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Evaluation of Different Models for Predicting Vertical Pressure Gradient of Yemeni Oil Fields

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ABSTRACT
Pressure drop in a vertical or deviated borehole is mainly due to hydrostatic changes and friction when the produced fluids flow to the surface, when the oil is flowing upwards, the flowing pressure along the tubing string will drop and gas starts to liberate from the oil. Thus, multiphase flow forms in the tubing string. Hence, adequate modeling of vertical lift performance is required to predict the pressure drop and subsequently the wellbore pressure.
The purpose of this research study is to predict the bottom hole pressure in the vertical wells of Yemeni oil fields using PROSPER, a program developed by Petroleum Experts. The most accurate correlations were chosen from 15 selected built-in correlations to predict the pressure drop via gradient matching.
The results showed the best correlation appeared to be the best-fit correlation for wells to predict the bottom hole pressure gradient in the vertical wells in Yemeni oil fields is Hydro-3p.
Key words: *multiphase flow, tubing string hydraulic, vertical, PROSOER, Yemeni*

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I. INTRODUCTION

Multiphase flow in tube strings has gotten a lot of interest in the upstream petroleum sector since it has remained a black box problem for decades [1].

Multiphase flow studies, which began in the 1950s, require a better understanding of how hydrocarbon liquid, water, and gas travel from the bottom hole to the surface [2,3] and even in the gathering lines [4,5,6] before reaching the onshore crude oil terminal in order to save money.

Multiphase flow has a far more intricate flow behavior than single phase flow because it involves the integration of numerous flow variables.

In a tubing string, liquid and gas normally do not flow at the same speed. This is because the gas phase, which is less dense and has a lower viscosity, may flow much quicker than the liquid phase in upward vertical flow. On the other hand, due to gravity and density differences, liquid flows faster than gas when traveling downwards.

The computations are complicated even when multiphase flow is subjected to modest pipeline geometry [2, 3].

As a result, accurate prediction of two-phase flow behavior frequently necessitates the development of a correlation based on multiple trials.

Every multiphase flow correlation has its own set of constraints and can only be used in a limited number of well circumstances.

Poettmann and Carpenter [8, Duns and Ros [9], Fancher and Brown [10], Hagedorn and Brown [11], Orkiszewski [12], Govier and Aziz [13], Beggs and Brill [14], Mukherjee and Brill [15], and Hasan-Kabir [16] are only a few of the relationships.

The flow pattern is one of the most important variables in determining the quality of multiphase flow, but it is not as simple to analyze as laminar or turbulent flow in a single phase flow. The relative quantities between the two phases, as well as the topology of the interfaces, must be explained.

Tubing string flow patterns include bubbly flow, slug flow, churn flow, annular flow, and others [2].As Ismail et al. [5] and Piroozian et al. [17] point out, flow patterns become more complex in waxy crude.

Each flow pattern is diverse due to the relative magnitudes of forces operating on fluid, such as surface tension and buoyancy force, which also vary with flow rates, pipe diameter, and phase fluid properties.
As a result, calculations of pressure gradient utilizing any correlation necessitate a large number of flow condition parameters such as fluid density, velocity, viscosity, and so on [2, 13].

Due to the phenomenon of gas/liquid slippage, the calculations for pressure losses in multiphase flow are quite difficult. Today, two basic techniques are utilized to forecast pressure losses in multiphase flow in pipes: empirical and mechanistic.

The empirical technique empirically connects pressure losses with all essential factors without explaining the source of the event, whereas the mechanistic approach uses physics to analyze and explain the phenomenon [18, 19].

A substantial amount of real data and multiphase flow calculations are necessary to build the model of a well production system [20]. As a result, over the years, various empirical multiphase flow correlations for estimating liquid holdup and pressure gradient have been created. Nonetheless, none of these multiphase flow correlations could perform well across the entire spectrum of production settings and characteristics such as tube size, gas liquid ratio, water cut presence, and so on.

In other words, there is no single correlation that can be applied to all types of flow regimes in the well successfully.

As a result, distinct multiphase correlations can be used in different parameter ranges to avoid significant mistakes generated primarily by the fluid's PVT properties [1,2].

Using the basic energy balance equation, the generic equation of pressure gradient that applies to any fluid flowing in a vertical or deviated well was obtained. It was created for two-phase flow under the assumption that their flow regimes and attributes are homogeneous in a fixed volume of pipe [2].
The goal of this research is to forecast bottom hole pressure in vertical wells in Yemeni oil fields.

II. RESEARCH METHODOLOGY

To achieve the objectives of the research using PROSPER software following the below mentioned steps:
Step.1 Describe the type of the system that we are attempting to model.
Option summary use in order to describe the type of system that you are attempting to model.
Step.2 Entering Information which can be used to customize reports and plots.
Also, entering free form comments which may be utilized for the purposes of logging what has been done to the file since its creation.

Step.3 Enter the relevant PVT data and choose the best correlation that matches the laboratory data.

Step.4 Select a reservoir model for the IPR model that is appropriate for the target reservoir and execute the IPR sensitivity test.
Step.5 Entering survey and equipment data, such as downhole and surface equipment, geothermal gradient, and average heat capacity .Matching data and calculating the pressure gradient

Step.6 To make a comparison between the calculated data and the actual data
Step.7 To assess the accuracy and performance of the correlation developed in the study, statistical and graphical error analyses were utilized to compare the calculated data to the real data.

Statistical Error Analysis
The accuracy of the estimated value of a given fluid property was compared to the measured value using the following statistical parameters:

Average Absolute Error
The average absolute error, AAE, is defined as the sum of the relative absolute deviation of a calculated value from the corresponding measured value, divided by the number of observations, as given by Eq:

$$AAE = \frac{1}{n}\sum\left|\frac{X_i - X_m}{X_m}\right| \times 100 \quad (1)$$

Where:
X_m = measured value
X_i = calculated value
n = number of observations

Average Absolute Percent Relative Error

It is defined as:

$$AAPR = \frac{\sum_{i=1}^{i=n} AAR}{n} \tag{2}$$

and indicates the relative absolute deviation, in percent, from the experimental values. A lower value implies a better correlation.

Minimum/Maximum Absolute Percent Relative Error

After calculating the absolute error and the absolute percent relative error for each data point, E_i .i = 1 , 2 , ….. , n, both the maximum and minimum values were scanned to determine the range of error for each correlation. The lower the value of maximum absolute percent relative error, the higher the accuracy of the correlation.

Sum of Square Residuals

The sum of the square residuals, SSR, is the total absolute squared-error involved in the estimated values.

$$\mathrm{SSR} = \sum (\mathrm{X_m} - \mathrm{X_i})^2 \tag{3}$$

Standard Deviation:

Standard deviation of the errors, R, is a reflection of the dispersion of errors around the mean and a measure of the quality of the fit. It is expressed as the positive square root of the variance R^2

$$= \sqrt{\left(\frac{\sum_{i=1}^{i=n_d} (E_i - E_r)}{n_d - 1}\right)} \tag{4}$$

A lower value of standard deviation means a smaller degree of scatter and a better quality of fit.

The Correlation Coefficient:

The correlation coefficient, r, represents the degree of success in reducing the standard deviation by regression analysis.

$$r = \sqrt{\left(1 - \frac{\sum_{i=1}^{n_d} (x_{\exp} - x_{est})_i^2}{\sum_{i=1}^{n_d} \left(x_{\exp} - \bar{x}\right)_i^2}\right)} \tag{5}$$

where

$$\bar{x} = \frac{\sum_{i=1}^{n_d} (x_{\exp})_i}{n_d}$$

The correlation coefficient lies between 0 and 1. A value of 1 indicates a perfect correlation whereas a value of 0 implies no correlation at all among the given independent variables. The larger of the value of r, the greater is the reduction in the sum of squares of the errors, and the stronger is the relationship between the independent and the dependent variables.

Graphical Error Analysis:
Graphical means help in visualizing the accuracy of a correlation. One graphical analysis technique were used and presented below.

Cross plots:
In this technique, all the estimated values are plotted versus the measured values, and thus a cross plot is formed. A 45-degree straight line is drawn on the cross plot on which estimated values are equal to the experimental values. The closer the plotted data points are to this line, the better the correlation.

III. RESULTS AND DISCUSSION

Data Description:
Data points were collected from Yemeni oil fields which are being used in this study to calculate bottom hole pressure by using prosper program Table (1) shows Cases study data range.

Table (1): Data Range

Parameter	Range
Liquid Rate	7.025-6264
Water cut %	0-98.4
API	28.6-55
GOR	0.8 - 100000
Reservoir Pressure	1443-4065
Water Salinity	0-210000
Reservoir Temperature	135.8-221
True Vertical Depth	646.2-8972
Completion size	2.31-4.95 Tubing with 3.5-9.63 casing

Construct pressure gradient
In this part the field data is used to predict pressure gradient Table (2) Results of error analysis for all method to predict pressure gradient by using different correlations by using prosper program:
-1Duns and Roes Modified
2- Hagedorn Brown
3- Fancher Brown
4- Mukherjee Brill
5- Beggs and Brill
6- Petroleum Experts1
7- Orkiszewski
8- Petroleum Experts2
9- Duns and Ros Original
10- Petroleum Exoerts3
11- GRE(modified by PE)
12- Petroleum Experts4
13- Hydro-3P
14- Petroleum Experts5
15- OLGAS 2P

Duns and Roes Modified
Duns and Roes Modified method is used to predict pressure gradient by using prosper program:
The calculated bottom hole pressure is plotted versus field data as shows in Figure (1). Figure (1) shows that the cross plot of field data versus calculated are above 45 line.

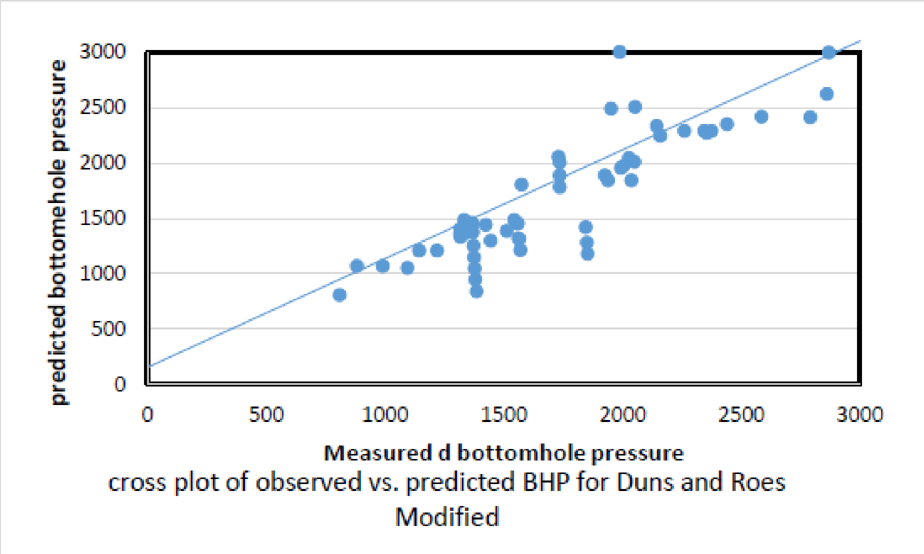

Figure (1) cross plot of observed vs. predicted BHP for Duns and Roes Modified

Hagedorn Brown

Hagedorn Brown method is used to predict pressure gradient by using prosper program:

The calculated bottom hole pressure is plotted versus field data as shows in Figure (2). Figure (2) shows that the cross plot of field data versus calculated is above 45 line.

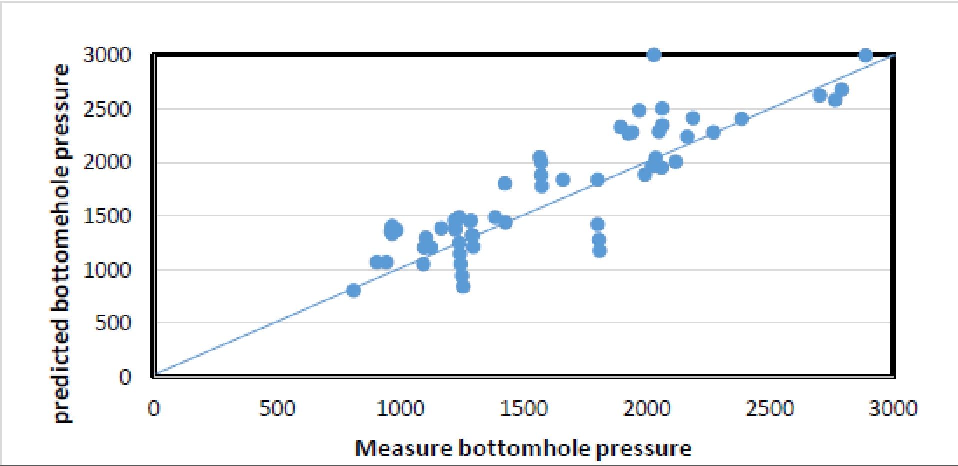

Figure (2) cross plot of observed vs. predicted BHP for Hagedorn Brown

Fancher Brown

Fancher Brown method is used to predict pressure gradient by using prosper program:

The calculated bottom hole pressure is plotted versus field data as shows in Figure (3). Figure (3) shows that the cross plot of field data versus calculated is above 45 line.

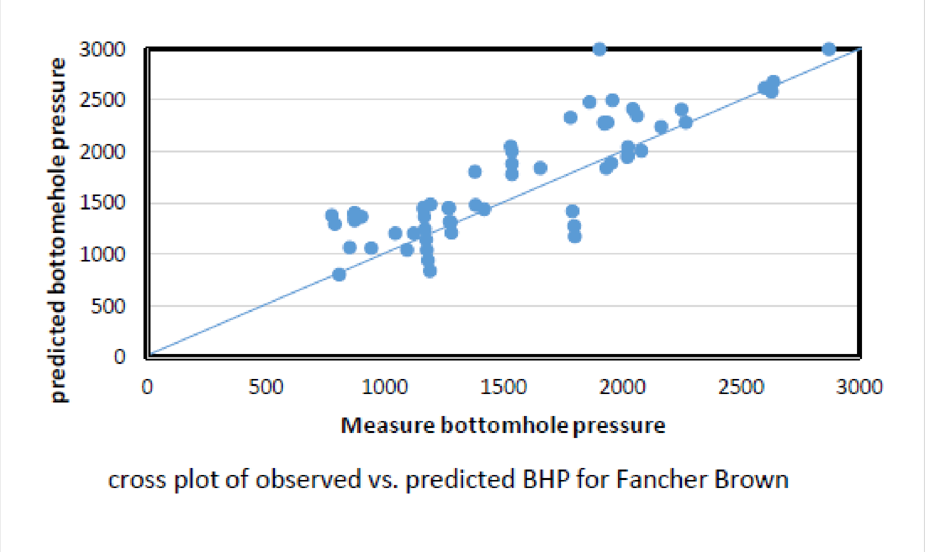

Figure (3) cross plot of observed vs. predicted BHP for Fancher Brown

Mukherjee **Brill**
Mukherjee Brill method is used to predict pressure gradient by using prosper program:
The calculated bottom hole pressure is plotted versus field data as shows in Figure (4). Figure (4) shows that the cross plot of field data versus calculated is above 45 line.

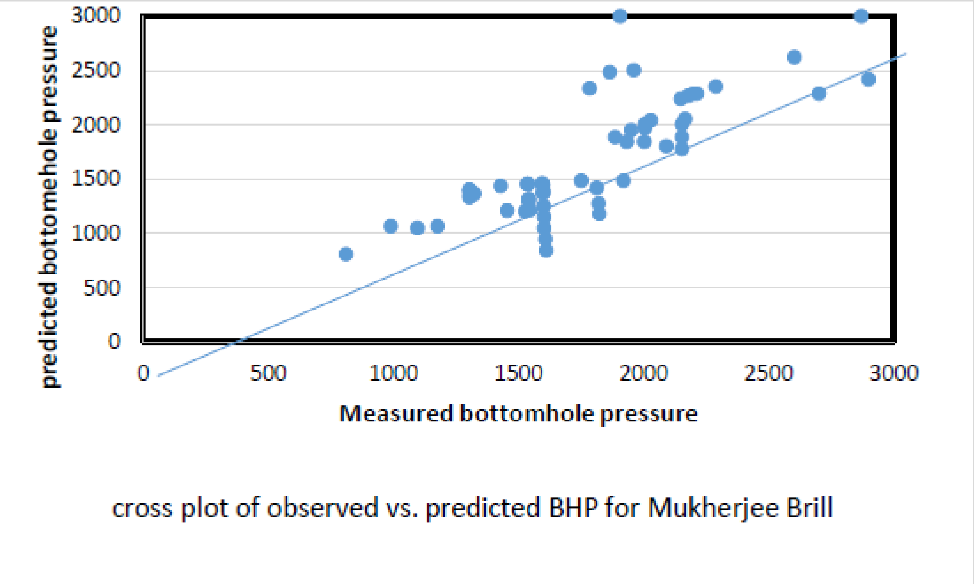

Figure (4) cross plot of observed vs. predicted BHP for Mukherjee **Brill**

Beggs and Brill method is used to predict pressure gradient by using prosper program:
The calculated bottom hole pressure is plotted versus field data as shows in Figure (5). Figure (5) shows that the cross plot of field data versus calculated is above 45 line.

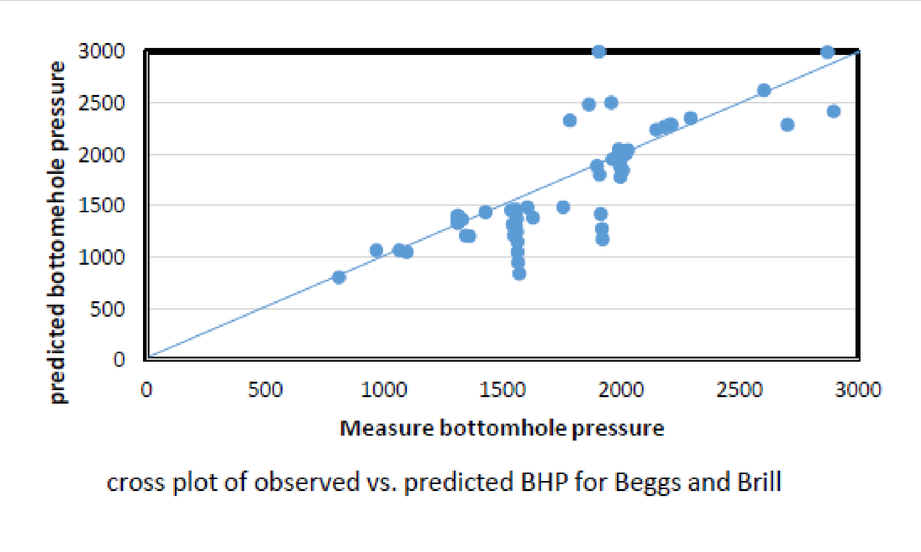

Figure (5) cross plot of observed vs. predicted BHP for Beggs and Brill

Petroleum Experts1

Petroleum Experts1 method is used to predict pressure gradient by using prosper program:

The calculated bottom hole pressure is plotted versus field data as shows in Figure (6). Figure (6) shows that the cross plot of field data versus calculated is above 45 line.

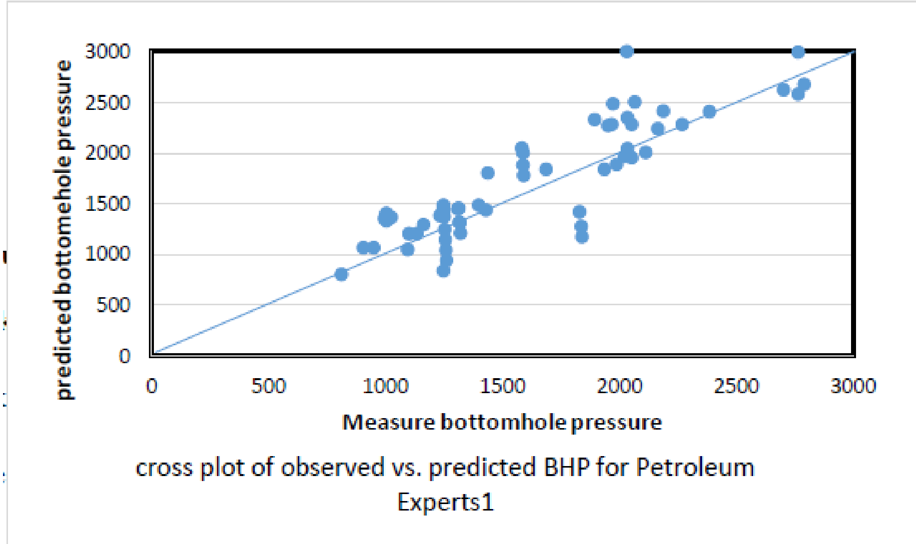

Figure (6) cross plot of observed vs. predicted BHP for Petroleum Experts1

Orkiszewski

Orkiszewski method is used to predict pressure gradient by using prosper program:

The calculated bottom hole pressure is plotted versus field data as shows in Figure (7). Figure (7) shows that the cross plot of field data versus calculated is above 45 line.

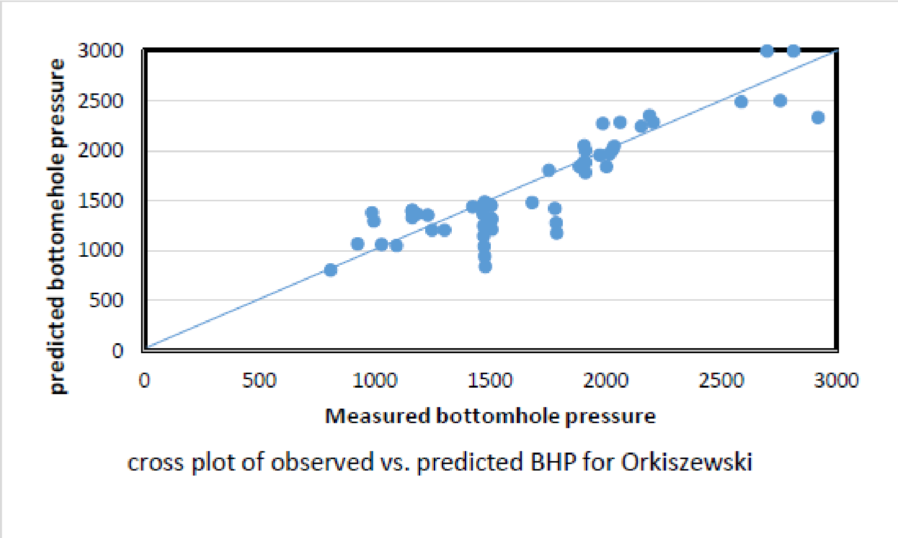

Figure (7) cross plot of observed vs. predicted BHP for Orkiszewski

Petroleum Experts2
Petroleum Experts2 method is used to predict pressure gradient by using prosper program:
The calculated bottom hole pressure is plotted versus field data as shows in Figure (8). Figure (8) shows that the cross plot of field data versus calculated is above 45 line.

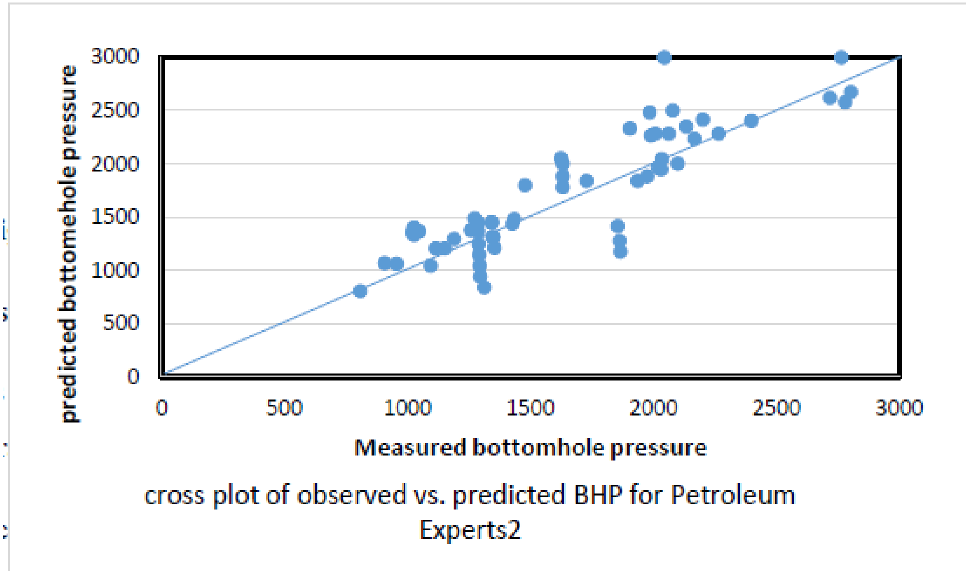

Figure (8) cross plot of observed vs. predicted BHP for Petroleum Experts2

Duns and Ros Original
Duns and Ros Original method is used to predict pressure gradient by using prosper program:
The calculated bottom hole pressure is plotted versus field data as shows in Figure (9). Figure (9) shows that the cross plot of field data versus calculated is above 45 line.

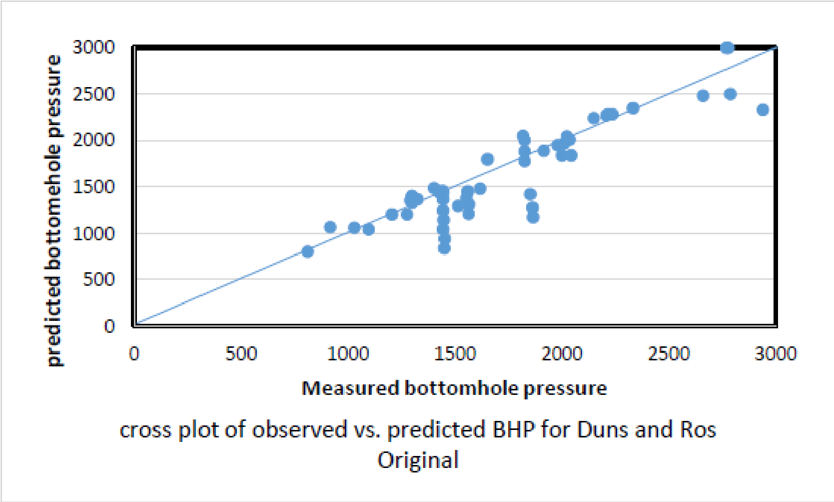

Figure (9) cross plot of observed vs. predicted BHP for Duns and Ros Original

Petroleum Exoerts3

Petroleum Experts3 method is used to predict pressure gradient by using prosper program:
The calculated bottom hole pressure is plotted versus field data as shows in Figure (10). Figure (10) shows that the cross plot of field data versus calculated is above 45 line.

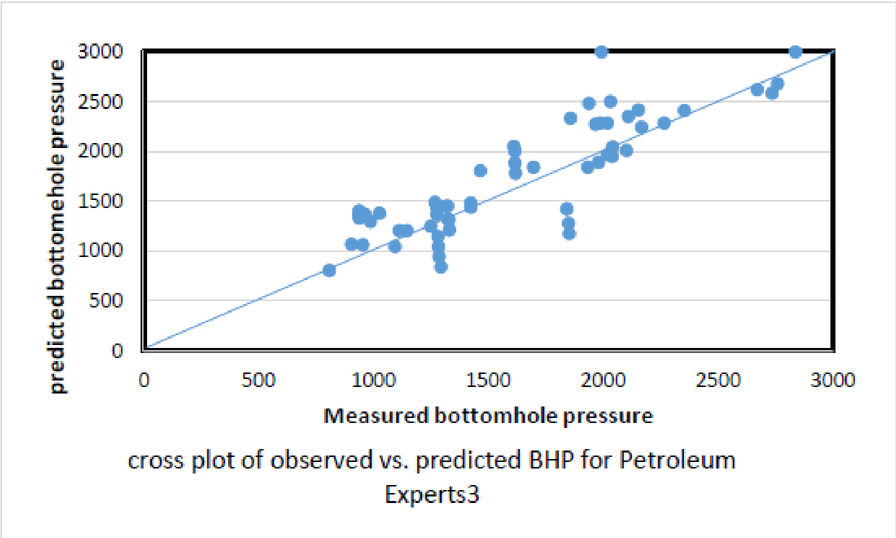

Figure (10) cross plot of observed vs. predicted BHP for Petroleum Experts3

GRE (modified by PE)

GRE (modified by PE) method is used to predict pressure gradient by using prosper program:
The calculated bottom hole pressure is plotted versus field data as shows in Figure (11). Figure (11) shows that the cross plot of field data versus calculated is above 45 line.

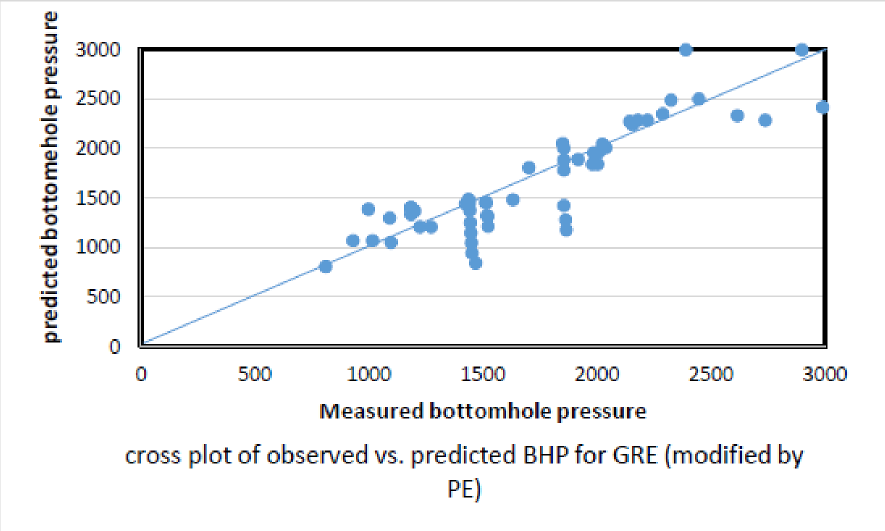

Figure (11) cross plot of observed vs. predicted BHP for GRE (modified by PE)

Petroleum Experts4
Petroleum Experts4 method is used to predict pressure gradient by using prosper program:
The calculated bottom hole pressure is plotted versus field data as shows in Figure (12). Figure (12) shows that the cross plot of field data versus calculated is above 45 line.

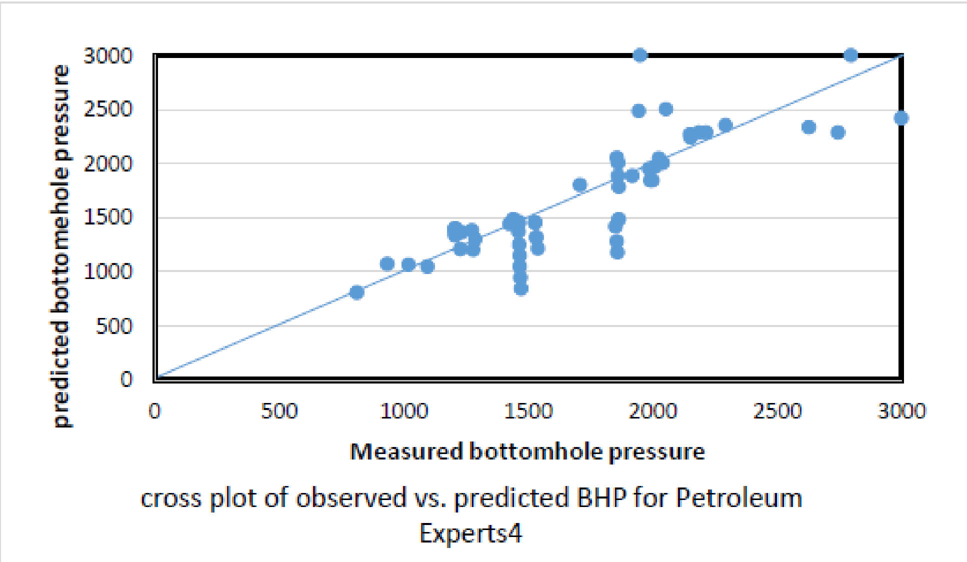

Figure (12) cross plot of observed vs. predicted BHP for Petroleum Experts4

Hydro-3P
Hydro-3P method is used to predict pressure gradient by using prosper program:
The calculated bottom hole pressure is plotted versus field data as shows in Figure (13). Figure (13) shows that the cross plot of field data versus calculated is above 45 line.

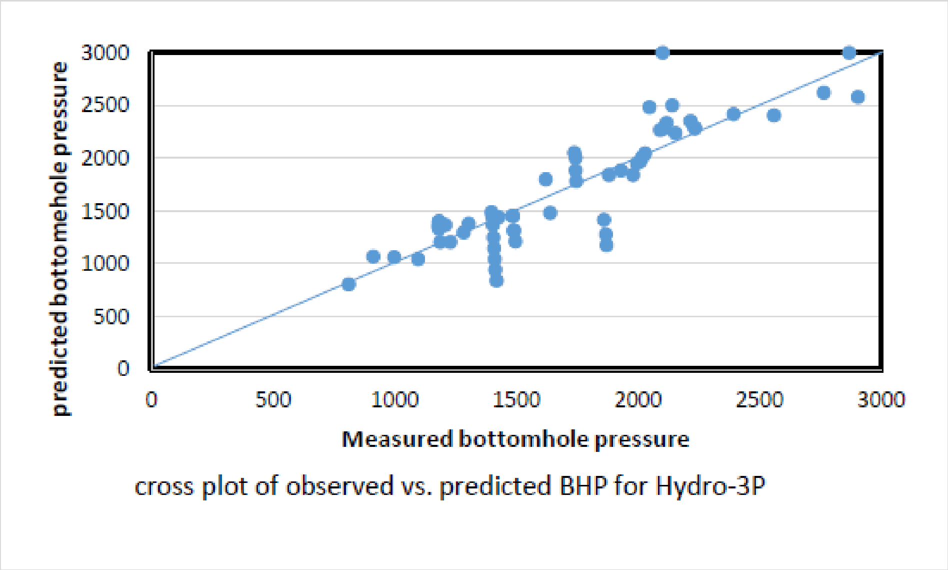

Figure (13) cross plot of observed vs. predicted BHP for Hydro-3P

Petroleum Experts5

Petroleum Experts5 method is used to predict pressure gradient by using prosper program:

The calculated bottom hole pressure is plotted versus field data as shows in Figure (14). Figure (14) shows that the cross plot of field data versus calculated is above 45 line.

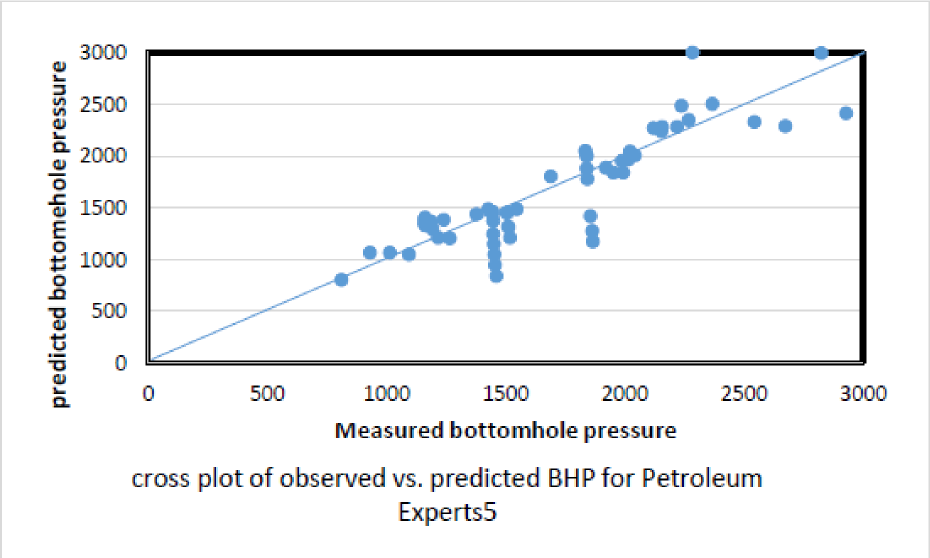

Figure (14) cross plot of observed vs. predicted BHP for Petroleum Experts5

OLGAS 2P

OLGAS 2P method is used to predict pressure gradient by using prosper program:

The calculated bottom whole pressure is plotted versus field data as shows in Figure (15). Figure (15) shows that the cross plot of field data versus calculated is above 45 line.

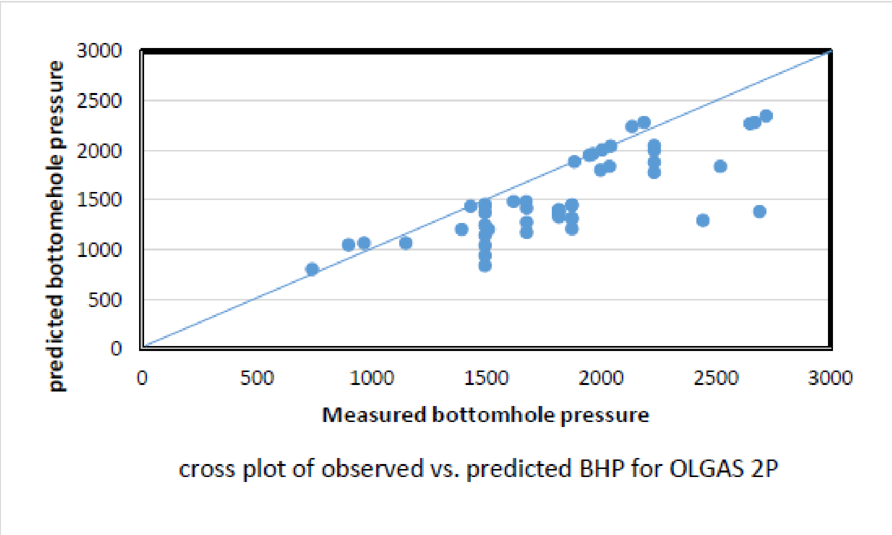

Figure (15) cross plot of observed vs. predicted BHP for OLGAS 2P

Error Analysis:

The average absolute percent relative error between the actual bottom hole pressure data and the calculated bottom hole pressure for predict pressure gradient methods that used in this study are shown in Figure (16). It is clear from this Figure that Hydro-3P pressure gradient has the lowest average absolute error percent that is 11.8780 %, while the average absolute error percent for Duns and Ros Modified method is 12.3043%. The other methods have average absolute errors percent ranging from 13 to 31% Table (17) presents the results of error analysis for all method to predict pressure gradient.

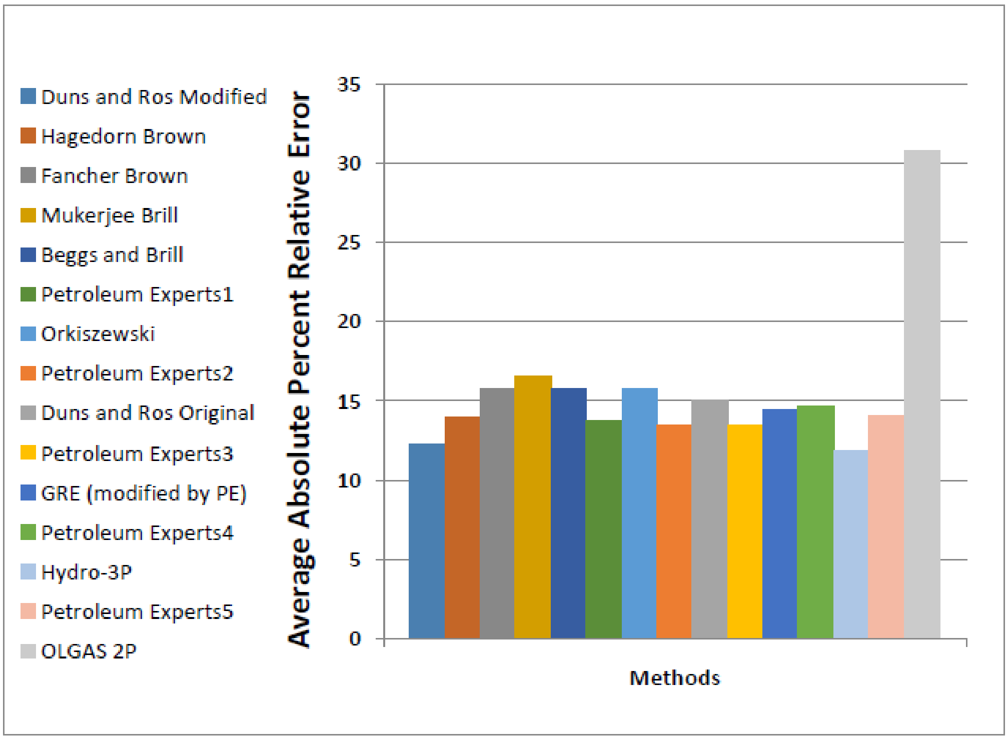

Figure 16) Average Absolute Percent Relative Error

The correlation factor is a statistical measure of the strength of the relationship between the relative movements of two variables. The values range between -1.0 and 1.0. A calculated number greater than 1.0 or less than -1.0 means that there was an error in the correlation measurement. A correlation of -1.0 shows a perfect negative correlation, while a correlation of 1.0 shows a perfect positive correlation. A correlation of 0.0 shows no linear relationship between the movement of the two variables.

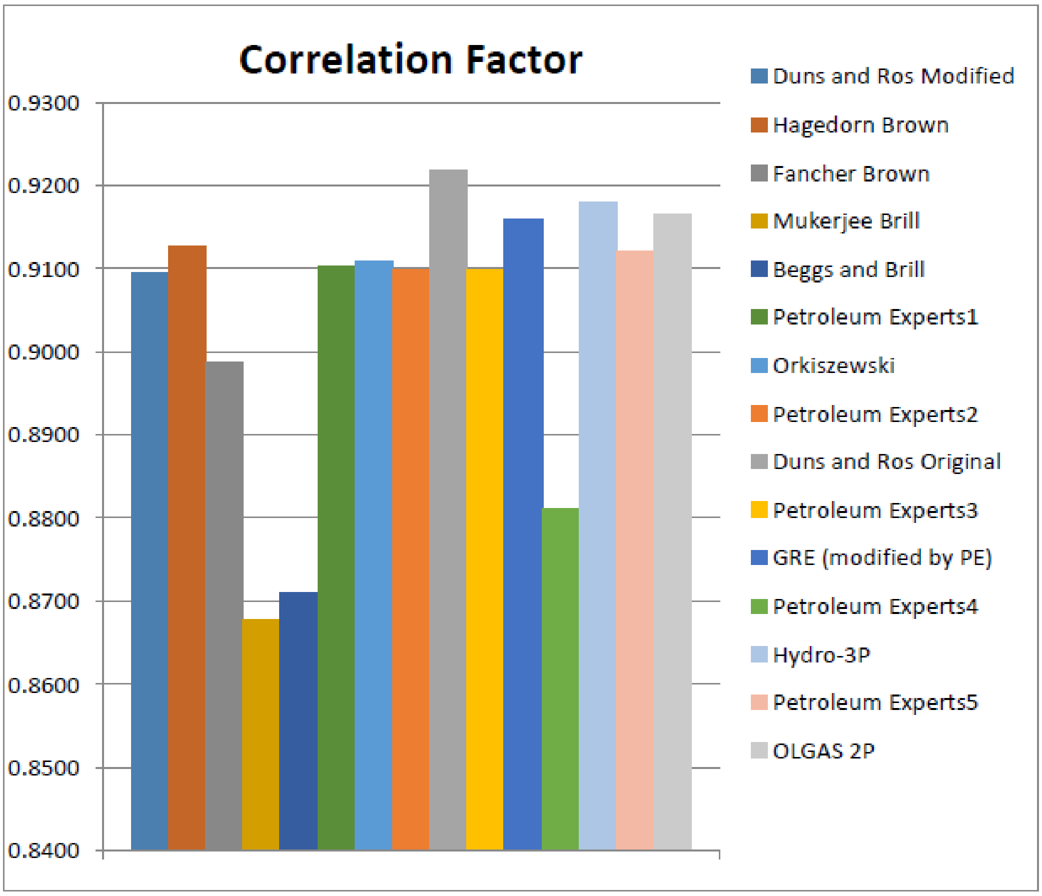

Table 2 .Table (17) presents the results of error analysis for all method to predict pressure gradient
Results of error analysis for all method to predict pressure gradient

Model	**AAPRE**	AAE	**Maximum AE**	**Minimum AE**	Correlation Factor
Duns and Ros Modified	12.30	245	1007	1.67	0.910
Hagedorn Brown	13.99	245	969	5.21	0.913
Fancher Brown	15.76	273	1091	5.21	0.899
Mukherjee **Brill**	16.49	285	1091	0	0.868
Beggs and Brill	15.76	282	1091	0.02	0.871
Petroleum Experts1	13.70	243	966	1.99	0.910
Orkiszewski	15.73	291	1224	4.7	0.911
Petroleum Experts2	13.41	237	952	5.21	0.910
Duns and Ros Original	14.99	282	1360	0.39	0.922
Petroleum Experts3	13.41	237	952	5.21	0.910
GRE (modified by PE)	14.42	259	1242	2.2	0.916
Petroleum Experts4	14.63	268	1242	0.74	0.881
Hydro-3P	11.88	204	894	5.37	0.918
Petroleum Experts5	14.01	252	1205	5.2	0.912
OLGAS 2P	30.75	609	2157	0	0.917

IV. Conclusion:

The following conclusions can be drawn based on the analysis of the findings of this study:

1. To predict pressure gradient, various pressure gradient methods determined with the prosper program were utilized.

2. Average absolute error, average absolute percent error, maximum absolute error, minimum absolute error, and correlation factor were used to assess the validity of the selected pressure gradient methods in comparison to actual data.

3. The findings of this validation revealed that the Hydro-3P approach was the best method for predicting pressure gradients.

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