Wettability – Interpreting the Myth

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PRELIMINARY COMMUNICATION

Wettability plays a significant role in the initial distribution of fluids, movement of fluids and as well as the displacement of one fluid by another, within the reservoir. Reservoirs wettability can range from extremely water-wet to extremely oil-wet. Wettability might be different in different parts of the reservoir at the time of discovery and can even change with the passage of time. So to properly understand the displacement behavior within the reservoir proper understanding of the type of wettability existing within a reservoir is very important, for optimized reservoir surveillance.

Key words: displacement, oil-wet, wettability, water-wet

1. Introduction

Wettability can be defined as the tendency of one fluid to spread on or adhere to a solid surface in the presence of other immiscible fluids.[5] When more than one immiscible fluid is present within the reservoir, then at least one of them will be the wetting phase. When the system will be in equilibrium, the wetting phase will completely occupy the smallest pore and be in contact with a majority of the rock surface, if the saturation of wetting fluid is sufficiently high. The non-wetting fluid will occupy the centers of the larger pores and will form globules that extend over several pores. The fluid, which occupies the larger pores have high relative permeability as compared to the fluid occupying the smaller pores.

2. Types of Wettability

Reservoirs can have different types of wettability depending on the adherence of the liquid with the pore surfaces. The following are the different types of wettabilities [2,8,23]:

- fully water wet
- fully oil wet
- intermediate wet
- fractionally wet

2.1. Fully Water Wet Rock

In this case water occupies[2,8] the small pores and contacts the majority of the rock surface. Perfect wetting state is the extreme wettability state also known as extremely water wet rock.

2.2. Fully Oil Wet Rock

In oil-wet system[2,8] the position of fluid is reversed from as in case of water-wet rock. In this case, oil occupies the smaller pores and spreads over the majority of the rock surface, while the water occupies the larger pores.

2.3. Intermediate or Neutrally Wet

This state exists when the rock has no strong preference[2,8] for either oil or water.

2.4. Fractional Wettability

Fractional wettability also known as heterogeneous, spotted, or Dalmation wettability.[4,8,11,12,14,16] In fractional wettability, crude oil components are strongly adsorbed in certain areas of the rock, so a portion of the rock is strongly oil-wet, while the rest is strongly water-wet.

The crude oil components which are adsorbed on rock surface are heavy oil components, known as surface-active components[7], like asphaltenes, which can precipitate due to several reasons like, depletion and adding a large volume of low-molecular-weight hydrocarbon to the crude oil, are some of them. For example, adding 40 volumes of pentane[19] in oil, will result into asphaltenes precipitation.

3. Different Ways of Expressing Wettability

To-date, different methods have been proposed and used for representing wettability[3,5,6,8,10,13,15,17,18,20,21] either in a qualitative or a quantitative way. Imbibition rates, microscope examination, flotation, glass slide method, relative permeability curves, permeability/ saturation relation-

Table 1. Approximate Relationship between wettability, contact angle and the USBM and Amott Wettability Indexes[3]

	Water-Wet	Neutrally-Wet	Oil-Wet
Contact angle (Degree)			
Minimum	0	60-75	105 - 120
Maximum	60 -75	105 - 120	180
USBM Wettability Index	W near 1	W near 0	W near -1
Amott Wettability Index			
Displacement-by-water ratio	Positive	Zero	Zero
Displacement-by-oil-ratio	Zero	Zero	Positive
Amott-Harvey wettability index	0.3 # / # 1.0	-0.3 < /< 0.3	-1.0 # / # -0.3

ships, capillary pressure curves, capillarimetric method, displacement capillary pressure, reservoir logs, nuclear magnetic resonance, and dye adsorption are the examples of qualitative methods, while contact angle measurement, forced displacement (Amott), and USBM wettability method are some of the most widely known and accepted way of representing wettability in quantitative way. By representing the wettability in a quantitative way, it is possible to interpret the type of wettability existing or the types of wettability co-existing within a reservoir.

3.1. Contact Angle Measurement for Determining Type of Wettability

Wettability can also be expressed in terms of angle of contact,"θ", between the smooth solid surface and the droplet. Idealized contact angles[19] are shown in figure 1, from strongly water wet case (θ = 0°) to extremely oil-wet case (θ = 180°).

3.2. Wettability Index

The second way of expressing wettability in a quantitative manner is in terms of wettability index[3,8] (*W.I.*). Wettability index ranges from +1 for extremely water-wet case to -1 for extremely oil-wet rock, while "θ" is for neutral wettability, when rock surface has no strong preference to the fluids present. To measure the wettability index several tests[1,3,8,9] are available, like Amott test, modified Amott test, USBM method, etc. When either the contact angle or the wettability index is known the second one can be calculated by using the cosine or cosine inverse, respectively.

The advantage of measuring wettability index is that, it gives the average wettability of the core, while the contact angle measurement is at localized scale, where it has been measured. Table 1, gives the idea of different ranges[3] of contact angle and wettability index with reference to wettability. Please note that the ranges of the contact angle and wettability index, can be different based on the properties of fluids involved and the characteristics of the rock surfaces, in addition to the different terms used to describe different types of wettability.

4. Discussion and Conclusion

Different reservoirs have different wettabilities or even different types of wettabilities can even co-exist within a reservoir and moreover the wettability existing at the time of discovery may change with time. Fluid distribution is different for different wettabilities, thus the fluid (oil or water) present in the larger pore have a tendency to move faster which will also impede the flow of other fluid. Therefore, for proper field development/ extension and selection of enhanced oil recovery methods, correct type(s) of wettability which exists within a reservoir, should be known.

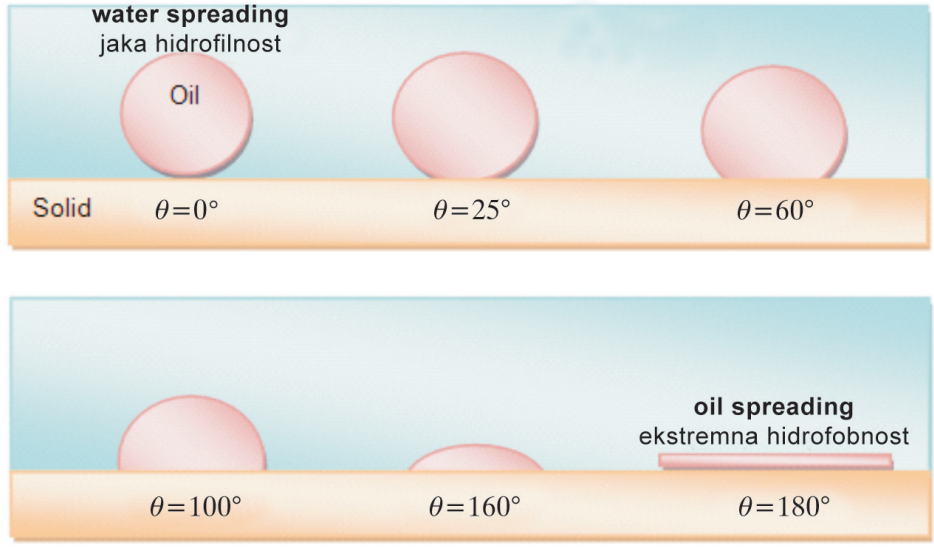

Fig. 1. Contact Angles at smooth solid surface
Sl. 1. Rubni kutovi na glatkoj čvrstoj površini

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6. Nomenclature

W.I. – wettability index

θ – conatct angle, degrees

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