"A Modified Correlation for Calculating Klinkenberg Permeability"

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Abstract:

In this paper, a new correlation for direct and easy method of calculating Klinkenberg permeability was introduced. Furthermore, a representation of *some* previously used work on how to calculate this petrophysical rock parameter has been done. The main aim of this work was to introduce a new and direct method for calculating Klinkenberg permeability of the porous media in petroleum reservoirs using one simple equation. However, the base of this work has depended on some of the available published papers about the determination of Klinkenberg effect on gases flow through a porous media.

As a new method for correlating some of the petrophysical rock properties such as porosity and absolute air permeability which were measured at ambient conditions in order to calculate Klinkenberg permeability, a simple three dimensional model was generated using a three dimensional software which was used to evaluate this method using more than 200 core plug samples retrieved from different oil wells.

The obtained results were plotted against the previously calculated data using the old methods and it gave an excellent matching. Moreover, the regression output of the three dimensional software has showed that the value of the Multiple

Determination Coefficient (R^2) was very high (0.99999) which indicates that the final obtained equation can be used for calculating Klinkenberg permeability instead of using the currently available correlations which require a lot of calculation procedures and plenty of time for a large number of samples.

Introduction

In this paper, a new correlation for direct and easy method of calculating Klinkenberg permeability was introduced. Furthermore, a brief representation of some previously used work on how to calculate this petrophysical rock property has been done. The main aim of this paper is to introduce a new and direct method for calculating Klinkenberg permeability of the porous media within the petroleum reservoirs using one simple equation.

However, the base of this work has depended on using some of the available published papers about the determination of Klinkenberg effect on gases flow through a porous media. As a new method for correlating some of the petrophysical rock properties such as porosity and absolute gas permeability which were measured at ambient conditions with Klinkenberg permeability, a simple three dimensional model (Fig. 1) was generated using a three dimensional software which was used to evaluate this method using 203 core plug samples retrieved from different oil wells in Libya.

Method

The method followed for completing the work done in this paper has depended mainly on analysing the collected data using a three dimensional software called DataFit. This software was used in order to produce a three dimensional correlation between the absolute core permeability, *ka*, and sample pore-space porosity, *Ø*, and the corrected Klinkenberg permeability, *Kl*, which was previously calculated using the methods mentioned by Kewen and Roland (2001) whose used the gas slippage assumptions suggested by Sampath and

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Keighin (1982) in equation (1) and applied it into Klinkenberg equation (2):

$$b = 0.0955\ (\frac{kg\infty}{\emptyset})^{-53} \quad \text{..... (1)}$$

$$kg = kg\infty\ (1 + \frac{b}{P_m}) \quad \text{..... (2)}$$

Where *b* is the gas slip factor, *kg* is the absolute gas permeability in millidarcy, *kg*∞ (or *Kl*) is the intrinsic gas permeability in millidarcy which is also known as Klinkenberg permeability (*Kl*) and *Pm* is the mean pressure.

The method of correlating the data in this paper has started with collecting the required petrophysical data; porosity, air permeability and the calculated Klinkenberg permeability values which were calculated using the method mentioned by Kewen. These data was collected from a number of 203 core samples retrieved from some oil wells in Libya.

The three dimensional correlation was constructed between these three parameters using DataFit in order to avoid the sub-calculations of the gas slippage factor and the conversions of the mean pressure and the use of Microsoft solver and to produce a one general equation with new constant coefficients.

The following equation and constants were obtained from this three dimensional analysis:

$$Kl = a \times \emptyset^{b} \times k_a^{c} \quad \text{..... (3)}$$

Where: *(Kl)* is the Klinkenberg permeability, *(Ø)* is the porosity in %, *(ka)* is the absolute gas permeability in md and *(a,b* and *c)* are the regression coefficients.
Regression Variable Results:

a = 0.9562
b = 7.0474E-03
c = 1.0032
Coefficient of Multiple Determination, $\mathbf{R^2}$ = **0.99999**

Thus, equation (3) can be described as an easy and simple module for calculating Klinkenberg permeability where it only requires the availability of routine core analysis data then it can be applied for as large number of samples as possible.

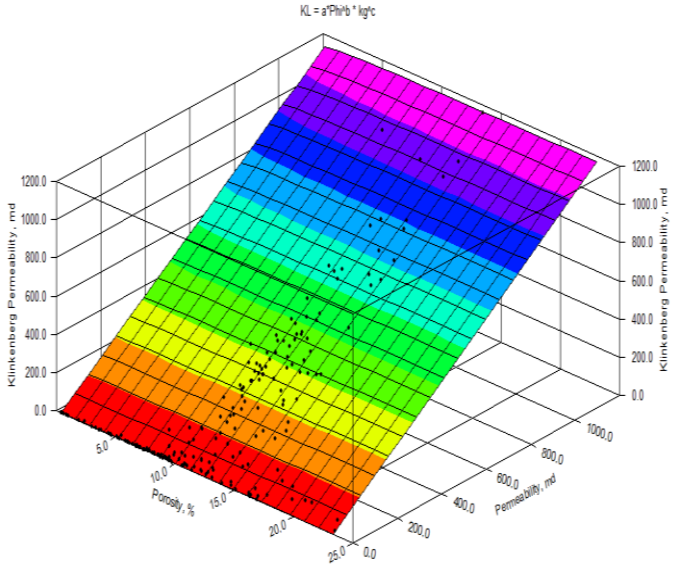

Figure 1.*This figure illustrates the three dimensional relationship obtained using DataFit between core porosity, the absolute air permeability and Klinkenberg permeability.*

Conclusions

In conclusion, it can be summarized that the use of the three dimensional software has helped a lot in saving the time of calculating Klinkenberg permeability where the final equation obtained from it, eq. (3), can be applied for this calculation using core porosity and air permeability values obtained at ambient conditions and there will be no need for using any other complicated methods like Microsoft solver which has been used in other old methods.

Moreover, the regression output of the three dimensional software has showed that the value of the Multiple Determination Coefficient (R^2) was very high (0.99999) which indicates that the final obtained equation can be used for calculating Klinkenberg permeability instead of

using the currently available correlations which require a long calculation procedures and plenty of time for a large number of samples.

Finally, it can be suggested that for making this new method more applicable and valid in the petroleum engineering industry, more data can be collected and the method followed in this paper can be tested for as large number of samples as possible in order to find the best correlating coefficients which are; *a, b* and *c* mentioned in equation (3) that can be considered for a more general correlation.

Key words: Klinkenberg permeability; porosity; water saturation; excel software; DataFit; Coefficient of Multiple Determination

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