IJCPE
Iraqi Journal of Chemical and Petroleum Engineering

Iraqi Journal of Chemical and Petroleum Engineering
Vol.14 No.2 (June 2013) 21- 27
ISSN: 1997-4884

University of Baghdad
College of Engineering

The Application of Microwave Technology in Demulsification of Water-in-Oil Emulsion for Missan Oil Fields

Sawsan A.M. Mohammed* **and Mortatha S. Mohammed**
* Chemical Engineering Department, College of Engineering, University of Baghdad

Abstract

A series of batch demulsification runs were carried out to evaluate the final emulsified water content of emulsion samples after the exposure to microwave. An experimental study was conducted to evaluate the effects of a set of operating variables on the demulsification performance. Several microwave irradiation demulsification runs were carried out at different irradiation powers (700, 800, and 900 watt), using water-in-oil emulsion samples containing different water contents (20-80%, 30-70%, and 50-50%) and salt contents (10000, 20000, and 30000 ppm). It was found that the best separation efficiency was obtained at 900watt, 50% water content and 160 s of irradiation time. Experimental results showed that microwave radiation method can enhance the demulsification of water -in- oil emulsions in very short time compared to the conventional methods.

Keywords: Demulsification, Microwave radiation, water-in-oil emulsion, dielectric

Introduction

Water -in- oil emulsions are commonly encountered in the petroleum industry, such as in petroleum refineries and transportation stations dealing with crude oil and natural gas through pipelines. Emulsions can cause difficulties in crude oil storage and transportation as well as pipeline corrosion. Emulsions are undesirable because the volume of dispersed water occupies space in the processing equipment and pipelines and increases operating and capital costs. Moreover, the characteristics and physical properties of oil change significantly upon emulsification. The density of emulsion can increase from 800 kg/m^3 for the original oil to 1030 kg/m^3 for the emulsion. The most significant change is observed in viscosity, which typically increases from a few mPa.s or less to about 1000 mPa.s [1] (i. e., emulsion viscosity can be substantially greater than the viscosity of either the oil or the water because emulsions show non-Newtonian behavior. This behavior is a result of droplet crowding or structural viscosity.

In order to maintain normal production, emulsions must be broken down for separating water from oil. After separation, the water content in the oil must be below 0.5% [2, 3]. Moreover, the oil content must be less than 0.05% in the water separated from the emulsion for environmental reasons and to minimize the loss of oil. Therefore, demulsification is very important for the petroleum industry[4].

A lot of activities have been developed recently regarding the use of microwave irradiation for demulsification purposes. This is because the microwave irradiation offers a clean, inexpensive, and convenient method of heating, which often results in higher yields and shorter reaction times. However, the reports about the practical application of microwave demulsification are very limited up to now [5].

In microwave irradiation, energy is supplied by an electromagnetic field directly to the material [6]. This results in rapid heating throughout the material thickness with reduced thermal gradients. The microwave energy is volumetric heating, which can reduce processing time and save energy. When microwave is supplied, it attacks the polar molecules which are in this case molecules of water. Therefore, molecules get energy and vibration occurs. The vibration will lower the interfacial tension or film around water molecules in the emulsions. This will result in film rapture and increase the degree of water molecules coalescence. The break-down of emulsions is a three step process. In the first step called flocculation, the dispersed droplets of internal phase flocculate into some large group but drops still exist without coalescence. In the next step called coalescence, the drops in group coalesce into a large drop with the result of the decrease of drop numbers. In the sink step, large internal drops sink by gravity to the interface between oil and water and coagulate into water phase resulting in the break-down of emulsion [7].

The main objectives of this study are to examine the performance of microwave application in demulsification of water-in-crude oil emulsions in comparison to the conventional methods and study the influence of the below parameters on demulsification efficiency by microwave:- (Water content, Microwave application power, Irradiation time, Settling time and salt content).

Experimental Work

The demulsification tests applying microwave radiation were conducted using microwave oven (LG), which provide 900W with operation frequency at 2450 MHz. A 900 ml graduated cylindrical glass was used as sample container. Three thermocouples type (K) were connected to data logger and then connected to microwave oven as shown in Fig. 1.

Fig. 1, Photograph of experimental apparatus

Materials

Heavy crude oil was used in this study is supplied by Missan Oil Company. The characteristics of crude oil have given in table 1.

Table 1, Crude Oil Characteristics

Characteristic	Missan Crude Oil
Density (20°C gm/cm^3)	0.905
API	24
Salt content(ppm)	42.92
Water content	18%
DS	16
Viscosity(cp)	22.572

Sodium Hydroxide was used as an emulsifying agent for emulsion preparation. In the present study.

Emulsion Preparation

In this study, the microwave demulsification method was carried out using different emulsion of water in crude oil emulsions. To assure the stability of emulsion samples prepared in the laboratory, 1ml of 0.95 N NaOH solution was added to distilled water used in preparation of samples. Emulsions were agitated vigorously using a standard three blade propeller at constant speed of 1800 rpm for 8 minutes to facilitate the contact among the water droplets in the emulsion.

The prepared samples were tested for their stability under gravity at room temperature. The amount of water resolved is a measure of the emulsion stability. The system should not be separated into bulk oil and water phases after 3 days of gravity settling.

Demulsification

An experimental study was conducted to evaluate the effects of a set of operating variables on the demulsification performance. Several microwave irradiation demulsification runs were carried out at different irradiation powers (700, 800, 900watt), using water –in-oil emulsion samples containing different water contents (20, 30, 50 %) and different salt content (10000, 20000, 30000ppm). After microwave irradiation, emulsion samples were put into graduated cylinders for settling measurements. The volumes of the separated water phase were recorded every 20 minutes for 3 hours. The separation efficiency (S) can be calculated from the following equation:

$$s, \% = \frac{v_s}{v_\circ} \times 100\% \qquad \dots (1)$$

Where:

s is the separation efficiency

v_s represents the volume of separated water.

v_o represents the original volumes of water.

Results and Discussion

1. Effect of Water Content on Demulsification Efficiency

It is necessary to determine the relationship between dielectric properties and the water content in the emulsion, because the dielectric properties are influenced by the medium composition. This is especially important in demulsification processes, where water content variations are expected to occur. Besides emulsion water content can also influence the coalescence efficiency during the demulsification process, leading to reduced distance between droplets in the sample. This distance can be severely narrowed with the increase of the volume of the aqueous phase in the emulsion, raising the probability of collision between the droplets [8].

From experimental results, it was observed that when the volume ratio of water is less, the emulsion is more stable. According to Figure (2) improved emulsion resolution was obtained for emulsions with greater initial water content.

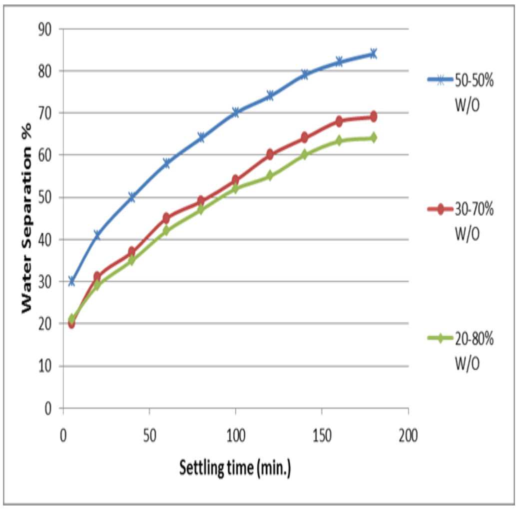

Fig. 2, Effect of water volume ratio on demulsification efficiency

2. Effect of Irradiation Power on Demulsification Efficiency

Separation efficiency and sample temperature continuously increased with microwave irradiation power until no further improvement in efficiency or increase of sample temperature occurred with increasing irradiation power. It can be seen from Fig. (3) that an increase in microwave power resulted in higher percentage of water separation, because the wavelength and penetration depth increases along with microwave power [9,10].

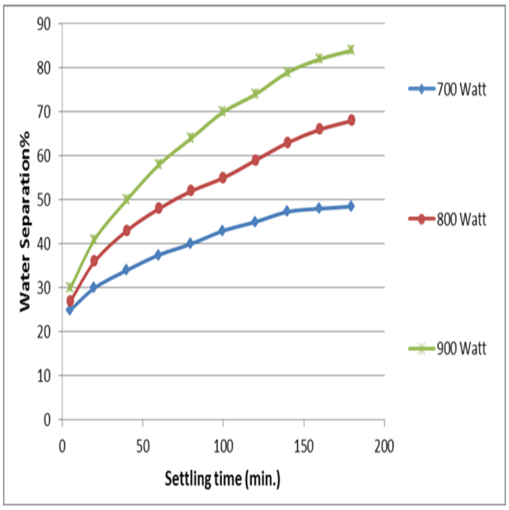

Fig. 3, Effect of different irradiation power for 50-50% W/O

3. Effect of Microwave Irradiation Time on Demulsification Efficiency

The separation efficiency continuously increases with irradiation time until 160 sec have passed after that the emulsion starts to boil. The separation efficiency at this irradiation time reaches 85% using 900 W of microwave irradiation for (50-50%) W/O emulsion. From Fig. (4), it can be concluded that the microwave exposure time is of great importance for separation of emulsions. Less exposure time is not sufficient for large crops of small droplets to coalesce and settle.

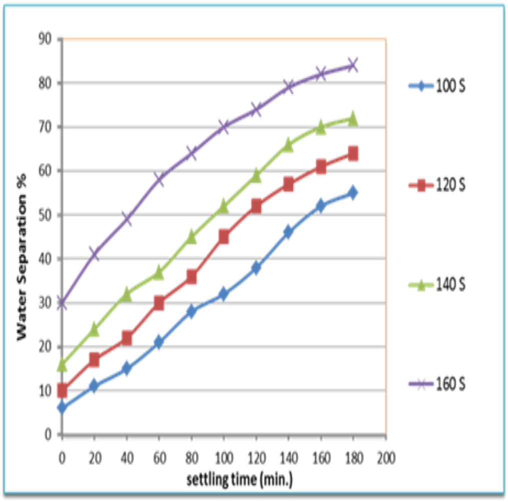

Fig. 4, Effect of different irradiation time for 50-50% W/O emulsion

4. Effect of Salt Content on Demulsification Efficiency

The study of the salt content effect on the microwave demulsification can be helpful for breaking emulsions that generated during petroleum production and also during desalting process. The dielectric heating is influenced by the salt content in the aqueous phase. It is also well-known that existence of ionic species in the media enhances the heating efficiency of the mixture [11]. Besides, the salt content may also play a role over the interfacial properties of the emulsion and over stability. Specific ions present in the brine solution can influence interfacial film behavior. At the interface, these ions may react chemically with hydrophilic groups to form insoluble salts [12].

It can be observed from Fig. (5) that water separation efficiency increases with increasing salt content, this could be due to the destroying of the double charge layers by the NaCl, as well as the somewhat higher density of the aqueous phase, these results are in agreement with those of Xia *et. al*[13].

To understand this observation, one may consider the characteristic changes in the oil water emulsion behavior as a result of salt (NaCl) addition. From the diffuse ion theory, it is known that for the same water content, as the salt concentration increases, the internal energy of the system increases [14].

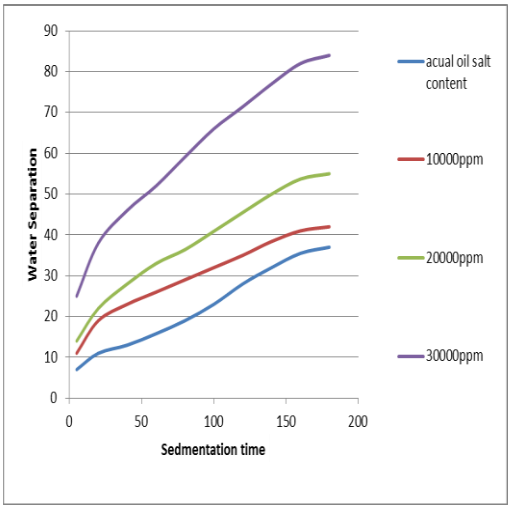

Fig. 5, Effect of different salt content for 50-50% W/O emulsion

5. Dielectric Properties and Heating Rates of Irradiated Emulsions

The rate of heat generation from microwave radiation depends upon physical and dielectric properties of emulsion. The dielectric constant of water and oil are given by the following equations [15]:

$$\varepsilon'_{r,w} = 85.215 - 0.33583\Delta \qquad \ldots(2)$$

$$\varepsilon'_{r,o} = 2.24 - 0.000727\Delta T \qquad \ldots(3)$$

Where $\varepsilon'_{r,W}$, $\varepsilon'_{r,O}$ are the dielectric constant of water and oil respectively, ΔT is the temperature increase in °C.

The dielectric constant of the emulsion $\varepsilon'_{r,Emulsion}$ is calculated from Wiener equation [16, 17]:

$$\varepsilon'_{r,Emulsion} = \emptyset_w \varepsilon'_{r,w} + \emptyset_o \varepsilon'_{r,o} \qquad \ldots(4)$$

Where ϕ_W and ϕ_O are the volume fractions of water and oil respectively.

The rate of temperature increase is calculated from the temperature increase divided by irradiation time. It is observed that the heating rate (*dT/dt*) is inversely proportional to the increase in temperature; this was an expected result since the dielectric loss of water is small. Fig. (6) illustrates the heating rate for of 20 – 80% W/O, 50 – 50% W/O emulsions, and pure water. It could be concluded from the figure that, emulsion with smaller water volume fraction has a higher heating rate due to larger heat generation per unit volume.

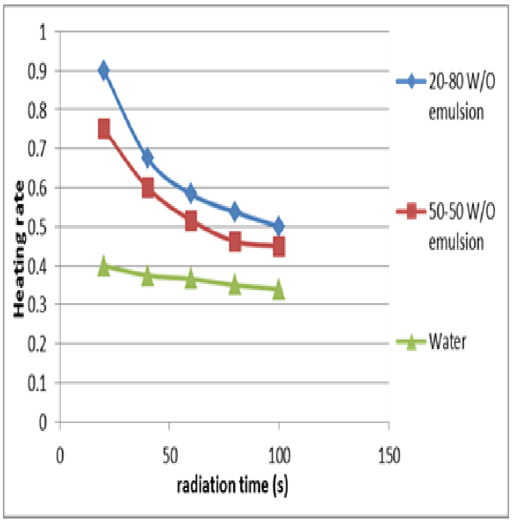

Fig. 6, The relation between water volume ratio and heating rate

The ability of sample to absorb and convert thermal heating within the samples is computed by measuring dielectric properties. As shown in Fig. (7), It is clear that the dielectric constant depends strongly on the dispersed phase volume fraction. The dielectric constant increases with increasing water volume fraction in emulsion, which can be explained according to Weiner equation knowing that the value of dielectric constant of water is much higher than that of oil. This result is in good agreement with that found by [18].

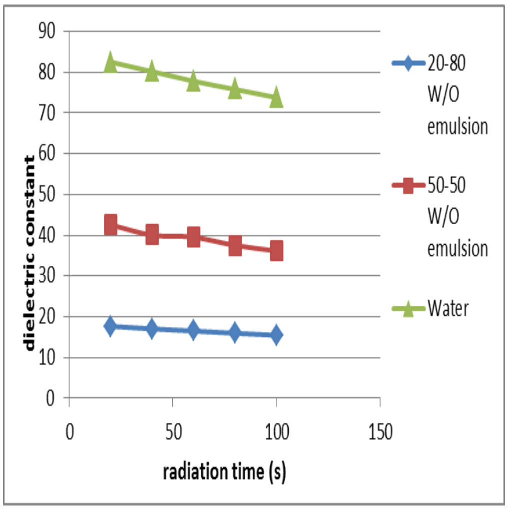

Fig. 7, The relation between water volume ratio and dielectric constant

Conclusions

1. Microwave radiation is effective in separating dispersed water from water – in – oil emulsions. The separation is much faster than conventional methods.
2. Improved emulsion resolution was obtained for emulsions having higher water volume ratio due to the increase in electrical conductivity and energy dissipation per unit volume and therefore the heating effect.
3. An increase in microwave power resulted in higher percentage of water separation, because the wavelength and penetration depth increases along with microwave power.
4. The microwave exposure time is of great importance for separation of emulsions. The separation efficiency increases with irradiation time due to viscosity reduction which results in a faster film drainage rate and faster drop coalescence.
5. Separation efficiency increases with increasing salt content of emulsions; this could be due to the destroying of the double charge layers by NaCl that delay the coalescence of water droplets, and higher density of the aqueous phase.
6. Emulsions with smaller water volume fraction have a higher heating rate due to larger heat generation per unit volume.
7. The dielectric constant increases with increasing water volume fraction in emulsion.

References

1. Fingas M. and Fieldhouse B. (2003), "Studies of Formation Process of water-in-Oil Emulsions", Marine Pollution Bulletin 47, 9-12: 369-396.
2. Jin Qinghan, Dai Shushan, and Huang Kama (1999), "Microwave Chemistry", Beijing: Science Publishing Company: 17-22
3. Bhardwaj, A. and Hartland, S. (1994), "Dynamics of Emulsification and Demulsification of Water-in-Crude Oil Emulsions", Industrial and Engineering Chemistry Research 33: 1271-1279
4. Das P. K., And Hartland S. (1990), "Effect of Demulsifiers on the Separation of Water-in-Oil Emulsions", Chem. Eng. Commun. 92:169-181.
5. Abdurahman H.N., Yunus R.M., and Azhary. H.N. (2012), "Demulsification of Water-in-Oil (W/O) Emulsion via Microwave Irradiation: An Optimization", Scientific Research and Essays, 7(2): 231-243.
6. Thostenson, E.T., and Chou, T.W. (1999), "Microwave Processing: Fundamentals and Applications", Composite, part A, 30:1055-1071.
7. Johnk, C.T. (1975), "Engineering Electromagnetics Fields and Waves", 3^{rd} Ed. New York: John Wiley.
8. Coutinho R.C., Heredia M.F., de Souza, M.N. and Santos A.F. (2008), "Method for the Microwave Treatment of Water-in-Oil Emulsions", US Patent 2008/0221226 A1.

9. Nuurul Huda S. and Abdurahman H.N. (2011), "Microwave Separation of Water-In-Crude Oil Emulsions", Inter. J. of Chemical and Environmental Eng., 2(1):69-75.
10. Khan R.M. and Emad N. Al-Shafei (2009), "Use of Advanced Nonconventional Technology to Improve Flow Properties and Upgrading/Desulfurizing Heavy and High Sulfur Crude", Saudi Aramco Journal Of Technology.
11. Fortuny M., Oliveira C.B.Z., Melo R.L.F.V., Nele M., Coutinho R.C.C., and Santo A.F. (2007), "Effect of Salinity, Temperature, Water Content, and pH on the Microwave Demulsification of Crude Oil Emulsion", Energy Fuels, 21 :1358–1364
12. Mortatha S. Mohammed, " The Application of Microwave technology in Demulsification of Water-in-Oil Emulsion for missan oil fields", MSc. Thesis, Chemical Engineering Department, College of Engineering, University of Baghdad.
13. Xia L.X., Lu S.W., and Cao G.Y. (2004a), "Salt-Assisted Microwave Demulsification", Chem. Eng. Comm., 191: 1053-1063.
14. Mohamed A.M.O., Gamala M, Zekri A.Y. (2003), "Effect of Salinity and Temperature on Water Cut Determination in Oil Reservoirs", J. Petrol Sci. Eng. 40: 177-188.
15. Fang C.S. and Lai P.M.C. (1995), "Microwave Heating and Separation of Water-in-Oil Emulsions", J. Microwave Power and Electromagnetic Energy, 30 (1): 46–57.
16. Erle U., Re pegier M., Persch C., and Schubert H. (2000), "Dielectric Properties of Emulsion and Suspensions: Mixture Equations and Measurement Comparisons", Inter. Microwave power Institute.
17. Hippel A.R. (1954), "Dielectric Materials and Applications", MIT Press, Cambridge, MA.
18. Hanai T., Koizumi N., and Gotoh R., 1962, "Dielectric Constants of Emulsions", Bull. Inst. Chem. Res., Kyoto Univ., 40: 240.