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A METHODOLOGY FOR OBTAINING THE SARA ANALYSIS OF LIVE CRUDES FROM THE SARA ANALYSIS OF DEAD CRUDES USING THE GAS/CRUDE MASS RATIO

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ABSTRACT

This paper presents a method to correct the values of the mass fractions of saturates, aromatics, resins and asphaltenes (SARA analysis) of dead crudes by adding the dissolved gas to the saturated fraction of SARA analysis. This paper also shows the procedure to obtain the necessary equations to correct each fraction from the volumetric gas/crude ratio (R_s). Four hypothetical crudes were analyzed to calculate the different mass ratios. The SARA analysis of 27 Colombian crudes was performed and the incidence of dissolved gas was determined in the calculation of live crude SARA. The change in the saturated fraction was between 2 and 22% for Black Oil and between 14 and 74% for Volatile Crude Oil. Furthermore, a modification of the "Colloidal Instability CII Index" is presented, and the values obtained by this new methodology are compared to this index.

Keywords: SARA analysis, live crude, colloidal stability index.

INTRODUCTION

Generally, crude oils are divided into four fractions known as saturates, aromatics, resins and asphaltenes [1, 2]. This characterization is known as SARA analysis; however, the techniques used to perform this analysis are not reproducible [3, 4]. SARA analysis is usually performed in laboratory conditions. Therefore, the crude oil does not contain dissolved gas, so its SARA analysis is considered an analysis of dead oil. This implies that it would be illogical to use this dead oil SARA analysis to predict the behavior of crude oil at reservoir conditions. This is because crude oil at reservoir conditions contains dissolved gas and is called live crude [5]. Due to these difficulties, preserving the living characteristics of crudes during SARA analysis [6], requires specialized laboratory techniques that have been developed for the recombination of dead crudes with synthetic gas mixtures. This is done so that the gas/oil ratio (GOR) coincides with that of a live crude, which is then analyzed by specialized devices [7]. The results of the SARA analysis are often used for various purposes [8-11]. From the SARA analysis, the relation between the fractions, commonly used in methodologies and indexes, are obtained to predict whether the asphaltenes in the crudes at reservoir conditions [12, 13] are stable and whether the deposit will have formation damage problems due to the precipitation of asphaltenes [7, 9, 14].

The effects of reservoir conditions on SARA analysis and its use for the prediction of precipitation potential were also shown evidenced by Nakhli *et al.* [15], who employed two types of live crudes (light and heavy) and showed that the variation of temperature and pressure have strong effects on asphaltene precipitation. In the case of temperature, the precipitation results showed opposite behaviors for light and heavy crudes. These were determined by the resin content and its peptizing role, which stabilizes the asphaltene molecules to avoid their agglomeration [16]. The effect of pressure is directly related to the evolution from the liquid phase to the gas phase, depending on whether it is above or below the bubble point of the fluid [6]. The authors also evaluated the effects of injecting gases (CO_2, enriched gas and dry gas), from which CO_2's stabilizing and reducing effects were determined up to a critical mole fraction of CO_2 in crude oils [9]. The other gases showed a tendency to increase asphaltene precipitation. Therefore, the use of the fraction ratios of the SARA analysis of dead oil for the prediction of the precipitation potential of live oil has less reliable results. To provide greater reliability to the results of the SARA analysis, a methodology was developed in this investigation that proposes the inclusion of dissolved gas in crude oil within the analysis.

The above is due to that gas content is part of the dynamics inherent to the reservoirs or by the use of gaseous solvents in improved recovery processes, primary depletion or treatments. The inclusion of the effect of reservoir gases in the SARA analysis guarantees that the correlations used to characterize the dynamics of the reservoir and the stability of asphaltenes are more reliable.

METHODS AND MATERIALS

SARA Analysis Correction

In the mass fractions of hydrocarbons at reservoir conditions (live crudes), it is essential to consider the mass fraction of the dissolved gas at a given pressure. Natural gas is a mixture of light hydrocarbons of saturated chains, composed mainly of methane and ethane. The value of saturated hydrocarbons in live crude is the sum of saturated dead oil plus the amount of dissolved natural gas. The value of gas dissolved in the oil at different pressures is obtained from a PVT analysis and is represented by the parameter R_s and given by equation 1. The mass equivalence of 1 cubic foot of gas at standard

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conditions and the mass equivalence of a barrel of oil are represented by equations 2 and 3, respectively.

$$R_s = \frac{V_g \; volumen\, de\, gas \;\; @\, s.c.}{V_o \; volumen\, de\, crudo \;\; @\, s.c.} \left(\frac{scf}{STB} \right) \qquad (1)$$

$$1 scf = \frac{M_g}{379.4836} (lbm) \qquad (2)$$

$$1 STB = 5.6146 \times \rho_o (lbm) \qquad (3)$$

$$1 \left(\frac{scf}{STB} \right) = 4.69 \times 10^{-4} \frac{M_g}{\rho_{STO}}, \left(\frac{lbm}{lbm} \right) \qquad (4)$$

$$R_s^w = 4.69 \times 10^{-4} \frac{R_s M_g}{\rho_{STO}}, \frac{lbm_g}{lbm_l} \qquad (5)$$

$$m_t = m_g + m_l \qquad (6)$$

$$\frac{m_t}{m_l} = R_s^w + 1 \qquad (7)$$

$$w_l = \frac{m_l}{m_t} = \frac{1}{R_s^w + 1} \qquad (8)$$

$$w_g = 1 - w_l \qquad (9)$$

$$w_g = \frac{R_s^w}{R_s^w + 1} \qquad (10)$$

The volumetric and mass ratio for 1 cubic foot of gas per barrel of crude oil is represented by equation 4, which is rewritten in terms of mass and volumetric gas / crude ratios in Eq.5. Where R_s^w is the mass ratio of gas and crude oil, R_s is the ratio of dissolved gas per barrel of crude oil in standard conditions, M_g is the molecular mass of natural gas and ρ_{STO} is the density of dead oil at standard conditions (lbm/ft^3). Thetotal mass of the fluid in the reservoir at pressures above the bubble point is the sum of the liquid mass plus the mass of the gas that is dissolved at these conditions (equation 6). Equation 6 can also be rewritten in terms of the mass ratio of gas and crude oil, R_s^w (Eq.7). The mass fraction of liquid is the reciprocal of equation 7, as presented in equation 8. The mass fraction of the dissolved gas is given by equation 9, which is expressed in equation 10 when rewritten in terms of R_s^w.

To obtain the SARA analysis at reservoir conditions, the natural gas content is added to the value of the saturated gases obtained from the SARA analysis of the dead oil and the composition is normalized. In this way, the most reliable mass fraction of crude oil is obtained at the conditions of the reservoir. Then the fraction of saturates, aromatic, resins and asphaltenes in the corrected SARA analysis is written in terms of R_s^w. This is given by equations 11 through 14.

$$S' = \frac{R_s^w + S}{R_s^w + 1} \qquad (11)$$

$$A' = \frac{A}{R_s^w + 1} \qquad (12)$$

$$R' = \frac{R}{R_s^w + 1} \qquad (13)$$

$$As' = \frac{As}{R_s^w + 1} \qquad (14)$$

Equation 15shows that the sum of the 4 corrected mass fractions must be equal to 1.

$$S' + A' + R' + As' = 1 \qquad (15)$$

Materials

In this investigation, the analyses and calculations were made from four different types of crude oil: 2 Black Oil and 2 Volatile Crude Oil, whose characteristic values were taken from the existing literature shown in Table-1. The most important indicator for determining the type of crude oil is the initial GOR (i.e., the gas / oil volumetric ratio). The Black Oils have a GOR of between 200 and 700 scf / STB and an API gravity between 15 and 40. The Low Shrinkage Oil had a GOR of less than 2000 scf / STB and API gravities less than 35. The Volatile Crude Oil hada GOR of between 2000 and 3000 scf / STB and an API gravity between 45 and 55. The Near-Critical Crude Oil had a GOR of more than 3000 scf / STB.

Table-1. Mass ratio of gas / liquid.

Properties	Black Oil 1	Black Oil 2	Volatile Crude Oil 1	Volatile Crude Oil 2
API	35	40	45	55
R_s (scf/STB)	200	700	2000	3000
M_g (lb/lbmol)	20	20	20	20
Density (lbm/ft^3)	53.03	51.48	50.03	47.34

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The SARA analyses of 27 Colombian crudes were taken from the research carried out by Lache-Garcia [17] and are presented in Table-2.

Table-2. SARA analysis of dead crudes from colombian crude oil [17].

Crude Oil	S	A	R	As
Col-1	0.3071	0.3194	0.3378	0.0357
Col-2	0.3577	0.3373	0.2709	0.0341
Col-3	0.3681	0.3518	0.2490	0.0311
Col-4	0.4002	0.3026	0.2685	0.0287
Col-5	0.3812	0.3483	0.2495	0.0210
Col-6	0.3357	0.3056	0.3357	0.0230
Col-7	0.3673	0.3479	0.2652	0.0196
Col-8	0.3918	0.3053	0.2442	0.0587
Col-9	0.3715	0.3096	0.3040	0.0149
Col-10	0.4255	0.2821	0.2544	0.0380
Col-11	0.4250	0.3000	0.2688	0.0062
Col-12	0.4682	0.2809	0.2475	0.0034
Col-13	0.4522	0.2503	0.2907	0.0068
Col-14	0.3840	0.3249	0.2880	0.0032
Col-15	0.4163	0.2464	0.3313	0.0060
Col-16	0.4389	0.3146	0.2414	0.0051
Col-17	0.3850	0.3253	0.2855	0.0042
Col-18	0.4666	0.2452	0.2847	0.0036
Col-19	0.4661	0.2699	0.2617	0.0023
Col-20	0.3941	0.2956	0.3032	0.0072
Col-21	0.4917	0.2167	0.2000	0.0915
Col-22	0.3414	0.2987	0.2561	0.1038
Col-23	0.6228	0.2491	0.1180	0.0101
Col-24	0.6621	0.2119	0.1148	0.0112
Col-25	0.4986	0.2043	0.2370	0.0601
Col-26	0.3441	0.2503	0.2753	0.1304
Col-27	0.4252	0.2505	0.2548	0.0695

RESULTS AND DISCUSSIONS

The mass ratio R_s^w of the 4 types of crude oil was calculated (equation 5) and are presented in Table-3. The table shows that the gas / crude oil ratio R_s^w increases as the GOR and the crude oil API increase and decrease, respectively. Volatile Crude Oil, due to its lower density and higher GOR, has the highest mass ratio R_s^w.

Table-3. Mass / gas ratio values R_s^w calculated for the 4 types of crude.

Property	Black Oil 1	Black Oil 2	Volatile Crude Oil 1	Volatile Crude Oil 2
R_s^w	0.035	0.128	0.375	0.595

The SARA fractionation is corrected for the 27 Colombian crude oils in Table-2 using the values of R_s^w presented in Table-3, considering in each case the 4 types of crude oil. Percentage changes that occur between each fraction of SARA analysis for the dead crude and corrected SARA (i.e., live crude) because of the presence of dissolved gas are presented in Tables 1 and 2 of supplementary information. As expected in the SARA analysis of live crudes, the fraction of saturated hydrocarbons increased, while aromatic, resin and asphaltene fractions decreased. The percentage by which the saturated fraction increased was not constant, but it depended on the density of the oil, the amount of dissolved gas and the molecular weight of the gas. Additionally, the change in the saturated fraction for the 27 crude oils analyzed was observed, and it was between 2 and 7% for Black Oil 1, between 6 and 22% for Black Oil 2, between 14 and 54% for Volatile Crude Oil 1 and between 19 and 74% for Volatile Crude Oil 2. Changes in the fractions of each of the SARA analyses of the crude oils selected are directly proportional to the amount of gas dissolved in the crudes when corrected; therefore, at higher R_s^w, there is a greater change in the mass fractions of the SARA crudes, as with Volatile Crude Oil. Light crudes have the greatest variation in the SARA analysis because they contain a greater amount of dissolved gas and lower density. As expected, the asphaltene stability predictions made for these light crudes with the SARA analysis of dead crude oil are the least reliable.

The SARA analyses of dead and live crudes were used to apply the Stankiewicz stability criteria and the colloidal stability index corrected (CII') and uncorrected (CII) are presented in Figure-1 and in Table-3 of supplementary information, respectively. In Figure-2 and Table-3 of supplementary information, it is observed that depending on the type of crude oil (i.e., the value of R_s^w), some crude oils that dead SARA analysis classified as within the region of stability or metastability are now located in the region of metastability or are unstable. This is because the ratio between saturates and asphaltenes increased, promoting agglomeration and precipitation of asphaltene, which is increased with a smaller proportion of resin; therefore, there less destabilizing effect.

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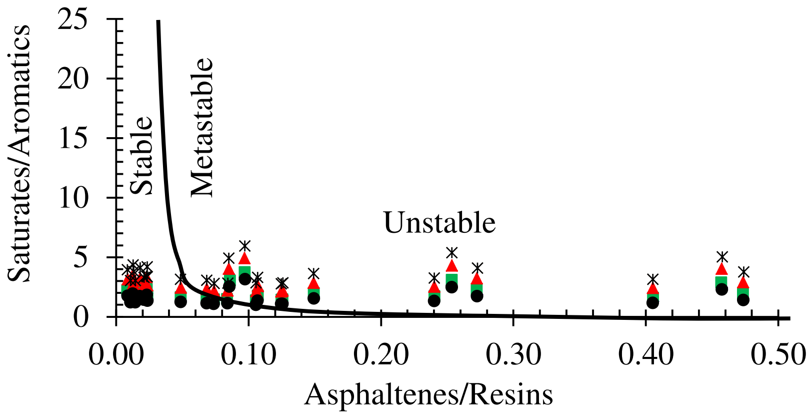

Figure-1. Stability Criteria of Stankiewicz[12]
♦Black oil l, ■ Black oil 2, ▲ Volatile crude oil 1,
∗ Volatile crude oil 2 and •Dead SARA

CONCLUSIONS

The SARA analysis of dead oil does not provide enough information to predict with high reliability the behavior of the oil in the reservoir because it excludes dissolved gas, which alters its composition and properties. However, with the corrections proposed in this research, the reliability of the predictions increases when the fractions of the corrected SARA analysis are used.

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