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Prediction of Asphaltene Mole Fraction and Cumulative Mass of Asphaltene in Oil: A Simulation Based Approach

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ABSTRACT

Asphaltene precipitation is a major flow assurance challenge in the oil and gas industry that can significantly impact reservoir performance, leading to reduced production and increased operational costs. Therefore, understanding the mole fraction of asphaltene that precipitated nd its cumulative mass is crucial for optimizing production strategies and maximizing oil recovery. This work adopts a simulation approach for prediction of asphaltene mole fraction and cumulative mass of asphaltene in oil under pressure depletion. A 3 dmensional homogeneous reservoir model was built and created, populated with petrophysical properties, characterized and tunned with PR 1978 EOS model. The created fluid model was run for asphaltene precipitation prediction.Results shows that the cumulative mass of asphaltene produced increases gradually up to 20 days after which it remains the same. The mole fraction of asphaltene in oil was zero above the upper onset pressure and later increase as pressure deplete till the end. The mass of asphaltene precipitated was higher than the mass absorbed. The field oil recovery factor increases as the reservoir pressure depletes over time, with 12.49% of oil recovered after 150 days. Effective asphaltene management is crucial for minimizing the impact of asphaltene precipitation on reservoir performance.

Keywords: Asphaltene, Mole fraction, Cumulative mass, Suspension, Precipitate, Recovery factor.

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1. INTRODUCTION

Asphaltene precipitation and deposition is one of the flow assurance problem that threaten the production and transportation of crude oil (Hasanvand et al., 2015).Therefore, study on the factorsthat influence precipitation and deposition of asphaltene has gained significant attention in the oil and gas industry (Wang and Civan, 2005a). Nghiem (2000) opined that to analysis the behavior of asphaltene and prevent deposition, proper understanding of the fluid mechanics, oil field chemistry, process instrumentation, and control as well as heat transfer is very important. Asphaltene management has thus far received only empirical treatment with some successful field trials, with no robust analytical model or numerical simulation to predict its onset and deposition. In fact, the word asphaltene is still ambiguous, as not much can be said to be known explicitly about the molecule. However, it has been defined as a solubility class that is insoluble in alkanes and soluble in toluene and aromatic fluids (Leontaritis and Mansoori, 1988).

Asphaltene is a composition of hydrocarbon with thousands of known structures that differ with crude oil origin (Buckley et al., 1997). Inadequate knowledge of asphaltene has not only been a problem during crude oil production but also affects the modeling of reservoir fluid behavior (Indo et al., 2009).

The molecular weight and structure of asphaltene has been a subject of debate among researchers and given rise to several research have a general acceptable weight and structure (Mullins et al., 2007). Asphaltene fluid property behavior has been an interesting area of research due to its complex nature among several researchers (Alian et al., 2011; Takahashi, 2009; Ghosh et al., 2016; Guan et al., 2018; Punnapala and Vargas, 2013; Tavakkoli et al., 2014b; Panuganti et al., 2013). The impact of asphaltene on the petrophysical properties of the formation, which controls fluid production, transport, and storage have proved its significance and enhanced its study (Kokal and Sayegh, 1995).

Several factors influence asphaltene deposition, including changes in pressure, temperature, composition, and its interactions with other components present in the crude oil (Nielsen et al., 1994). The understanding of asphaltene deposition mechanisms and its impact on flow assurance is crucial for the effective and safe operation of oil and gas production systems.

The deposition of asphaltenes can result in severe consequences, such as reduced production rates, increased pressure drop, and even complete blockage of flow paths (Subramanian et al., 2016). The precipitation and deposition of asphaltene can lead to corrosion, fouling, and increased operational costs since it will require frequent cleaning and maintenance of equipment (Rabbani et al., 2015).

Amidst these asphaltene challenges, numerous modeling approaches, including thermodynamic models, kinetic models, and computational fluid dynamics simulations, have been utilized to predict and understand asphaltene deposition behavior (Mohammadi et al., 2016; Chen et al., 2019). However, prediction of the fraction of asphaltene in oil, mass of adsorb asphltene, precipitated asphaltene, and asphaltene in suspension is vital to solve the problem of deposition, which this wok elucidates.

2. METHODOLOGY

A simulation based approach was adopted to predict asphaltene mole fraction and cumulative mass of asphaltene in oil from a black oil model under pressure depletion.
CMG and input parameters on fluid composition, heptanes plus fraction, reservoir and asphaltene properties, grid properties, water and gas relative permeability, model initialization properties presented in Table 1 to Table 6 were used for asphaltene precipitation prediction.

Table1. Fluid compositional analysis.

Component	Composition
Nitrogen	0.57
Carbon Dioxide	2.46
Methane	36.37
Ethane	3.47
Propane	4.05
i-Butane	0.59
n-Butane	1.34
i-Pentane	0.74
n-Pentane	0.83
Hexanes	1.62
C7+	47.96

Table 2. Heptane plus fraction, reservoir and Asphaltene properties.

Property	Value
C_{7+} molecular weight	329
C_{7+} specific gravity	0.9594
Live oil molecular weight	171.4
Stock tank oil API gravity	19
Asphaltene content in stock tank oil, wt%	16.8
Reservoir temperature, °C	212
Saturation pressure, KPa	20339.53

Table 3. Grid properties data (Kinate and Epelle,2024).

Properties	**Value**
Grid Top	1200m
Grid thickness	5m
Permeability (I, J and K)	500 millidarcies
Porosity	0.3
Rock compressibility	4e-6 per kPa
Reference pressure for rock compressibility	11800 kPa

Table 4. Water relative permeability data (Kinate and Epelle,2024).

Sw	**krw**	**krow**
0.2	0	1
0.2899	0.0022	0.6769
0.3778	0.018	0.4153
0.4667	0.0607	0.2178
0.5556	0.1438	0.0835
0.6444	0.2809	0.0123
0.7	0.4089	0
0.7333	0.4855	0
0.8222	0.7709	0
0.9111	1	0
1	1	0

Table 5. Gas relative permeability data (Kinate and Epelle,2024).

Sg	**krg**	**krog**
0	0	1
0.05	0	0.88
0.0889	0.001	0.7023
0.1778	0.01	0.4705
0.2667	0.03	0.2963
0.3556	0.05	0.1715
0.4444	0.1	0.0878
0.5333	0.2	0.037
0.6222	0.35	0.011
0.65	0.39	0
0.7111	0.56	0
0.8	1	0

Table 6. Model initialization data.

Properties	Value
Temperature	100°C
Reference pressure	34473.78 kPa
Datum depth	1200m

CMG's Builder was used for writing the dataset and validated with CMG-GEM. A three-dimensional (3D) homogeneous reservoir model of dimensions 30x30x3 (2700 grid blocks) and block width of 10ft was developed. The model was populated with petrophysical, grid and rock properties using the data in Table 3. CMG's compositional fluid modeling package was used to create an asphaltene deposition fluid model required in the component section of CMG-GEM data file. Data in Table 1 and Table 2 were used for the characterization and tunning of the fluid model with PR 1978 selected as the Equation of State for thermodynamic properties calculation. The created fluid model was imported into the component section of GEM data file. The relative permeability data in Table 4 and Table 5 were used to define the relative permeability curves and the model was initialized with the user input method that requires the data presented in Table 6. A producer well PRD was completed in three layers at the bottom of the model at 1210m, 1220m and 1230m.The producer well has a minimum BHP of 2000kPa and the model was run for asphaltene deposition prediction.

3. RESULTS

3.1. Cumulative Mass of Asphaltene Produce in Oil

The cumulative mass of asphaltene produce in the oil phase is presented in figure 1. The cumulative mass of asphaltene produces increases from 0 kgmole to 3013.779053kgmole after 20days and remains the same as the reservoir pressure depletes with time. A uniform asphaltene mole was produce after 20 days with oil up to the asphaltene onset pressure at which asphaltene deposited on the rock surface for duration of 47days.

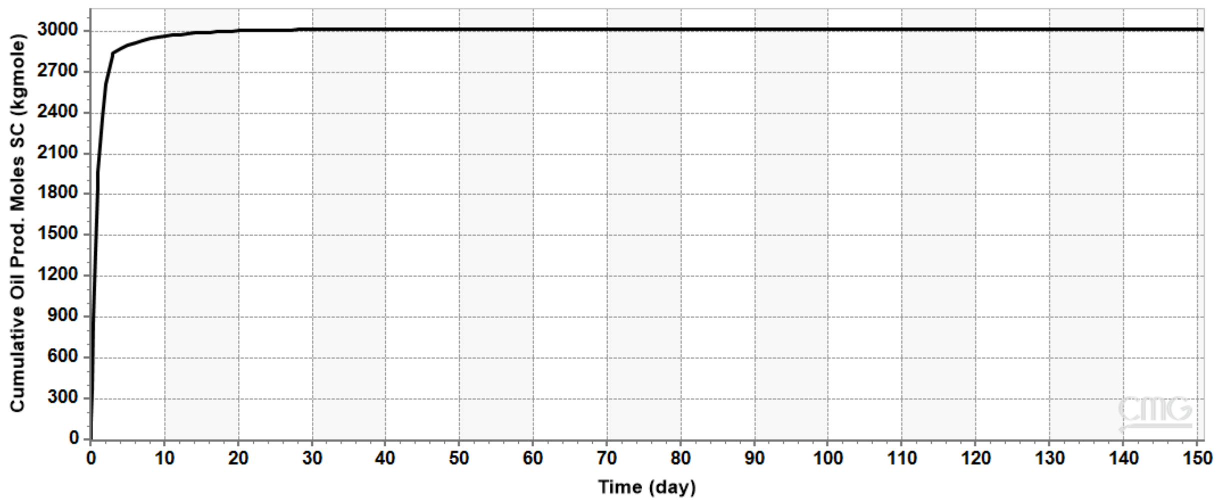

Figure 1. Cumulative mass of Asphaltene.

3.2. Oil Recovery Factor

Figure 2 shows the field oil recovery factor. The field oil recovery factor increases from 0% to 12.488% as the reservoir pressure depletes over a period of 6days. Results shows that 12.488% of oil was recovered after 150days.

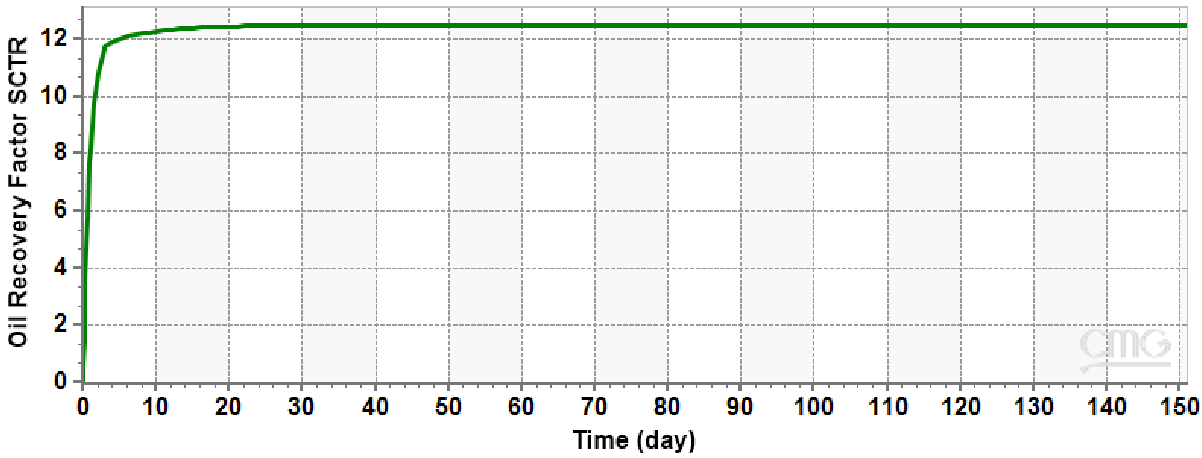

Figure 2. Field oil recovery factor.

3.3. Mole Fraction of Asphaltene in Oil

The mole fraction of asphaltene in oil due to reservoir pressure depletion is presented in figure 3. Result shows that above the asphaltene upper onset pressure, the mole fraction of asphaltene in oil was zero. As the reservoir pressure depletes up to the upper asphaltene onset pressure, the mole fraction of asphaltene in the oil phase increase as the pressure deplete further to the saturation pressure 16394.05664KPa for a maximum concentration of asphaltene. At the saturation pressure, 0.020344628moles of asphaltenes were present in the oil phase.

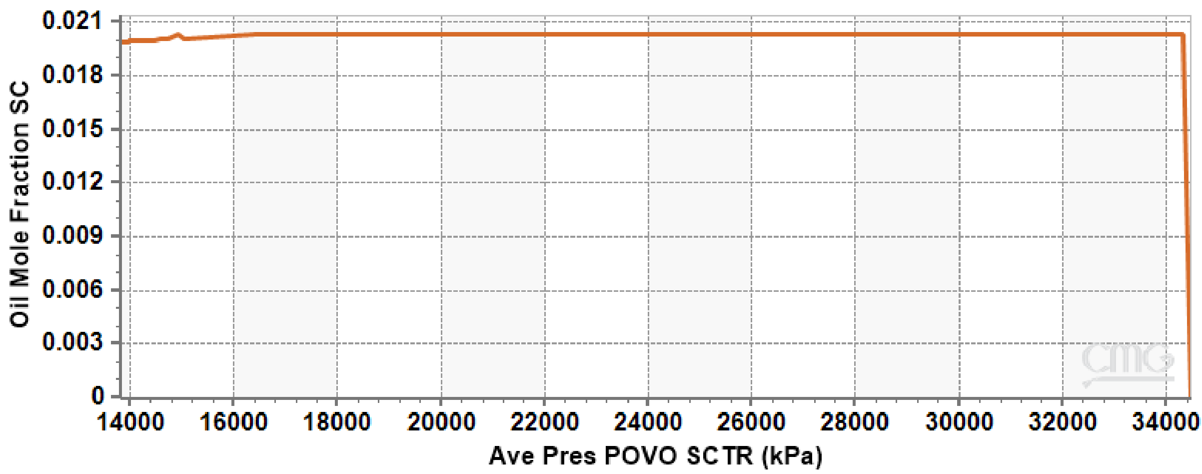

Figure 3. Fraction of asphaltene in oil.

3.4. Asphaltene Inventory

The asphaltene inventory (total mass of adsorbed asphaltene, total mass of precipitated asphaltene and total mass of asphaltene in suspension) for a period of 150days is presented in Table 7. There was a depletion of reservoir pressure up to the upper asphaltene onset pressure and to the saturation pressure, which resulted in a higher mass of asphaltene precipitated than the adsorbed.

Table 7. Asphaltene inventory.

Properties	Value
Total mass of adsorbed asphaltene	1.94701E+05kg (kg/kg of rock)
Total mass of precipitated asphaltene	2.55026E+05kg (kg/kg of rock)
Total mass of asphaltene in suspension	60324.6ppm

4. CONCLUSION

This work evaluates the cumulative mass of asphaltene produce in oil, mole fraction of asphaltene in oil, and oil recovery during asphaltene precipitation. A simulaton based approach was adopted, and the cumulative mass of asphaltene produced increase at the initial stage and became steady after a period of time. Also, as the reservoir pressure depletes to the upper asphaltene onset pressure, the fraction of asphaltene in oil phase increases. The mass of asphaltene precipitated was higher than the absoreded.This work has shown the necessity of sphaltene precipitation prediction to solve the problem of deposition.

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