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An experimental study on electrical effect on asphaltene deposition

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ABSTRACT
Asphaltene generally existed in colloidal form in cruds and will precipitate in non-equilibrium conditions. 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 pipe blockage. Any change in oil composition or pressure and temperature at any stage of production will destabilize crude oil producing asphaltene precipitation. In this paper, the stability of target crude oil under the influence of a direct current and contacting with polar fluid, water, is investigated. The amount of the asphaltene deposit and its electrical charge at various operating conditions are investigated. The fact that deposits form on the anode surface proves that asphaltene particles possess a positive charge. The amounts of asphaltenes precipitation were increased considerably by increasing water as polar component.

KEYWORDS
asphaltene; electrodeposition; electrical field; water; precipitation

1. Introduction

Formations with high crude oil are subject to asphaltene precipitation damage while operating well stimulation treatment with water base fluids such as acidizing or fracturing. Also if water coning is occurred in a production well, appearance of asphaltene slugs in tubes may be possible. On the other hand some secondary and tertiary recovery methods are suggested for producing oil such as gas injection or water injection (Speight 2013). Several laboratories and field case studies have reported possibility of deposition and precipitation of asphaltenes in porous media and production facilities during recovery of heavy oil containing high asphaltene percentage by miscible or immiscible flooding operations. Many oil fields, if not the majority, are under production using water injection which plays the two roles of sweeping oil towards the production wells, and maintaining pressure and therefore productivity at the production well (Khorram Ghahfarokhi, Kharrat and Soltani Soulgani 2016; Bahram S. Soulgani et al. 2011; Speight, Long and Trowbridge 1984). But what will happen if the field has asphaltene precipitation problem?

The eventuality of asphaltene precipitation in porous media can be affected by parameters such as changes in temperature, pressure and composition but there is no distinct data about effect of environment electrical changes on asphaltene precipitation. Thus finding a capable solution for slug damage removal is a serious industry concern. The polar nature of asphaltene can cause attraction of charged objectives and electrodeposition occurred anywhere along reservoir to surface facilities. Several studies have been reported electrodeposition in different heavy crudes especially in electrostatic separators. Also many researches are done to use this property to fix deposition of asphaltene in porous media and remove formation damage (Kostarelos et al. 2017).

Often there is an amount of formation water which is produced with crude oil and appears in three different forms in production system: solubilized, emulsified or free water. Solubility of water in nonpolar

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oil is limited and depends on the type of oil beyond the saturation limit. Also water can exist in emulsified form by adding surfactant or accumulated in the bottom of container as a free water phase in water/oil mixture. In previous studies there have been evidences that prove that solubility of water will increase by adding asphaltene molecules to the mixture. It can suggest the theory of existing hydrogen bond between water and asphaltene molecules. Several researches through emulsified water in crude oil indicate that asphaltene precipitation yields are the same for both samples with and without emulsified water. Also the composition of asphaltene precipitation has no difference in those samples. There are also no reports of increased water solubility in petroleum fluids. In flowlines asphaltene aggregates and may deposit (Adialalis 1982; Newberry and Barker 1985; Sulaimon and Govindasamy 2015; Yarranton 2005). There are no reports of the effect of free water on deposition. The main goal of this work is, first to investigate the effect of water on asphaltene precipitation and predict amount of it and second evaluate the effect of electrical field on asphaltene precipitation to removed them from oil.

2. Background review

Prediction – Kamath et al. (Kamath, Yang, and Sharma 1993) examined the asphaltene deposition under dynamic condition in porous media with water. They reported pore plugging by asphaltene precipitation and reduction in absolute permeability of rock samples. Tharanivasan (Tharanivasan 2012) investigated the effect of emulsified water on asphaltene precipitation. He reported that above the onset of precipitation for water free oil, asphaltene yields in oils with emulsified water were equal to water-free oils. Below the onset precipitations were not detectable. Existence of emulsified water did not affect stability of asphaltenes. Aslan and Firoozabadi (Aslan and Firoozabadi 2014) saw clear changes in asphaltene deposition with presence of water. But it had no effect on aggregation size. Wang et al. (Wang, Fan, Buckley, and Creek 2014) designed a series of experiments to compare between asphaltene deposition for distilled water-oil and brine-oil system.

Resolution – Gonzales et al. (González, Neves, Saraiva, Lucas, and dos Anjos de Sousa 2003) designed several experiments to evaluate electrokinetic behavior of asphaltene particles in asphaltene-resins system. They reported that solid asphaltic phase naturally is soluble in hydrocarbon environment but existence of resins in system successfully stabilizes asphaltene deposition. This action is the main duty of a commercial surfactant. Khvostichenko and Andersen (Khvostichenko and Andersen 2009) described asphaltene electrodeposition behavior much complex. They stated that net charge of asphaltene particles is dependent on balance between dissolved and flocculated asphaltene fractions. Next year they studied effect of additives on asphaltene-resins system (Khvostichenko and Andersen 2010).

Gheitani et al. (Gheitani, Bayat, Mousavi, and Kananpanah 2014) investigated an asphaltenic crude oil with 11.32 wt.% asphaltene and determined the effect of different values of electric field and exposure time. They discussed about the amount of precipitation during exposure time. In 2014, Khalifeh and Haroun (Abu Khalifeh, Belhaj, and Haroun 2014) examined Abu Dhabi crude oil electrodeposition. Dead oil with synthetic brine of 280 ppm salinity was induced by direct current. They reported electro nature of solid asphaltic in Abu Dhabi crude oil. Kostarelos et al. (Kostarelos et al. 2017) suggested an operational way to solve asphaltene precipitation problem in transportation pipeline, production tubing and surface facilities. By electrokinetic deposition rod they removed solid particles from crude oil but further studies are needed to introduce it as a certain solution.

3. Material and methods

An Electrodeposition cell has consisted of 100 ml container, two removable parallel stainless-steel rods as electrodes and a Teflon cap (holder) which are placed in a plastic cylinder. The dimension of electrodes is 0.6 cm in diameter and 15 cm long and spaced 0.4 cm apart of each other. The cylinder and holder are used to prevent any evaporation. This set-up allows holding the electrodes which are applying adjusted electronic field, in samples. A power supply generates a direct current (DC) field with a 4kV/cm strength in maximum power. Samples were prepared from heavy crude oil from one of Iranian oil field. Analysis results show it is containing 53% saturations, 16.5% Aromatics, 12% Resins and 18% Asphaltene. Five types of experiments were designed, which are:

1. Asphaltene Precipitation with Direct Current
   The electrodes were placed in 100 ml. of oil for 16 hours and exposed to 3500 v electric field. After that they were taken out and measured their Precipitation.
2. Asphaltene Precipitation in Various n-Hexane Percent
   Different n-Hexane-Oil mixtures (100 ml n-Hexane and Oil) were exposed to 3500 n electric field in range of 1 to 99 n-Hexane percent for steps of 10 percent. The duration of the experiment was approximately 30 min, which is sufficient. The objective of this is determination of asphaltene charge and amount of Precipitation on both electrodes.
3. Asphaltene Precipitation in Various Direct Current Field.
   Electrodes were immerged into 100 ml ideal mixture and applied electric field from 100 to 3500 v on system. Ideal mixture is described as 99 ml n-Hexane and 1 ml crude oil. Seven separated tests were carried out for seven different voltages 200, 300, 400, 500, 1000, 2000 and 3500 v.
4. Asphaltene Precipitation during Time
   According to pervious tests, proper data was collected but the amount of asphaltene was still missing. Two ideal mixtures were exposed to 1000 and 3500 v fields separately. Each electrode was hanged from a loader to monitor any changes electrodes mass during time. The electrodes are placed 1.1 cm away from each other to prevent any short-circuiting. After 5 min the charges of electrodes were changed.
5. Asphaltene Precipitation with Polar fluid (water)

Asphaltene represent the polar fraction of crude oil. Existence of large heteroatom content like nitrogen, oxygen and sulfur and also metal content like vanadium and nickel give asphaltic solids polarity nature. Injection of polar fluids as a reservoir-aim operations like water injection or near wellbore-aim operations like acidizing or fracturing can threat hydrocarbon production. Contact of asphaltene with water creates an adhesive slug phase that plugs production wells and pipelines and reduces flow. The following test is designed to evaluate the behavior of asphaltene particles while are contacting with polar fluid like water.

The asphaltene solution should be prepared by adding a known mass of asphaltene to a known volume of toluene, for this purpose 0.5 gram of asphaltene was added to 20 ml of toluene. So a 2% weight solution of asphaltene in toluene is made. 20 ml of the asphaltene solution was poured in 5 erlen myer separately, and then a known volume of distillated water was added to each of them to prepare 5, 20, 50, 70 and 83 percent of oil-water mixture. Then samples were put on the shaker for 24 hours to shake gently. This is followed by filtration under vacuum using 0.2 pm Whatman 42 filter paper to separate precipitated asphaltenes caused by presence of water. After that, the filtrate of water-solution mixture was completely transferred to a dry clean primary weighed beaker and then was put in the oven to evaporate toluene and water and collect asphaltene which was soluble in the presence of water and to weigh it.

The asphaltenic filter papers then were put in retracing set up to be washed with toluene, retracing continued until all the asphaltenes have been dissolved from the paper and collected in the flask as an asphaltene toluene solution. The content of the flask was completely transferred to a dry clean primary weighed beaker. The beaker and content were dried in the oven and weighed. This procedure was repeated for all samples respectively. After the data were obtained, percentage of asphaltene which is precipitated in presence of water (A(%(m/m))) was calculated by the following equation where m (gr) denotes the weight of asphaltene collected in filter paper and M (gr) stands for the weight of asphaltene collected in filter paper plus what passed through.

$$A\,(\%) = 100 \times \left(\frac{m}{M}\right) \tag{1}$$

4. Results and discussions

1. The precipitation on both electrodes were soluble in Toluene and insoluble in n-Hexane. Thus this proves both on them contained asphaltene particles but can't determine asphaltene charge. Slow rate of precipitation made duration of test longer because of slow movement of asphaltene

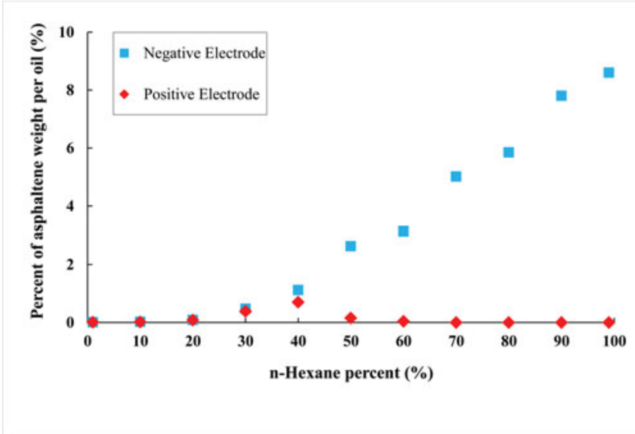

Figure 1. Percent of asphaltene weight per oil vs. n-hexane percent in system for negative and positive electrodes.

particles through heavy crude oil. So n-Hexane was added to the oil to increase the particles precipitation rate. Also it removed the resins from electrodes precipitation and helped to clarify and evaluate asphaltene charge for next tests.

2. Two different scenarios are encountered for charges of asphaltene-resin system. A positive asphaltene particle surrounded among negative resins particles or a negative asphaltene particle surrounded among positive resins particles. Adding n-hexane to oil increase the particles movement in mixture (Sedghi and Goual 2010; Andersen and Speight 2001). Thus this effect is obvious in Fig. 1 percent of asphaltene weight per oil on both electrodes are increasing till 40% of n-hexane in the system. After this quantity second effect of n-hexane presence shows itself. Adding more n-hexane increases percent of asphaltene weight per oil just on anode electrode meanwhile asphaltene particles are detached from cathode electrode. N-hexane separates resins from collide system so asphaltene particles can freely participate on opposite charged electrode. Thus this fact shows the asphaltene is positively charged and resin is negatively charged.
3. In third test series just after applying electrical field with 400–500 v strength deposition starts and increases beyond that accidentally on anode electrode. According to Fig. 2 there is a threshold electrical field for asphaltene deposition beginning. Asphaltene particles have a very wide size distribution. Small ones deposit in low strength electrical field but applying more strength field, the bigger particles deposit.

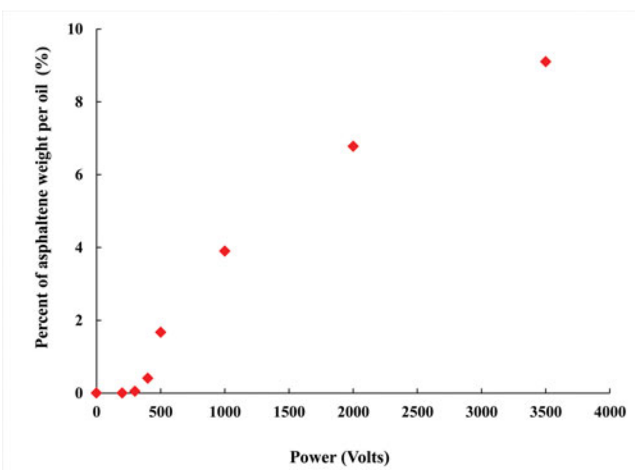

Figure 2. Percent of asphaltene weight per oil vs. power of electric field.

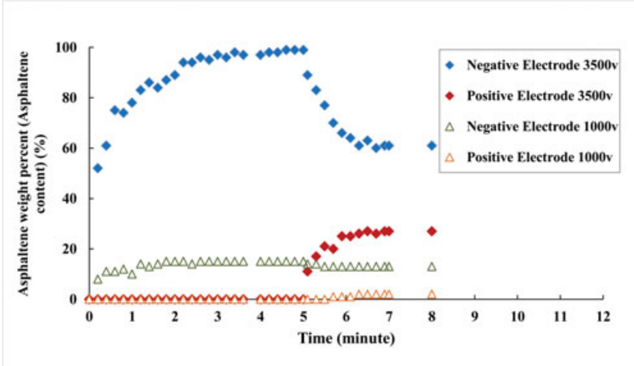

Figure 3. Asphaltene weight percent (asphaltene content) vs. time for negative and positive electrodes in two different field powers 1000 and 3500v.

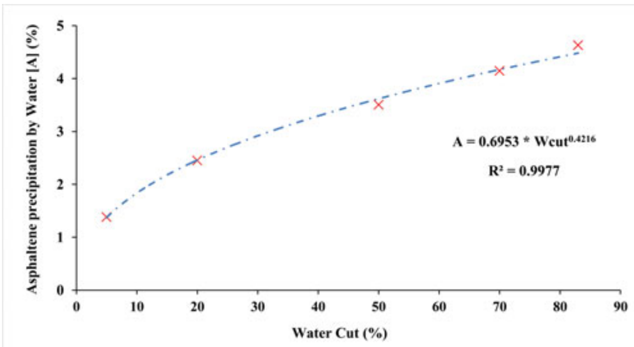

Figure 4. Percentage of asphaltene precipitation by water vs. water cut.

4. As it is shown in Fig. 3 after 1 minute applying 3500 v filed, near 80% of total asphaltene particles are absorbed. This absorption is continued and reached 100% after 5 minutes. Meanwhile there is no absorption on cathode electrode. But after charge changing aspaltene particles are detached and moved to new anode electrode. Same behavior is existed for lower electrical field. But the amount of deposition is lower and rate of particles transportation is slower.
5. Water and asphaltene solution was stable in two separated phases but in the interphase an emulsion phase was observed. Also asphaltene is too sensitive about temperature and it was too important to do experiments in the same conditions. Based on the experimental precipitation final Data obtained are listed in Table 1.

Based on gathered data, the higher the water cut was, the more asphaltene precipitated in presence of water. By plotting these data and fitting an equation it is possible to predict amount of asphaltene precipitation. The best matched equation is illustrated in Fig. 4. Adding more water will result in more asphaltene precipitations. Rate of asphaltene precipitation is higher in lower water cut.

Table 1. Obtained data.

Water cut (%)	Asphaltene in filter paper (gr)	Asphaltene in filtrate (gr)	Percentage of asphaltene precipitation (%)
5	0.0065	0.4707	1.381
20	0.0124	0.4935	2.451
50	0.0176	0.4845	3.505
70	0.0194	0.4487	4.144
83	0.0222	0.4572	4.6308

5. Conclusions

- The results of electrodeposition test confirmed that behavior of asphaltenes particles under electrical changes in system is significantly much complex. Precipitation on both electrodes in pure oil proves the presence of dipole charged system between asphaltene and resin. Asphaltene Particles possess positive charge in the collide.
- There is a threshold electrical field to make asphaltene deposition starting; it depends on oil composition, actually the size distribution of asphaltene particles and their stability. For attraction all of them stronger field is needed.
- Electrodeposition can be used as a unique technique to solve asphaltene deposition problem in porous media, tubing and surface facilities.
- Higher n-hexane dilution in oil, higher effect of Direct Current field in term of deposition rate and quantity.
- By reversing the current this is possible to return the enormous amount of precipitation into oil.
- Adding water to asphaltene toluene solution causes asphaltene precipitation. More water adding will result in more asphaltene precipitations. Rate of asphaltene precipitation is higher in lower water cut. (The slop of the plot is decreasing in higher water cut.) Also by a simple correlation the amount of precipitation can be predicted.

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