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Asphaltene Precipitation in Algerian Oilfields: Experimental Investigation and Field Mitigation

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This study addresses two aspects for mitigating the asphaltene precipitation and deposition problem in Algerian oilfields: experimental study and field solution to the deposition problem. In the experimental study and in order to differentiate cases with substantially impaired production requiring well intervention from those with minimal or no wellbore deposition, we followed a three step strategy mainly; representative single phase sampling, fluid characterization and experimental determination of onset pressure for live oil samples collected from three wells. The near infrared technique, commonly known as solid detection system (SDS), was used to determine asphaltene upper onset pressure (AUOP) and live oil saturation pressure at reservoir temperature combined with compositional and SARA characterization. The obtained results showed that saturates to aromatics ratio, saturates and light ends concentrations in the crude oil can be used to predict the potential for the oil to exhibit asphaltene stability problems. Asphaltene precipitation in Algerian oilfields is aromticity controlled rather than resin controlled. Algerian crude oils can be classified as oils with possible severe asphaltene deposition problems, oils with mild problems and oils with no asphaltene deposition problems. Based on these results, we designed and conducted a series of experiments to attempt to solve the precipitation problem by injecting asphaltene solvent into the well. Results showed that the periodic injection of 5 % solvent, by volume, can ensure solubility of asphaltenes in the entire flow string during production.

1. Introduction

The tendency of asphaltenes to precipitate and deposit due to changes in pressure temperature and composition makes them a challenge in the petroleum industry upstream and downstream (Sheu, 2002). Asphaltenes could precipitate out of the crude oil solution causing blockage in the oil reservoir, in the well tubing, in the pipelines and in the oil production (Mansoori 1995; 1996) and processing facilities (Akmaz et al, 2013). Asphaltenes are defined as the fraction of petroleum that is soluble in aromatics but insoluble in normal alkanes (Wang et al., 2006). They are polar components consisting mostly of poly-nuclear aromatics with varying proportions of aliphatic and alicyclic moieties and small amounts of heteroatoms (Mullins and Sheu, 1998; Speight, 1994). In crude oil, they are taught to be totally soluble (Kawanka et al., 1991; Bruke et al., 1990) or as solid colloidal particles suspended and kept in solution by resins, which peptize them (Mansoori, 1997; Hirshberg et al., 1984). In Algeria, the deposition of asphaltenes in the production tubing is a very serious production problem and necessitated frequent tubing washings (Haskett and Tartera, 1965) and in some cases injection of asphaltenes solvents and dispersants (Hamadou et al, 2008) to maintain production. From the start of production asphaltene deposits were observed in the production tubing. Wells often lost 20 to 25 % of the wellhead pressure in 15 to 20 d, causing considerable loss in production. This dramatic scenario could be avoided if an asphaltene risk assessment was performed before starting production. The importance of such risk assessment study is to differentiate asphaltenes problematic wells from asphaltenes trouble free wells and elaborate a tailor made

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and cost effective mitigation strategy. In this work we presented a solution to the asphaltene deposition problem in Algerian oilfields using a four-step strategy viz. sampling; compositional characterization, experimental measurements and field solution to the problem.

2. Experimental

2.1 Materials

The three oil samples (oil A, oil B and oil C) used for this study are bottom-hole samples collected from three different oilfields using open-hole Modular Formation Dynamics Testing (MDT™) described elsewhere (Jamaluddin et al., 2002).

2.2 Fluids compositional analysis

The sample chambers are first validated by determining their opening pressure. Subsequently, a sample is chosen for study, and the sample bottle is then placed into a rocking stand and agitated for a minimum of five days to ensure homogenization of the reservoir fluid. After stabilization, a small portion of the single-phase reservoir fluid is transferred isobarically to a PVT cell, and then the sample is heated to reservoir temperature. Small amount was subjected to a single-stage flash experiment, from reservoir temperature to normal conditions, to determine the gas/oil ratio (GOR), C7+ composition and Saturates, Aromatics, Resins and Asphaltene (SARA) fractions. These properties are summarized in Table 1.

Table1: Compositional properties of the investigated live Oil samples

Components	Oil A (mole%)	Oil B (mole%)	Oil C (mole%)
N2	2.48	2.02	0.411
CO2	1.74	1.60	0.466
C1	24.48	25.50	43.11
C2	12.24	12.22	10.724
C3	10.50	10.38	7.657
iC4	1.56	1.52	3.246
nC4	5.36	5.29	1.346
iC5	1.44	1.43	1.45
nC5	2.62	2.58	2.035
C6	4.38	4.30	3.709
C7+	33.20	33.16	25.846
SARA Analysis (Weight %)			
Saturates	56.22	51.77	56.76
Aromatics	38.76	44.72	41.16
Resins	3.97	2.65	1.91
Asphaltenes	1.05	0.87	0.16
PVT analysis			
Reservoir T°	120 °C	120 °C	90 °C
Reservoir P	4,000 psi	3,460 psi	5,500 psi
Bubble point	1,980 psi	1,960 psi	3,125 psi
GOR	175 (m^3/m^3)	155 (m^3/m^3)	190(m^3/m^3)

2.3 Asphaltene Precipitation onset

Apparatus description

A modern laser solid detection system (SDS) was adopted to measure the onset of asphaltene precipitation. The principle behind the measurement is based on the transmittance of an optimized laser light in the NIR wavelength (~1,600 nm) through the test fluid undergoing pressure change. As shown in Figure 1, the SDS system consists of a volume-variable, visible JEFRI PVT cell retrofitted with an optical fiber light transmission probes. The cell is equipped with a floating piston and a magnetic stirrer to accelerate the equilibrium process. A variable volume displacement pump is used to control the volume and hence the pressure of the fluid under investigation. The PVT cell is housed in a temperature controlled forced-air circulation oven. The working temperature range of the cell is 150 °C and the maximum working pressure is 10,000 psi. The entire system is controlled by a proprietary software package that (in real time) records and presents the system temperature, pressure, solvent volume, time and most importantly, the power of transmitted light (PTL) from the detector.

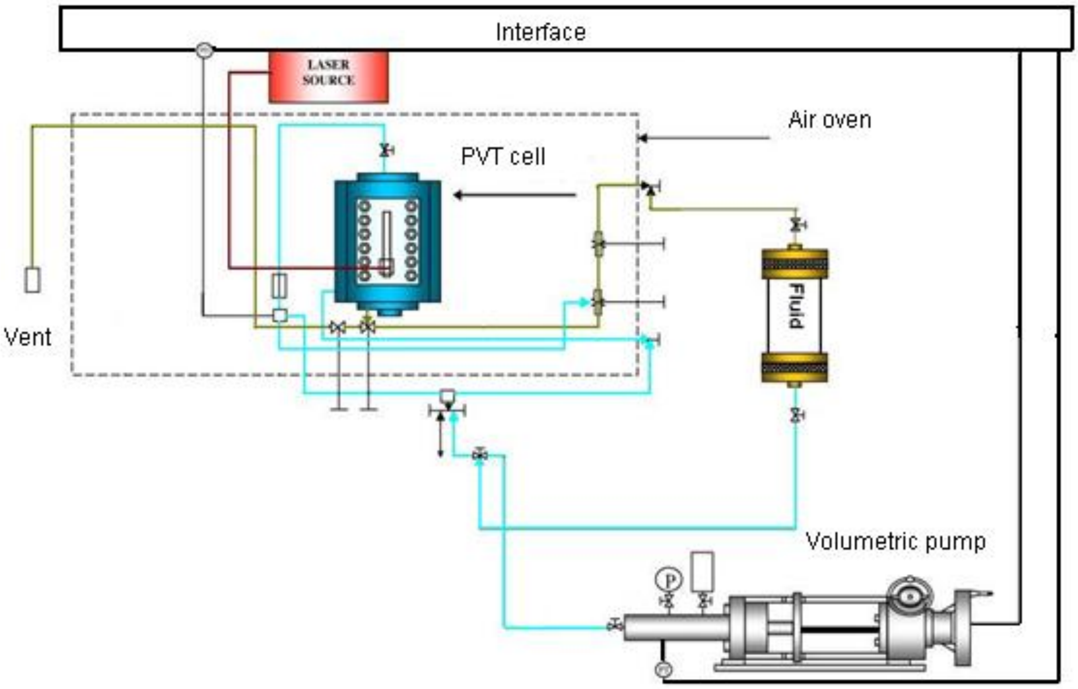

Figure 1: Schematics of the high-pressure high-temperature solid detection system

Experimental procedure

A typical experimental run is as follows (Hammami, 2000):

60 mL of the test fluid is charged isobarically into the PVT cell at reservoir temperature. The light scattering components are then mounted across the windows of the PVT cell. The cell content is homogenized at a maximum mixer speed of 1,400 rpm for about 30 minutes. Subsequently, the light-transmittance scan is conducted to establish the reference baseline. The system pressure is lowered stepwise (40 psi/minutes) under isothermal condition down to the bubble point pressure (Pb). At each pressure step the oil in the cell is agitated for 2 minutes and then the light transmittance data is taken. Meanwhile, a cathetometer is used to check whether vapor phase is formed in the equilibrium. The average transmitted light power and the corresponding pressure are recorded every minute.

3. Results and discussion

Table 2 shows the stability data for the three crude oil samples.

Table2: Stability data for the Oil systems

Stability Criteria	Oil A	Oil B	Oil C	Range of instability (DeBoer et al, 1991) & (Yen et al, 2001)
C1-C3	47	48	62	>37 mole%
CII(a)	1.34	1.11	1.32	>0.90
ARR(b)	0.26	0.32	0.09	>0.35
SAR(c)	1.45	1.16	1.38	Not available

(a): Colloidal Instability Index = (asphaltenes + saturates)/(resins + aromatics)
(b): ARR=(asphaltenes)/(resins)
(c): SAR= (saturates)/(aromatics)

It is apparent from the data that the three oil systems are likely to be unstable. The Oil B has the lowest value of CII and the highest power of solvency (lowest SAR) whereas; Oil A and Oil C have higher values of CII with poor solvency power. Oil C has the highest C1-C3 concentration, well above the threshold value of instability, which makes it the most unstable system. On the other hand, the values of ARR of the three systems are below the threshold of instability of 0.35. Based on the conflicting results, about the potential of asphaltene instability, obtained by applying these five criteria, it can be said that further laboratory testing could clarify this potential.

The recorded transmitted light power as a function of pressure for oil A, oil B and oil C is shown schematically in Figure 2, Figure 3 and Figure 4 respectively. For oil B, the transmitted light power increases monotonically (almost linearly) with a decrease in pressure, resulting from a decrease in fluid density. As the pressure reaches the bubble-point pressure, the evolved gas bubbles scatter the light and transmittance drops sharply. However, for both Oil A and Oil C, the transmittance drops before the bubble point. This drop in the transmitted light power is related to the appearance of solids that scatter light and cause the power of the transmitted light to deviate from the expected linear relationship. The point at which the curve deviates from the straight line break points is the upper onset pressure of asphaltene (UOPA). Most importantly, the steadily decreasing behavior of the portion of the curve after the onset point shows that the asphaltenes aggregate into bigger flocks.

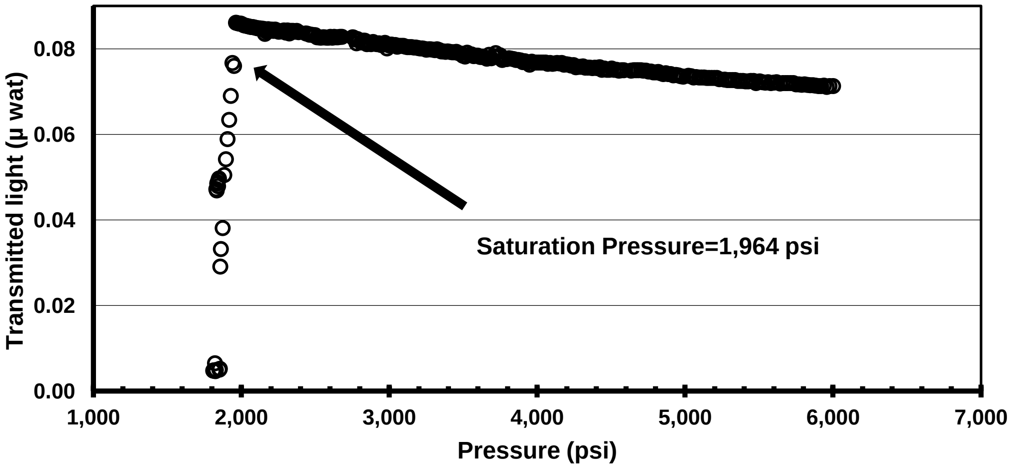

Figure 2: Plot of light transmittance versus pressure for oil B @120°C

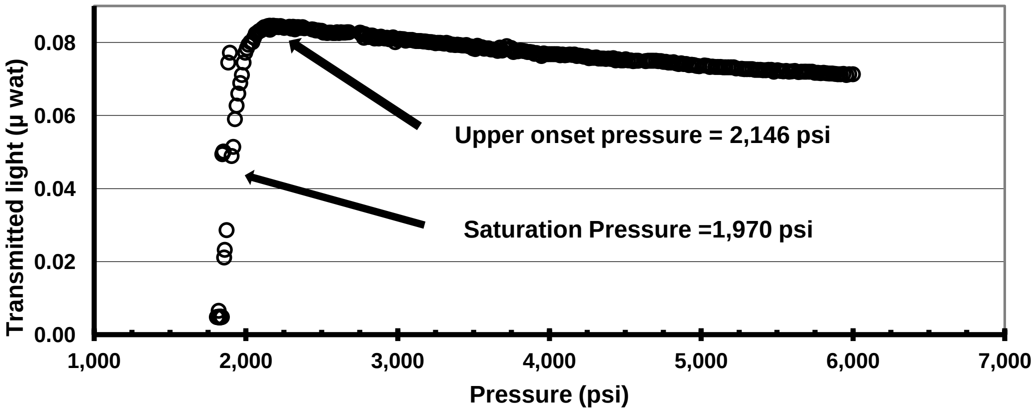

Figure 3: Plot of light transmittance versus pressure for oil A @120°C.

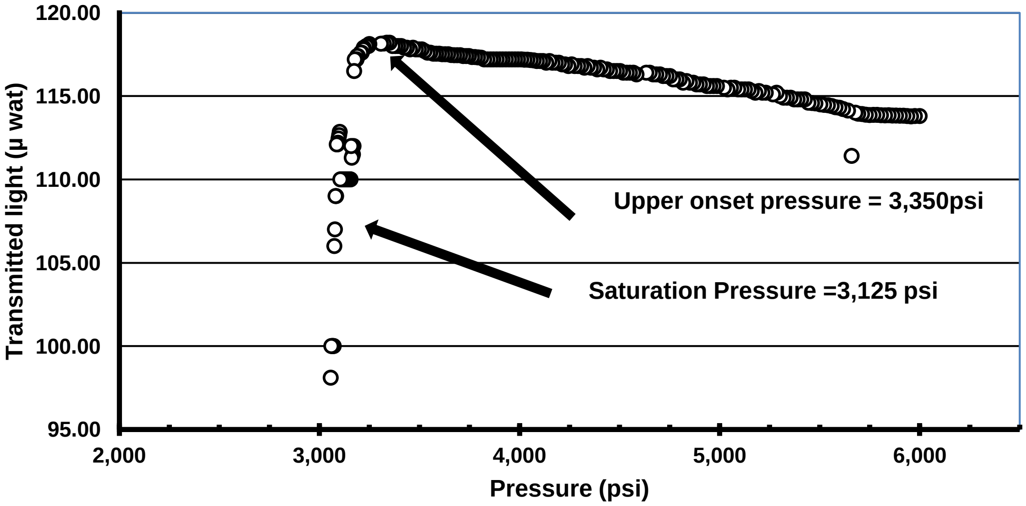

Figure 4: Plot of light transmittance versus pressure for oil C @ 90 °C.

Table 3 shows the depressurization and precipitation parameters for the three oils. Oil A has an (UOPA) of 2,146 psi which is very near the saturation pressure and about 2,000 psi below the bottom-hole pressure. Given the depth of the well (3,100m), it is reasonable to conclude from these data that asphaltene deposition could begin in the production tubing. Oil B have no precipitation onset and can be operated trouble free. Oil C has an (UOPA) of 3,350 psi which is close to the initial reservoir pressure making deposition problems more severe.

Table 3: Precipitation and Depressurization Parameters for Oils

Stability Criteria	Oil A	Oil B	Oil C
Reservoir pressure (psi)	4,200	4,100	5,000
Asphaltene onset pressure (psi)	2,146		3,350
Saturation pressure (psi)	1,970	1,960	3,125

4. Field solution to the deposition problem

Since the beginning of well C production life, an anomalous decline in production rate was observed. This decline was attributed to asphaltene deposition in the near wellbore region and production tubing. Thus, a series of solvents injection operations, optimized at 5 % by volume, were performed and the well effluent was collected distilled and analyzed for SARA contents. *Table 4* summarizes SARA composition of well C effluent during solvent injection operation. The obtained results clearly shows an increase of asphaltene content with time till reaching a maximum value of 2.26 (wt%) then decreases to approach its initial value.

Table 4: SARA analysis of well C effluent during solvent injection

Sample	Collection time (Hours)	Saturates (wt%)	Aromatics (wt%)	Resins (wt%)	Asphaltene (wt%)
1	0	56.76	41.16	1.91	0.16
2	2	55.23	41.27	2.50	1.00
3	6	54.12	41.21	2.80	1.87
4	12	53.66	41.18	2.90	2.26
5	18	55.15	41.17	2.23	1.45
6	24	56.45	41.17	1.98	0.60

5. Conclusions

Asphaltene precipitation in Algerian oilfields is a pressure driven process and it is likely to happen around the saturation pressure. Algerian oilfields can be divided into three main categories:

- Oilfields with possible severe asphaltene deposition problems.
- Oilfields with mild asphaltene deposition problems.
- Oilfields with no asphaltene deposition problems.

The C1-C3 concentration, and saturates to aromatics ratio of the oil can be used as a screening parameters to check the potential for the oil to exhibit asphaltene stability problems. The small difference between precipitation pressure and saturation pressure makes the use of another detection technique, such as filtration, very useful for more accurate onset determination. A solvent concentration of 5% was found to give satisfacting results while performing solvent injection operation.

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