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Asphaltene Stability in Crude Oil during Production Process

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Abstract

Asphaltene instability may take place in the reservoir leading to permeability damage and contributing to flow restriction issues. It may also occur in production strings and surface facilities causing conduit clogging. Any change in oil composition or pressure and temperature at any stage of production will destabilize crude oil producing asphaltene precipitation. In this study, the stability of target crude oil under the influence of a direct current (DC) is investigated. The amount of the asphaltene deposit and its electrical charge at various operating conditions are investigated. The method consists of applying a DC voltage between two metal electrodes immersed in the crude oil sample. The amounts of deposits accumulated on the surfaces of the electrodes are recorded during experiment time utilizing a miniature two load cells connected to the electrodes.

Electric field strength up to 500V is applied. This study confirms that asphaltene colloids are electrically charged. The fact that deposits form on the anode surface proves that asphaltene particles possess a negative charge. The experiment shows that time and potential differences are sensitive parameters. At the first 24 hours, all the asphaltene in the crude oil were extracted. This phenomenon reflects either limited amount of asphaltene exists in the sample, or that the resin content plays a major role in asphaltene colloids charge switch.

Introduction

The procedural definition of asphaltene is the heavy organic components in crude oil that is soluble in toluene but insoluble in heptane/pentane. Asphaltenes are attached to similarly structured molecules, resins, which interact with asphaltenes to improve their solubility in aliphatic media to become stable in the crude oil [1]. A number of studies have indicated that the asphaltenes and the dispersion medium nature are important factors that decide the stability of crude oils [2-4].Changing composition of crude oil, pressure or temperature destabilizes the crude oil resulting flocculation and deposition of asphaltene molecules.The deposition of asphaltene is the utmost challenge faced during the production of oil reservoirs. When asphaltene deposits an array of problems emerges such as permeability reduction and wettability alteration in the formation, pipeline plugging, and pumps failure at the surface, catalyst poisoning and heat exchangers fouling at the refinery. Asphaltene deposition can be significant in many EOR processes including gas injection [5], CO_2 injection [6], nitrogen injection [7] and Vapex [8].

As an example, several major onshore fields in Abu Dhabi are challenged with asphaltene deposition in their producing wells. One asphaltene clean-up operation using organic solvents and coiled tubing unit costs US $200,000 [9]. In addition, during the existence of CO_2 pilot project three asphaltene removal jobs were conducted [10]. Asphaltene remediation techniques are very expensive with the potential impact on health and environment. Petroleum industry is seeking other alternatives to remediate or prevent asphaltene deposition.

One of the interesting approaches is using electricity. Eelectrical means have been suggested to enhance oil recovery by applying an electrical potential difference between a producing well and electrode well [11]. Also, it has been involved in technologies utilized to solve a specific problem [12] or as process-side effects (e.g., streaming potential induced by the oil flow).

It is believed that electrical effects play an important role on the asphaltene deposition. Application of electrical potential causes the precipitation of asphaltene particles on one of the electrodes (elecrtro-deposition) [13,14]. Thus controlling the electro-deposition of the asphaltene particles can lead to the development of preventive techniques [15,16].

There are limited publications devoted to the investigation of the asphaltenes electrical charge, how important it is to their stability and the behavior of asphaltenes when crude oil is under the influence of an electric field [17-21].

The effect of various resins on asphaltene precipitation from different petroleum fluids was examined by Goual et al. [4]. Various resins were added to three different petroleum fluids to measure precipitation with n-pentane. Results showed that the polarity of resins had a strong effect on precipitation. Resins with higher polarity were more effective than resins with lower one. The stability of asphaltene suspended in oil by resins is related to the electrical characteristics between asphaltene, resins and the remainder of the crude.

Alkafeef [3] found that the electrical charge of asphaltene in Marrat oil is very low and had a negligible impact on flocculation and deposition.

Khvostichenko et al. [22] investigated the effect of different parameters that may affect the net charge of asphaltene particles. They investigated the charge switching under various conditions in oil/diluent media. They concluded that application of a DC electric field to stable oil or a solution of asphaltenes in toluene did not causes aggregation or precipitation of asphaltenes.

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Hashmi et al. [23] indicated that asphaltene colloids have a heterogeneous surface charging. Some particles carry a small net positive charge that can deposit on cathode while others carry a small net negative charge that can deposit on anode. Metallic components, Pi electron clouds, and acid-base surface groups could contribute to the surface charge.

As discussed above, the topic is still an active debate. More research is needed to look into the mechanisms that generate the asphaltene surface charge and the parameters that could affect it.

In this study, an intensive experimental program will be conducted to investigate the stability and electrical charges of asphaltene in crude oil at various operating conditions. Target crude oil samples from selected Abu Dhabi reservoirs will be collected. This project can be an inspiration for a potential pilot project to tackle asphaletene deposition problem from Abu Dhabi oil reservoirs. An optimum criterion or scheme can be developed to prevent or minimize asphaltene deposition in the reservoir or during production.

Methodology

The experimental setup is composed of a cylindrical container of 500 ml capacity holding two electrodes extending into the oil sample in the vessel. The length of the electrodes is in the range of 10-15 cm. The electrodes are 1 to 2 cm wide. The two electrodes are connected to a Direct Current (DC) electric field. The electric field strength can be up to 500 V. Each electrode is hanged from a load cell (capacity is up to 200 gram) to monitor the change in the mass of the electrode with time. This method is capable of measuring asphaltene mass with real time all through the experiment.

The temperature of the oil sample is measured by a thermocouple and maintained at the set temperature by a temperature controller connected to a heating tape surrounding the oil container. The experimental variables such as temperature, mass of electrodes, electrical field strength are connected to a data acquisition system to record the values as a function of time. An 8.0 Megapixels camera is used to take shots at specific time intervals.

As shown in Figure 1, the two electrodes (Cathode and Anode) connected to the power source are immersed in the oil container. The electrodes are 1.1 cm away from each other to prevent any short-circuiting.

To begin with, light crude oil was used at a voltage of 200 V for 24 hours. Asphaltene precipitation was observed. The load cell connected to the electrodes recorded the change in the mass of the electrodes with time. The electrodes removed out of the oil and left to dry to allow oil droplets to drain and light components to evaporate. Asphaltene deposition has been observed on the anode as can be seen in Figure 2a. But, no deposition was seen on the cathode as shown in Figure 2b. The data recorded by the load cells confirms the results. A continuous increase in the mass of the anode with time is observed by the load cell while the one connected to the cathode doesn't detect any change in the mass. Then, the same potential difference of 200V was applied to the left crude oil from the first run for additional 24 hours. In the end, 200 V and 400V were applied to heavy crude oil for 24 hours.

Results

Experiments involving electrical effects were conducted in order to relate these effects to the deposition problem as well as to define the type of charge that the asphaltene particle may possess.

The load cell sensed the increase in the mass of the electrode with time as deposits adhered to it. This mass increase was recorded by the data acquisition system and cumulative mass percentage was calculated from the load cell data recorded.

The temperature of the oil in the container throughout an experiment was controlled by the temperature control system. The

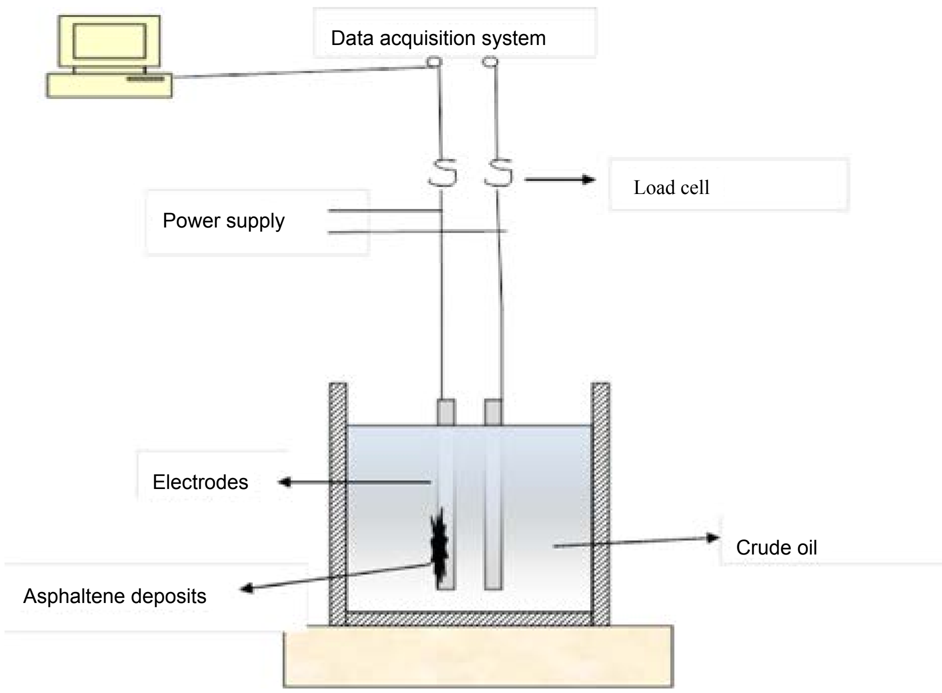

Figure 1: Schematic of the static experiment.

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(a) (b)

Figure 2: a)Asphaltene deposition on the anode; b) No asphaltene deposition.

relative deviations of the temperature lie between ± 2%, which indicates a relatively good temperature control.

As shown in Figure 2a, a significant amount of asphaltene deposition on the positive electrode (anode) was detected after applying an electric current on the crude oil sample. Moreover, since aphaltene deposited on the anode the electric charge on the asphaltene particles was predicted to be negative. Toluene was added to deposits on the anode to verify if the deposits were asphaltene. The deposits dissolved in toluene and then precipitated in n-heptane which confirmed that deposits were asphaltene particles.

Figure 2b showed that no deposits were found on the electrodes when the left crude oil from the first run was stimulated by a potential difference of 200 V for another 24 hours. This indicated that all the asphaltene in the crude oil were taken out in the first run producing asphaltene-free crude oil. Theoretically, if all the asphaltene can be extracted from the crude oil in the reservoir then no more asphaltene would be deposited onto the production well.

The two electrodes were immersed in heavier crude oil and a 200 V potential difference was applied to the heavier crude oil for 24 hours. No asphaltene deposition was observed on either of the electrodes. This can be due to the following reasons: 1- the heavier crude oil was very stable 2-the voltage was not high enough to destabilize the crude oil 3- the distance between the two electrodes was too large to allow the current to pass, 4- the time was not sufficient to induce deposition. Therefore, the voltage was increased to 400 V and left for 24 hours. After the 24 hours, asphaltene deposition was observed on the anode as shown in Figure 3. On the anode, there was a small swelling, which was a sign of the asphaltene deposits. On the cathode, there was no asphaltene deposition. Toluene was added to the deposits on the anode to verify if the deposits were asphaltene. The deposits dissolved in toluene and then precipitated in n-heptane which confirmed that deposits were asphaltene particles.

Discussion

The cumulative mass, as a percentage of the total asphaltene mass deposited on the anode, versus time for light crude oil experiment at 200 V is shown in Figure 4. These kinetic data suggests that deposition occurred over 120 hours, and no deposition is observed after this time. Level of deposition is initially rapid. Cumulative mass reached 60% of the total mass deposited over the first hour of the experiment but gone down as the time increases. A 40% cumulative mass was obtained through the remainder time. No accumulation was observed on the cathode.

Figure 5 shows the cumulative mass deposited on the anode as a function of time for heavy crude oil experiment at 400V.The time of deposition extended to 140 hrs. After 1 hour, the cumulative mass reached 41%.At 200 V the rate of movement of deposits to the anode is too slow to build up a significant amount. The electrical potential is insufficient to trigger the particles to stay on the electrode. However, above 200 V an increase in the field strength stimulates deposition. Higher potential is required to destabilize heavy crude oil. On the other hand, the application of high electric fields may trigger field-induced dissociation, charge reversal [19] and other related effects.

Comparing the two runs and in spite of the higher potential, less deposition is obtained over the same period of time.

These experimental results prove that the amount of asphaltene in crude oil is limited evident by the no increase of asphaltene deposit after 120 hours in the light crude case and no deposit after 140 hours in the heavy crude case. The fact that the largest amount of asphaltene deposited in the first one 1 hour in both cases indicate that all the nearby asphaltene colloids are affected very early and it took some time for the rest to be dragged to the anode. It will be very interesting to study the dynamic mode and compare to the static results.

In line with our experimentation, we believe that aggregation of asphaltene particles starts somewhere in the reservoir; therefore, in order to prevent asphaltene deposition at the surface facilities from taking place, aggregation of these molecules have to be stopped downhole.

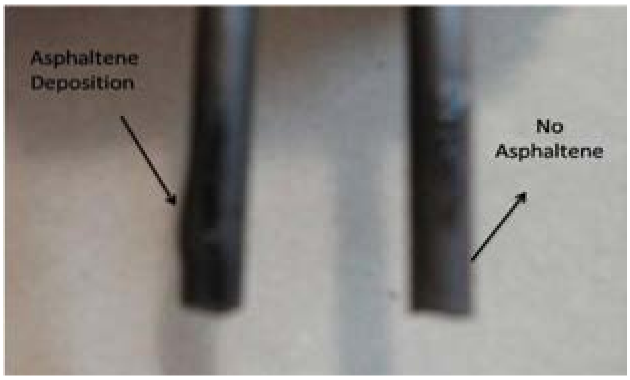

Figure 3: Asphaltene deposition on the anode for a heavy Abu Dhabi crude upon applying 400 V for 24 hours.

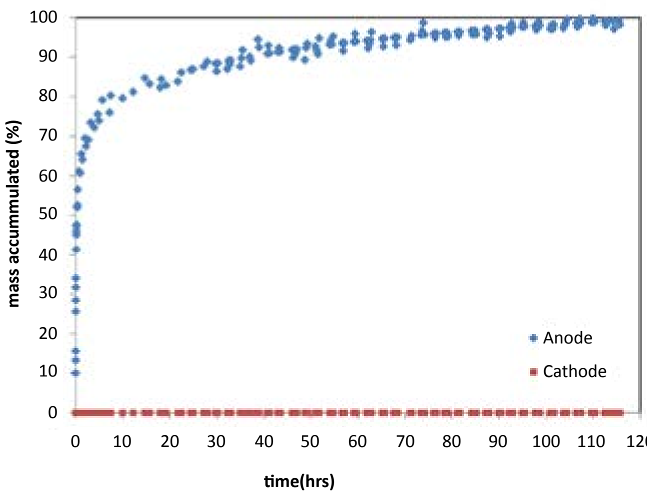

Figure 4: Mass accumulated with time for light crude oil at 200V.

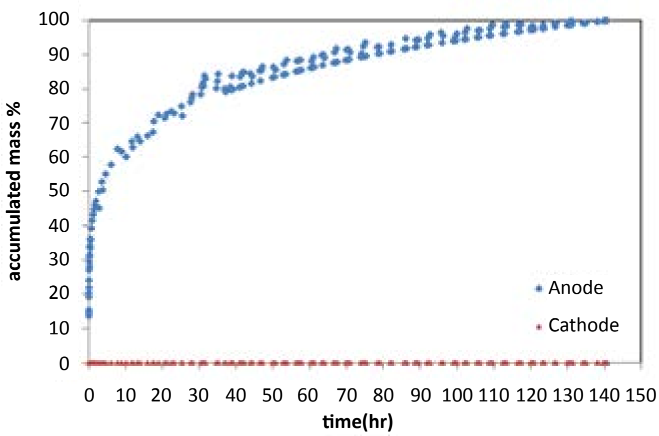

Figure 5: Mass accumulated with time for heavy crude oil at 400V.

One of the interesting approaches is using electricity to stop the aggregation or withdraw them into a dumpster well. The usage of electricity in lab scale has been done since 1945; however, there are many discrepancies among researchers, when dealing with asphaltene electric charge. Some researchers claimed that asphaltene is positively charged; conversely considersasphaltene particles to be negatively charged. However, in this study asphaltene molecules have proven to be negatively charged as demonstrated above, which confirms that results found by Taylor, Preckshot et al. and Khvostichenko et al. [13,21,22]. There is a possibility though that may be, some types of asphaltenes are naturally negatively charged and others are positively charged. Notably, most of the work on asphaltene has been on modeling and analyzing the chemical composition of the fractions, which have not contributed much to the prevention of asphaltene precipitation and deposition. This study provides a new approach to resolve the problem of asphaltene deposition by means of applying a constant voltage to remove asphaltene particles from the crude oil.

To implement this method in field scale, an observer well should be used as the anode and the production well as the cathode. In this way, asphaltene particles will be extracted from the oil by moving away from the production well and going toward the observer. The implementation of this experiment would be facilitated if a conductive chemical was used to accelerate the deposition rate without inducing corrosion into the tubing. This is possible by virtue of utilizing the observer well as a dumpster for asphaltene, so to speak. Consequently, if no more asphaltene particles existed in the crude that would intuitively imply no asphaltene deposition would occur. In addition to that, removing asphaltene from the oil will improve the quality of the crude and reduce the cost of processing. Having the ability to control the deposition rate or ultimately prevent it from occurring is the prime target for this study and the ones thereafter. The downside to using electricity is power consumption, which can appreciably increase the cost of oil production. However, the ability to understand how precipitation and deposition occur would set a new ground to research in this field. Before implementing this experiment on a full-scale, corrosion and consequently economic feasibility studies have to be conducted. Safety measures should be taken into account due to the potential danger involved with passing electric currents.

It has been repeatedly reported in the literature, that one of the main causes of asphaltene deposition is electrical streaming potential; however, not much has been done to, effectively, to tackle this issue. Due to the nature of the experiment, the electrokinetic effect caused by the flow of oil cannot be studied. This experiment is merely an attempt to study the effect of electricity on asphaltene deposition in static mode. The results found in the experiment however are the cornerstone for future work in this area. The next step is testing this idea on dynamic mode to try to resolve the electrokinetic negative effects caused by the flow of oil through any conduit.

Conclusions

Experimental runs showed that significant amounts of asphaltene deposits were obtained when light crude oil was destabilized by the application of a DC current. Destabilization of the heavier crude oil was achieved at higher voltages. Asphaltene particles possess negative charge in heavy and light Abu Dhabi crude oils. Application of a DC current on crude oil for a specified time may extract all asphaltene particles dissolved in crude oil. Therefore, time is a very critical factor. This study provides a new approach to resolve the problem of asphaltene deposition by means of applying a constant voltage to remove asphaltene particles from the crude oil.

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