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An interface-analyzing technique to evaluate the heavy oil swelling in presence of nickel oxide nanoparticles

Yousef Kazemzadeh [a], S. Ehsan Eshraghi [b,*], Saeed Sourani [c], Mahshid Reyhani [c]

[a] Young Researchers and Elite Club, Lamerd Branch, Islamic Azad University, Lamerd, Iran
[b] Institute of Petroleum Engineering, School of Chemical Engineering, College of Engineering, Tehran University, Tehran, Iran
[c] Department of Petroleum Engineering, School of Chemical and Petroleum Engineering, Shiraz University, Shiraz, Iran

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ABSTRACT

Metal oxide nanoparticles, with their unique adsorption capacity, are able to reduce the asphaltene aggregation and precipitation onto the rock surface or tubing wall. The oil phase and the gas phase, which might be from the gas injection for Enhanced-Oil-Recovery (EOR) purposes or solution gas, would have different interface properties in the presence of metal oxide nanoparticles. In this investigation, the effect of NiO nanoparticles would be studied on the liquid–gas system interface of methane gas and different heavy oil samples. In details, Fluid behavior such as Surface to Volume Ratio (SVR) of the oil drop or the amount of swelled gas into the oil drop would be attended at a wide range of reservoir pressures and oil asphaltene content at the reservoir temperature. The results show that the presence of NiO nanoparticles can decrease the asphaltene aggregation and accumulation at the interface; in other words, it would increase the drop swelling and reduce the SVR increasing rate as pressure or asphaltene content increases. The key role of NiO nanoparticles, which resulted in the above-mentioned phenomena, is its high adsorption capacity. It means that in the presence of NiO nanoparticles, asphaltene molecules tend to be adsorbed by these nanomaterials instead of aggregating around each other or at the interface of gas and liquid.

1. Introduction

For a multiphase hydrocarbon system, it is necessary to study the effective forces on the interface of two fluids [1]. When two fluids are adjacent to each other, they would be separated by a layer, called interface [2–5]. The interface thickness is about the sum of several molecule diameters, and it has all the fluid phase characteristics [6]. It is clear that the surface wettability would result in an adhesion force; therefore, the resultant of this force and capillary force would specify Interfacial-Tension (IFT) in porous media [4,7–10]. In other words, there is always an IFT at the surface of oil and gas phases [8–16].

Pendant drop is an IFT measurement approach; more precisely, in this method, a drop would be injected through a narrow needle [2–4], and it, interestingly, tends to form like a sphere to minimize its interface due to the interfacial and intermolecular forces [17].

Either through the porous media, production string, or surface facilities, asphaltene will always cause lots of problems. Recently, studies of prevention methods of asphaltene precipitation are attended very much [18]. Vanishing-Interfacial-Tension (VIT) is a new method, which could be used for understanding the asphaltene precipitation onset point [19–23]. This accurate method needs a small amount of sample for laboratory experiments [24–26]. In this method, IFT would drastically increase after the onset point [27,28]. Precipitation mechanism, its rate, and onset point could be determined by analyzing the slope changes in the graph of IFT versus pressure [29,21–25]. In addition, the VIT method gives information about the drop volume either at a specific pressure and temperature or during their increasing. Bond number and different drop dimensions are other outputs of this approach [17,29]. Owning such information would make it possible to study the oil and gas interface behavior.

To solve the asphaltene-caused damages, solvents and other traditional methods could be used as alternatives; they, however, would not be applicable for all cases due to their high prices, high pollution levels, and slightly low efficiencies. Nanoparticles are assumed to be a good candidate to have a successful asphaltene treatment [17]. They are supposed to be much more efficient since they would solve the asphaltene problems economically and would not have environmental hazards [30–32]; undoubtedly, such newfound and advanced methods would be much more effective in comparison with traditional approaches [33–40].

It is a true fact that almost all of the nanoparticles that are used in oil and gas industries are metal or metal oxide nanoparticles. Such nanoparticles have some advantages such as high SVR, high suspending ability, great absorption capability, and suitable catalytic properties [40].

* Corresponding author at: Institute of Petroleum Engineering, School of Chemical Engineering, College of Engineering, Tehran University, P.O. Box: 113654563, Tehran, Iran.
E-mail address: eshraghi.ipe@ut.ac.ir (S. Ehsan Eshraghi).

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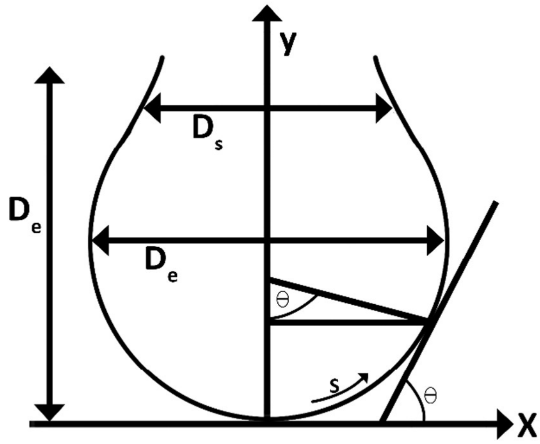

Fig. 1. Shape of pendent drop in a liquid–gas system.

Recently, the effect of ZnO nanoparticles on the IFT behavior of an oil–water system has been investigated, and it resulted that IFT would decrease in the presence of ZnO nanoparticles [41]. Nanoparticles are considered as multipurpose chemicals in the petroleum industry. These particles can suspend petroleum asphaltene content and prevent their precipitation using their thermal catalytic characteristics [37–39]. Therefore, the role of nanoparticles could be categorized into two groups. First is their adsorption capability, which depends on particle sizes, their surfaces, and their composition. To clarify, they absorb asphaltene content to reduce their aggregation; as a result, oil recovery would be improved. Second, they could be implemented for in-situ heavy oil upgrading purposes [17,39,40,42,43].

In the current work, the introduction of a new approach to alternate heavy oil and gas interface characteristics using metal oxide nanoparticle of NiO has been attempted. To make it clear, the objective of this study is to improve the interface of methane gas and heavy oil, contained NiO nanoparticles. To this end, as time is passing, drop volume has been measured at each pressure and temperature, with and without the nanoparticles. Thereafter, changes of drop SVR have been analyzed by increasing in pressure to find out the extension of nanoparticle effect on SVR.

2. Computational parameters

The Young–Laplace equation is a non-linear partial differential equation; it, moreover, determines the capillary pressure at the surface of two static fluids using IFT [1,29,44]. This equation expresses that there is a vertical tension balance at the interface of two static fluids if the interface thickness is assumed to be negligible. As it is shown in Fig. 1, drop shapes are considered for calculations when a force balance is achieved [4]; in addition, the Young–Laplace equation can be applied after a drop reaches the mechanical balance.

$$P_2 - P_1 = \gamma\left(\frac{1}{R_1} + \frac{1}{R_2}\right) \tag{1}$$

where P_1 and P_2 are the inside and outside sphere pressures, respectively, and R_1 and R_2 are the radiuses of main curvature, respectively, and γ is the IFT.

In the presence of two immiscible fluids, IFT could be calculated by measuring the drop dimensions and using the following formula [17,29]:

$$\gamma = \frac{\Delta\rho g D_e^2}{H} \tag{2}$$

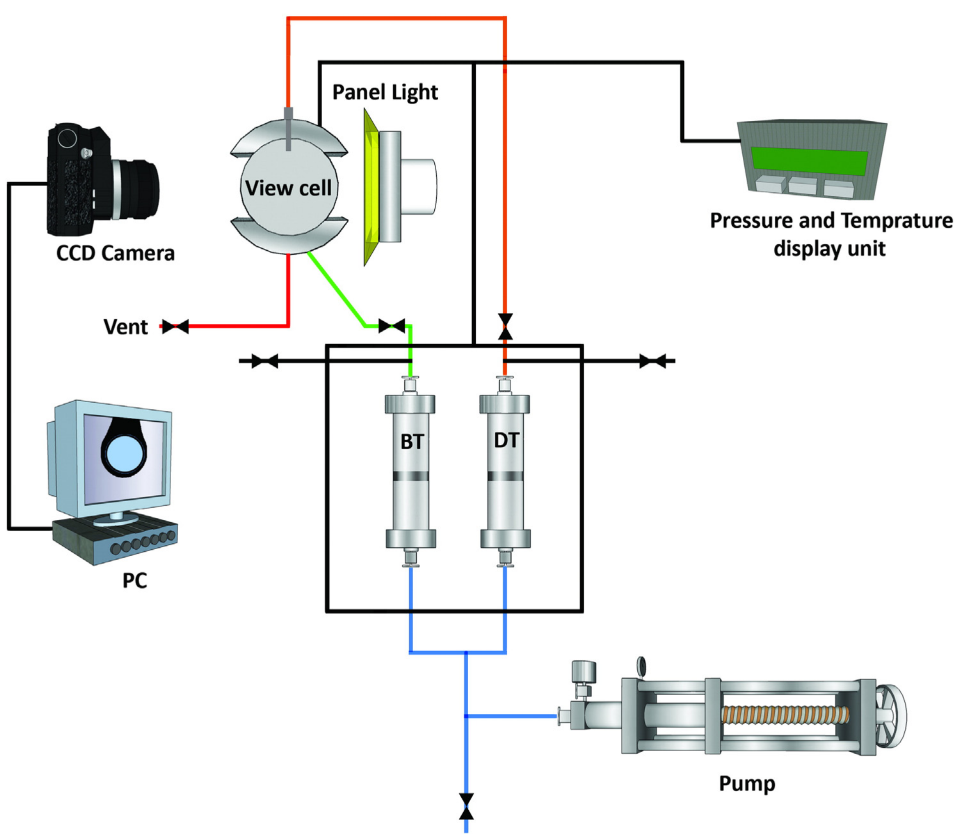

Fig. 2. Schematic view of IFT measurement apparatus.