KPU International Journal of Engineering & Technology
Volume 1, Issue1,
September 2021

Date Received: 2021-03-20
Date Accepted: 2021-06-16
Date Published: 2021-09-30

Open Access

Permeability And Relative Permeability Analysis of Aptian Sandstone Reservoir of Kashkari Oil Field In Northern Afghanistan

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Abstract:

The purpose of this research is to analyze the permeability and relative permeability of oil and water in Aptian sandstone reservoir of Kashkari oil field, which is located in Amu-Darya basin in northern Afghanistan. Analysis of relative permeabilities of oil and water are important issues in petroleum reservoir engineering, specifically to evaluate the amount of irreducible water, residual oil and recoverable oil from a petroleum reservoir. The improvement in exploitation efficiency, which allows the maximum production of oil from the reservoir, has become significantly important. The oil production of Kashkari oil field is basically influenced by groundwater. Furthermore, water fingering is one of the challengeable problems in the petroleum industry, during oil exploitation and oil recovery. Kashkari oil field has four oil reservoirs such as; Albian (XIa), upper Aptian (XIIa), lower Aptian (XIIb), and Hauterivian (XVI), only upper Aptian (XIIa) reservoir is explored in this paper. Unfortunately, not enough exploitation work has been done, especially for analyzing of permeability and relative permeability of oil and water in the Aptian sandstone reservoir. Therefore, this research is carried out to empirical determine the permeability and relative permeability of oil and water in Aptian sandstone reservoir of Kashkari oil field. The samples (cores) are taken out from a new well 21st of upper Aptian sandstone reservoir in Kashkari oil field. Afterward, the samples of Aptian reservoir are shipped intact from Northern Directorate of Hydrocarbon Unit in Sheberghan province to Tokai University for analyzing of permeability, relative permeability, and other physical properties. In laboratory falling head test is performed for determining of absolute permeability and also the steady-state laboratory experiments are done for analyzing of relative permeability.

Finally, the permeability, relative permeability, irreducible water saturation, residual oil saturation, average water saturation, front flow water saturation, and the fractional flow of water are obtained in Aptian sandstone reservoir of Kashkari oil field.

Keywords: Kashkari Oil Field, Permeability Analysis, Relative Permeability,

Introduction

Exploitation and recovery of oil is a challenging issue in the petroleum industry. Permeability, relative permeability, oil and water saturation, and pressures are the parameters that influence oil exploitation and oil recovery. The water fingering is one of the challenging problems during the oil exploitation, oil recovery, and another comprehensive problem is, to exactly evaluate the amount of recoverable oil from a petroleum reservoir. The better ways to mitigate these problems are to empirically analyze the important parameters before the events occur.

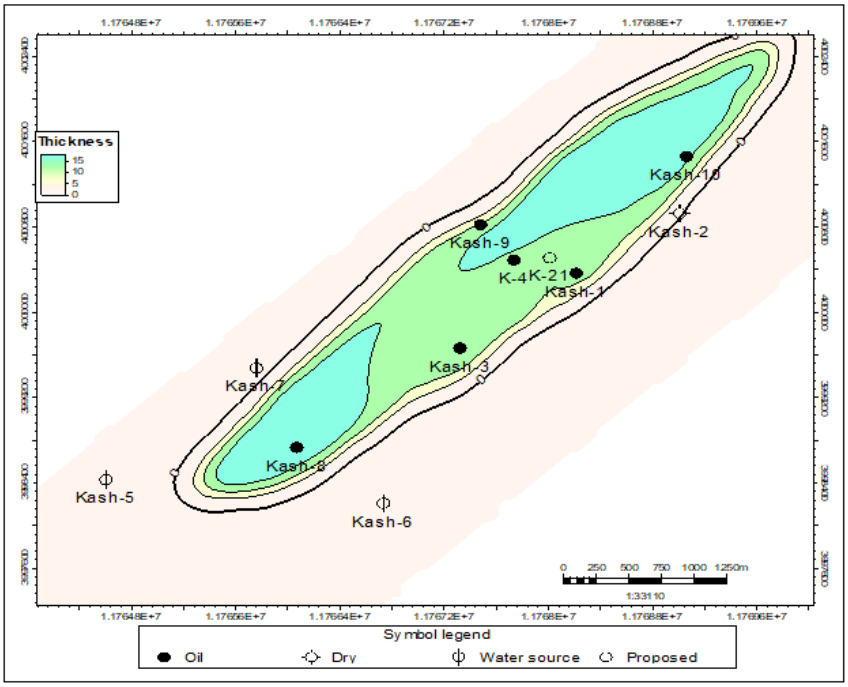
The purpose of this study is to empirically analyze the permeability and relative permeability of oil and water in upper Aptian sandstone reservoir of Kashkari oil field. The cores (samples) had held from upper Aptian sandstone reservoir of a new well No 21st which has drilled by CNPCI (China National Petroleum Corporation International) Company in 2012.

Permeability describes how easily fluid is able to move through reservoirs and it is related to the connectedness of the void spaces and to the grain size of the reservoir. Obviously, a reservoir could be extremely porous, but if each pore was isolated from the others, the reservoir would be impermeable and thus make a poor penetration of fluid. The valuable parameter of permeability of upper Aptian sandstone reservoir of Kashkari oil field is analyzed by Darcy's method. Henry Darcy 1856, who is known as the father of fluid flow researchers, carried out laboratory experiments and analyzed the flow of fluid through a sand layer. His result is widely used in petroleum reservoir engineering and generalized to an empirical law named after him. The analysis of relative permeabilities is more important during oil exploitation and oil recovery in a petroleum reservoir. Hence, to maintain accurate oil exploitation and oil recovery from upper Aptian sandstone reservoir of Kashkari oil field, the relative permeability of oil and water is analyzed by steady-state laboratory

Finally, the permeability, relative permeability of oil and water, irreducible water saturation and residual oil saturation of upper Aptian sandstone reservoir of Kashkari oil field are obtained.

The structure map of upper Aptian

The structure of the Kashkari field is an asymmetrical anticline with double-high layered edge water. The oil field has four different oil reservoirs which placed vertically in different depths from 950 to 1570m. These four reservoirs have different oil-water contact and oil-bearing area from 2.41 km^2 to 8.57 km^2. The structural map of upper Aptian reservoir is illustrated in Fig 1.



The structural map of upper Aptian

Well No-21

The well No-21 is drilled on the top of anticline for evaluation and exploitation of Kashkari oil field. The depth of the well is 1782.0 m. The casings are shown in Figure 2.

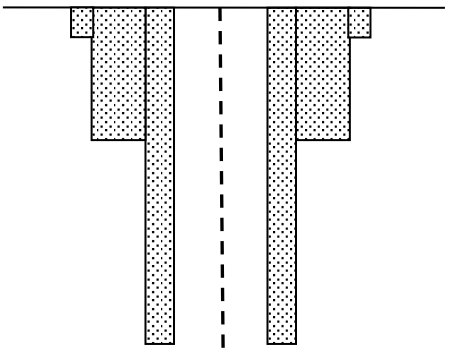


Figure 2. Casings of well-21 in Kashkari oil field

Conductor: $426.0mm \times 15.00\ m$
Bit: $311.2mm \times 538.50\ m$
First casing: $244.5mm \times 537.7\ m$
Bit: $215.9mm \times 1782.0\ m$

The Stratigraphy of Well 21 of Kashkari Oil Field

Q+N: 0 – 46m
P_1^g: 46 – 516m
K_2^{t+k}: 516 – 722m
K_2^{sm}: 722 – 817 m
K_1^a8: 17 – 1065 m Oil reservoir
K_1^{ap}: 1065 – 1264m Upper and lower oil reservoir
K_1br: 1264 – 1377 m
K_1^h: 1377 – 1512m Oil reservoir
K_1^v: 1512 – 1588m
K_1^k: 1588 – 1649m
J: layer is not available
T: 1649 – 1767 m
PZ: 1767 – 1782 m

Oil Estimation in Kashkari Oil Field

The different companies were estimated the reserve oil-in-place in Kashkari oil field, but the volumetric estimation results were varied from each other. However, the estimation results of the reserve oil in place were close to each other. The total oil-in-place for all four reservoirs was estimated about 19.629 million tons oil in place.

Table 1. The reserve oil estimation of Kashkari oil field by companies and organization

Companies and organization	OOIP MM BBL.	OOIP MM TON
Gustavson (2005)	99.48	13.93
Soviet Union (1978)	122.99	17.22
Research institute of soviet union (1980)	137.40	19.615
Geological institute of soviet union (1987)	137.40	19.629
Sofregaz (2004)	137.31	19.615
CNPC (2012-2013)	133.99	19.141

As mentioned, the oil field has four reservoirs, and each reservoir has a different amount of oil. The largest amount of oil is reserved in Hauterivian sandstone reservoir and the smallest amount is reserve in Aptian XIIb.

Table 2. Reservoir oil estimation of Kashkari oil field

Reservoir	GROUP	ESTIMATION OOIP MM TON
Albian	XIa	2.485
Aptian	XIIa	7.034
Aptian	XIIb	1.290
Hauterivian	XIV	8.806
Total		19.615

Methodology

The method of Analyzing the absolute Permeability, Effective Permeability, and Relative Permeability.

Absolute permeability

The absolute permeability is the ability of reservoir which allows fluid to move through it. There are many factors which effect on the value of absolute permeability and can decrease the permeability of reservoir such as: Grain size distribution, Shape of grains, Package of grains, Pore size, Type of cement, and Fluid direction.

The above factors have the main rule to increase or decrease the absolute permeability of reservoir. The natural factors such as; grain size, shape, and clay cementing and the artificial factors such as; drilling mud and experimental fluid are both effects on absolute permeability. Furthermore, the horizontal permeability is higher than vertical permeability because the pores are well connected to each other in the horizontal direction. Therefore, the fluid can penetrate easily in this direction.

According to Darcy's law, the equations of absolute permeability and hydraulic conductivity through falling head test are obtained as;

$$k = \frac{Q\mu L}{A\Delta p} \qquad (1)$$

The absolute permeability in Radial flow system is obtained:

$$k = \frac{Q\mu \ln(r_e/r_w)}{2\pi h(P_e - P_{wf})} \qquad (2)$$

In falling head permeability test the absolute permeability can be obtained as:

$$k = \frac{\mu}{\rho g}\frac{2.30\,a\,L}{A(t_2 - t_1)}\log\left(\frac{h_1}{h_2}\right) \qquad (3)$$

Relative Permeability

It is easily imaged that absolute permeability "to either fluid to be lower than that for the single fluid since it occupies only part of the pore space and may also be affected by interaction with other phases. The concept used to address this situation is called relative permeability". The relative permeability to oil k_{ro} is defined as:

$$k_{ro} = \frac{k_{eo}}{k} = \frac{effective\ oil\ \ permeability}{absolute\ \ permeability} \qquad (4)$$

Similarly for water;

$$k_{rw} = \frac{k_{ew}}{k} = \frac{effective\ water\ \ permeability}{absolute\ \ permeability} \qquad (5)$$

The effective permeabilities of fluid can be analyzed where two or three phases of fluid are simultaneously flow based on Darcy's law. Additionally, Effective permeability of reservoir is the ability to transmit a particular fluid when other immiscible fluids are available in the reservoir. Absolute permeability is considered more than effective permeability because the size of pores available for the flow of single fluid to be reduced due to the presence of the second fluid.

$$k_{rw} = \frac{k_{ew}}{k} \quad \rightarrow \quad k_{ew} = k\,k_{rw} \qquad (6)$$

$$q_{ew} = \frac{k_{ew}\,\rho_w\,g}{\mu_w}\cdot\frac{\partial p/\rho_w g}{\partial z}\cdot A = \frac{k\,k_{rw}}{\mu_w}\cdot\frac{\partial p}{\partial z}\cdot A \qquad (7)$$

After integration, the relative permeability of water can be obtained;

$$k_{rw} = \frac{q_{ew}\,\mu_w\,z}{k\,A\Delta p} \qquad (8)$$

Relative permeability of oil is obtained;

$$k_{ro} = \frac{q_{eo}\,\mu_o\,z}{k\,A\Delta p} \qquad (9)$$

Laboratory Measurements of Relative Permeability by Steady State Method

In the experimental procedure, both phases are injected simultaneously into the core at constant rates and pressures. The system is assumed to be at steady state when the measured pressure drop across the core remains relatively constant. At this point, the pressure drop and the outlet flow rate of each phase are measured, and the subsequent values are used in Darcy's Law to calculate the effective permeability of the fluid at that saturation. The below is a typical steady-state experimental apparatus:

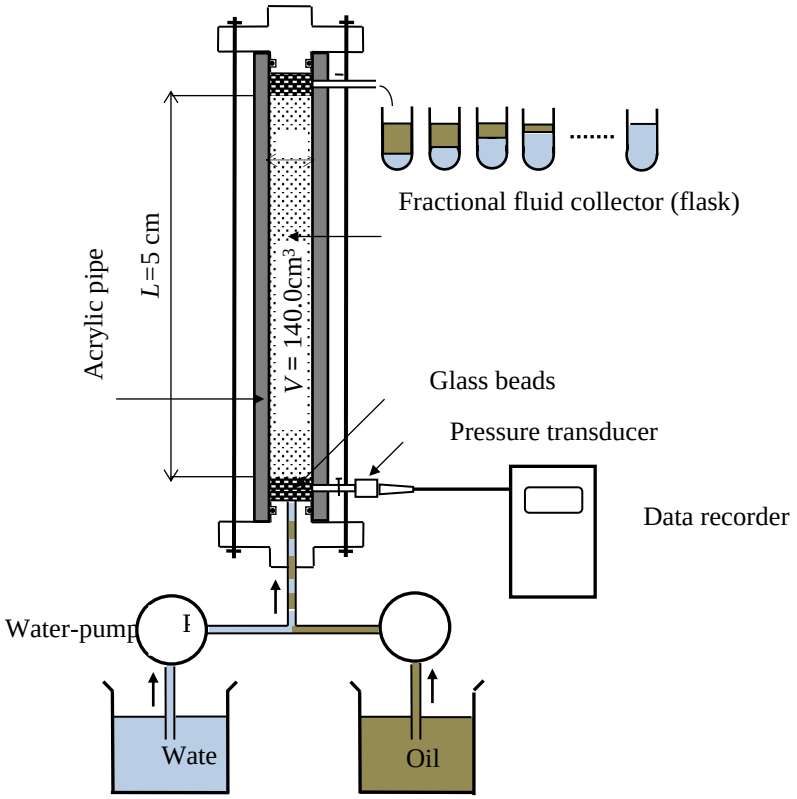


Figure3. Relative permeability Apparatus

During the experiments the pumping flow rate ratio is changed, the rate of water is increasing and the rate of oil is decreasing, and the process repeats in various ratio. In this way, different points of relative permeability curves for each phase can be achieved. The sequence of data points can be controlled through the system reach to the steady-state levels

The outlet flow rates are recorded by burettes of oil and water on the outlet end. The drop pressure is measured across the core by pressure gage.

Below is a typical diagram indicating the fluid saturation during the steady-state experiments.

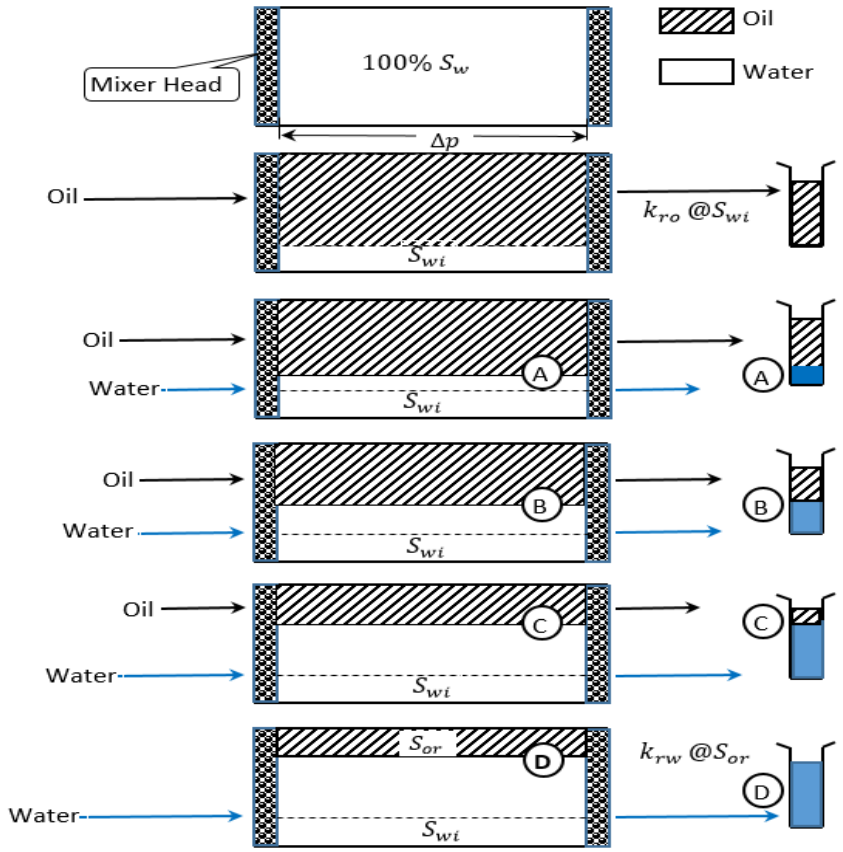


Figure 4. Fluid saturation during steady state experiments

The sequence of saturation can be illustrated by various experimental steps in a steady state process as shown in Fig 4 and summarized by the following standpoints:

At the initial step, in the case of a clean core plug, it is completely saturated by water. Then, the experiment begins by injecting only oil until steady state is reached. At this point, some amount of water is remaining in core plug which called irreducible water or irreducible water saturation. Theoretically, only oil should be flowing through the core. However, there is evidence that a small amount of water is

still flowing in the system. At this point, the pressure drop across the core and the flow rate of oil are measured and according to Darcy's law, these values use to calculate the effective permeability of oil at the irreducible water saturation. Next, the oil and water are injected simultaneously into the core at point A. when a new steady state condition is reached and the outlet flow rates are measured for each phase along the pressure drop, and effective permeabilities of each phase (oil and water) at the given saturation are calculated. The inlet flow rate ratio is changing (the amount of water is increasing and the amount of oil is decreasing) and the procedure is again repeated. In this stepwise manner, many points of relative permeability curves can be obtained. To find the value of last end point for effective water saturation, only water flows through the core until residual oil saturation is reached at point D.

Furthermore, in these subsequent steps, the objective is to decrease the oil phase and increase the water phase saturation steadily so that a number of data points on the relative permeability curve can be obtained. The injection of oil and water is continued simultaneously until the injection ratio is equivalent to the production ratio, while a condition is obtained, at which the system existing saturations are considered the stable and steady state.

Laboratory experiments

The cores have obtained from Kashkari oil field which is located in Amu-Darya basin in the north of Afghanistan. The cores had cut out from upper Aptian, sandstone reservoir of a new well No 21st which has drilled by CNPCI (China National Petroleum Corporation International) Company in 2012. The cores are illustrated in Fig.4.



Figure 0 Cores of upper Aptian sandstone reservoir of Kashkari oil field

Core Plug Sample

A core plug sample refers to a much smaller portion or a subsample of the whole core sample. Generally, core plugs are cut from whole core samples in two different orientations: perpendicular or parallel to the axis of the whole core. To perform the experiments the core plugs are cut perpendicular to the axis of the whole core in the size of 3cm diameter and 5cm lengths, the core plug, and the whole samples are illustrated in Fig 5.

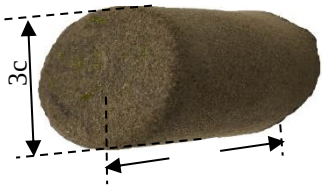


Figure 05. Core plug sample of upper Aptian sandstone reservoir of Kashkari oil field

Permeability

Laboratory measurement of absolute permeability involves the measurement of individual variables such as flow rate, pressure drop, sample dimensions, and fluid properties. The typical steps involved in performing and absolute permeability measurement are as follows:

Firstly, the plug core is prepared in size of 5 cm length and 3 cm diameter, then the core is fixed to the Acrylic pipe. Prior to using the core sample for permeability test, the residual fluid is completely removed so that the core is 100% clean.

The falling head permeability experiments are performed in three different steps. The apparatus is shown in Fig.6.



Figure 6. Permeability apparatus

The experiments data of permeability and hydraulic conductivity are shown in Table 3.

JIS A 1218 JSF T 311	**Permeability Test for Sandstone (Constant head, Falling head)**						
Sampling Place : Kashkari oil field, Afghanistan					Test Date: 2016-2-25		
Depth of sample: Well No 21, 1065m					Tester : Abdul Jamil Nazari		
Sample	Sample name		Upper Aptian Sandstone	Test tube	Container No.		002
	Particle diameter mm		?		Inside diameter D		3.0
	Density ρ_s g/cm^3		2.6		Length L cm		5
Stand pipe [1]	Diameter D cm		0.5		Mass[2] m_2 g		95
	Area a cm		0.196		Water test		Clean water
Specimen dimensions	Sample No.		Specimen body			before test	After test[3]
	Diameter D cm	3.0		Mass(soil +pipe) m_1 g			
	Area A cm^2	7.065		Mass of specimen $m = m_1 - m_2$ g			
	Length L cm	5		Wet density $\rho_t = m/v$ gr/m^3			
	Volume V cm^3	35.325		Dry density $\rho_d = \rho_t/(1+w/100)$ gr/m^3			
				Void ratio $e = (\rho_s/\rho_d) - 1$			
				Saturation $S_r = w\rho_s/(e\rho_w)$ %			
Water content ratio		Before test			After test		
	Container No.						
	m_a g						
	m_b g						
	m_c g						
	w, w_f %						
	Average value						
No.			1	2	3	4	5
Start time t_1			0	1245	0		
End time t_2			1245	4149	6240		

First step

$$K = \frac{2.30\,a\,L}{A(t_2 - t_1)} \log\left(\frac{h_1}{h_2}\right)$$

$$K = \frac{2.30 \times 0.196 \times 5}{7.065(1347 - 0)} \log\left(\frac{70}{60}\right) = \frac{0.44256}{9516.55} = 1.51 \times 10^{-5}\ cm/\text{sec}$$

$$= 1.51 \times 10^{-7}\ m/\text{sec}$$

$$k_s = \frac{K\,\mu_o}{\rho\, g} = \frac{1.51 \times 10^{-7} \times 0.00242}{795 \times 9.81} = \frac{3.65 \times 10^{-10}}{7798.95} = 4.680 \times 10^{-14}\, m^2$$

$$= 0.04680 \times 10^{-12}\, m^2 = 0.0468\, D = 46.8\, mD$$

Second step

$$K = \frac{2.30 \times 0.196 \times 5}{7.065(2951 - 1347)} \log\left(\frac{60}{50}\right) = \frac{0.1784}{11332.26} = 1.574 \times 10^{-5}\ cm/\text{sec}$$

$$= 1.574 \times 10^{-7}\ m/\text{sec}$$

Third step

$$K = \frac{2.30 \times 0.196 \times 5}{7.065(6954 - 0)} \log\left(\frac{70}{30}\right) = \frac{0.82941}{49730.01} = 1.688 \times 10^{-5}\ cm/\text{sec}$$

$$= 1.688 \times 10^{-7}\ m/\text{sec}$$

$$k_s = \frac{K\,\mu_o}{\rho\, g} = \frac{1.688 \times 10^{-7} \times 0.00242}{795 \times 9.81} = \frac{4.0849 \times 10^{-10}}{7798.95} = 5.237 \times 10^{-14}\, m^2$$

$$= 0.05237 \times 10^{-12}\, m^2 = 0.05237\, D = 52.37\, mD$$

The average hydraulic conductivity K in these three experiments are calculated below.

$$K_{15} = K \times \eta_T \Big/ \eta_{15} = \frac{1.51 \times 10^{-7} + 1.574 \times 10^{-7} + 1.688 \times 10^{-7}}{3} = \frac{4.772 \times 10^{-7}}{3}$$

$$= 1.5906 \times 10^{-7}$$

The average intrinsic permeability K_s in these experiments are calculated below.

$$k_s = \frac{k_1 + k_2\, k_3}{3} = \frac{46.8 + 48.8 + 52.37}{3} = 49.323 mD$$

As a result of experimental studies on the flow of Kerosene through the upper Aptian sandstone sample of Kashkari oil field, the intrinsic permeability, and hydraulic conductivity is analyzed in three step, the result of every step is very close to each other. The average hydraulic conductivity is $K = 1.59 \times 10^{-7}\ m/\sec$, and average absolute permeability is $k_s = 52.37\, mD$ obtained. The result of intrinsic permeability is much higher than the result of well logging, which was done many years ago in Kashkari oil field.

Relative permeability

The laboratory steady state experiments of relative permeability of oil and water are performed in Upper Aptian sandstone reservoir samples of Kashkari oil field. The measurement technique for obtaining the two-phase relative permeability data based on the flow experiments are fairly well established on different water saturation. During the experiments, the volume of water, volume of oil, pressure of outlet and inlet, and breakthrough time of the injected fluid are recorded. Next, the quantity of oil and water are calculated by equation (4.1). The result of experiments is shown in Table 5.

Table 5. the steady state experiments initially data.

S_w	$V_w\ (cm^3)$	$V_o\ (cm^3)$	$T(sec)$	$q_w\ (cm^3/sec$	$q_o(cm^3/sec$	$P_1\left(kgf/cm^2\right.$	$P_2\left(kgf/cm^2\right.$
0.23	3.100	38.40	601	0.0051	0.0639	0.12	3.19
0.31	7.490	32.21	690	0.0100	0.0466	0.22	3.12
0.35	12.20	27.30	721	0.0169	0.0379	0.19	2.99
0.42	16.80	22.55	940	0.0177	0.0239	0.20	2.30
0.49	21.60	17.26	763	0.0283	0.0226	0.20	3.10
0.55	24.90	14.65	660	0.0377	0.0221	0.21	3.11
0.62	33.18	9.320	650	0.0510	0.0010	0.20	2.30
0.71	49.90	5.400	733	0.0680	0.0073	0.21	2.51
0.75	40.60	1.900	650	0.0624	0.0020	0.18	1.68

When the initial data are achieved during the steady state experiments then the relative permeability of oil and water are calculated by Darcy's law equations (4-8 and 4-9). Furthermore, relative permeabilities of oil and water are mentioned mostly depend on the saturation of water. Therefore, the experiments are performed with the different ratio of water saturation. The minimum saturation of water in which the less water flow is achieved equal to 23%, at the maximum water saturation in which the oil flow is minimum equal to 75%. The result of relative permeability of water is shown in Table 6.

Table 6. The relative permeability of water

S_w	$q_w\ (m^3/sec)$	$L\ (m)$	μ_w	$k_s\ (m^2)$	$A\ (m^2)$	$\Delta p\left(kgf/cm^2\right)$	k_{rw}
0.23	1.34×10^{-8}	0.05	0.001	4.92×10^{-9}	7.06×10^{-4}	2.68	0.024
0.31	1.41×10^{-8}	0.05	0.001	4.92×10^{-9}	7.06×10^{-4}	2.10	0.049
0.35	1.69×10^{-8}	0.05	0.001	4.92×10^{-9}	7.06×10^{-4}	2.80	0.086
0.42	1.77×10^{-8}	0.05	0.001	4.92×10^{-9}	7.06×10^{-4}	2.10	0.121
0.49	2.83×10^{-8}	0.05	0.001	4.92×10^{-9}	7.06×10^{-4}	2.90	0.140
0.55	3.77×10^{-8}	0.05	0.001	4.92×10^{-9}	7.06×10^{-4}	2.90	0.186
0.62	5.10×10^{-8}	0.05	0.001	4.92×10^{-9}	7.06×10^{-4}	2.10	0.349
0.71	6.80×10^{-8}	0.05	0.001	4.92×10^{-9}	7.06×10^{-4}	2.30	0.426
0.75	6.24×10^{-8}	0.05	0.001	4.92×10^{-9}	7.06×10^{-4}	1.50	0.598

The laboratory empirical data of vary pressure and quantity of water is obtained during steady state experiments.

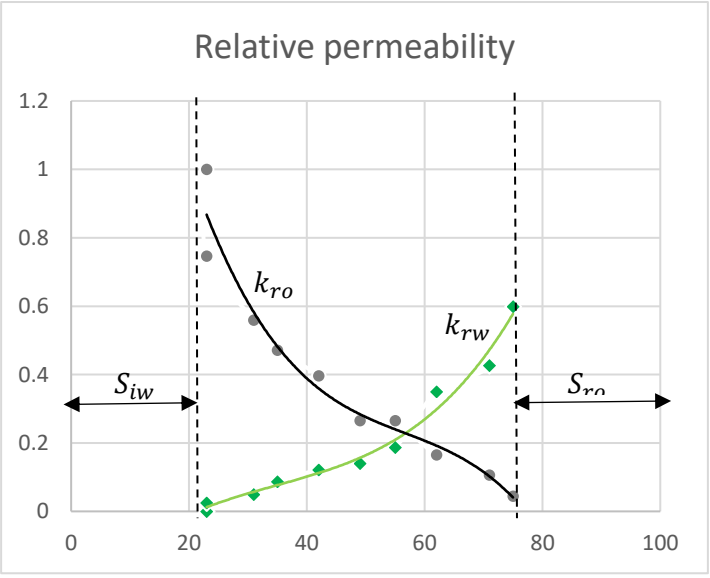
The result of Relative permeability of oil in Kashkari sandstone reservoir is obtained by experiments which are shown in Table 7.

Table 7 the data of relative permeability of oil.

S_w	$q_w\ (m^3/sec)$	$L\ (m)$	μ_w	$k_s\ (m^2)$	$A\ (m^2)$	$\Delta p\left(kgf/cm^2\right)$	k_{ro}
0.23	6.88×10^{-8}	0.05	0.00242	4.92×10^{-9}	7.06×10^{-4}	2.68	0.746
0.31	3.39×10^{-8}	0.05	0.00242	4.92×10^{-9}	7.06×10^{-4}	2.10	0.559
0.35	3.79×10^{-8}	0.05	0.00242	4.92×10^{-9}	7.06×10^{-4}	2.80	0.471
0.42	2.39×10^{-8}	0.05	0.00242	4.92×10^{-9}	7.06×10^{-4}	2.10	0.396
0.49	2.21×10^{-8}	0.05	0.00242	4.92×10^{-9}	7.06×10^{-4}	2.90	0.265
0.55	2.21×10^{-8}	0.05	0.00242	4.92×10^{-9}	7.06×10^{-4}	2.90	0.260
0.62	1.00×10^{-9}	0.05	0.00242	4.92×10^{-9}	7.06×10^{-4}	2.10	0.165
0.71	7.30×10^{-9}	0.05	0.00242	4.92×10^{-9}	7.06×10^{-4}	2.30	0.105
0.75	2.00×10^{-9}	0.05	0.00242	4.92×10^{-9}	7.06×10^{-4}	1.50	0.044

The relative permeability curves of oil and water in Kashkari sandstone reservoir is illustrated in Fig 5.

Fig 4. The relative permeability of oil and water



Result

The points are the exact value of relative permeability of oil and water and the curves illustrate the average relative permeability of oil and water during the different water saturation. The irreducible water is less than residual oil. Therefore, the amount of oil which remain in the reservoir is more than water.

The distribution of the two phases according to their wetting characteristics results in characteristic wetting and non-wetting phase relative permeabilities. Since the wetting phase occupies the smaller pore openings at small saturations, and these pore openings do not contribute materially to flow, it follows that the presence of a small wetting phase saturation will affect the non-wetting phase permeability only to a limited extent. Since the non-wetting phase occupies the central or larger pore openings which contribute materially to fluid flow through the reservoir. However, a small non-wetting phase saturation will drastically reduce the wetting phase permeability.

Conclusion

In this research, different aspect of permeability and relative permeability of oil and water have been studied to reveal the advantageous via of oil exploitation and oil recovery from upper Aptian sandstone reservoir of Kashkari oil field.. The amount of reserve oil in upper Aptian reservoir is 7.034 OOIP MM ton. Ten wells have been drilled until 1980, and after a long pause, the well No-21 is drilled by CNPCI Company in 2012. Two samples of the upper Aptian reservoir are carried out from Northern Directorate of Hydrocarbon Unit in Sheberghan to Tokai University for analyzing of permeability and relative permeability. The importance of research is to recover a huge amount of oil from petroleum reservoir.

- The absolute permeability experiments are performed on the core plugs of upper Aptian sandstone reservoir in three different steps. In every experiment, the valves of absolute permeabilities are close to each other, and the average permeability is found out.

Absolute permeability $k = 52.37mD$.

The permeability, which empirically obtained is the appropriate value of permeability in the petroleum industry.

- The relative permeability of oil and water are determined by steady state method in different water saturation. During the experiment different parameters are determined.

    1. Irreducible water saturation $S_{wi} = 0.22$
    2. Residual oil saturation $S_{or} = 0.25$

3. The relative permeability curves of both phases are obtained in Fig.5.

The relative permeability curves illustrate the behavior of flow of both phases when the saturation of water is increasing the relative permeability of oil is decreasing. The relative permeability and fractional flow values are controlled by rock types and properties, and its appropriate description helps engineers to make confident predictions from the waterflooding calculation.

Finally, this research is opened to study more. Therefore, the amount of residual oil which obtained by experiments is little bit more. The researchers are always trying to decrease residual oil and increase oil recovery from petroleum reservoir. They may test many types of fluid to increase oil recovery.

My recommendation for future research is that to test steam or hot water for recovering of oil in upper Aptian sandstone reservoir of Kashkari oil field. Thus, the steam or hot water can decrease the viscosity of oil and may increase the recovery of oil in petroleum reservoir.

Reference

1- A. Jamil NAZARI and S.HONMA; Analysis of Fractional Flow and Relative Permeability of Heavy Oil and Kerosene during Recovery in Petroleum Reservoir, International Journal of GEOMATE, 2017, Vol. 12, Issue 29, pp. 2900-2907 (online), Japan.

2- A. Jamil NZARI and S. HONMA; Oil Displacement by Water in Hauterivian Sandstone Reservoir of Kashkari Oil Field, ICASPG 2017 (19TH International Conference on Applied Seismology and Petroleum Geology), London, United Kingdom.

3- A. Jamil NAZARI and S. HONMA; Effect of Fractional Flow Curves on the Heavy Oil and Light Oil Recoveries in Petroleum Reservoirs, International Journal of ICGPE 2016 (18TH International Conference on Geosciences and Petroleum Engineering) Osaka, Japan.

4- A. Arabzai and S.Honma: Numerical Simulation of the Buckley-Leverett Problem, Proceedings of School of Engineering of Tokai University, Vol.38 (2013) pp.9-14.

5- A.Y. Dandekar “petroleum Reservoir, Rock and Fluid Properties” Book, CRC Press, 2013 pp.45-83

6- Amerex energy today for tomorrow, www.amerexco.com/recovery.html

7- Apostolos Kantzas, Jonathan Bryan, and Saeed Taheri: Fundamentals of Fluid Flow in Porous Media. Online book.

8- B. Philip and M. A. Celia: Practical implementation of the fractional flow approach to multi-phase flow simulation, Advance in water resource, Vol. 22, No. 5, (1991), PP461-487

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