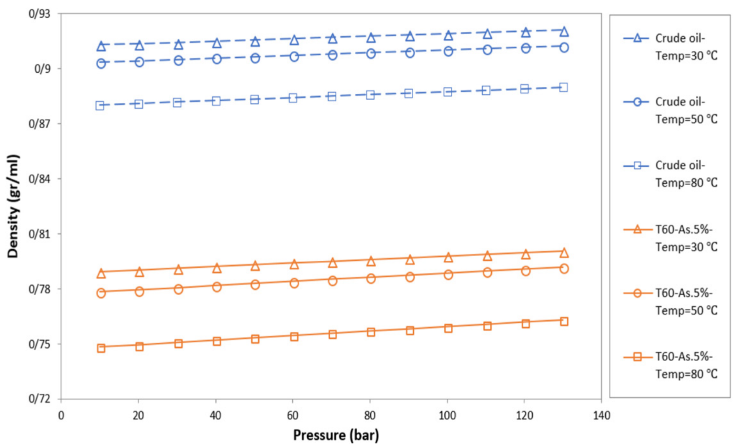

Figure 1: Density of the crude oil and synthetic oil solution (T60- As. 5 wt%) at the different pressures and temperatures

1. At a constant pressure, the crude oil density is more than the synthetic oil. This trend was visible for all attempted pressures. It referred to the difference in components of the both types of oil. The synthetic oil contains toluene, n-heptane and some asphaltene, while crude oil contains various components that cause to be heavier. In addition, increase in temperature at a constant pressure, caused density reduction for both the oil types. These changes are related to increasing the fluid volume by increase in temperature. The reason can be attributed to the phase change of the volatile compounds from the liquid phase to the gas by increasing the temperature. Therefore, the volume and the density of the fluid increases and decreases respectively.

Within the range of operating condition for 546 experimental data of asphaltenic synthetic oils, a correlation is proposed for synthetic oil including toluene, normal heptane and asphaltene extracted from various crude oils by Design Export (V.7) software. The correlation showed in Equation 1.

Density (Synthetic oil) g/cc = 0.0017) + 0.7069× X toluene) + (0.0031 × W asphaltene) + (0.0001× Pressure (Bar)) – (0.0009 × Temperature (°C)) (1)

The comparison between the experimental data and the predicted densities showed that the proposed correlation accurately predicted the experimental data with correlation coefficients (R^2) of more than 0.97.

Figure 2 shows the effect of increasing the pressure on the density of asphaltenic synthetic oil (for solutions with 60% vol. toluene as a model) with 5 wt% of asphaltene in a constant temperature. Furthermore, the comparison between these two dates in the figure has been observed.

An increase in pressure caused the trend of measured density of synthetic oil for both of experimental and predicted ones to increase. In addition, due to that for the synthetic oil solution, the density and the concentration of toluene is more than n-heptane, Therefore, more toluene concentration cause increase in synthetic oil density.

Based on Figure 3, the synthetic oil density reduces by increasing the temperature. It is necessary to emphasize that the trend of these changes is completely similar for the synthetic oil compositions and a constant pressure range which it indicated the overall effect of increasing the temperature on density.

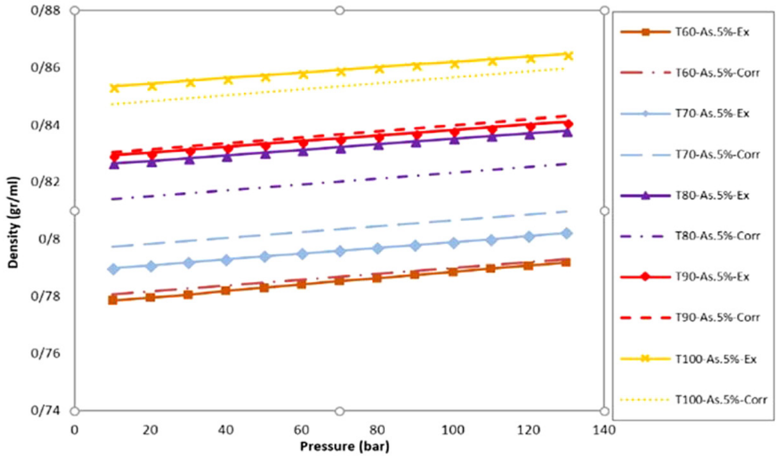

Figure 2: Density difference between experimental and correlation dates for various synthetic oil solutions with 5wt% asphaltene at different pressures and temperature of 50°C

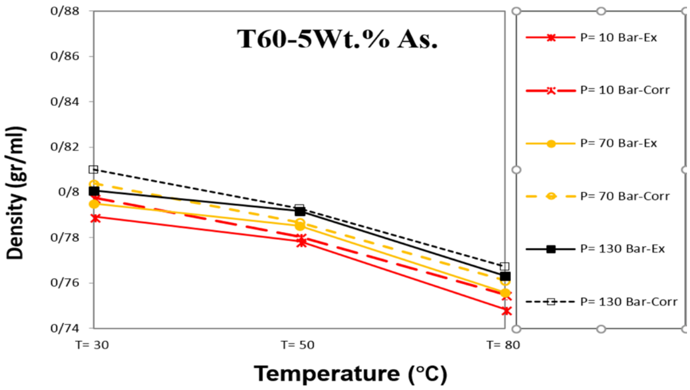

Figure 3: Effect of temperature on density measured of experimental and correlation methods for the synthetic oil solutions (T-60As. 5 wt%) at different pressures

2. In Figure 4, the effect of asphaltene concentration on the density is evaluated for the chosen pressures (10,70,130 bar) for synthetic oil containing 60 vol% of toluene and n-heptane 40 vol% with different weight fraction 5 ,1 ,0 and %10 asphaltene.

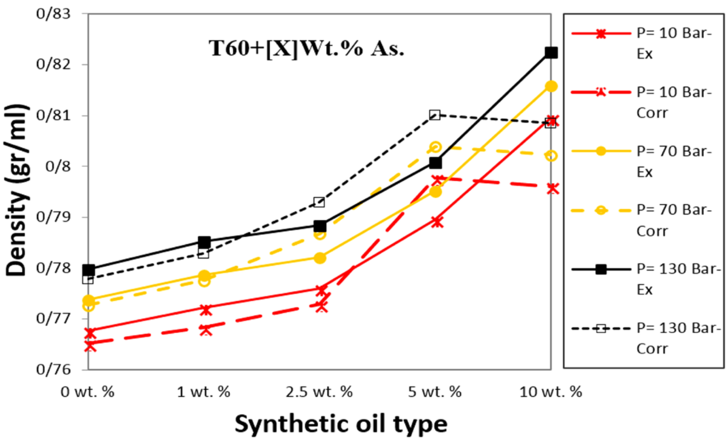

Figure 4: Effect of asphaltene concentration on density measured of experimental and correlation methods for the synthetic oil solutions containing 60 vol% toluene at different pressures and temperature of 50°C

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2. In Figure 4, the effect of asphaltene concentration on the density is evaluated for the chosen pressures (10,70,130 bar) for synthetic oil containing 60 vol% of toluene and n-heptane 40 vol% with different weight fraction 0, 1, 5 and 10 % asphaltene.

Density changes are more pronounced for asphaltenic synthetic oils by increasing asphaltene concentration. By the way, the changes in density of synthetic oil is more important compared to those without asphaltene to 5 wt% asphaltene. Nevertheless, by increasing the asphaltene concentration from 5 to 10 wt%, a decreasing trend observed in correlation data.

Conclusions

The comparison between the experimental and predicted densities indicated that the proposed model successfully predicted the experimental data with correlation coefficients (R^2) of more than 0.97. In addition, for both types of oils, at different pressures, the increase in temperature caused density to reduce. The reduction was more pronounced by changing the temperature from 50 to °80C. In addition, for asphaltenic synthetic oil, the increase in the concentration of asphaltene, especially from 5 to 10 wt%, resulted in a significant increase in the density of oil. The results also confirmed that the trend densities by changing the various parameters are as follows: at a constant temperature as pressure increases, the densities would increase substantially for both types of crude and synthetic oils.

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