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Estimation of Minimum Miscibility Pressure for CO_2 Flood Based on EOS

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ABSTRACT

CO_2 Gas is considered one of the unfavorable gases and it causes great air pollution. It's possible to decrease this pollution by injecting CO_2 gas in the oil reservoirs to provide a good miscibility and to increase the oil recovery factor. MMP was estimated by Peng Robinson equation of state (PR-EOS). South Rumila-63 (SULIAY) is involved for which the miscible displacement by CO_2 is achievable based on the standard criteria for success CO_2 EOR processes. A PVT report was available for the reservoir under study. It contains deferential liberation (DL) and constant composition expansion (CCE) tests. PVTi software is one of the (Eclipse V.2010) software's packages, it has been used to achieve the goal. Many trials have been done to match the data of DL test by tuning some of the PR-EOS parameters through the regression analysis process, but no acceptable match was obtained especially for saturation pressure. However; splitting the mole fraction of (C_{6+}) to many pseudo components was carried out, and then a regression analysis process was made again to improve the matching by tuning some of the PR-EOS parameters. A good estimate of saturation pressure and a good match of PVT properties was noted. Ternary diagram has been constructed to represent the phase behavior of CO_2-Oil and to calculate MMP for the South Rumila-63 (SULIAY) oil well.
Keywords: minimum miscibility pressure, CO_2, PR-EOS, differential liberation.

تخمين ادنى ضغط امتزاج لازاحة غاز ثنائي اوكسيد الكاربون بالاعتماد على معادلة الحالة

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الخلاصة

غاز ثنائي اوكسيد الكاربون هو احد الغازات الغير مرغوبة وهو ملوث هوائي كبير. يمكن حقن هذا الغاز في المكامن النفطية لتقليل التلوث وتحقيق امتزاجية جيدة وبالتالي زيادة في عامل استحصال النفط. ان ادنى ضغط لإمتزاج غاز ثنائي اوكسيد الكاربون مع النفط قد تم تخمينه بالإعتماد على معادلة الحالة ل بينغ روبينسون, لقد اختير البئر رميلة الجنوبي-63 (سلي) كنموذج ناجح لتنفيذ حقن غاز ثنائي اوكسيد الكاربون فيه بالإعتماد على معايير خاصة بالغاز المحقون. تقارير الخواص الفيزيائية والثرموديناميكية

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تضمنت فحص معامل التركيب الثابت والتحليل المرحلي. استخدم برنامج pvti وهو احد البرامج الموجودة في حزمة المحاكيات eclipse-2010 لتحقيق الهدف المقصود. الكثيرمن المحاولات انجزت لعمل تطابق للخصائص البتروفيزيائية للمائع المكمني في فحص التحرير المرحلي, لكن لم يتم الحصول على أي تطابق خاصة لضغط الفقاعة. تم عمل فصل للمكون الثقيل +C6 الى عدة مكونات زائفة وعمل تحليل تراجعي وذلك بالتلاعب واعطاء وزن معين لمتغيرات معادلة الحالة. تم ملاحضة تحسن ضغط الفقاعة المحسوب مقارنة بالقيمة المقاسة وحصول تطابق للخصائص البتروفيزيائية. بعد ذلك تم حساب ادنى ضغط للإمتزاج مع انشاء مخطط تيرنري ثلاثي لتمثيل سلوك الطور الثنائي لإوكسيد الكاربون مع النفط ومعرفة تحقق الامتزاجية بينهم.
الكلمات الرئيسية: ادنى ضغط للامتزاج, ثنائي اوكسيد الكاربون, معادلة الحالة - بينغ روبينسون, التحرير التفاضلي.

1. INTRODUCTION

Paitoon, et al., 2013 declared that CO_2-oil MMP is an important parameter to be specified in CO_2 EOR processes as it plays a key role in the design of CO_2 miscible flooding.

Stalkup, 1978 confirmed that the high solubility of CO_2 in the oil causes swelling it and increases in their volume with high oil recovery rate due to a significant reduction in viscosity and interfacial tension. However, a complete miscibility between CO_2 and oil is done at a displacement pressure. Which must be greater than a specified minimum, this minimum refer to MMP (minimum miscibility pressure) and/or MME (minimum miscibility enrichment).

Abu-Khamsin, 1989 determined MMP for carbon dioxide flooding process by slim tube method for three standard Arabian stock tank crude oils: Arab Light, Medium and Heavy. He found the higher temperature or oil density causes increase in CO_2-MMP for Saudi Arabian crudes.

Hameed, 2017 estimate MMPs according to PR-EOS for selected twenty-seven Iraqi oil samples by using eclipse (v.2010)/PVTi software and finally tried to correlate MMPs with the major parameters, till to conclude MMP correlation with R^2=0.8806 using Statistics (v.10) software.

2. AIM OF STUDY

Determination of minimum miscibility pressure for CO_2 flood into South Rumila-63 (SULIAY) oil sample.

3. STUDY AREA

South Rumila-63 (SULIAY) oil sample has been selected from different fields and formations that are located in the southern part of Iraq based on screening criteria for CO_2 gas flooding. The selection is done on the base of EORGUI software that designed according to Martin et al. **Fig.1** shows the location of South Rumila oil field

4. RESERVOIR FLUID PROPERTIES

As an example, the properties of Suliay reservoir fluid in South Rumila field are presented here. The oil has a light API gravity of 45.9, GOR and Saturation Pressure at reservoir temperature 252

°F, are 299.2 m^3/m^3 and 3506 psi, respectively and the initial pressure is 9956.3 psi and the reference depth is 4219 mRTKB.

5. FINAL PVT MODEL

Many trials have been made in order to find a match between the measured data of DL test with tuning some of the main PR-EOS parameters were: (Ωa, Ωb, P_c, T_c, acentric factor and binary interaction coefficient) that have been used in the regression process, but they didn't give satisfactory results. Splitting techniques were used to characterize or to tune the EOS to be able to simulate the PVT experiments. This was a multi-step process that was started by splitting the heavy components (C_{6+}) as suggested by Whitson. Then, regression was done by a return to tune PR-EOS to get matched PVT properties.

There are several ways to split the plus fraction (C_{6+}) in the PVTi software. Finally, Whitson method has been selected, which gave an appropriate split for the mole fraction of plus component. In addition, Lee Kesler correlation was selected for the critical properties correlation to demonstrate the newly defined components. **Fig.2** shows the new components for South Rumila-63 (SULIAY) after splitting the heavy component (C_{6+}) into 12 pseudo-components, and the total components number of the current oil reservoirs had increased to 23 components. These 23 components were used to tune the EOS by regressions processes to match the measured data.

6. REGRESSION

Immediately after making a split for plus component mole fraction, regression was done by tuning PR-EOS parameters by changing some of them until calculated PVT properties matched the observed data in several attempts. This procedure consumes a larger time with each trial. The major regression parameters that have been changed to give the best match for different physical properties of reservoir fluid are (Ωa, Ωb, P_c, T_c). **Fig.3** represents final matching of fluid physical properties. And **Table 1** represents statistical parameter for the final result of D.L. test. While **Table 2** illustrates average absolute percent relative error before and after splitting process for bubble point pressure.

7. TERNARY DIAGRAM AND MMP ESTIMATION

A ternary diagram is used to illustrate the occurrence of miscibility. The resulted ternary diagram from MCM (vaporizing gas displacement) after splitting and lumping process for South Rumila-63 (SULIAY) are presented in **Fig.4**. This diagram consists of three peaks, the upper apex denotes the CO_2, the lower-right apex denotes the light and intermediate component (L+I): [C_1 , N_2, C_2, C_3, C_4, C_5] and the lower-left apex denotes the heavy component [C_{6+}]. The green envelope represents the two-phase immiscible region (oil + gas), red point represents the oil composition at reservoir pressure and temperature and the blue point represent 100 % composition of pure CO_2 injection (without impurities), the green line represents the limiting tie line. **Green and willhit**, 2003 presented the main purpose from drawing ternary diagram is to know that the CO_2 gas is miscible or immiscible with the reservoir oil. However; when the oil composition point on the right side of the tie line, the system is miscible. While if the oil composition point on the left side of the tie line, the system is immiscible because of oil composition and the two-phase envelope region is the same side of the critical point tangent line. Finally, after obtaining a suitable matching between observed and calculated PVT properties, MMP can be calculated in the PVTi software. The MMP for South Rumila-63 (SULIAY) is 2589.443 psia.

8. CONCLUSIONS

- The equation of state is found to be a powerful tool for estimating PVT properties where a good match was shown for all experimental PVT. Accordingly, the value of MMP can be considered accurate.
- The match with the measurements was obtained after adjusting (P_c, T_c, Ω_a, Ω_b) that effect on PR-EOS calculation.

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10. NOMENCLATURE

AAERR=average absolute percent relative error.

CCE=constant composition expansion.

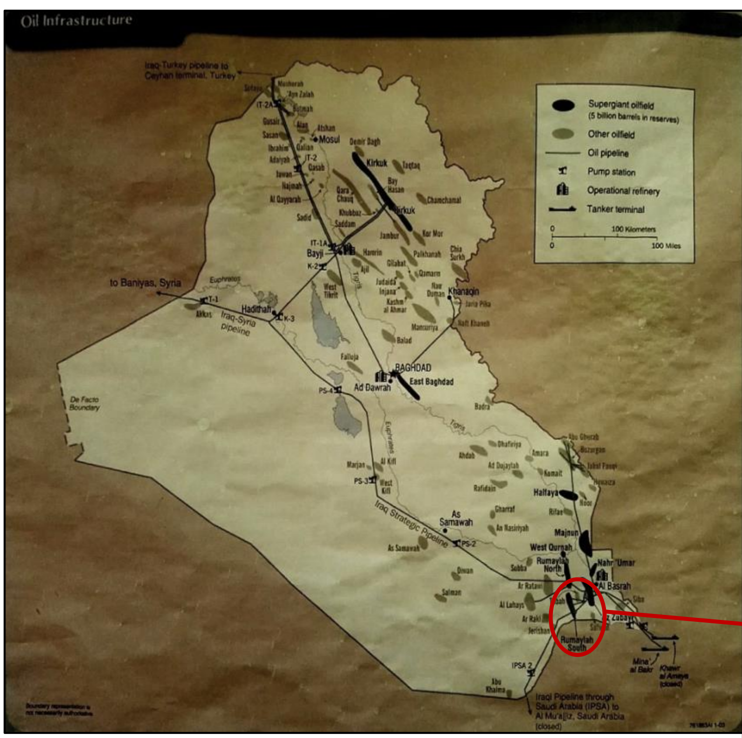
CO_2= carbon dioxide.

DL= differential liberation.

MMP= minimum miscibility pressure.

PR-EOS= peng Robinson equation of state.

SD= standard deviation.



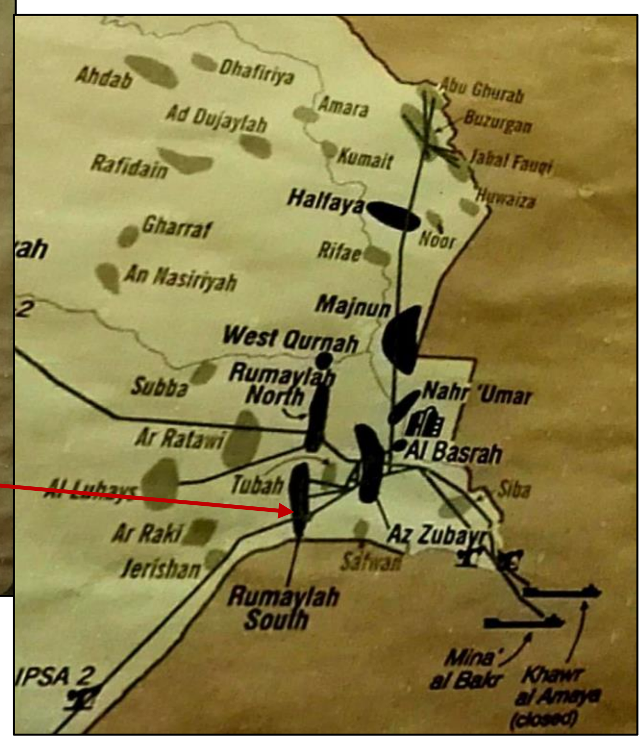
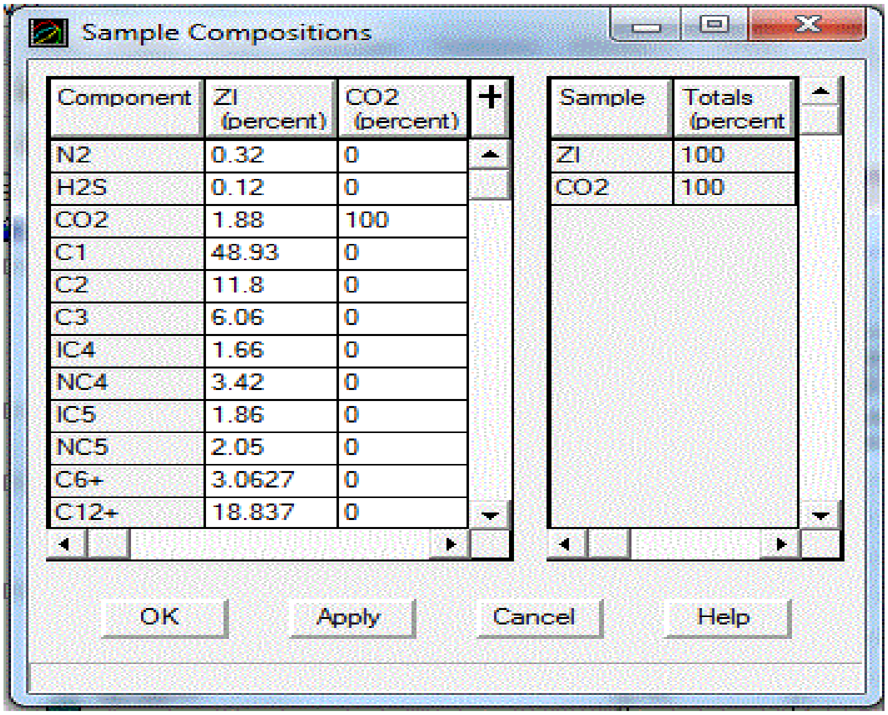


Figure 1. The location of the South Rumila that have been considered in the present work.



Component	ZI (percent)	CO2 (percent)
N2	0.32	0
H2S	0.12	0
CO2	1.88	100
C1	48.93	0
C2	11.8	0
C3	6.06	0
IC4	1.66	0
NC4	3.42	0
IC5	1.86	0
NC5	2.05	0
C6+	3.0627	0
C12+	18.837	0

Sample	Totals (percent
ZI	100
CO2	100

Figure 2. Oil composition in mole Percent after splitting.

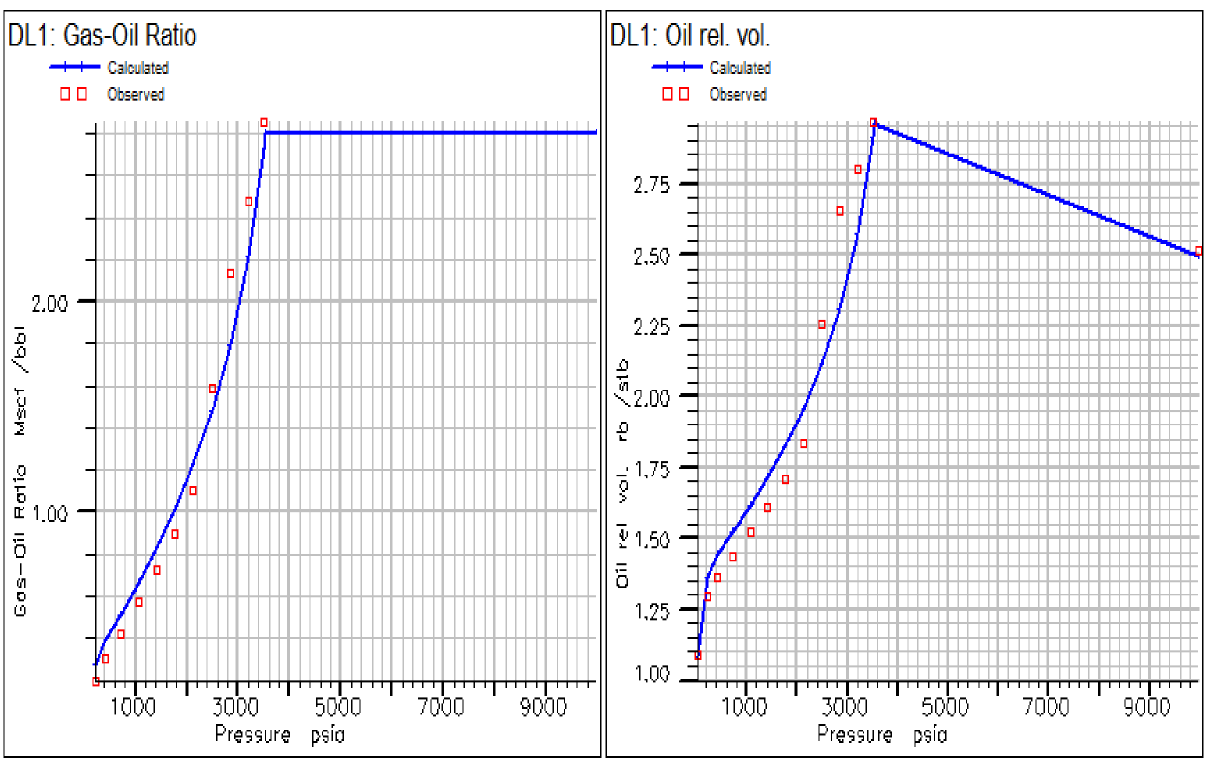


Figure 3. Calculated and observed oil FVF with GOR after splitting process.

Table 1. Statistical parameter for final Result of DL test (after splitting process).

property	AAERR %	SD %
Oil rel. vol. (Rb/STB)	5.71	6.73
Gas-Oil Ratio (Mscf/bbl)	16.827	20.45

Table 2. Average absolute percentage relative error between Observed and calculated saturation pressure.

Method of calculation	Measured saturation pressure (psia)	Calculated saturation pressure (psia)	AAERR%
Before regression	3506.4	3433.7	2.071
After splitting and groping	3506.4	3541.5	1.001

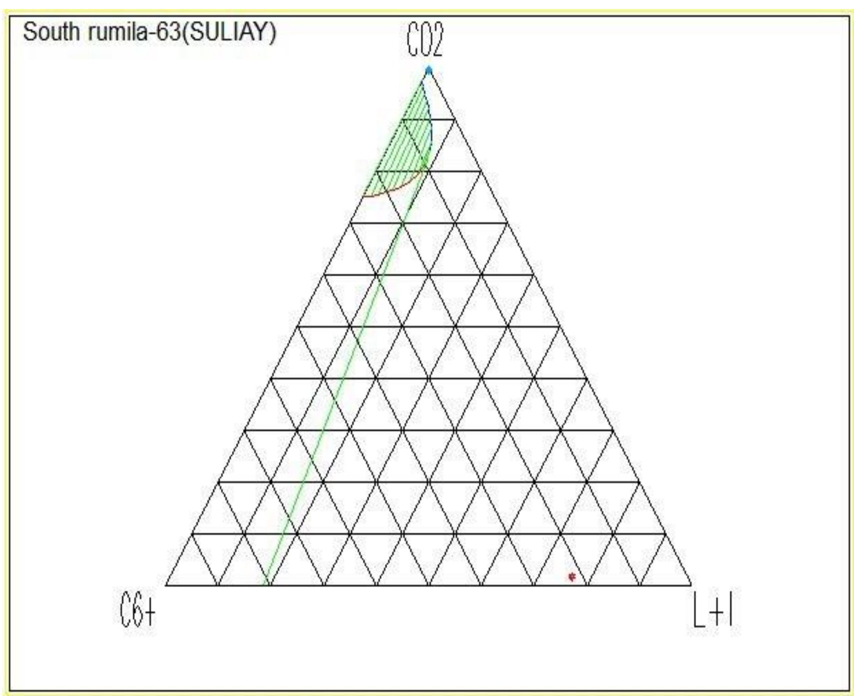


Figure 4. Ternary diagram for South Rumila oil field/ Suliay formation with two phase region in CO_2/hydrocarbon system.