



Modifying an Equation to Predict the Asphaltene Deposition in the Buzurgan Oil Field

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Abstract

Buzurgan oil field suffers from the phenomenon of asphaltene precipitation. The serious negatives of this phenomenon are the decrease in production caused by clogging of the pores and decrease in permeability and wettability of the reservoir rocks, in addition to the blockages that occur in the pipeline transporting crude oil. The presence of laboratories in the Iraqi oil companies helped to conduct the necessary experiments, such as gas chromatography (GC) test to identify the components of crude oil and the percentages of each component. These laboratory results consider the main elements in deriving a new equation called modified colloidal instability index (MCII) equation based on a well-known global equation called colloidal instability index (CII) equation.

The modified (MCII) equation is considered an equation compared to the original (CII) equation because both equations mainly depend on the components of the crude oil, but the difference between them lies in the fact that the original equation depends on the crude oil components at the surface conditions, while the new equation relies on the analysis of crude oil to its basic components at reservoir conditions by using (GC) analysis device.

The components of the crude oil in the reservoir conditions according to the number of carbon atoms of each component compared with the elements of the original equation, which are (saturates, aromatics, resins, and asphaltene).

The new MCII equation helps in predicting the possibility of asphaltene precipitation which can be used and generalized to other Iraqi oilfields as it has proven its worth and acceptability in this study.

Keywords: Asphaltene deposition, modified equation, colloidal, precipitation, predict.

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1- Introduction

Asphaltene is considered the heaviest and complex series of hydrocarbons within the crude oil mixture; also it can be defined from its solubility, as it is completely soluble with aromatic solvents like toluene, benzene, or xylene, while it does not dissolve with light paraffinic solvents like as n-heptane or n-pentane [1]

One of the most important challenges facing the development of Mishrif formation in Buzurgan oilfield at present is the asphaltene deposition problem near the wellbore.

The most important reasons for the asphaltene deposition in Buzurgan oilfield are:

- a- High gas-oil ratio (GOR) in crude oil components.
- b- The value of the API is relatively low.

The process of determining the conditions of asphaltene precipitation called (Asphaltene onset point) (AOP) is very complex and depends on several factors within the reservoir [2]

A study of asphaltene deposition took great importance in most oil-producing countries, including the oilfields in southern Iraq, especially the Buzurgan oilfields.

In order not to increase this problem, it needs to be prevented before the reservoir or oil formation is damaged and lead to the closure of the well. Asphaltene is physically similar to coal as it can precipitate with alkanes, they can be classified as heptane insoluble [3]

Fig. 1.

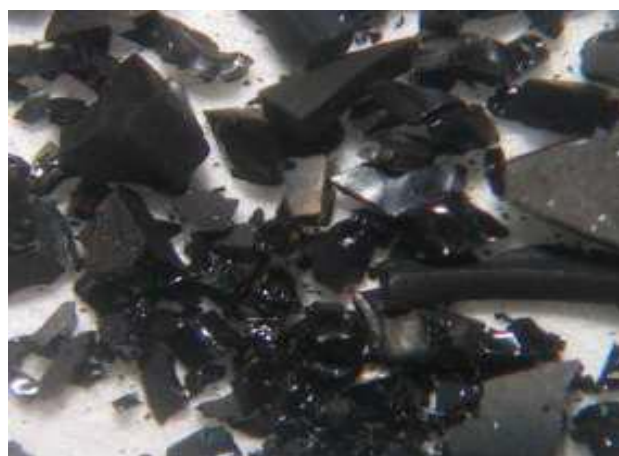


Fig. 1. The physical form of asphaltene [4]

Buzurgan oilfield located in southern Iraq near the Iraqi-Iranian border and about (60km) south of Amara as shown in Fig. 2. From the structural point of view, the Buzurgan oilfield is about 40km *7km with a northern and southern dome. The southern dome is shallow at a depth of 850m and covers a larger area. The cretaceous Mishrif is considered the most important formation and it mediates two layers, Abu khasib formation above Mishrif formation and Rumila formation below it. The Mishrif formation has 7 pay zones which are MA, MB11, MB12, MB21, MB22, MC1, and MC2, the MB21 consider the main pay zone in Mishrif formation. The approximate depth of the reservoir is 4000m [4].

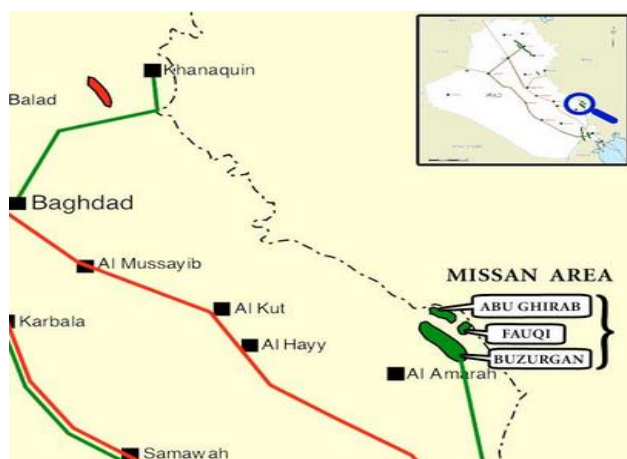


Fig. 2. Location of Buzurgan oilfield [4]

The calculation of the asphaltene ratio in the hydrocarbons is determined using (Saturates, Aromatics, Resins, and asphaltene) analysis called (SARA) analysis. SARA test is performed in the laboratory by splitting crude oil into four types of compounds according to their solubility in selected solvents [5].

A more efficient way of modeling asphaltene precipitation as a pure dense phase by dividing the heavy phase into its components in terms of precipitating and non-precipitating components thus making quantitative experiments to find suitable algorithms and numerical correlations [6]. A model for predicting phase equilibria of heavy mixtures by using Soave-Redlich-Kwong equation of state, by determining the portion of the heavy crude that can potentially precipitate to form waxes such as asphaltene [7].

The large number of parameters that affect asphaltene precipitation makes it very difficult and challenging to produce and model data fitting without a lot of data inputs and even harder to simulate using programs without data. In this paper, a new scaling model has been developed by incorporating more parameters, such as GOR, resin to asphaltene ratio, mole percent, and oil density.

This new scaling model has been evaluated with a second set of experiments and the results were very valid in terms of accuracy in predicting the amount of precipitated heavy asphaltene. However, its dependency on many factors makes it very time and effort-consuming in application [8].

The precipitation of asphaltene and wax are the main problems that can cause reduced permeability and even block the formation.

Four different samples were taken from four Malaysian oilfields and were subjected to SARA analysis, CII (Colloidal instability index), Refractive Index (RI), and molecular weight. The authors proved that results from mathematical relations derived from experimental data were accurate and predictions were very reliable in terms of forecasting the onset of precipitation [9].

Asphaltene precipitation is a very serious problem when it comes to plugging wellbore or reducing formations permeability and also affecting surface facilities negatively. It also affects production negatively. Sometimes the production stops as a result of the accumulation of asphaltene. In this paper, the author studies different techniques and modeling approaches and studies the best possible way to come up with a proper understanding of how and why precipitation occurs at a certain pressure and temperature and not in other situations [10].

This study aims to model asphaltene precipitation from laboratory experiments and to come up with a new equation that can help in understanding the tendency of particular crude to have asphaltene problems. However, this model is going to be built from the ground to be adapted to specific reservoir parameters in Buzurgan oilfield.

In general the aim of this study to investigate the use of a new method that uses the compositional analyses of reservoir fluids instead of using SARA (Saturates, Aromatics, Resins, Asphaltene) analysis for crude oil to predict the potential of crude to cause problems of asphaltene.

2- Methodology

This part deals mainly with two tasks. The first task is obtaining the crude oil sample and other data from the desired location to conduct practical experiments for the crude oil sample laboratory. The second task is to find the relationship between laboratory results and the (CII) equation to find a new model that can be used to confirm the possibility of asphaltene deposition as a result of production in the Iraqi oilfields.

The field data and the crude oil sample were taken from the Buzurgan oilfield in southern Iraq which was produced from three formations where the Mishrif is the main formation and lies between the formation of Abu khasib and Rumaila. The main average depth of the reservoir is about 4000 meters [4].

The experimental work involves conduction the (Gas and liquid chromatography) test on the crude oil sample in the Missan oil company laboratories to determine the percentages of hydrocarbons and non-hydrocarbon present in the crude oil sample.

The working principle of the gas chromatography (GC) device, as the name implies, GC uses a carrier gas in the separation, this plays the part of the mobile phase. The carrier gas transports the sample molecules through the GC system, ideally without reacting with the sample or damaging the instrument components.

The sample is first introduced into the gas chromatograph (GC). The sample is injected into the GC inlet through a septum which enables the injection of the sample mixture without losing the mobile phase. Connected to the inlet is the analytical column a long (80 m), narrow (0.4) mm internal diameter) fused silica or metal tube which contains the stationary phase coated on the inside walls. The analytical column is held in the column oven which is heated during the analysis to elute the less volatile components. The outlet of the column is inserted into the detector which response to the chemical components eluting from the column to produce a signal. The signal is recorded by the acquisition software on a computer to produce a chromatogram **Fig. 3** explains these steps.

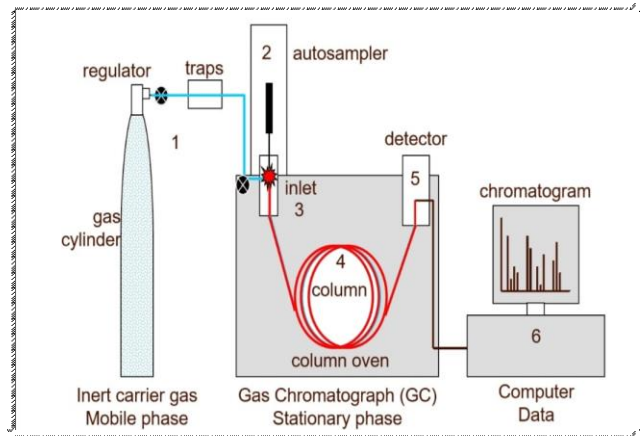


Fig. 3. A simplified diagram of a gas chromatograph

3- Experimental Work

3.1. Gas and Liquid Chromatography Experiment

Gas and liquid chromatography is a technique used to separate different components of a compound according to their volatility and polarity. For this purpose, a device is called (AGILENT GC) with two columns is used to identify the compositions of crude oil in the laboratory. The device is fully automated and gives the required results. This device is made up of the following components: -

- 1- Oven: - used to heat the column and the sample injected
- 2- Sample injection point
- 3- Column
- 4- Detector
- 5- Carrier Gas (Hydrogen)
- 6- Chart recorder: - Computer for data acquisition

3.2. Calibration of GC Device

GC device needs periodic calibration to perform the required of separate hydrocarbons to percentages. Each compound within the crude oil has a special retention time that responds to the detector in the device. Calibration of GC can be done with a sample of crude oil in which the compounds it is known previously. The standard retention time for each component is mainly recorded in the GC programming.

3.3. Steps of the Experiment

- 1- The sample taken from the reservoir is left within a laboratory temperature (25C°) until its temperature is equal to the surrounding temperature (laboratory temperature) by leaving it at the laboratory for (3) hours because the temperature of the sample taken from the reservoir is high.
- 2- Wait for a few seconds after running a chromatography device to stabilize (stability of the device).
- 3- Sample injection: enter a limited amount of the crude oil sample automatically by the (injector) which is located above the heater (oven) and push-button entry to inject it.
- 4- Temperature control: adjust the temperature at 200°C by the control panel with a temperature rise rate (30°C/min) before startup the oven.
- 5- The analysis takes about 1 hour and then the results appear on the chromatograph screen.

4- New Equation Formulation

4.1. Colloidal Instability Index Equation

The CII equation can be formulated depending on experimental data to predict significantly the possibility of asphaltene precipitation. The new equation will reduce the cost and the time required to perform the needed tests to determine the probability of asphaltene deposition. The original equation from which the modified equation is derived is:-

$$CII = \frac{\text{Saturated} + \text{Asphaltene}}{\text{Aromatic} + \text{Resin}} \quad (1) [5]$$

The terms of the equations are

- If $CII < 0.7$ No asphaltene deposition problems.
- If $CII > 0.9$ the asphaltene deposition problems are certain.
- If $0.9 > CII > 0.7$ Possible asphaltene deposition problems

In this work, a mathematical equation is formulated based on a basic equation known as the CII equation. This basic equation was depended on the fractionate of crude oil into its four parts SARA analysis of crude oil.

The current equation was modified using hydrocarbon components obtained from the gas chromatography experiment instead of SARA analysis as explained earlier.

4.2. Modified Colloidal Instability Index Equation Derivation

The CII equation (1) can be modified and developed according to the available parameters to highly appropriate data from the experimental work.

This equation is being reformulated and modified to be more suitable for Buzurgan oilfield and called MCII, the reliability of this new equation will be discussed later.

The CII equation will be the basis for the formulation of this new equation

The SARA fractions in the CII equation can be replaced by reservoir fluid components obtained from GC analysis **Table 1** because the sum of these components also represents the total original oil.

Table 1. Compositional analysis by GC [11]

Component	Separator gas molar	Separator liquid molar %	Reservoir Fluid molar %
N2	1.03	0.09	0.63
CO2	6.06	0.53	3.71
H2S	1.06	0.32	0.72
RSH	0.28	0.03	0.2
C1	61.47	2.59	36.43
C2	16.01	2.94	10.45
C3	8.44	3.77	6.45
I-C4	1.01	0.8	0.92
N-C4	2.7	3.28	2.95
I-C5	0.66	1.91	1.19
N-C5	0.67	2.83	1.59
C6	0.49	6.45	3.02
C7	0.12	7.33	3.19
C8		6.45	2.74
C9		5.69	2.42
C10		5.25	2.23
C11		5.25	2.23
C12+		44.49	18.93
Total density	1.074 kg/m3	936.638 kg/m3	1061.984 kg/m3
Total molecular Weight	25.53	250.52	124.86
Density C12+	979.54		
M.W C12 +	467.43		

A statistical representation of GC analysis shows the different compositions of crude oil with their concentration values.

To match this comparison, each fraction of (SARA) must be compared with the corresponding components of laboratory tests as shown in **Table 2**.

Table 2. Comparison of hydrocarbon components with corresponding SARA fractions

Name	Components	Corresponding SARA
Light Components	C ₁ -C ₅	Aromatics
Medium Components	C ₆ -C ₈	Saturates
Heavy Components	C ₉ ⁺	Asphaltene
Non-Hydrocarbon	CO ₂ ,N ₂ ,H ₂ S,etc	Resins

This comparison doesn't represent the real values of the (SARA) fractions but is approximate values intended to formulate the new equation as the asphaltene the heaviest hydrocarbons and aromatics are the lightest and between them the saturated, while resins in this comparison represent by non-hydrocarbon components.

The second part in modifying this equation, which is the most important part, it is necessary to take into consideration the different reservoir conditions on which the new equation is based and the surface conditions on which the original equation is based, and the physical and chemical changes that occur on the components of the crude oil as a result of the pressure difference.

Physically, most of the light components in the reservoir as a result of high pressure become in an unstable condensed liquid state within the crude oil solution, and when the pressure drops these components become more active for movement and liberation of production, unlike the heavy components that are less active for production. Chemically, the light and medium components are interacting and homogeneous with the heavy components at the reservoir pressure, and when the pressure drops these components are separated leaving the heavy components to flocculate inside the reservoir and therefore the product of the heavy components is few compared to the remainder inside the reservoir.

Therefore, the MCII equation is written in the following formula:

$$MCII = \frac{Lc+Nc}{Hc+Mc} \tag{2}$$

- Lc = Light component mole %
- Hc = Heavy components mole %
- Mc = Medium components mole %
- Nc = Nonhydrocarbon components mole %

This does not mean flipping the equation but rather flipping the elements of the equation only.

It is clear from the study of physical and chemical effects on the crude oil in the two different conditions that the percentage of light components in the reservoir is much less than the ratio that was produced, in contrast to the heavy and flocculating components, so the ratio of heavy components in the reservoir is more than that produced on the surface. **Table 3** and **Table 4** explain how the percentages of each component are calculated and used in the modified equation.

Table 3. Different hydrocarbon components corresponding to SARA analysis

Components	Reservoir fluid mole%	Molar weight	
N ₂	0.63	28.02	
CO ₂	3.71	44.01	Non-hydrocarbons Components Nc
H ₂ S	0.72	34.08	
RSH	0.2		
C ₁	36.43	16.04	
C ₂	10.45	30.07	Light Hydrocarbons Components Lc
C ₃	6.46	44.09	
I-C ₄	0.92	58.12	
N-C ₄	2.95	58.12	
I-C ₅	1.19	72.15	
N-C ₅	1.59	72.15	Medium Hydrocarbons Components Mc
C ₆	3.02	85.5	
C ₇	3.19	95.6	
C ₈	2.74	107.4	Heavy Hydrocarbons Components Hc
C ₉	2.42		
C ₁₀ ⁺	23.39	269.5	

Table 4. Summation result of different hydrocarbons

Name of the fraction	Sum of the components %
Components light hydrocarbons Lc	59.98
Component medium hydrocarbons Mc	8.95
Components heavy hydrocarbons Hc	25.81
Components non-hydrocarbons Nc	5.26
Total	100%

Applying the MCII equation

$$MCII = \frac{Lc+Nc}{Mc+Hc} \quad (2)$$

$$MCII = \frac{59.98+5.26}{25.81+8.95} = 1.89$$

If MCII < 0.7 No asphaltene problem.

If MCII > 0.9 the asphaltene problem is certain.

If 0.7 < MCII < 0.9 Possible asphaltene problem.

Note: conditions of MCII taken from original CII equation.

The obtained result from MCII = 1.89 confirms the occurrence of asphaltene deposition as a result of continued production.

4.3. Evidence on the Reliability Of The New Equation

The reliability of this equation and its wider applicability in Iraq are discussed as follow:-

MCII equation was applied using real data obtained from one of northern Iraq oilfield that suffers from the asphaltene deposition problem [12], the results support the validity of this equation as shown in **Table 5** and **Table 6**.

Table 5. Gas chromatography results [12]

Component	Recombined mole%	Molar weight
Nitrogen	0.316	28.02
Carbon dioxide	2.073	44.01
Hydrogen sulfide	15.354	34.08
Methane	40.986	16.04
Ethane	6.941	30.07
Propane	4.452	44.09
iso-butane	0.868	1
n-butane	2.573	58.12
Neo pentane	0.019	72.15
iso-pentane	1.115	72.15
n-pentane	1.596	72.15
Hexane C ₆	2.640	85.5
Heptane C ₇	2.538	95.6
Octane C ₈	2.616	107.4
Nonanes C ₉	2.219	119.4
Decane plus	13.694	269.5

Table 6. Summation result of different hydrocarbons

Name of the fraction	Sum of the components %
Light hydrocarbons (Lc)	58.55
Medium hydrocarbons (Mc)	7.794
Heavy hydrocarbons (Hc)	15.914
Non- hydrocarbons (Nc)	17.743
Total	100%

By applying the MCII equation

$$MCII = \frac{Nc+Lc}{Mc+Hc} \quad (3)$$

$$MCII = \frac{17.743+58.55}{7.794+15.914} = 3.218$$

∴ MCII > 0.9

The value of MCII also confirms the matching problem of asphaltene precipitation in that oilfield.

The second step in the proof of the reliability of the MCII equation can be done using the plot of De Boer [13], which is considered to be a commonly used equation.

Held De Boer and his colleague's laboratory analysis and theoretical work for different crude oils sample around the world and invented the versatile plot **Fig(4)**, which many researchers still rely on because the plot was based on the analysis of many oilfields sample under reservoir conditions.

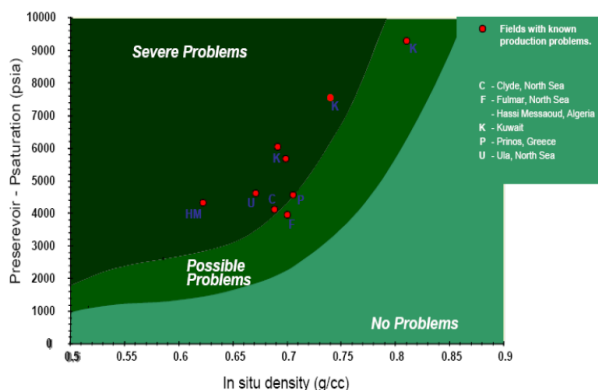


Fig. 4. De Boers plot for asphaltene problem prediction [13]

By using reservoir pressure ⁽⁴⁾ = 6300 psi, bubble point pressure = 3220 psi, and fluid density of Buzurgan oilfield = 0.73 gm/cc, the result indicated that there is a problem of asphaltene deposition in the Buzurgan oilfield. In general, it can be said that the derived equation MCII has good reliability and can be used in other Iraqi oilfields. Just conducting a component analysis indicates the probability of precipitation problem, as it is noticeable that the ratios of light components in crude oil are high and this means that the GOR is high.

5- Conclusions

Through this study the following conclusions are listed:

- 1- The modified equation showed that MCII= 1.89, this value is greater than 0.9 which means that there is an actual problem of asphaltene deposition in the Buzurgan oilfield.
- 2- The present study helps to find a suitable strategy to treat the asphaltene deposition problem in the Buzurgan oilfield.
- 3- Given the possibility of applying this equation to two oil fields, one in northern Iraq and the other in the south, the likelihood of its successful application in other Iraqi oil fields that may need some minor modifications.

Nomenclatures

API:	American Petroleum Institute
CII:	Colloidal Instability Index
GC:	Gas Chromatography
GOR:	Gas Oil Ratio
MCII:	Modified Colloidal Instability Index
SARA:	Saturates, Aromatics, Resins, Asphaltenes
Pb:	Bubble point pressure
VLE:	Vapor liquid-Equilibrium
RI:	Refractive Index
BHP:	Bottom Hole pressure
BHT:	Bottom Hole Temperature
BHS:	Bottom Hole Sample
PVT:	Pressure Volume Temperature
AOP:	Asphaltene Onset pressure

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تحديث معادلة للتنبؤ بترسب الاسفلت في حقل بزركان النفطي

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الخلاصة

يواجه حقل بزركان النفطي من مشكلة ترسب الاسفلت، السليبات الخطيرة لهذه الظاهرة تتمثل بانخفاض الانتاج الناجم عن انسداد المسامات وتقليل النفاذية والتبالية للصخور المكمنية بالاضافة الى الانسدادات التي تحصل في الانابيب والمعدات السطحية. إن وجود المختبرات في شركات النفط العراقية ساعدت على إجراء الفحوصات الضرورية لإتمام هذه الدراسة مثل فحص الطيف اللوني للغاز للتعرف على نسب مكونات النفط الخام حيث تعتبر النتائج المختبرية اساس لتحديث معادلة عالمية موجودة اساسا تدعى (مؤشر عدم الاستقرار الغروي) والمعادلة المحدثة تسمى (مؤشر عدم الاستقرار الغروي المستحدث).

يعتبر المعادلة الجديدة معادلة مقارنة للمعادلة الاصلية لان كلا المعادلتين تعتمدان على مكونات النفط الخام ، لكن الاختلاف بين المعادلتين تكمن في كون معادلة الاصلية تعتمد على مكونات النفط الخام في الظروف السطحية بعد الانتاج ، بينما المعادلة الجديدة تعتمد على تحليل النفط الخام الى مكوناتها الاساسية في الظروف المكمنية باستخدام جهاز فحص الطيف اللوني للغاز .

تتم مقارنة عناصر معادلة (مؤشر عدم الاستقرار الغروي) والتي هي :
(المواد المتشعبة والعطريات والراتجات والاسفلتين) مع مكونات النفط الخام الناتجة عن تحليل (فحص الطيف اللوني للغاز) وحسب عدد ذرات الكربون الموجود ضمن كل عنصر من عناصر النفط الخام.
ان المعادلة المستحدثة اعطت نتائج مقبولة في التنبؤ بترسب الاسفلت في حقل بزركان النفطي بالاضافة الى حقل آخر في شمال العراق مما يعني بانها قد تكون قابلة للتطبيق في الحقول العراقية الاخرى.

الكلمات الدالة: ترسب الاسفلتين، المعادلة المستحدثة، الغروائية، ترسيب، تنبؤ.