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Measurement of Isoelectric Point of Sandstone and Carbonate Rock for Monitoring Water Encroachment

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Abstract: Excessive water production is one of the main problems in oilfields. Isoelectric point (IEP) is defined as the point of pH at which a solid surface, such as sandstone or carbonate rock, submerged in an electrolyte, exhibits zero net charge. Previous studies reported different values of IEP for carbonate and sandstone rocks, mostly utilizing the electrophoresis technique. Precise values of IEP for both types of reservoir rocks need to be investigated in order to interpret the streaming potential signal. Recently, streaming potential measurement has been proposed to be applied in managing oilfields. By combination of intelligent well technology and streaming potential measurement, water encroachment will be able to be detected proactively. The IEP measurement will start in low salinity (1×10^{-3} M), seawater salinity (0.6 M) and high salinity (5.5 M) brine solutions. The voltage measurements will be recorded continuously by National Instrument Data Acquisition System using Labview software. Values of IEP were determined from a plot of voltage against pH for every run. Measured values of IEP for both carbonate and sandstone rocks were lied in range of 9.40-9.60 and 2.2-2.8, respectively. As the pH of the flowing fluid get closer to the IEP, the surface charge becomes smaller and so does the magnitude of the streaming potential. The knowledge of the IEP values for both types of reservoir rocks plays a crucial role in understanding the ion-sorption processes at the mineral and solution interface. Having the understanding will enable the streaming potential signal to be interpreted accurately. As a result, water encroachment issue will be overcome efficiently.

Key words: IEP, sand stone, carbonate rock, streaming potential

INTRODUCTION

One of the major problems encountered in the reservoir management is excessive water production which may reduce the oil production. At the same time, the produced water must be treated, which caused the increment in handling and operating costs. Most of prolific oil production and giant oilfield are in sandstone and carbonate reservoirs. Generally, sandstones exhibit higher permeability and porosity characteristic compared to carbonate rocks. Based on the porosity characteristic, the streaming potential method is applicable to measure the isoelectric point (IEP) for both of the reservoir rocks. Jackson *et al.* (2005) suggested that streaming potential measurement could be applied in 'smart well' by installing permanent downhole electrodes. This idea was supported by Navarro *et al.* (2006) by two successful field test of streaming potential measurement in a horizontal oil production and in a vertical water injection. The combination of 'smart well' technology and streaming potential measurement could be used to improve the reservoir management in monitoring the water encroachment.

According to Hunter (1981), streaming potential arise from flow of fluid in porous media, this is due to the excess charges in the diffuse layer being dragged with the flow of the fluid. Streaming potential is one of the electromagnetic phenomena resulted from the Electrical Double Layer (EDL) model (Fig. 1) which consists of a stationary layer (Stern layer) and diffuse layer (Gouy-Chapman layer) which was started by Davis *et al.* (1978). In case of reservoir rocks and formation fluid, the EDL formed on the surface of mineral comprising the rock and a diffuse layer on the aqueous side of this interface that extends into liquid phase. The potential at this shear plane is commonly called as a charge on the surface or zeta potential (ξ).

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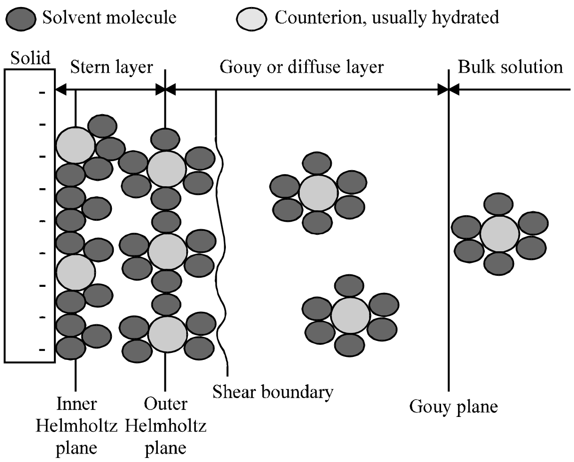

Fig. 1: Electrical double layer model (Railsback, 2006)

However, there are few significant uncertainties in the interpretation of streaming potential measurements, particularly concerning the IEP and streaming potential coupling coefficient of the carbonate and sandstone rocks. The IEP is defined as the pH at which a solid submerged in an electrolyte exhibits zero net charge at the surface of a solid. If the pH of the flowing fluid adjacent to the reservoir rock surface is above IEP of the rock, the rock surface will have a negative charge and if the pH of the flowing fluid adjacent to the reservoir rock surface is below IEP of the rock, the rock surface will have positive charge.

Incorrect values of IEP could lead to an overestimation or underestimation of the magnitude of streaming potential. As a result, poor data interpretation will be obtained, which lead to bad reservoir management decisions including management of water production. Previous studies recorded different values of IEP based on different methods. For precise streaming potential data interpretation, the concept of IEP must be well understood in order to study the ion-sorption processes at the mineral and solution interface. The aim of this study is to determine the precise value of IEP for sandstone and carbonate rocks at low and high salinity of brines.

MATERIALS AND METHODS

Materials: The core samples were obtained from Petronas Geo Sample Center (PGSC) and originated from Baram field, Sarawak. The core samples were cut into cylindrical samples. Porosity and permeability of both rocks were determined by using gas parameters and helium parameters, respectively. Sandstone rocks recorded porosity of 11.76% and permeability of 344 mD. Carbonate rocks recorded extremely low porosity and permeability which was only 2.08% and 19.6 mD, respectively. Based on these characteristic, an artificial hole was made up, new porosity and permeability of carbonate rock were recorded as shown in Table 1. Table 1 summarized the properties of both of the reservoir rocks.

Table 1: Properties of carbonate and sandstone rocks

Core sample	Carbonate rock	Sandstone rock
Diameter (mm)	34.36	34.23
Length (mm)	55.06	75.11
Bulk volume (cm^3)	51.06	69.13
Porosity (%)	5.99	11.76
Permeability (mD)	67512.00	344.00

Table 2: Brine specification for sandstone rock

	pH (±0.02)								
Salinity (M)	1	2	3	4	5	6	7	8	9
0.001	SA1	SA2	SA3	SA4	SA5	SA6	SA7	SA8	SA9
0.600	SB1	SB2	SB3	SB4	SB5	SB6	SB7	SB8	SB9
5.000	SC1	SC2	SC3	SC4	SC5	SC6	SC7	SC8	SC9

Table 3: Brine specification for carbonate rock

	pH (±0.02)								
Salinity (M)	4	5	6	7	8	9	10	11	12
0.001	CA4	CA5	CA6	CA7	CA8	CA9	CA10	CA11	CA12
0.600	CB4	CB5	CB6	CB7	CB8	CB9	CB10	CB11	CB12
5.000	CC4	CC5	CC6	CC7	CC8	CC9	CC10	CC11	CC12

Brine solutions were prepared from sodium chloride (NaCl) to avoid multiple ion interactions as described by Alotaibi *et al.* (2011). Concentrated hydrochloric acid (HCl) and sodium hydroxide (NaOH) were added into the brine to obtain the desired pH. Table 2 and 3 shows the specification of salinity and pH for sandstone and carbonate rocks, respectively.

Before any pumping, the core sample was saturated with the selected brine by submerging it into the brine solution in a beaker which was then left in a vacuum pump overnight. This step is necessary to remove air from the core. In exchange, the brine was filled up the pore volume of the core sample.

Experimental set-up: This study adopt experimental setup used by Jaafar *et al.* (2009). Based on Fig. 2, both columns were filled with brine and synthetic oil until there has an interface between oil and brine. Synthetic oil was used as a hydraulic fluid to push the brine through the sample by using the Quizix QL700 pump. The core sample was located in the core holder with a confining pressure of 250 psi to allow the brine flow only in the axial direction from one end to another. The pH of the brine was checked by Eutech Instrument PCD650 pH meter before and after passing through the core sample.

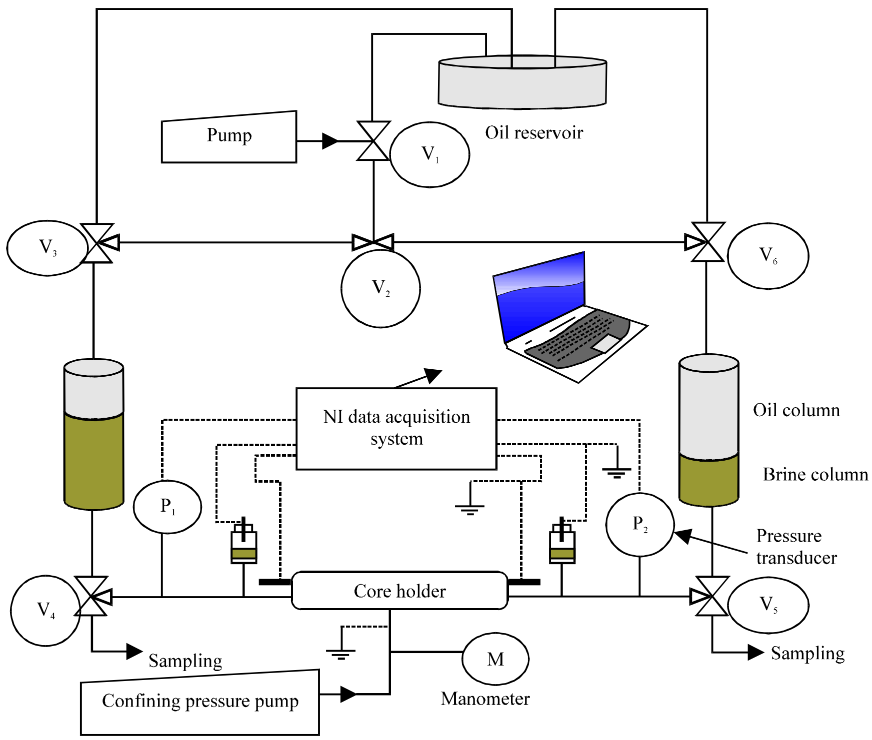

Fig. 2: Experimental set-up for streaming potential measurement which inspired by Jaafar *et al.* (2009)

Once the pH equilibrated, the streaming potential was measured by electrodes which are connected to NI9219 (National Instrument Universal Analog Input) voltmeter and LabVIEW (Laboratory Virtual Instrument Engineering Workbench) software. A plot of voltage versus time was generated for every run. Average voltages for every pH at specified salinity were determined. Plot of voltage against pH for all salinities were analyzed to determine IEP of the core samples.

RESULTS AND DISCUSSION

The precise values of IEP for both carbonate and sandstone rocks could assist in streaming potential data interpretation. When the pH of flowing fluid passed through the core is approaching IEP of the core, the reading of streaming potential will gradually decrease until zero thus give a small reading of streaming potential signal. Even amplification of streaming potential reading available, there is uncertainty where previous studies recorded different values of IEP at different salinity of brine.

Many authors have proposed different values of IEP for carbonate and sandstone by using different methods. Farooq *et al.* (2011) stated IEP of sandstone lies in a range of 2.9-3.3, Lorne (1999) 2.4-2.6, Scales *et al.* (1992) 2.6-3.0 and Cerda and Non-Chhom (1989) 3.5-4.0. While Alotaibi *et al.* (2011) mentioned in his study, IEP for carbonate lies in the range 9.8-11.9, while Farooq *et al.* (2011) stated the range is between 8.2-8.5.

IEP of both of the cores were measured by a wide range of pH at various salinities. In this study, IEP of the core samples was determined in a more straightforward way. Changes in the sign of voltage based on the plot of voltage against pH at various salinities were considered as the point where the surface charge is zero.

Based on Fig. 3, the PZC of sandstone rock was determined at 2.20 at high salinity brine. At seawater and low salinity of brine, PZC is at pH 2.80 and 2.30, respectively.

Based on Fig. 4, IEP for carbonate rock was determined at pH 9.40 at seawater salinity brine. At low and high salinity of brine, the IEP is at pH 9.60. Comparison between the IEP values of the carbonate and sandstone rocks could be seen clearly from the plot in Fig. 5.

As salinity of brine increases, the magnitude of the measured streaming potential coupling coefficient (C) decreases as predicted by model of the Electrical Double Layer (EDL), since the EDL will compressed at higher salt concentrations. These IEP values could explain the difference in value of streaming potential coupling coefficient for carbonate and sandstone rocks.

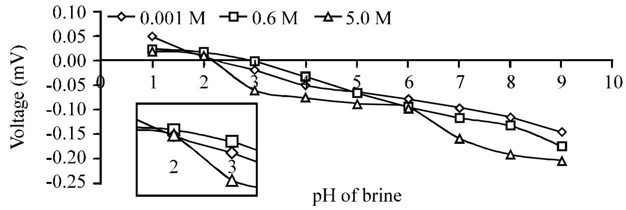

Fig. 3: Plot of voltage against pH for sandstone rocks

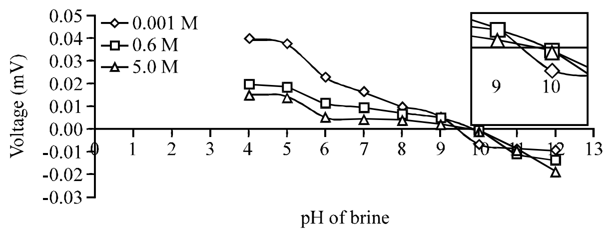

Fig. 4: Plot of voltage against pH for carbonate rocks

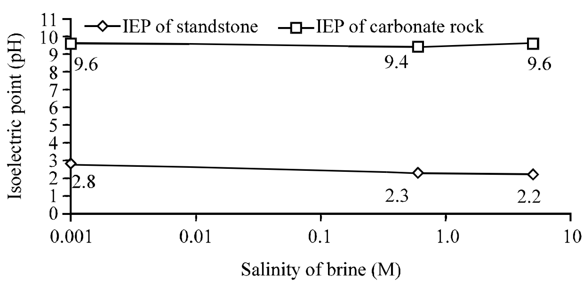

Fig. 5: Plot of isoelectric point against salinity

Recent studies conducted by Jaafar and Pourbasirat (2011) recorded small value of streaming potential coupling coefficient for carbonate compared to sandstone rocks. The difference of C is based on the IEP value of the sandstone and carbonate rocks which lies in the range of pH 2.20-2.80 and pH 9.40-9.60, respectively. Since IEP of carbonate is closer to the seawater pH which is around pH 7.00, the surface charge on the carbonate rock might be smaller compared to the one in sandstone. Therefore, there will be less countercharge in the diffuse layer, which results in a lower streaming potential signal in carbonate rocks.

CONCLUSION

Several conclusions could be drawn through this study. By using the streaming potential method, the isoelectric point of sandstone lied in the range of 2.20-2.80 while, point of zero charge of carbonate lied in the range 9.40-9.60. IEP values for both of the rocks were determined from low salinity of the brine up to the high salinity of brine. The precise values of IEP could prevent the misinterpretation of the precise date of streaming potential signals. Thus, water encroachment could be managed very well and intervention costs such as separation and disposal of water from hydrocarbon could be reduced. Better water control also leads to efficient oil production and maximum reservoir production.

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