Indexed in
Scopus Compendex and Geobase Elsevier,
Geo-Ref Information Services-USA, List B of Scientific
Journals, Poland, Directory of Research Journals

International Journal of Earth Sciences and Engineering

www.cafetinnova.org

ISSN 0974-5904, Volume 09, No. 01

February 2016, P.P. 22-24

Effects of Kaolinite Clay on Omani Heavy-Oil Rheology in Considering Enhanced Oil Recovery by Steam Injection

IBRAHIM AL HADABI, KYURO SASAKI AND YUICHI SUGAI
Department of Earth Resources Engineering, Faculty of Engineering Kyushu University, Fukuoka, Japan
***Email:** Ibrahim.hadabi@gmail.com, krsasaki@mine.kyushu-u.ac.jp, sugai@mine.kyushu-u.ac.jp*

Abstract: The presence of clays in the reservoir plays an important role in EOR applications. The focus of this paper is to characterize the heavy oil rheology behaviour with the presence of kaolinite clay mineral in considering an EOR process using steam injection. The effect of the kaolinite clay concentration has been investigated for viscosity changes in heavy oil and its water-in-oil emulsion formed after steam injection. The clay mineral used in this study is powder kaolinite clay for the Omani heavy-crude oil with 21 °API at 23 ºC. A viscosity was measured to understand the rheology changes by including kaolinite in the original heavy oil and its water-in-oil emulsion formed after steam injection. The experimental results showed that presence of kaolinite clay in the heavy oil results in reducing the viscosity of heavy crude oil and its emulsion at high share rate.

***Keywords:** Steam injection, EOR, kaolinite, viscosity, rheology, shear rate.*

1. Introduction

Thermal oil recovery process is one of effective EOR technologies to recover heavy oil. Most oil and gas sand reservoirs contain certain quantities of clays [1]. Different types of clays were found in the reservoirs for instance the main types montmorillonite, kaolinite and illite. During steam injection, the formation of the reservoir is exposed in higher temperature for long period, then there is a possibility that damage may occur following fines migration, dissolution, and precipitation of new phases [2]. Kaolinite could produce illite after 75 days at 35 ºC, and at 80 ºC in 15 days in highly alkaline KOH solution [3]. A chemical reaction is expected during steam injection and it may play an important role in changing the formation gaseous component [4]. It was reported that during steam injection in to heavy crude oil, the interpretation effect in the presence of minerals results on oil composition alteration [5]. Other studies concentrated their research on minerals modification of reservoir rocks such as permeability, porosity and wettability [4]. All of these studies have shown that mineralogy plays a major role in the process of thermal recovery of heavy oil. In sandstone reservoirs kaolin minerals plays a petrogenetic role that is it still debated in petroleum explorations [6].

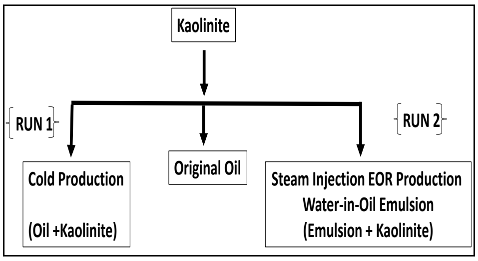

***Fig. A.** Present research frame (RUN 1 and 2).*

The schematic diagram of present research frame on the measurements (Fig. A.) divided in tow runs. RUN 1 considered the cold production of heavy oil containing kaolinite, whilst RUN 2 is for water-in-oil emulsion that is used to be observed in produced fluids by a thermal process using steam injection.

In this paper, we have investigated the effects of kaolinite clay mineral included in heavy-oil and water-in-oil emulsion on their viscosity changes in cold production and thermal production by steam stimulation.

2. Materials and Methods

An Omani heavy crude oil (21 °API at 23 ºC) was used in this study. To understand the interaction between kaolinite clay and heavy oil, different concentrations of kaolinite were mixed in the crude oil in a bottle. To mix the sample properly, sample were heated in a water bath at 80 ºC for five-minutes then shaken for 5 five-minutes using a mixer (Vortex-Genie 2) at 600 rpm.

To investigate the effect of kaolinite on heavy-oil-recovery by steam injection, the clay were mixed with the heavy-crude oil, then the steam were injected in to the mixture with forming water-in-oil emulation by steam injection (water/oil ratio=1:1).

In the experiments, the samples including kaolinite (Fig. B.) were prepared by mixing kaolinite clay powder into heavy oil with different concentrations in oil that are 0.99, 2.9, 4.8 and 9.0 wt%.

The sample of water-in-oil emulsion consisting steam-condensed water and heavy oil including 9.0wt% of kaolinite were formed by injecting seam into mixture of oil and kaolinite clay.

The viscosity measurements were carried by using a viscometer (Brookfield Model DV-I Prime) with a thermos-cell to control the fluids temperature. The viscosity of the original oil samples was measured at 50 ºC.

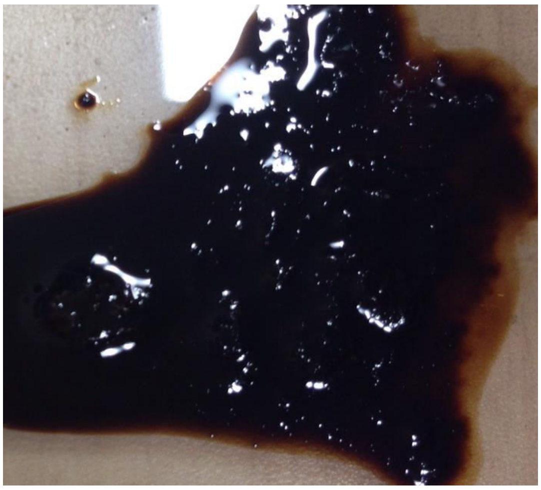

Fig. B. *Heavy oil sample (kaolinite clay; 9.0wt% in oil)*

3. Results and Discussion

3.1. Viscosity of original heavy oi and its mixture with kaolinite clay (RUN 1)

To establish a base line for comparisons, the mixtures of heavy oil and kaolinite clay powder with different concentrations were measured under the same conditions (mixing time, heating time, measuring time, and oil volume) as those of the emulsion formed by steam injection.

The measurement results of viscosity vs. temperature for the mixture of heavy oil and kaolinite clay are shown in (Fig. 1). The higher the kaolinite clay concentration the lower the viscosity observed compared with the original heavy-crude oil at reservoir temperature condition 40°C to 50°C, and the largest difference between lines for constant kaolinite clay concentrations was observed at 50ºC.

3.2. Viscosity of emulsion including kaolinite clay (RUN 2)

As well as for the case of the emulsion sample formed by steam injection, the emulsion viscosity was decreased with including of kaolinite clay (9.0wt% in Oil) as shown in Figure 4. The viscosity of the emulsion was higher even than the original oil viscosity due to fine water droplets in the emulsions. This could be linked to some reasons discussed in a previous study by Bennion and Thomas (1992).

They found that kaolinite clay is converted in to smectite at high temperature and zeta potential of the kaolinite clay becomes more negative with the temperature increase. These reasons could be clay particles to segregate carrying oil with them and changing surface to water-wet [8]. The increase of the temperature would lead to decrease the salt concentration due to condensed water. It makes an effect that zeta potential increases and stabilization of dispersion as well as to enhance particle mobility [2].

Furthermore the temperature rise changes the surface wettability to be more water-wet [9]. The emulsion with kaolinite clay are more stable than those without kaolinite clay (Fig. 2). Wang and Alvarado (2011) found the emulsion with kaolinite clay are more stable than the emulsion without kaolinite clay by different brine tested [10].

3.3. Viscosity variation with shear rate

As shown in (Fig. 3), viscosities of the original heavy oil and its water-in-oil emulsion without any additions of kaolinite clay are constant with increasing the share rate, because their characteristics are Newtonian fluid. On the other hand, the viscosity of the emulsion including 5wt% (9.0wt% in Oil) decreased with the increasing of shear rate because of thixotropic flow by including kaolinite clay. At low share rate, the variation of viscosity was high and at higher shear rate the viscosity values tend to stabilization. Barbato (2008) reported the similar rheology behaviour of kaolin slurries without deflocculant.

4. Discussion and Conclusion

Understanding rheological behaviours of heavy oil and its water-in-oil emulsion including clay minerals is important for steam injection EOR process for heavy-crude oil reservoirs. In this study, effects of the kaolinite clay concentration in heavy oil were investigated by measuring the viscosity of oil at the reservoir temperature condition. The presence of kaolinite clay in heavy-crude oil would help to reduce the viscosities original of original heavy oil and its water-in-oil emulsion formed during the steam injection process. These reductions in viscosities of heavy oil and its emulsion are due to including kaolinite clay content especially under the conditions temperature increases by stream injection. Also the effects of shear rate on the viscosity of the heavy oil, emulsion including kaolinite clay were measured. The viscosity was decreasing as the shear rate increases (thixotropic flow) and the viscosity values tend to stabilize at high shear rate. The presence of kaolinite clay in heavy oil or its emulsion has an effect on their viscosity and mobility.

Further investigation need to be done on the wettability alteration, asphalting precipitation effect and distillation of heavy oil effect be minerals. Also, the impact of other types of clay needs to be investigated for steam injection EOR.

5. Acknowledgements

The author acknowledges the financial assistance by the Mitsubishi Corporation, for doing his PhD.

References

[1] Johnston N., (1952) "Role of Clay in Oil Reservoirs" International Journal of Clays Clay Minererals, ISSN 0009-8604, Vol. 1, No. 1, 1952 pp 306–313

[2] Wilson M., Wilson L., Patey I., (2014) "The influence of individual clay minerals on formation damage of reservoir sandstones: a critical review with some new insights" International Journal of Clay Minerals, ISSN 0009-8558, Vol. 49, No. 2, April 2014, pp 147–164

[3] Bauer A., Velde B., Berger G., (1998), "Kaolinite transformation in high molar KOH solutions" International Journal of Applied Geochemistry, ISSN 0883-2927, Vol. 13, No. 5, July 1988, pp 619–629

[4] Monin J. C., Audibert A., (1987) "Thermal Cracking of Heavy Oil/Mineral Matrix Systems" International Symposium on Oilfield Chemistry, SPE 16269, ISSN 0891-0901, January 1987

[5] Monin J. C., Audibert A., (1984) "Alteration of heavy crudes under high pressure steam conditions" Preprints - American Chemical Society. Division of Petroleum Chemistry, ISSN 0569-3799, Vol. 29, No. 4, 1984, pp 1223–1231

[6] Beaufort D., (1998), "Kaolinite-to-Dickite Reaction in Sandstone Reservoirs" International Journal of Clay Minerals, ISSN 0009-8558, Vol. 33, No. 2, 1998, pp 297–316

[7] Bennion D. B., Thomas F. B., Sheppard D. A., (1992), "Formation Damage Due to Mineral Alteration and Wettability Changes During Hot Water and Steam Injection in Clay-Bearing Sandstone Reservoirs" Formation Damage Control Symposium, SPE 23783, January 1992, pp 165-177

[8] Schembre M., Kovscek R., (2005) "Effect of Temperature on Relative Permeability for Heavy-Oil Diatomite Reservoirs" Western Regional Meeting, SPE 93831, March 2005, pp 1–8

[9] Punase A. , Zou A., Elputranto R., (2014) "How Do Thermal Recovery Methods Affect Wettability Alteration ?", Journal of Society of Petroleum Engineering, SPE 35462, April 2014, pp 623-640

[10] Wang X., Alvarado V., (2011) "Kaolinite and silica dispersions in low-salinity environments: Impact on a water-in-crude oil emulsion stability" Energies, Vol. 4, No. 10, 2011, pp 1763–1778

[11] Barbato C. N., Nele M., Pinto J. C., França S. C. a., (2008) "Studies of kaolin rheology" IX Jornadas Argentinas de Tratamiento de Minerales, January 2008, pp 1-11

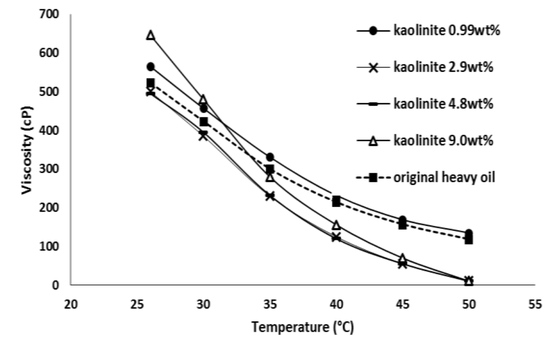

Fig.1. Effect of kaolinite clay concentration on heavy-oil viscosity at variable temperature

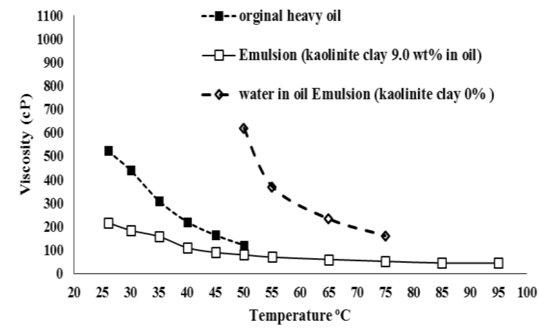

Fig.2. Effect of kaolinite clay concentration on heavy-oil viscosity at variable temperature

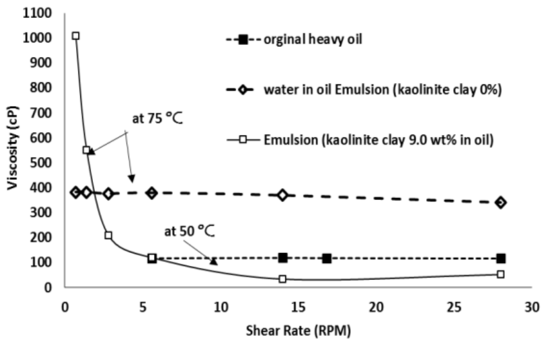

Fig.3. Effect of kaolinite clay concentration on heavy-oil viscosity at variable temperature