Journal of Oil, Gas and Petrochemical Technology 10(1): 25-34, Winter and Spring 2023

RESEARCH PAPER

The Comparison of Experimental Relative Permeability Data with Corey's Model Results: A Case Study

Naomi A. Ogolo[1*], Obinna S. Ezeaneche[2], Mike O. Onyekonwu[1]

[1] *Institute of Petroleum Studies, University of Port Harcourt, Rivers State, Nigeria*
[2] *Laser Engineering and Resources Consultants Limited, Port Harcourt, Rivers State, Nigeria*

ARTICLE INFO

Article History:
Received 9 August 2022
Revised 24 April 2023
Accepted 26 April 2023

Keywords:
Reservoir
Sweep Efficiency
Saturation
Error
Exponent

ABSTRACT

Using Corey model for determining relative permeability in a two-phase flow in porous media has been a remarkable achievement; however, determining the correct exponents for relative permeability to oil and water still remains a challenge. In addition, laboratory obtained relative permeability data is very essential because it is more reliable despite being tedious and expensive. In this work, laboratory relative permeability values were obtained with exponents of 3.39 and 3.22 for K_{ro} and K_{rw} respectively as against the closest Corey exponents of 3.3 and 3.2 for K_{ro} and K_{rw} respectively. These results and the assumed Corey exponents of 3.5 and 3.1 for K_{ro} and K_{rw} respectively selected in error were used to show how seemingly insignificant errors in Corey exponents can be magnified when used for calculations in reservoir studies. Therefore, in this study obtaining laboratory relative permeability data is emphasized since it captures most rock properties that affect relative permeability which Corey models do not consider.

How to cite this article
Ogolo NA, Ezeaneche OS, Onyekonwu MO., The Comparison of Experimental Relative Permeability Data with Corey's Model Results: A Case Study, Journal of Oil, Gas and Petrochemical Technology, 2023; 10(1): 25-34. DOI:10.22034/jogpt.2023.355385.1106

1. INTRODUCTION

The relative permeability of a fluid is the ratio of its effective permeability to the absolute permeability in the presence of another fluid. When two or more fluids flow at the same time, the relative permeability of each phase at a specific saturation is the ratio of the effective permeability of the phase to the absolute permeability. Relative permeability is an important dimensionless parameter when analyzing fluid flow in porous media and in reservoir studies. The data and curves are used in history matching, assessing reservoir performance, predictions and for determining fluid mobility ratios, relative permeability ratios and for oil and gas field planning and development. Relative permeability is considered in many fluid flow equations in porous media and in secondary and tertiary oil recovery calculations

* Corresponding Author Email: amoniogolo@yahoo.com

[1]. It is therefore imperative that accurate relative permeability values be determined because wrong values can make a huge impact even when the errors in value are small.

Relative permeability values can be obtained through experiments or by using existing models. Obtaining laboratory relative permeability data using reservoir core samples is commendable because factors that affect relative permeability such as wettability, pore geometry, fluid saturation and reservoir history are all captured [2, 3]. However, experimental relative permeability is tedious, expensive and time-consuming; hence, predictions using mathematical models have been heavily relied upon. Although using models to obtain relative permeability results is easier, it has faced challenges, especially for heterogeneous and carbonate formations.

There are several mathematical correlations for relative permeability but Corey Correlations and Stone's correlations have been widely accepted for two- and three-phase relative permeability respectively. Nevertheless, this work is limited to two-phase flow of water and oil, and only Corey model is considered. The Corey model for obtaining two-phase relative permeability is very good and simple; however, the model only considers connate water saturation and other water saturation levels. The model does not consider the effect of other factors such as pore geometry, wettability and rock heterogeneity in samples [4]. The variations in these factors can considerably affect relative permeability data and curves and invariably affect the outcome of other parameters and outputs that are partly dependent on relative permeability values. In spite of these short comings, it must be admitted that Corey correlations for relative permeability is a great achievement. Nevertheless, laboratory results using core samples are better representatives of the formation than correlations.

The shortcomings of the obtained relative permeability data using Corey correlation have been mentioned in the literature. It has been pointed out that Corey model cannot correctly predict the behavior of capillary pressure and relative permeability of transition zones in carbonate reservoirs [5]. It has also been shown that Corey model cannot represent capillary pressure curves of Geysers rock samples, necessitating the development of other models [6]. Errors have been reported with the use of Corey model to predict relative permeability at low saturations. When predicted relative permeability values from this model was used to calculate reservoir performances, the seemingly small error had a significant impact on results, emphasizing the need for accurate relative permeability results in reservoir studies [7].

In a particular study, the Corey model of estimating relative permeability was compared with Purcell's model. It was observed that Purcell's model gives a better fit to experimental data of the wetting phase relative permeability as long as the measured capillary pressure curve has the same residual saturation as the relative permeability curve. However, Purcell's model did not give good match for imbibition [8]. Other studies have also come up with models that can be used to predict relative permeability under different scenarios [9, 10]. The method of predicting relative permeability for oil-water systems using in-situ downhole wireline logging data has been proposed [11].

Sometimes steady state relative permeability experiments cannot be predicted using Corey model and efforts have been made to develop other analytical correlations [12]. Unsteady state method is easier than the steady state method; however, the method of calculation is complex. Simplifying the method of calculation by comparing the experimental average water saturation at the moment of breakthrough with the modeling derived from fractional flow curve has been proposed [13].

One major problem with Corey model is selecting the most correct exponent which depends on the level of rock consolidation. Hence, a primary objective in this work is to compare relative permeability results obtained experimentally with results obtained using Corey model for exponents 3 to 4. Corey exponents that are closest to the experimentally obtained exponents are also determined. These results and an assumed set of relative permeability results close to the obtained Corey exponents are used to demonstrate the importance of acquiring accurate relative permeability data from the laboratory for reservoir studies.

2. Research Method

There are two experimental methods for obtaining relative permeability values: the steady and unsteady state methods. The steady state method involves flowing two fluids at the same time with specified saturations for each fluid while the unsteady state entails displacing one fluid with another. The steady state method is more reliable but tedious compared to the unsteady state method. The process for the steady state method has been discussed in several studies [14 – 19]. In this work, the steady state method was deployed to determine the relative permeability of a gas condensate oil and water. The gas condensate was obtained from the Niger Delta and its fluid properties are presented in Table 1. The rock sample is unconsolidated with a porosity of 28% and absolute permeability of 0.8002 Darcy. The experiment was conducted with an overburden pressure of 2000 psi (136.09 Atm), a pore pressure of 450 psi (30.62 Atm) and at an ambient temperature of 25 °C.

Table 1. The Crude Oil Properties

Parameter	Value
Density	0.82 g/cm^3
Dynamic Viscosity(μ_o)	2.45 cp
API Gravity	40.23 ° API
Specific Gravity	0.82

The equipment used to conduct the experiments was a standard core flooding equipment (AFS-300) manufactured by Core Laboratories in USA. It can be used to conduct experiments under reservoir temperatures and pressures. A schematic of the flow paths from the core holder is shown in Figure 1.

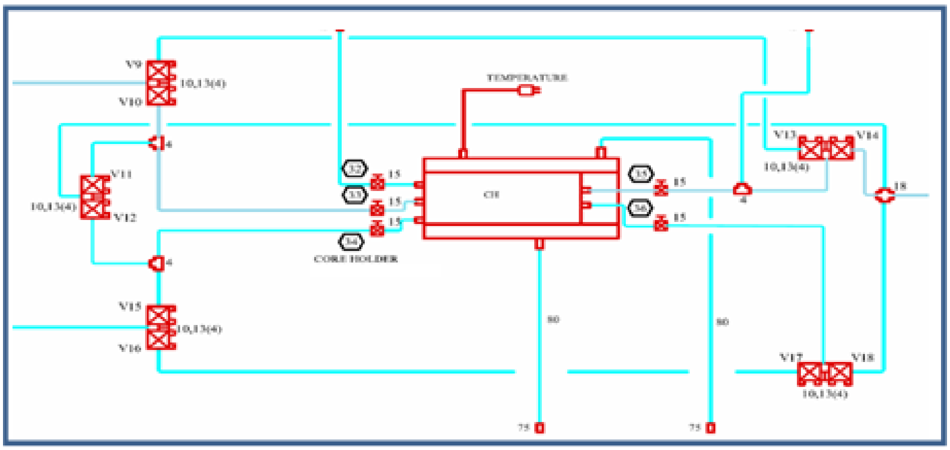

Figure 1. A schematic of the Flow Setup and Flow Paths

Darcy Equations were deployed in determining the relative permeability values from data obtained from the core flooding equipment, of which change in pressure (dp) is important.

The Darcy Equations used in determining permeability (K), relative permeability to water (K_{rw}) and relative permeability to oil (K_{ro}) are given as follows:

$$K = Q\mu_w L/AdP \quad (1)$$

$$K_{rw} = Q_w \mu_w L/KAdP \quad (2)$$

$$K_{ro} = Q_o \mu_o L/KAdP \quad (3)$$

The equation for obtaining relative permeability in "phase i" can also be expressed as:

$$K_{ri} = K_i / K \quad (4)$$

Where

K_{ri} = Relative permeability of fluid "i" (which could be water, oil or gas)

K_i = Effective permeability of fluid "i"

K = Absolute permeability

The relative permeability data were also generated using Corey correlations for two-phase flow of water and oil. The Corey correlations [19] used for water and oil relative permeability values are given as follows:

$$k_{ro} = \left(\frac{1-S_w}{1-S_{wc}}\right)^n \quad (5)$$

$$k_{rw} = \left[\frac{S_w - S_{wc}}{1-S_{wc}}\right]^m \quad (6)$$

Since it is difficult to determine the most correct Corey exponent to use, values of Corey exponents ranging from 3.0, 3.1 – 4.0 were used to generate the relative permeability values. The obtained sets of values were compared against the experimental results to determine exponents that give the closest results to experimental values. The statistical method used to carry out this task was the sum of the squares of residuals (SSR) and is given as:

$$SSR = \sum_{i}^{n} (y - y_i)^2 \tag{7}$$

Where y is the experimental value and y_i is the calculated (Corey) value.

Effort was made to determine the equivalent Corey exponents for oil and water relative permeability values. The experimental relative permeability values were used on the left-hand sides of Corey models in Equations 5 and 6, and made equal to the right-hand side of Corey models with exponents "n" and "m" for oil and water respectively. The values of exponents "n" and "m" were obtained by taking the log on both sides of the equations as shown in Equations 8 and 9.

$$\log(k_{ro}) = n \log\left(\frac{1-S_w}{1-S_{wc}}\right) \tag{8}$$

$$\log(K_{rw}) = m\log\left(\frac{S_w - S_{wc}}{1 - S_{wc}}\right) \tag{9}$$

In hydrocarbon reservoirs, permeability variation can occur vertically according to layers, laterally or it can be heterogeneous. In the case of layered vertical variation of permeability, arithmetic mean is applied, harmonic mean is applied to lateral variation while geometric mean is used for heterogeneous cases [19]. In this work, lateral permeability variation was assumed, necessitating that harmonic mean be applied to permeability values. Harmonic mean generates straighter curves, incorporates all entries in the series and allows a significant weighting to be given to smaller values in the series.

The harmonic averages of each set of values were determined as the experimental Corey exponents. The harmonic average was used because it mitigates the effect of large numbers and enhances the impact of small numbers. Harmonic average is the reciprocal of the arithmetic mean of the reciprocals of a given set of observations and it is usually less than the arithmetic and geometric averages. The harmonic mean is expressed in Eq. 10, where H is the harmonic mean, n is the number of observations and x_1 ---- x_n are the observed figures.

$$H = \frac{n}{\frac{1}{x_1} + \frac{1}{x_2} + \cdots + \frac{1}{x_n}} = \frac{n}{\sum_{i=1}^{n} \frac{1}{x_i}} = \left(\frac{\sum_{i=1}^{n} x_i^{-1}}{n}\right)^{-1} \tag{10}$$

3. Results and Discussion

Figure 2 shows the experimental relative permeability curves obtained from the use of AFS-300 core flooding equipment.

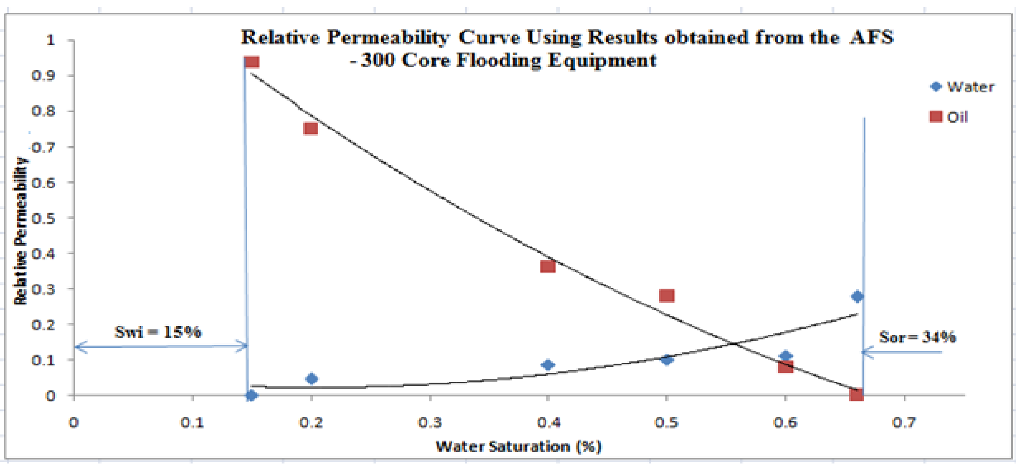

Figure 2. Relative Permeability Curves for Sample A obtained from the Core Flooding Equipment

The S_{wc} and S_{or} are 15% and 34% respectively.

The different relative permeability plot points for Corey models are presented in Figure 3 and Figure 4 for oil and water respectively. This demonstrates the challenge of determining the most correct Corey exponent. Usually in reservoir studies using simulation, the most correct exponent is determined by history matching which is not ideal because it does not consider a number of other factors such as pore geometry and rock heterogeneity. Experimental relative permeability is basically preferred because it is representative of the rock under study despite its limitations.

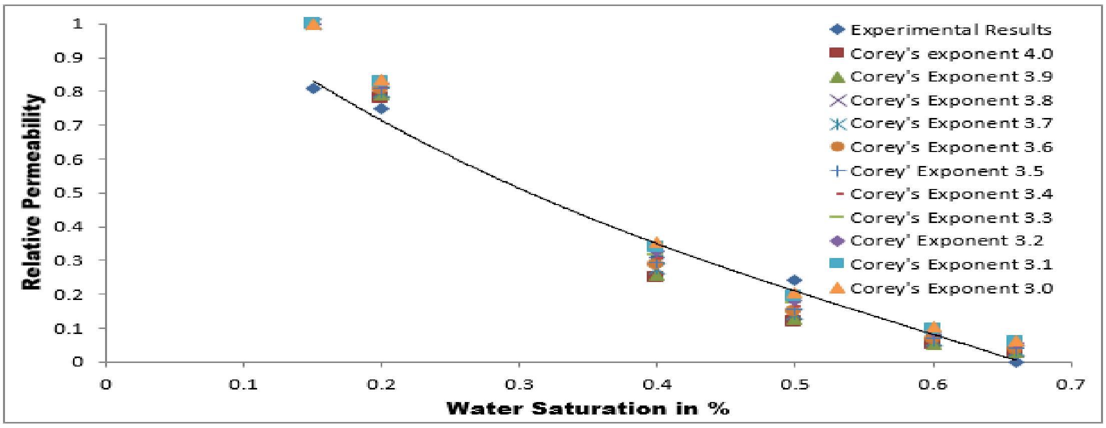

Figure 3. Comparison of the Experimental Kro Curves with Corey Model for Different Exponents

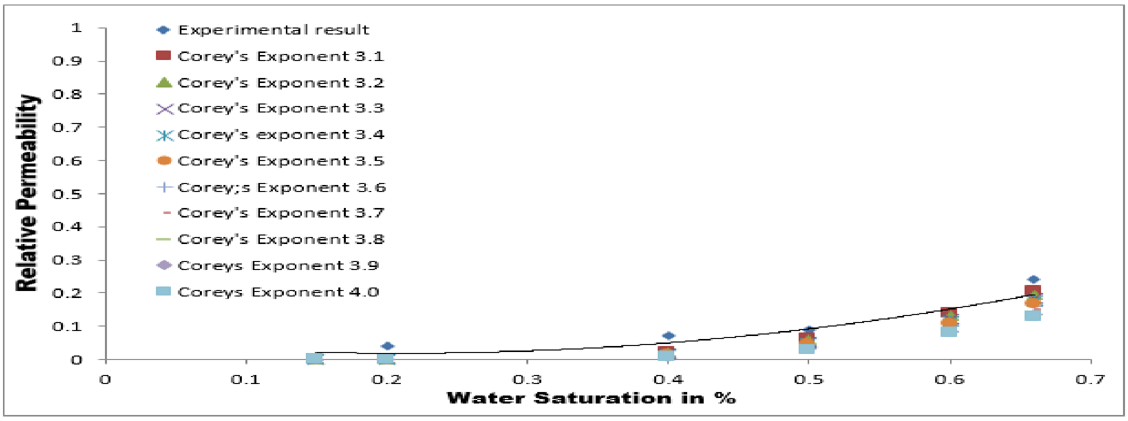

Figure 4. Comparison of the Experimental Krw Curves with Corey Model for Different Exponents

The statistical approach SSR was used to determine the least deviated Corey exponents to experimental results. The deviations for oil and water relative permeability (K_{ro} and K_{rw}) values are displayed in Tables A and B respectively (Appendix). For K_{ro}, the closest Corey exponent is 3.3 while for K_{rw} it is 3.2. The comparison of the relative permeability data for the experimental results and Corey exponents of 3.3 and 3.2 for K_{ro} and K_{rw} are presented in Figure 5 and Figure 6 respectively.

The determined experimental Corey exponents were 3.39 and 3.22 for K_{ro} and K_{rw} respectively using harmonic averaging and knocking off outrageous points. It would not have been easy to determine these values (3.39 and 3.22) without experimental results, emphasizing the need to conduct laboratory relative permeability experiments which help to obtain more reliable relative permeability values for reservoir studies. A comparison of how the experimental values for K_{ro} and K_{rw} match the closest Corey exponents of 3.3 and 3.2 is shown in Figure 7.

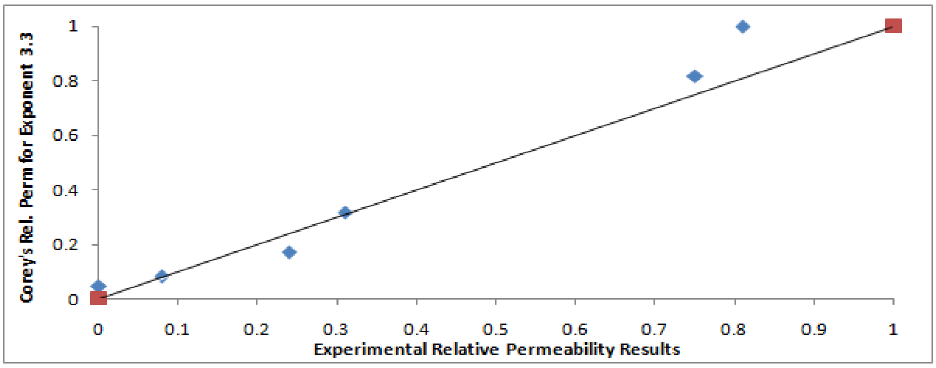

Figure 5. Comparison of Experimental Kro with Corey Exponent of 3.3

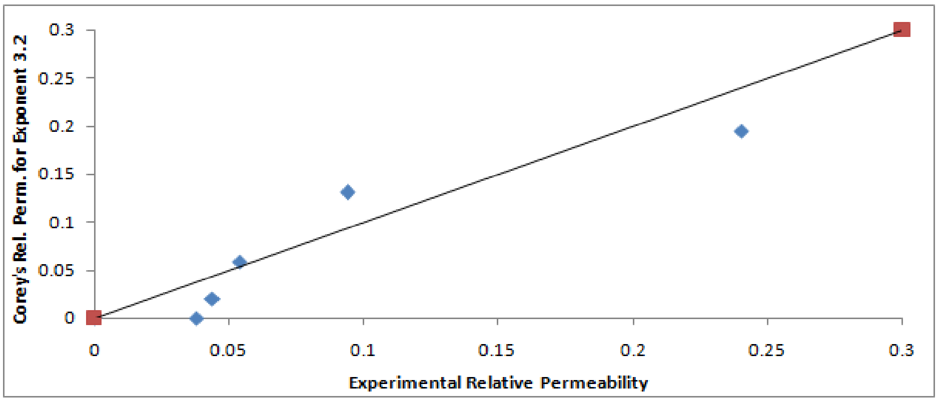

Figure 6. Comparison of Experimental Krw with Corey Exponent of 3.2

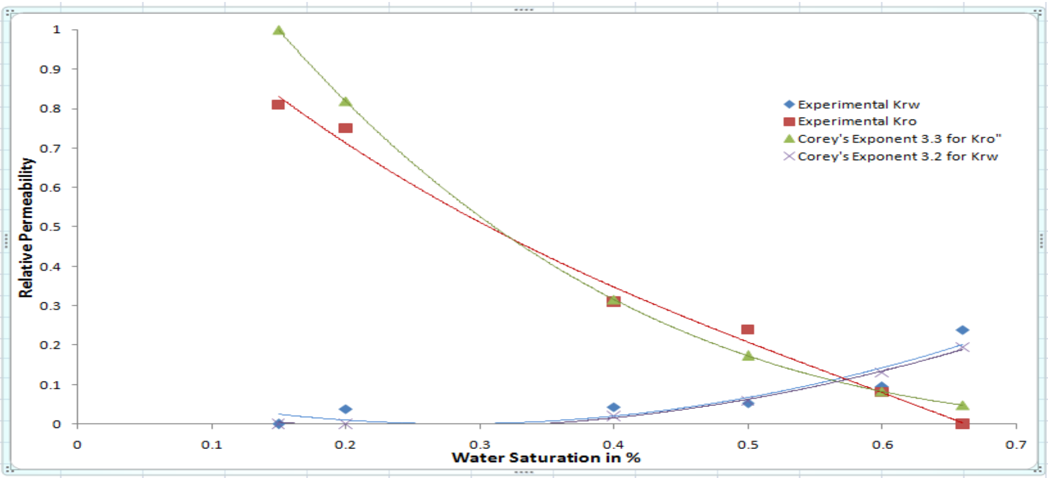

Figure 7. Comparison of the Experimental Kro and Krw Results with the Closest Corey Exponents

Importance of using Correct Corey Exponents

It is very important that the correct Corey exponents be determined because using incorrect exponents can negatively impact the reservoir studies. To illustrate, assumming that incorrect Corey exponents of 3.5 for oil and 3.1 for water were selected for this work (instead of the closest values of 3.3 and 3.2 respectively) and these were used to calculate mobility ratio (M), water cut (f_w) and areal sweep efficiency at water breakthrough (E_{ABT}) for Kro@0.15 and Krw@0.6. The values of these parameters for two sets of Corey exponents are presented in Table 2. The Equation used to determine E_{ABT} [6] is given as:

$$E_{ABT} = 0.54602036 + \frac{0.03170817}{M} + \frac{0.30222997}{e^M} - 0.00509693M \quad (11)$$

Table 2. Mobility Ratio, Water Cut and Areal Sweep Efficiency for Different Corey's Exponents

Parameters	Experimental Results	Corey's Exponents of K_{ro} – 3.3 and K_{rw} – 3.2	Corey's Exponents of K_{ro} – 3.5 and K_{rw} – 3.1
Mobility Ratio (M)	0.319	0.361	0.383
Water Cut (f_w)	0.242	0.265	0.277
Areal Sweep Efficiency at water breakthrough (E_{ABT})	0.86	0.84	0.83

The errors introduced in calculations when using Corey exponents get larger as the exponents shift away from the correct values. For example, the errors in mobility ratio, water cut and areal sweep efficiency at water breakthrough in this work for Corey exponents of K_{ro} – 3.3 and K_{rw} – 3.2 (which are the closest to experimental values) are 13.17%, 9.5% and -2.33% respectively while the errors for K_{ro} – 3.5 and K_{rw} – 3.1 are 20.06%, 14.46% and -3.49% respectively as presented in Figure 8. In fact, the errors of -2.33% and -3.49% for E_{ABT} might seem small but these errors are quite significant when the figures are multiplied by the reservoir swept area, and the same applies for water cut. All these emphasize the importance of conducting laboratory relative permeability experiments and determining the correct Corey exponents in reservoir studies to minimize errors.

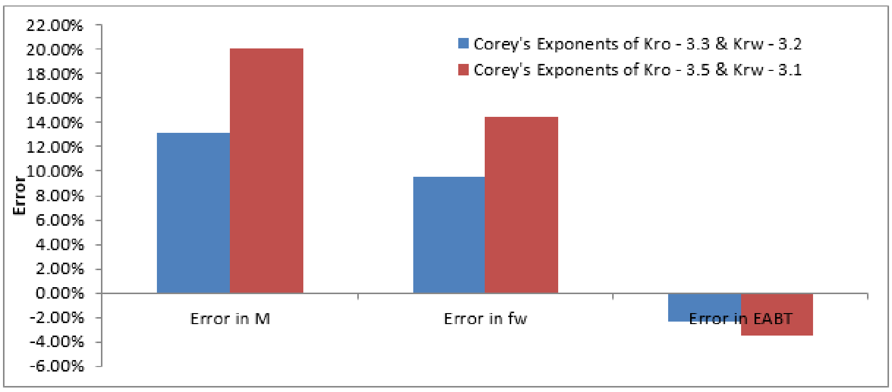

Figure 8. Introduced Errors in Using Incorrect Corey's Exponents

4. Conclusion

Relative permeability is a very important parameter in reservoir studies that describes fluid flow in porous media. Relative permeability data can be obtained directly through laboratory analysis or indirectly through correlations of which Corey model has been widely accepted. In this study, experimental relative permeability values for a gas condensate oil and water were obtained from the laboratory and the results were compared with Corey model for exponents between 3 and 4. The determined Corey exponents of 3.3 and 3.2 for K_{ro} and K_{rw} respectively were the closest to experimental result exponents of 3.39 and 3.22 for K_{ro} and K_{rw} respectively. Although the errors seemed insignificant but when they were used in calculating mobility ratio, water cut and areal sweep efficiency of a certain reservoir, the errors were magnified. This study showed that selecting incorrect Corey exponents can introduce serious errors in reservoir studies, emphasizing the importance of conducting laboratory relative permeability studies with reservoir core samples.

Acknowledgement

We thank the management of Laser Engineering and Resources Consultants Limited for permitting us to use their laboratory and state of the art Core Flooding equipment (AFS-300) for this research work without charge.

Nomenclature

K = Absolute permeability (Darcy)
K_{rw} = Relative permeability to water [-]
K_{ro} = Relative permeability to oil [-]
Q = Flow rate (cm^3/s)
Q_w = Flow rate of water (cm^3/s)
Q_o = Flow rate of oil (cm^3/s)
A = Cross sectional area of the plug sample (cm^2)
μ_w = Water viscosity (cp)
μ_o = Oil viscosity (cp)
dp = Differential pressure
S_w = Water saturation (%)
S_{wc} = Connate water saturation (%)

References

1. M. Honarpour and S. M. Mahmood, "Relative-Permeability Measurement: An Overview", Journal of Petroleum Technology, 40(08), 1988, pp. 963 – 966.
2. K. N. Seddiqi, Z. Mahdi and S. Honma, "Laboratory Measurement of Relative Permeabilities of Oil and Water in Sand", Proc. Schl. Eng. Tokai Uni., Ser. E, Vol. 41, 2016, pp. 47 – 51.
3. D. Yuqi, O. B. Bolaji and L. Dacun, "Literature Review on Methods to Obtain Relative Permeability Data", 5th Conference and Exposition on Petroleum Geophysics, Hyderabad, India, 2004, pp. 597 – 604.
4. R. T. Akhmetov and V. V. Mukhametshin, "Range of Application of the Brooks-Corey Model for Approximation of Capillary Curves in Reservoirs of Western Siberia", Advances in Engineering Research, Vol. 157, 2018, pp.5 – 8.
5. S. Shi, H. Belhaj, and A. Bera, "Capillary Pressure and Relative Permeability Correlations for Transition Zones of Carbonate Reservoirs", Springer, Journal of Petroleum Exploration and Production, 2017, pp. 1 – 18.
6. K. Li, and R. N. Horne, "Universal Capillary Pressure and Relative Permeability Model from Fractal Characterization of Rock", 29th Workshop on Geothermal, Reservoir Engineering, SGP-TR-175, 2004, pp. 1 – 9.
7. M. Zahoor, "Comparative Analysis of Relative Permeability Models with Reference to Extreme Saturation Limits and its Influence on Reservoir Performance Predictions", Sains Malaysiana, 44(10), 2015, pp. 1407 – 1415.
8. K. Li, and R. N. Horne, "Comparison of Methods to Calculate Relative Permeability from Capillary Pressure in Consolidated Water-Wet Porous Media", Water Resources Research, Vol. 42, WO6405, 2006, pp. 1 – 9.
9. J. Pie, Y. Zhang, J. Hu, J. Zhang, X. Zhu, Q. Wang, and H. Gong, "Experimental Verification of Reservoirs with Different Wettability Using Oil-Water Relative Permeability Model", MDPI Processes, 10, 1211, 2022, pp. 1 – 14.
10. E. Bohanar, Y. Ghalenoei, and S. Salmani, "New Relative Permeability Correlation for Carbonate Reservoirs through Data-Driven Modeling", Journal of Chemical and Petroleum Engineering (JChPE), 56(1), 2022, pp. 15 – 35.
11. S. Al-Ofi, H. Kesserwan, A. Hassan, and A. Al-Ramadhan, "Integrated Logging Data Technique to model Relative Permeability of Heterogeneous Reservoirs", Informamarket, ID#983, pp. 1 - 8.
12. F. Lomeland, E. Ebeltoft, W. H. Thomas, and S. A. Stavanger, "A New Versatile Relative Permeability Correlation", International Symposium of the Society of Core Analysts, Toronto, Canada, 2005, pp. 1 – 12.
13. M. Al-Mossawy, "A Simple Approach to Identify the Proper Relative Permeability Model", IOP Conference Series: Materials Science and Engineering, 495, 012074, IOP Publishing, CUTSE, 2019, pp. 1 – 8.
14. J. Cao, L. James, T. E. Johansen, "Determination of Two-phase Relative Permeability from Core Floods with Constant Pressure Boundaries", International Symposium of the Society of Core Analysts, at Avignon, France, 2014, pp. 1-6.
15. D. D. Huang and M. M. Honarpour, "Capillary End Effect in Coreflooding Calculations", SCA Conference, Paper Number 9634, France, 1996, pp. 1-10.
16. E. M. Bruan and R. J. Blackwell, "A steady State Technique for Measuring Oil-Water Relative Permeability Curves at Reservoir Conditions", SPE

10155, San Antonio, Texas, 1981, pp. 1 - 6.
17. K. N. Seddiqi, Z. Mahdi and S. Honma, "Laboratory Measurement of Relative Permeability of Oil and Water in Sand", Proc. Schl. Eng. Tokoi Univ., Ser. E., 41 2016, pp. 47 – 51.
18. C. D. Tsakiroglou, C. A. Aggelopoulos, K. Terzi, D. G. Avraam and M. S. Valavaanides, "Steady-state Two-phase Relative Permeability Functions of Porous Media: A Revisit", International Journal of Multiphase Flow, Elsevier, 73, 2015, pp. 34 - 42.
19. T. Ahmed, "Reservoir Engineering Handbook" Third Edition, Gulf Professional Publishing, Elsevier, USA, 2006, pp. 241- 250, 300 – 301, 943 – 946, 985 – 988, 990 - 991.

Appendix. Comparison of the Experimental Results with the Corey Correlation for Exponents 3.0 to 4.0

Table A. Experimental Krw SSR Comparisons with Corey Exponents to find the least Deviated

	Calculation Results of Krw for Sum of the Squares of Residuals (SSR) Using the Experimental Results with Corey's Exponents of 3.0 to 4.0									
	Krw. 3.0	residual	Krw3.1	residual	Krw3.2	residual	Krw3.3	residual	Krw3.4	residual
	0	0	0	0	0	0	0	0	0	0
	0.000204	0.001429	0.000153	2.35E-08	0.000115	0.001435	8.7E-05	0.001437	6.55E-05	0.001439
	0.025443	0.000344	0.022512	0.00024	0.019919	0.00058	0.017625	0.000696	0.015595	0.000807
	0.069815	0.000191	0.063887	0.000395	0.058462	6.06E-06	0.053499	6.26E-06	0.048956	4.96E-05
	0.148382	0.002957	0.139239	0.006929	0.130659	0.001344	0.122608	0.000818	0.115053	0.000443
	0.216	0.000576	0.205243	0.012375	0.195022	0.002023	0.18531	0.002991	0.176082	0.004086
SSR=		0.005497		0.019939		0.005388		0.005949		0.006824
	Kr3.5	residual	kr3.6	residual	kr3.7	residual	Krw 3.8	residual	Krw 3.9	residual
	0	0	0	0	0	0	0	0	0	0
	4.94E-05	0.00144	3.72E-05	0.001441	2.8E-05	0.001442	2.11E-05	0.001442	1.59E-05	0.001443
	0.013798	0.000912	0.012209	0.001011	0.010803	0.001102	0.009558	0.001186	0.008457	0.001263
	0.044799	0.000125	0.040996	0.000225	0.037515	0.000342	0.034329	0.00047	0.031415	0.000604
	0.107964	0.000195	0.101311	5.35E-05	0.095068	1.14E-06	0.08921	2.29E-05	0.083713	0.000106
	0.167313	0.005283	0.158981	0.006564	0.151064	0.00791	0.143541	0.009304	0.136392	0.010735
SSR=		0.007956		0.009295		0.010796		0.012426		0.014151
	krw 4.0	residual								
	0	0								
	1.2E-05	0.001443								
	0.007483	0.001333								
	0.028747	0.000743								
	0.078555	0.000239								
	0.1296	0.012188								
SSR=		0.015946								

Table B. Experimental Kro SSR Comparisons with Corey Exponents to find the least Deviated

	Calculation Results of Kro for Sum of the Squares of Residuals (SSR) Using the Experimental Results with Corey's Exponents of 3.0 to 4.0									
	(Kro)^3.0	residual	(Kro)^3.1	residual	(Kro)^3.2	residual	(Kro)^3.3	residual	(Kro)^3.4	residual
	1	0.0361	1	0.0361	1	0.0361	1	0.0361	1	0.0361
	0.833706	0.007007	0.828667	0.006189	0.823659	0.005426	0.818681	0.004717	0.813732	0.004062
	0.35172	0.001741	0.33968	0.000881	0.328053	0.000326	0.316823	4.66E-05	0.305978	1.62E-05
	0.203542	0.001329	0.193023	0.002207	0.183047	0.003244	0.173588	0.004411	0.164617	0.005683
	0.104213	0.000586	0.096647	0.000277	0.08963	9.27E-05	0.083122	9.75E-06	0.077087	8.49E-06
	0.064	0.004096	0.058396	0.00341	0.053283	0.002839	0.048618	0.002364	0.044361	0.001968
SSR=		0.050859		0.049064		0.048027		0.047648		0.047837
	(Kro)^3.5	residual	(Kro)^3.6	residual	(Kro)^3.7	residual	(Kro)^3.8	residual	(Kro)^3.9	residual
	1	0.0361	1	0.0361	1	0.0361	1	0.0361	1	0.0361
	0.808814	0.003459	0.803926	0.002908	0.799067	0.002408	0.794237	0.001957	0.789436	0.001555
	0.295504	0.00021	0.285388	0.000606	0.275619	0.001182	0.266185	0.00192	0.257073	0.002801
	0.156109	0.007038	0.148042	0.008456	0.140391	0.009922	0.133136	0.01142	0.126255	0.012938
	0.07149	7.24E-05	0.066299	0.000188	0.061485	0.000343	0.057021	0.000528	0.052881	0.000735
	0.040477	0.001638	0.036933	0.001364	0.033699	0.001136	0.030749	0.000945	0.028057	0.000787
SSR=		0.048518		0.049622		0.05109		0.05287		0.054917
	(Kro)^4	residual								
	1	0.0361								
	0.78	0.0009								
	0.25	0.0036								
	0.12	0.0144								
	0.05	0.0009								
	0.03	0.0009								
SSR=		0.0568								