International Journal of Petroleum & Geoscience Engineering (IJPGE) 1 (2): 82-90, 2013
ISSN 2289-4713

Research Article

Point of Zero Charge for Sandstone and Carbonate Rocks by Streaming Potential

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ARTICLE INFO

Accepted:
7 July 2013

Keywords:
Streaming potential
Point of zero charge
Reservoir rock

A b s t r a c t

Point of zero charge (PZC) is defined as the PH at which a solid surface submerged in an electrolyte, exhibits zero net charge. Previous studies have reported different values of PZC for carbonate and sandstone rocks, mostly utilizing the electrophoresis technique. The aim of this study is to investigate and verify the PZC of carbonate and sandstone rocks. The PZC measurements were conducted in various brine salinities. Voltage measurements were recorded at a sampling rate of 1 Hertz by the National Instrument Data Acquisition System, using LabVIEW software. The PZC for both carbonate and sandstone rocks has been observed in the range of 9.40 to 9.70 and 2.2 to 2.9 respectively. As streaming potential measurement has been proposed to monitor water encroachment, having the understanding of PZC value will enable the signal to be interpreted more accurately. As a result, water encroachment issue will be overcome efficiently.

1. Introduction

One of the major problems encountered in the reservoir management is excessive of 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 point of zero charge (PZC) 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 [1]. This idea was supported by

Chen, et al. (2006) by two successful field test of streaming potential measurement in a horizontal oil production and in a vertical water injection [2]. The combination of 'smart well' technology and streaming potential measurement could be used to improve the reservoir management in monitoring the water encroachment.

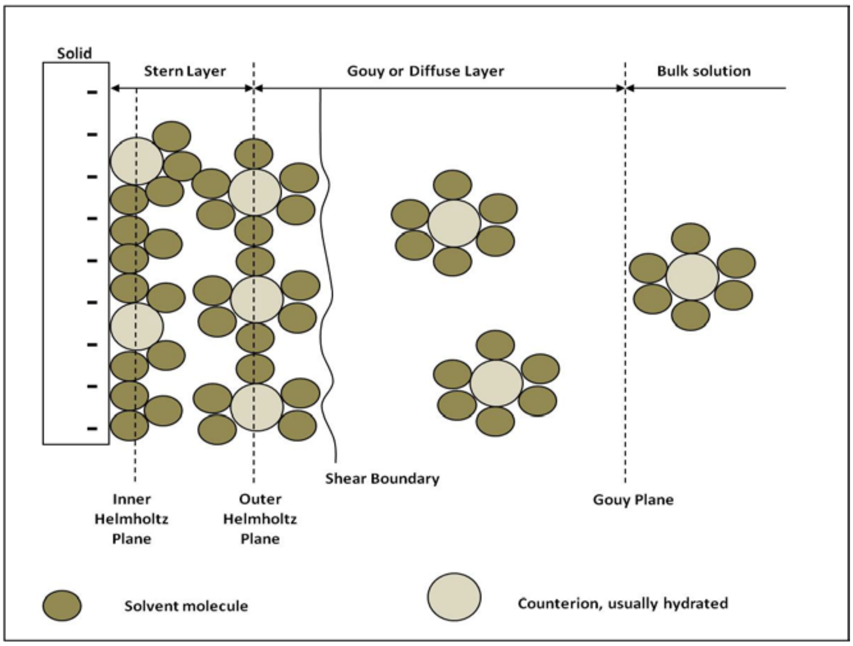

Fig. 1. Electrical Double Layer model (after Railsback, 2006) [5].

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 [3]. Streaming potential is one of the electromagnetic phenomena resulted from the Electrical Double Layer (EDL) model (Figure 1) which consists of a stationary layer (Stern layer) and diffuse layer (Gouy-Chapman layer) which started by Davis, et al. (1978) [4]. 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 (ζ).

However, there are few significant uncertainties in the interpretation of streaming potential measurements, particularly concerning the PZC and streaming potential coupling coefficient of the carbonate and sandstone rocks. The PZC is defined as the pH at which a solid submerged in an electrolyte exhibits zero net charge at the surface of a solid (Figure 2). If the pH of the flowing fluid adjacent to the reservoir rock surface is above PZC 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 PZC of the rock, the rock surface will have positive charge [6].

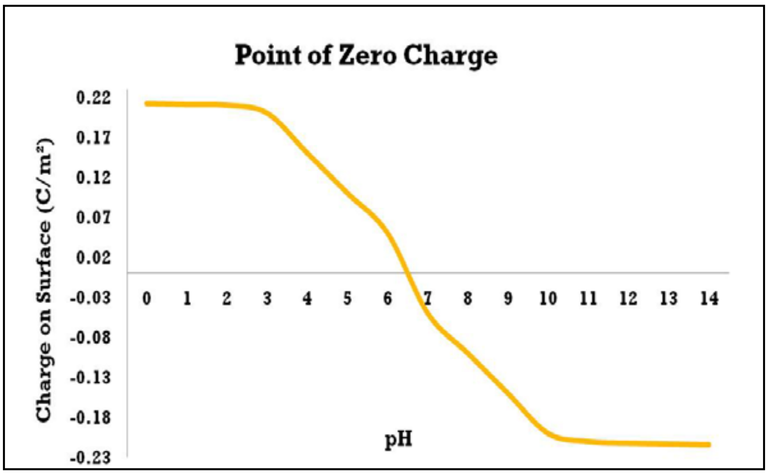

Fig. 2. A plot of charge on surface (zeta potential, ζ) against pH [6].

Incorrect values of PZC 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 PZC based on different methods. For precise streaming potential data interpretation, the concept of PZC must be well understood in order to study the ion-sorption processes at the mineral and solution interface. The aim of this work is to determine the precise value of PZC for sandstone and carbonate rocks at low and high salinity of brines.

2. Methodology

2.1. Materials

Core samples were cut into cylindrical shape with a diameter of 1.5 inches and a length of 3.0 inches. Porosity and permeability of both rocks were determined by using gas parameters and helium parameters respectively. Sandstone rocks recorded porosity of 30.82% and permeability of 326.63mD. Carbonate rocks recorded extremely low porosity and permeability. Based on this characteristic, an artificial hole was made up.

Brine solutions were prepared from sodium chloride (NaCl) to avoid multiple ion interactions [7]. Concentrated hydrochloric acid, HCl and sodium hydroxide, NaOH were added into the brine to obtain the desired pH. Table 1 and 2 shows the specification of salinity and pH for sandstone and carbonate rocks respectively.

Table.1: Brine specification for sandstone.

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

Table.2: Brine specification for carbonate.

Salinity (M)	PH								
	4	5	6	7	8	9	10	11	12
0.001	TA4	TA5	TA6	TA7	TA8	TA9	TA10	TA11	TA12
0.6	TB4	TB5	TB6	TB7	TB8	TB9	TB10	TB11	TB12
5.0	TC4	TC5	TC6	TC7	TC8	TC9	TC10	TC11	TC12

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 has filled up the pore volume of the core sample.

2.2 Experimental set-up

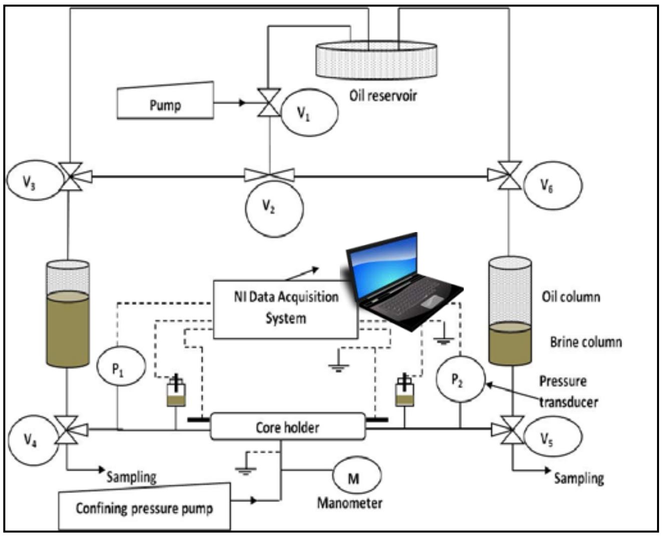

Fig. 3. Experimental set-up for streaming potential measurement [8].

Based on Figure 3, 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 a syringe pump. The core sample was located in the core holder with a confining pressure of 250psi to allow the brine flow only in the axial direction from one end to another. The pH of the brine was checked before and after passing through the core sample.

Once the pH equilibrated, the voltages from external and internal electrodes were recorded at a frequency of 1 Hertz by the National Instrument Data Acquisition System (NIDAS) LabVIEW 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 PZC of the core samples.

3. Results and discussion

The precise values of PZC 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 PZC 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 PZC at different salinity of brine.

Many authors have proposed different values of PZC for carbonate and sandstone by using different methods. Farooq, et al., (2011) stated PZC of sandstone lies in a range of 2.9 to 3.3 [9]. Lorne, et al., (1999) 2.4 to 2.6; Scale, et al., (1992) 2.6 to 3.0 and Cerda and Non-Chhom (1989) 3.5 to 4.0 [10, 11, 12]. While Alotaibi (2011) mentioned in his paper, PZC for carbonate lies in the range 9.8 to 11.9, while Farooq, et al. (2011) stated the range is between 8.2 to 8.5 [7, 9].

PZC of both of the cores were measured by a wide range of pH at various salinities. In this work, PZC 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.

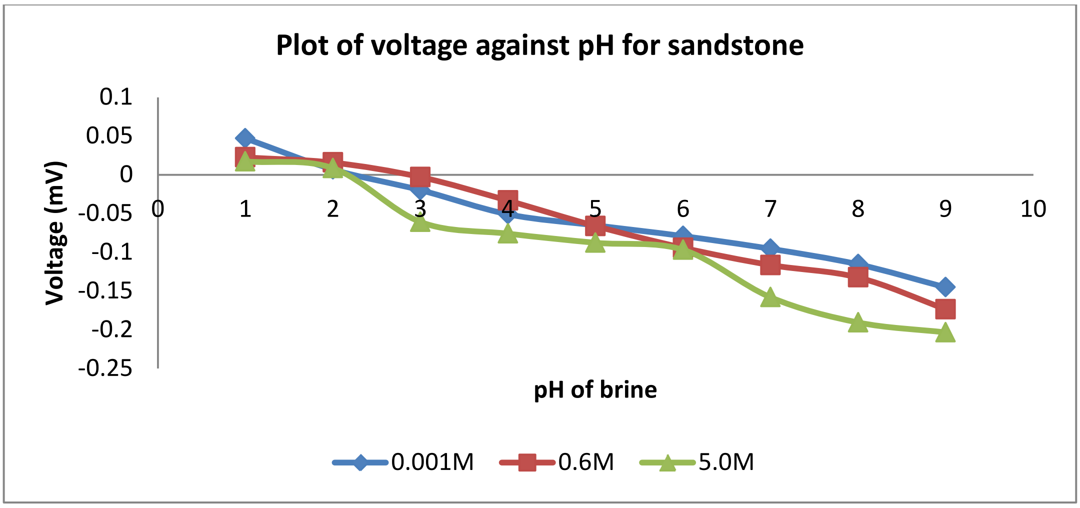

Fig. 4. Plot of voltage against pH for sandstone rocks.

Based on figure 4, the PZC for sandstone was determined at pH 2.20 at salinity 0.001M and 5.0M, while at seawater salinity brine, PZC value recorded at pH 2.90.

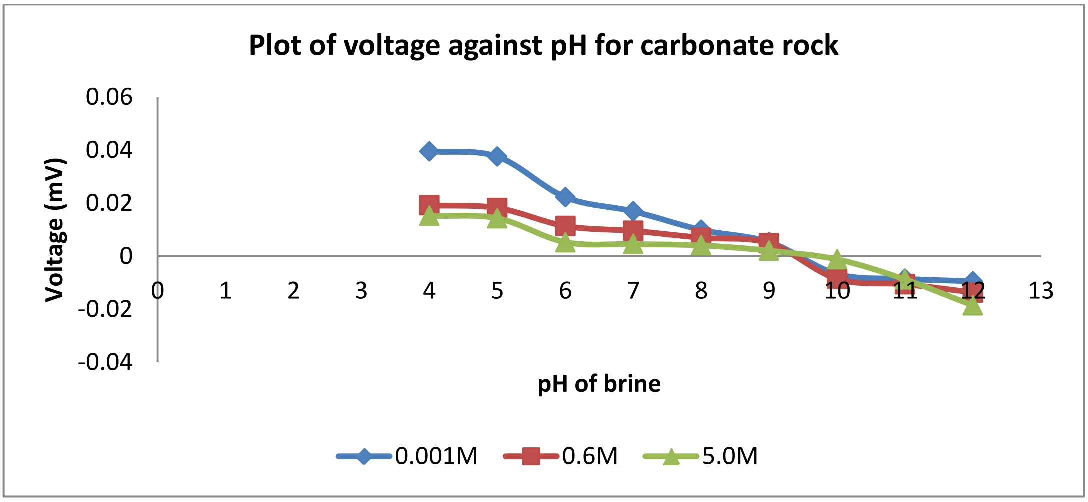

Fig. 5. Plot of voltage against pH for carbonate rocks.

Based on Figure 5, PZC for carbonate rock was determined at pH 9.70 at high salinity brine. At seawater and low salinity of brine, the PZC is at pH 9.40. Comparison between the PZC values of the carbonate and sandstone rocks could be seen clearly from the plot in Figure 6.

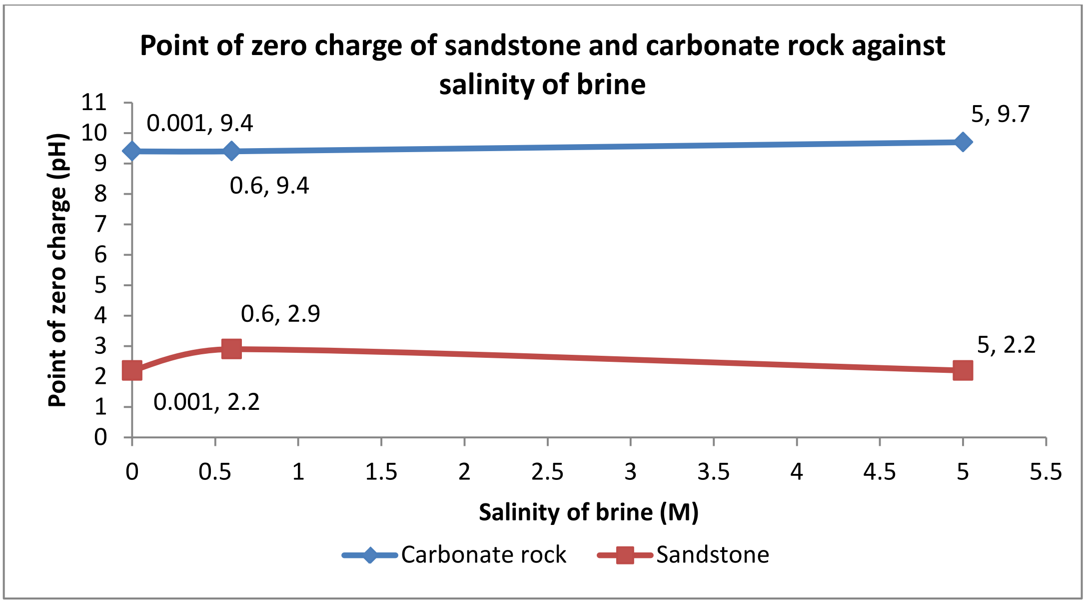

Fig. 6. Plot of point of zero charge against salinity.

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 PZC values could explain the difference in value of streaming potential coupling coefficient for carbonate and sandstone rocks.

Recent studies conducted by Jaafar and Pourbasirat (2011) which recorded small value of streaming potential coupling coefficient for carbonate compared to sandstone rocks [13]. The difference of *C* is based on the PZC value of the sandstone and carbonate rocks which lies in the range of PH 2.20 to 2.90 and pH 9.40 to 9.70 respectively. Since PZC of carbonate is closer to the brine 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.

4. Conclusions

Several conclusions could be drawn through this research. By using the streaming potential method, the point of zero charge of sandstone lied in the range of 2.20 to 2.90 while point of zero charge of carbonate lied in the range 9.40 to 9.70. PZC values for both of the rocks were determined from low salinity of the brine up to the high salinity of brine. The correct values of PZC 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.

Acknowledgments

This work was funded by Malaysia’s Ministry of Higher Education (MOHE) for Universiti Teknologi Malaysia (UTM) under Research University Grant (Vot Number: 06J23).

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