Evaluation the Impact of Mineralogical Composition of Reservoir Rocks on Wettability during Surfactant Flooding Processes

1. Introduction
As oil and gas reservoirs dwindle in parallel with rising energy demands, Enhanced Oil Recovery (EOR) techniques have grown in importance [1-5]. One of the main critical elements affects the ultimate oil recovery and flow efficiency is rock wettability. The wetting phase of reservoir rocks can be categorized to oil, water and intermediate-wet [6-8]. Many process aspects such as Temperature, brine composition and rock mineral composition are so important in wettability issue and some of them are still unclear [7-10]. Among them, the rock composition plays a key role in adsorption behavior of surfactant on mineral surface and subsequently affects the rock wettability [5, 11 and 12]. The appropriate surfactant by substantial (IFT) reduction can displace the residual oil and enhance the ultimate recovery. Many surfactants may reduce the IFT values substantially, but the best one should be selected based on the real reservoir rock and fluid conditions and regarding other stringent requirements [13 and 14].

HNermin Gence [15] studied the dolomite and magnesite wettability. The results showed that without any surfactant the measured contact angle was small and in the presence of petroleum sulphonates and sodium oleate, the contact angle value increased. Rui Zhang et al. [16] evaluated the wettability alteration of mica mineral by using trimeric cationic surfactant (Methyl dodecylbis [2-(dimethylidodecylammonio) ethyl] ammonium tribromide). The results represented that this surfactant was more effective at lower concentration for both oil and water wet mica surfaces. The effect of anionic surfactant and alcohol on wettability alteration of quartz was investigated by Anna Zdziennicka, Bronisław Jan’czuk [17]. They showed that the quartz wettability was changed substantially when the surfactant mixture in the solution was in the monomeric form.

The current study investigates the impact of rock mineralogy on wettability. Wettability tests were conducted by the contact angle method and anionic and non-ionic surfactants were used through these experiments. The rock wettability and oil mobility are the most influential characteristics that affect the EOR process and these parameters mainly depend on rock compositions.

2. Materials
Two different surfactants were utilized in the current study. Nonionic (Triton X-100) and anionic surfactant (Sodium dodecyl sulfate (SDS)). The X-100 (C14H22O (C2H4O)n) is characterized by an aromatic hydrophobic group and hydrophilic polyethylene oxide units (9.5 units, on average) [17]. The SDS (CH3(CH2)11OSO3Na) is an organic compound usually utilized for hygiene and cleaning products [18]. The oil samples were selected from Ahvaz oil field, Iran (density: 0.85 g/cm3 and viscosity: 12 cp at ambient temperature). In order to inhibit the brine precipitation during wettability tests, distillated water was utilized as the aqueous phase [19]. The rock samples in wettability experiments were pure calcite, dolomite, and quartz and these samples were obtained from different mines. Figure 1 depicts the crystal of used minerals.

Figure 1: A) calcite, B) dolomite, C) quartz.

3. Methods
Before conducting wettability tests, all samples should be washed and polished properly. To have clean and water-wet samples, the Soxhlet extractor was used to wash the polished pellets (1cm in diameter and 5mm in thickness) with toluene. The washed samples aged with crude oil for at least 100 hrs at 60 °C [20].
The wettability tests were conducted by sessile drop technique (Figure 2). Polished pellets were fixed onto the holder and then oil droplets were deposited on the rock surface (different surfactant concentrations dissolved in distilled water). All experiments were done at 250 °C. The drop profile was captured with a digital camera and the contact angle was obtained.

Figure 2: the schematic diagram of sessile drop technique.

4. Results and discussion
The initial measured of oil droplet on the calcite, dolomite, and quartz surface were 134°, 145°, and 127°, respectively (Figure 3). It indicates the strong oil-wet properties of these minerals. The effect of non-ionic surfactant on mineral wettability was tested with 0.05, 0.1, 0.2, 0.5, 1, 1.5, 2, and 2.5 wt % of Triton X-100. The addition of 0.05 wt% this surfactant, changes the initial contact angle of calcite mineral to 129° and with increasing the amount of surfactant, the contact angle value declines (the 93° contact angle by 2.5 wt% of surfactant is achieved). For the aged dolomite and quartz mineral, by increasing Triton X-100 to 2.5 wt %, the contact angle changes from 145° to 75°, and 127° to 67°, Respectively. The results show that all selected minerals have the same behaviour in the presence of Triton X-100 and the wetting phase changes toward water-wet.

The contact angle of minerals was measured with SDS (anionic surfactant) in 0.05, 0.1, 0.2, 0.5, 1, 1.5, 2, and 2.5 wt % concentrations. The addition of 0.05 wt% SDS, changes the initial contact angle of the calcite mineral to 126° and with increasing the concentration the contact angle value decreases (the lowest value (81°) of contact angle was gained in 2 wt% surfactant). For dolomite and quartz mineral, by rising SDS concentration 2.5 wt %, the contact angle changes from 145° to 72°, and 127° to 71°, Respectively.

In the next pace, mixture of both surfactants was utilized in measurements with 0, 0.1, 0.2, 0.4, 1, 2, 3, and 4 wt % of surfactants. 0.05 wt% Triton X-100 and 0.05 wt% SDS mixture changes the initial contact angle of the calcite mineral to 123° and with increasing the surfactant concentration, the contact angle value decreases (in the presence of 2 wt% Triton X-100 and 2 wt% SDS the contact angle is 72°, and the calcite surface is altered to slightly water-wet. For the dolomite and quartz mineral, the contact angle changes from 145° to 54°, and 127° to 47°, Respectively. Figure 4 and 5 compare the contact angle of minerals with addition of different surfactant concentrations.

It can be concluded that the minerals surface have the similar behaviour in contact with all aqueous solutions containing different surfactants approximately. For each mineral surface, one surfactant is more effective than others. The impact of surfactant mixture on wettability alteration of minerals is more than the standalone use of Triton X-100 or SDS. Triton is more impressive for wettability alteration of the quartz surface and for the calcite and dolomite the SDS surfactant is the appropriate candidate.

Figure 3: Treated crystalline minerals in distilled water
5. Conclusions
1. The minerals surfaces have similar behavior exposed to surfactants approximately, although for each mineral one surfactant is more effective than other.
2. The nonionic Triton X-100 surfactant is more efficient than anionic SDS surfactant for wettability alteration of quartz surface.
3. For calcite and dolomite surfaces wettability alteration the SDS surfactant is more effective than Triton X-100.
4. The impact of surfactant mixture on wettability alteration of mineral is more than either of Triton X-100 or SDS alone.

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References


