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Application of Microwave Heating in the Demulsification of Crude Oil Emulsions

Abstract- *In recent times the formation of pre-processing water-in-crude emulsions in petroleum industries has led to some inherent challenges such as the reduction in the efficiency of oil recovery, high cost of operation and corrosion in pipes. Traditional ways of pulverizing the emulsions using heat and chemical approaches have many disadvantageous from both economic and environmental points of view. Microwave irradiation is an efficient method for the demulsification of the water-in-oil (W/O) emulsion, encountered in refinery industries. The microwave technology is a cost-effective way of emulsifying water-in-crude-oil emulsion. Two methods were used for conducting the demulsification performance test, i.e. chemical and microwave. The method of chemical demulsification using octylamine was found to be the best water separation efficiency achieved at 2.5 vol.% Octylamine with (35-65%) W/O emulsion, the separation touched to 90% within 3 days and the greatest oil separation efficiency attained at 2.5 vol.% Octylamine at the same ratio of W/O emulsion, the separation reached 91% within 3 days. The demulsification process efficiency increased by microwave, where the water separation rate reached to (100%) at 4 minutes with (35-65%) W/O emulsion. Light crude oils were used. The fundamental principles of formation, formulation and breaking of O/W emulsions in the microwave heating process were adequately elucidated using some physicochemical characterization techniques This further helps in the development of a cost-effective method of demulsifying the W/O emulsion. Water-in-crude oil emulsions of volume percentage ranges, i.e. (25-75%) and (35-65%) were adopted.*

Keywords- *Crude oil; demulsification; chemical; W/O emulsion*

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1. Introduction

The emulsion is produced (oil with water) during crude oil production from the field. It should be controlled (or avoided) as emulsion would increase the fluid viscosity and slow down the transportation process of oil from the sand to the flow line. Failure in separating water from oil would lead to problems such as overloading of surface separation equipment, increased pumping cost, and corrosion [1]. There are majorly two categories of emulsions and this includes the water-in-oil emulsion (w/o) and oil-in-water emulsion (o/w) as reported by Langevin et al. [2]. Generally, emulsion demulsification is naturally divided into a two-step process viz: the flocculation and coalescence. The former involves the aggregation or component separation of the emulsion, while the formers deal with the coalescence of the emulsion. Moreover, both steps are regarded as rate-determining steps in emulsion breaking as supported by Kalogirou [3]. The undesired emulsion should be demulsified in order to have good crude oil quality. It is pertinent to note that the process required to effectively separate out the undesirable emulsions involves a complex multi-stages of formation and stabilization. This has been a major point of concern to many researchers and this has provoked the renewed interest to properly investigate the mechanism and fundamentals involved in obtaining a stable emulsion through the demulsification process [4].

The generation of the oil-water emulsion is inevitable in industrial sectors such as petroleum refinery, natural gas processing and transmission, as well as oil and gas production. These have resulted in many inherent operational mishaps which include the production of crude-oil below specification, the emergence of pressure drops in flow lines and tripping of separation plants, among other problems. The presence of natural surfactants in the crude oil results in the accumulation of emulsions in the valves, pumps and chokes. Xu et al. [5] reported that a rise n the water-volume fractions or temperature reduction could result in the increase in the water-in-oil

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viscosity of the emulsions. There is a different operation where emulsion can be detected and this includes during production, drilling, crude transportation and processing. Moreover, many location and facilities such as wellbores, reservoir, refineries and other surface auxiliary equipment the presence of emulsion can be. Usually, the viscosity of the emulsion is markedly higher than in crude oil and this could result in the rise in the energy requirement for flow pipeline transportation [6].

In order to address the problems mentioned above, demulsification strategies such as chemical, mechanical, heating, and ultrasonic methods should be performed [7]. The conventional demulsification method is not promising in terms of environmental and economic perspectives [8]. The use of mechanical centrifuge for demulsification is regarded as insufficient and ineffective due to its low efficiency in separating water from the crude oil. The chemical method relies on the addition of demulsifier into the emulsion, which is widely used in oil industries [9]. Since the last few years, the number of research works related to the microwave heating technology (MWHT) is increasing as MWHT is fast, inexpensive, clean, convenient, and offers a promising water separation efficiency [10]. In what follows, some important aspects of MWHT are reviewed.

Abdurahman et al. reported that the higher solubility of Octylamine in oil has a little effect on its solubility in water which is due to its shorter hydrophobic chain as compared to the other demulsifiers. Therefore, the interfacial film around the droplets can be broken thus increasing the demulsification rate. Furthermore, Rani reported that the use of oil-soluble surfactant has greater efficiency and effectiveness in a water-in-oil emulsion. This is due to the continuous and dispersed phase being oil and water, respectively. Therefore, the demulsifier can be directly absorbed into the oil phase. The author also claimed that the solubility of the amine group decreased upon increasing the hydrocarbon chain to more than six carbon chains. In this present study, the performance of microwave technology was evaluated for breaking crude oil emulsions. The physicochemical characteristic of crude oil was thereafter evaluated to determine the effect of microwave heating on the demulsification of emulsion.

2. Materials and Methods

I. Materials

Physical properties of crude oil are shown in Table1.

In this research, the crude oil sample and Octylamine were obtained from the Basrah Refinery. The light crude oil was blended with water at a ratio ranging from (25 % -75 %) and (35 % - 65 %). For destabilizing the emulsion, Octylamine was used as demulsifier in order to break the W/O emulsion.

II. Microwave

The demulsification of W/O emulsion was performed using the microwave oven model (MH943SAR) made in the chain, shown in figure 1. The 300 ml of prepared water-in-oil emulsions was placed in a 500 mL glass beaker. The microwave heating was performed at 360 W for 2, 3 and 4 minutes. The operating frequency was set as 2450 MHz, which was optimal for microwave demulsification.

Table.1: Physical Properties of Crude Oil

Properties	Measurement
Viscosity (Cst.) at 21.1℃	16.7
Density (g/cm^3) at 15 C	0.8703
API Gravity	31
Pour point (˚C)	Below -30
Surface Tension (mN/m) at 25 ˚C	62.883
Interfacial Tension (mN/m) at 25 ˚C	5.00
Shear Rate (sec $^{-1}$)	50
Shear Stress (pa)	4.7565
Sulfur Content Wt. %	2.99
Water content Vol.%	0.1
Ash content Wt. %	0.0130
Salt content Wt.%	0.0072
Asphaltenes content Wt.%	1.99
Nickel PPM	19.12

Figure 1: Microwave heating demulsification

III. Emulsion Preparation

In the laboratory, the water-in-oil emulsions at volume percentages (25-75) vol. % and (35-65) vol. % were prepared (these percentages were chosen to be different from previous studies). These emulsions were distributed into several 500 mL graduated beakers, with different volumes of water and oil. The emulsion prepared was analyzed to determine its properties (W/O or O/W) using the test tube method and only the W/O emulsion was selected for further processing. To prepare W/O emulsion, the dispersed phase (water) was added slowly into the oil phase while mixing using the standard three blade propeller for 4 min at room temperature (28 -30) ℃. The mixing speed was 1000 rpm.

3. Results and Discussion

I. Physical properties of crude oil

The physical properties of emulsion were studied in order to understand the behaviors of crude oil (e.g. emulsion stability and formation). According to the American Petroleum Industry API, crude oil is divided into light, medium, heavy, and extra heavy categories (light: API >31.1, medium: API >22.3, heavy: API > 10, extra heavy: API < 10) [13]. In the current work, the medium crude oil (API = 31) was used. The crude oil viscosity is also one of the important parameters in rheology. Note, viscous oil requires extra pumping work [14]. Pour point, which is the lowest temperature at which the liquid oil turns semi-solid, is very important particularly during the transportation. Pour point of crude oil rises with respect to specific gravity. Its value may vary from -60˚C to 30˚C. During preheating (e.g. 45 ˚C to 65 ˚C), the pour point decreases due to the paraffinic crystal in the crude oil [15].

II. Chemical properties of crude oil

The SARA (saturated, asphaltene, resin, aromatic) fractionation was determined in order to understand the chemical composition of crude oil. As reported, a very high amount of saturated crude oil (i.e. 65.2 wt.%) was obtained. Meanwhile, the aromatic fraction of 25.1 wt.% was recovered. The amounts of asphaltenes and resins were 5.5 wt.% and 4.2 wt.% as presented in Table 2. The increase in the crude oil quantity than the resin is attributed to the precipitation of asphaltene (Chrisman et al, 2012). Therefore, a very stable emulsion is formed. In fact, a hard film (i.e. alkene) exists on the oil interface. According to [16], the emulsion stability is inversely proportional to the resin/asphaltene ratio (R/A), i.e. higher RA ratio would reduce the emulsion stability.

Table.2: Chemical Properties of Crude Oil

Sample	Saturate (wt.%)	Aromatic (wt.%)	resins (wt.%)	Asphaltenes (wt.%)
Crude oil	60.3	30.1	1.87	1.99

It can be observed from Figures 2 that the W/O emulsion (25- 75) %, with 2.5% Octylamine achieved 78 % water separation during the third day. However, by increasing the volume of dispersed phase(water) (35- 65) % W/O emulsions, a higher water separation (i.e. 88 %) was obtained at the same conditions, and this is due to a rise in the water content which could lead to the reduction in the stability as a result of density difference between the water and oil, which leads to the oil droplets move more rapidly individually to the top and separate. Also, separation is more effective when the surfactant concentration is increased(1.5vol.% Octylamine, water separation 71% and 2.5vol.% Octylamine, water separation 88% at the same crude oil emulsion ratio 35-36%) because of enough quantity of surfactant to reduce the interfacial film strength, hence enabling the combination of two or more droplets to form larger droplet enhance quick movement of molecules inside the emulsion, and then subsequently separate individually [9].

Figures 3 show the oil separation trends with changes in water contents (crude oil emulsion of volume percentage range of (35-65%) and (25-75%). In fact, the best oil separation efficiency can be attained when octylamine is adopted.

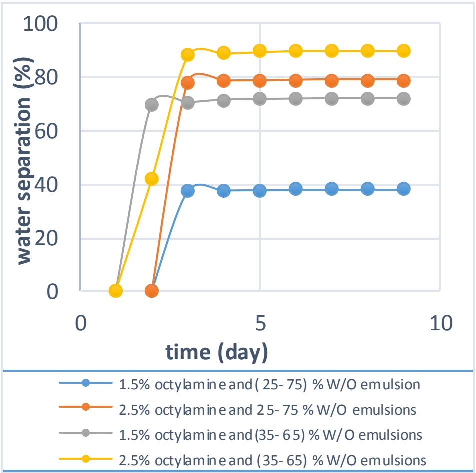

Figure 2: the effect of octylamine additives on the water separation of W/O emulsions

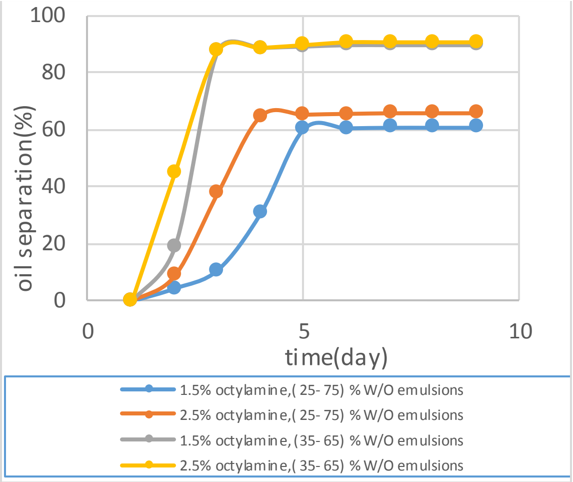

Figure 3: the effect of octylamine additives on the oil separation of W/O emulsions

In Figure 4 and 5 have shown the water separation efficiency from 35-65% and 25-75% W/O emulsions. All experiment tall teste has shown that the effect of microwave radiation is very effective in the separation of W/O emulsions, because of microwave radiation can increase the temperature of emulsion, thus reducing the viscosity of emulsion and hence the droplet size increase, which finally leads to the phase separation [17].

It can be observed that increasing the processing time from (2-4 minutes), had a significant influence on the result of water separation. Because by increasing the exposure time, the heating rate increases as well [18].

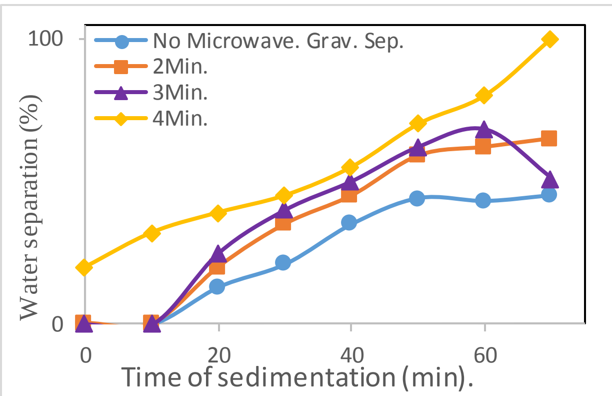

Figure 4: the separation of water from 35-65% W/O emulsion

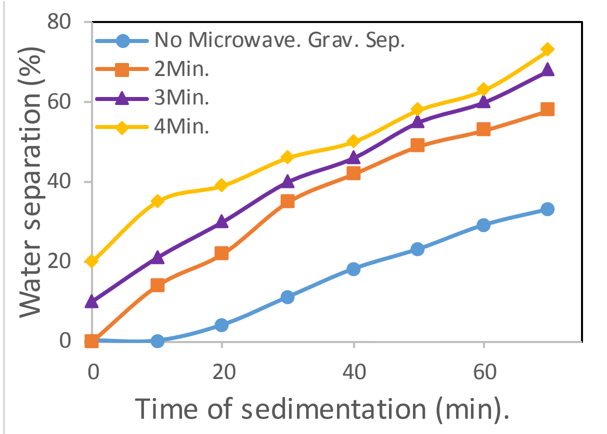

Figure 5: the separation of water from 25-75% W/O

4. Conclusions

This study entails the breaking of water-in-crude emulsion using microwave technology. The water-in-crude emulsion destabilization in petroleum industries portends a serious threat in the refining and separation process. The seriousness of this inherent challenge is due to the complexity of thousands of the hydrocarbons present in the destabilized emulsions. However, many previous investigations reported that fractions such as asphaltenes and resins are majorly involved in the destabilization mechanisms in water-in-oil emulsions. In this present study, the physical and chemical properties of the crude oil were evaluated using different characterization techniques. The physical properties of the crude oil include the determination of pour point, density, API gravity and viscosity which was respectively obtained as -30 C, 0.8703 g/cm3, and 16.7 Cst and 31 at room temperature.

Moreover, the SARA techniques were employed to determine the chemical characteristics of the crude oil. The results obtained reported the saturated aromatics compounds, resins, and asphaltenes as 60.3 %, 30.1%, 1.87% and 1.99 %, respectively. The results obtained after the demulsification process the water-in-oil emulsions were prepared in two ratios of 25-75% and 65%. The emulsion was demulsified using chemical, microwave method. The Octylamine was used for the chemical demulsification, and the result obtained gave the optimal efficiency of separation at 2.5 vol.% Octylamine with (35-65%) W/O emulsion, the separation reached to 90% within 3 days. Moreover, the microwave heating demulsification was designed with, time (2-4) minutes at different two ratios of W/O emulsions (25-75) %, (35-65) %. the results showed that the best water separation efficiency at 4 min and with the 35-65% W/O emulsion, the separation reached to 100%.

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