EVALUATION OF BOTTOMHOLE PRESSURE CORRELATIONS FOR YEMENI OIL FIELDS

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ABSTRACT

The objective of this study is to compare the validity of correlations for estimating bottomhole pressure of Yemeni fields.
The prediction was performed using published and unpublished data set collected from Yemeni oil fields. The calculations were performed for different models. Artificial neural network model was developed. The statistical analysis was performed by using Excel sheet.
Statistical parameters and graphical tools have been used to compare the accuracy and performance of the correlations and model.
Results obtained showed that the Mukherjee and Brill Empirical correlation is the best among available empirical correlations. The results also indicate that the developed ANN model outperforms all tested empirical correlations.

INTRODUCTION

Multiphase flow occurs in almost all producing oil and gas wells and surface pipes that transport produced fluids. The significantly different densities and viscosities of these fluids make multiphase flow much more complicated than the single-phase flow [1]. Complex heat transfer that occurs as fluids flow through the piping system and the mass transfer that takes place among hydrocarbon fluids as pressure and temperature change further complicate predicting multiphase-flow behavior in an oil and gas production system.

The pressure losses in vertical pipes carrying multiphase mixtures (gas and liquid) need to be estimated with good precision in order to implement certain design considerations. The estimation of the pressure drop in vertical multiphase flow is essential for the proper design of well completions and artificial-lift systems and for optimization and accurate forecast of production performance[2,3].

Because of the complexity of multiphase flow mostly empirical or semi-empirical correlations have been developed for prediction of pressure drop. Numerous correlations have been developed since the early 1940s. Most of these correlations were developed under laboratory conditions and are consequently inaccurate when scaled-up to oil field conditions.

FIELD DATA

The data sets were collected from Yemeni fields. Real emphasis was drawn on selecting the most relevant parameters involved in estimation of BHP. Validity of the collected data was first examined to remove the data that are suspected to be in error. For this purpose, the best available empirical correlations were used to obtain predictions of the flowing BHP for all data. These were the correlations of Duns and Ros modified, Hagedorn and Brown, Fancher Brown, Mukherjee and Brill, Beggs and Brill, Orkiszewski, Duns and Ros original and the a Neural networks model (ANN model)[4-8]. The reason for selecting the above-mentioned models and correlations is that they represent the state-of-the-art in vertical pressure drop calculations. Despite the limitations of the data collected, but it characterized by comprehensiveness, which includes a wide range of many parameters. Where the flow Rate have ranged from 280 to 19,618 STB/D for oil and from 0 to 11,000 STB/D of water, and 33 to 13 562 MScf of gas. Tubing diameter from 2 to 4 inches. The well depths - from 4,550 to 7,100 feet, the density in boundary 30 to 40 API. The reservoir temperature was between 157 - 215 °F and the wellhead 76-160 °F ranged. The wellhead pressure has ranged between 80-960 Psig. The measured bottomhole pressure between 1227 and 3217 Psig.

Discussion

Prosper program was used to predict the bottom hole pressure in vertical multiphase flow. We've got good and acceptable results to some extent, with varying error values. Using the artificial neural network model provides more accurate prediction of pressure drop in vertical multiphase flow. as shown in the table. (appendix A and B).

STATISTICAL COMPARISONS

Error analysis is utilized to check the accuracy of the model. The statistical parameters used in the present work are average percent relative error, average absolute percent relative error, minimum and maximum absolute percent error, standard deviation of error, and the correlation coefficient. Equations for those parameters are given below.

Average Percent Relative Error (APE)

It is measure of relative deviation from the experimental data, defined by:

$$E_r = \frac{1n}{} \sum_{i=1}^{N} E_i \quad (1)$$

Where;

E_i- is the relative deviation of an estimated value from an experimental value

$$E_i = \left[\frac{(BHP)_{maes} - (BHP)_{est}}{maes}\right] x100, i = 1,2,3 \dots, n \quad (2)$$

Where;

$(BHP)_{maes}$ - is the actual value of bottom hole pressure

$(BHP)_{est}$ - is the estimated value of bottom hole pressure

Average Absolute Percent Relative Error (AAPR)

It is measure of relative deviation from the experimental data, defined by:

$$E_a = \frac{1}{n} \sum_{i=1}^{N} |E_i| \quad (3)$$

Minimum Absolute Percent Relative Error

$E_{min} = min_{i+1}^{n}|E_i|$
(4)
Maximum Absolute Percent Relative Error
$$E_{max} = max_{i+1}^{n}|E_i| \quad (5)$$
Standard Deviation
It measures of dispersion and is expressed:
$$(6) \quad STD = \sqrt{\left[\left(\frac{1}{m-n-1}\right)\right]\sum_{i=1}^{m}\left[\left\{\frac{(BHP_{act}-BHP_{est})}{BHP_{act}}\right\}100\right]^2}$$
Where;
(m-n-1) represents the degree of freedom in multiple-regression. A lower value of standard deviation indicates a smaller degree of scatter.

The Correlation Coefficient
It represents the degree of success in reducing the standard deviation by regression analysis, defined by:
$$R = \sqrt{1 - \frac{\sum_{I=1}^{n}[(BHP)_{act}-(BHP)_{est}]}{\sum_{I=1}^{n}(BHP)_{act}-\overline{\Delta BHP}}} \quad (7)$$
Where
$$\overline{\Delta BHP} = \frac{1}{n}\sum_{I=1}^{n}[(\Delta BHP)_{act}] \quad (8)$$
R value range between 0 and 1. The closer value to one represents perfect correlation whereas zero indicates no correlation at all among the independent.
Comparison between average absolute percent error for all correlations and the new developed model is provided in Figure 11. Mukherjee and Brill correlation outperforms other correlations in terms of lowest average absolute percent error, lesser maximum error, lowest errors standard deviation, lowest average relative error. The developed model accomplished the lowest average absolute percent relative error (2.14%), lowest maximum error (21.35%), lowest errors standard deviation (2.32), and the highest correlation coefficient among other empirical correlations (97%). Statistical Analysis Results of Empirical Correlations and ANN model are listed in Appendix C.

Graphical Error Analysis
Graphical tools aid in visualizing the performance and accuracy of a correlation or a model. Two graphical analysis techniques are employed; those are cross plots, and residual analysis.
In this graphical based technique, all estimated values are plotted against the measured values and thus a cross plot is formed. A 45° straight line between the estimated versus actual data points is drawn on the cross plot, which denotes a perfect correlation line. The tighter the cluster about the unity slope line, the better the agreement between the experimental and the predicted results. Figures 1 through 8 present cross plots of calculated versus

the actual bottomhole pressure for empirical correlations and the developed ANN model. Investigation of these figures show that among the empirical correlations Duns and Ros modified correlation clearly give the best prediction while Beggs and Brill correlation the worst. It is also shown that the developed ANN model outperforms all correlations.
Graphical comparison between models is given in Figure 9 and 10, which show the correlation coefficients and standard deviation of all models. The ANN model achieved the highest correlation coefficient (0.97), while other correlations indicates higher scattering range, where 0.84 is obtained for Duns and Ros modified correlation, 0.79 for Hagedorn and Brown correlation, 0.81 for Fancher Brown correlation, 0.83 for Mukherjee and Brill correlation, 0.79 for Beggs and Brill correlation, 0.73 for Orkiszewski correlation, 0.81 for Duns and Ros original correlation, Duns and Ros modified correlation achieved the highest correlation coefficient among the other correlations.

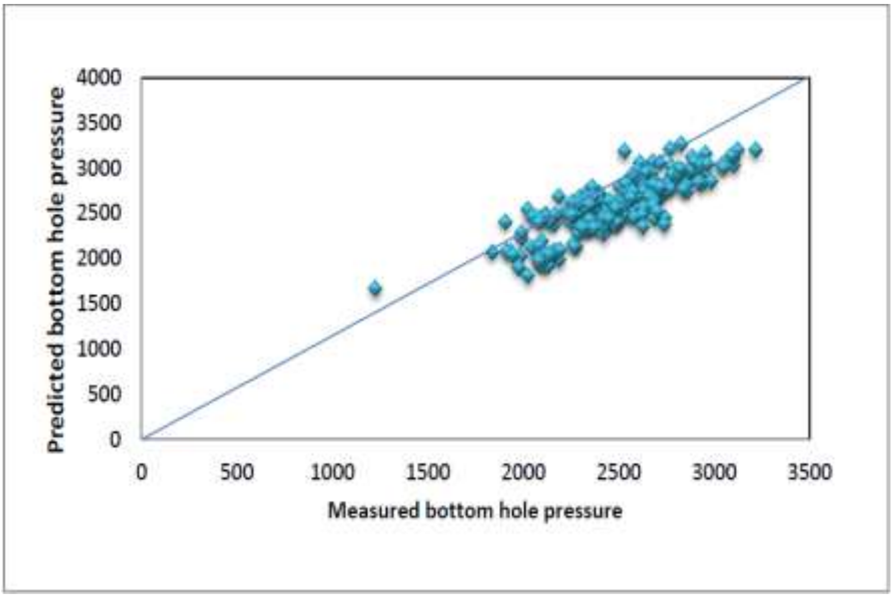

Figure 1: Cross plot of Observed vs. Calculated BHP for Duns and Ros- modified Correlation

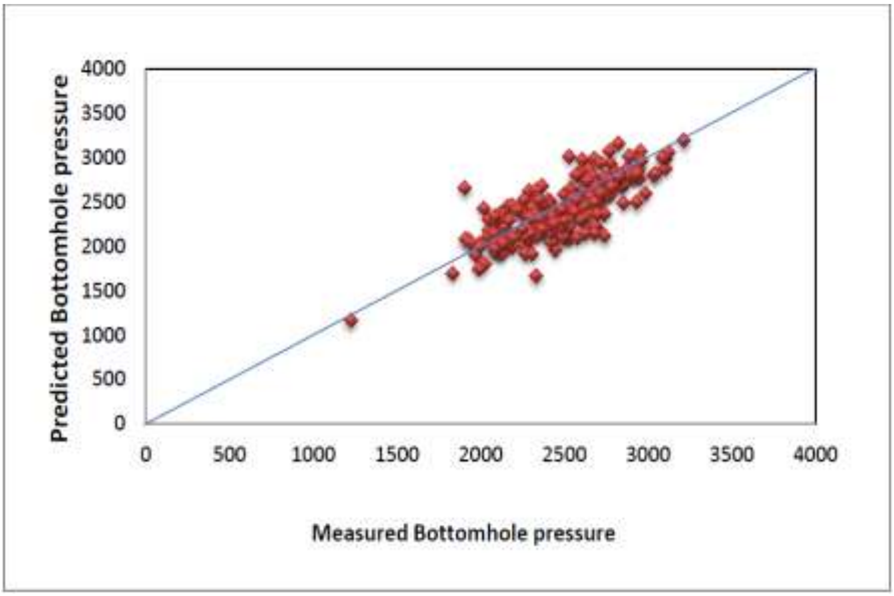

Figure 2: Cross plot of Observed vs. Calculated BHP for Hagedorn Brown correlation

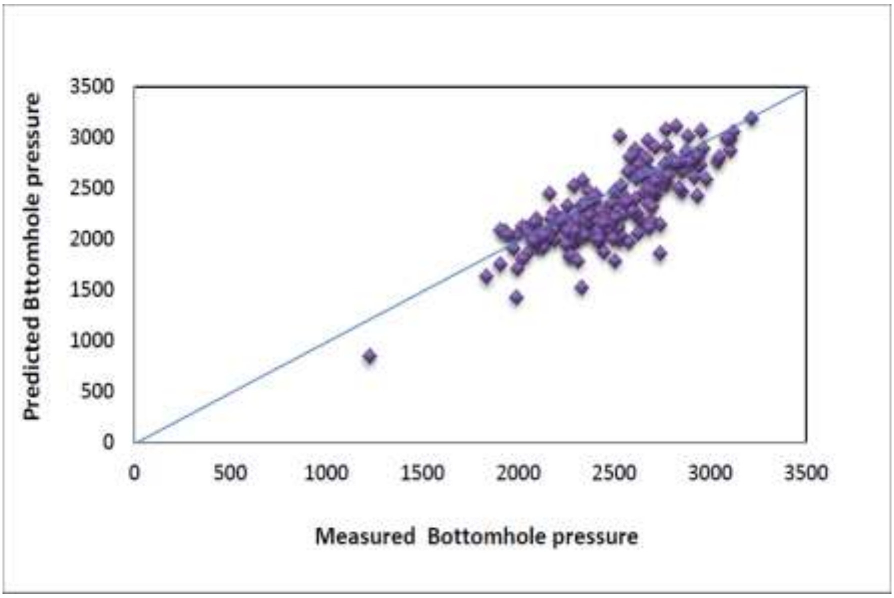

Figure 3: Cross plot of Observed vs. Calculated BHP for Fancher Brown correlation

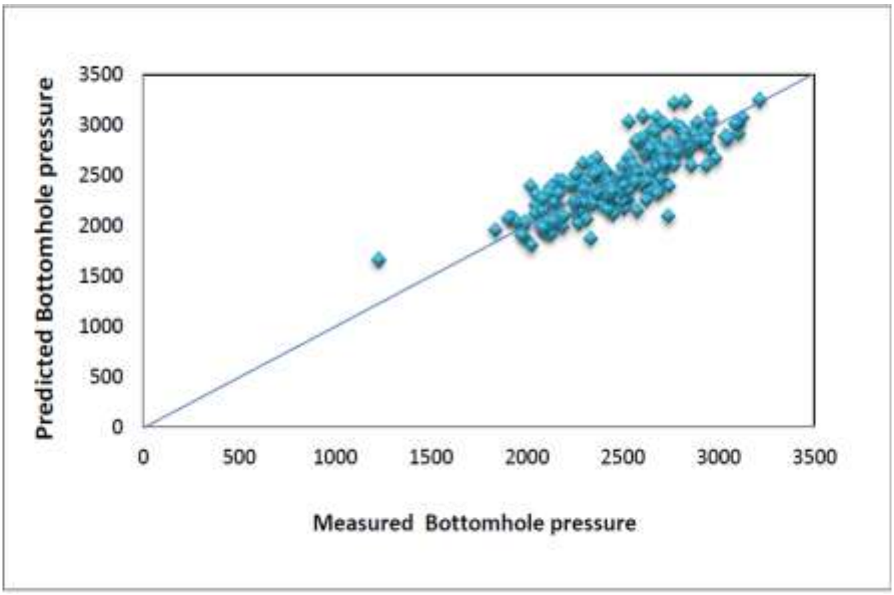

Figure 4: Cross plot of Observed vs. Calculated BHP for Mukherjee-Brill correlation

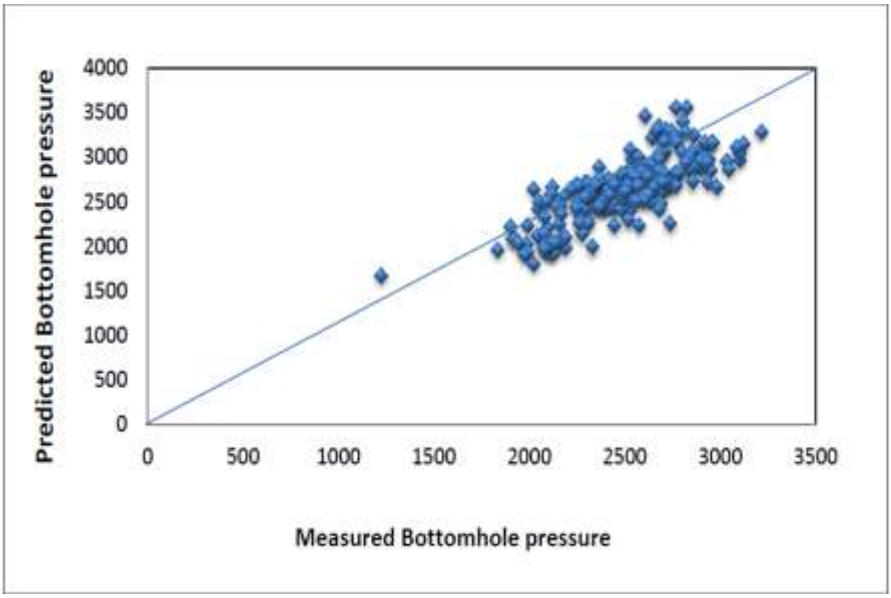

Figure 5: Cross plot of Observed vs. Calculated BHP for Beggs and Brill correlation

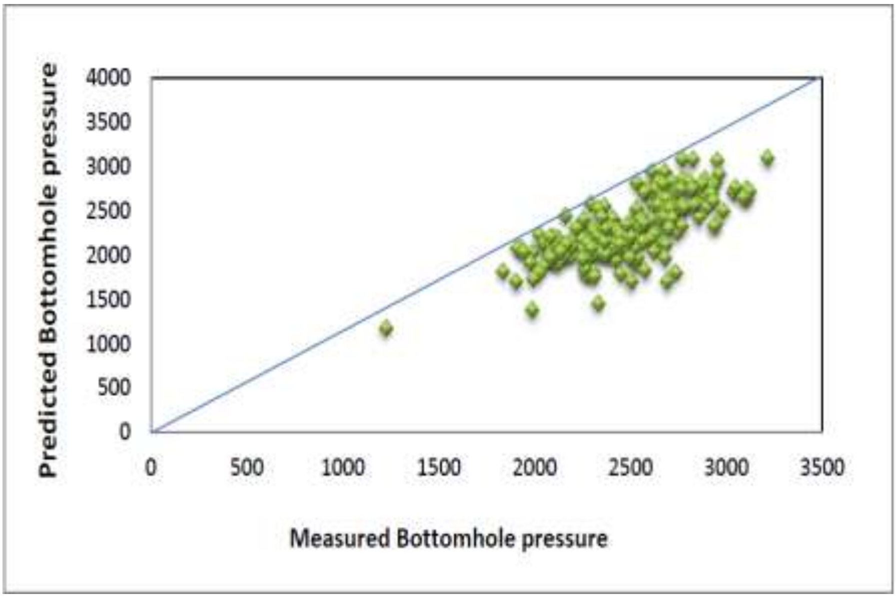

Figure 6: Cross plot of Observed vs. Calculated BHP for Orkiszewski correlation

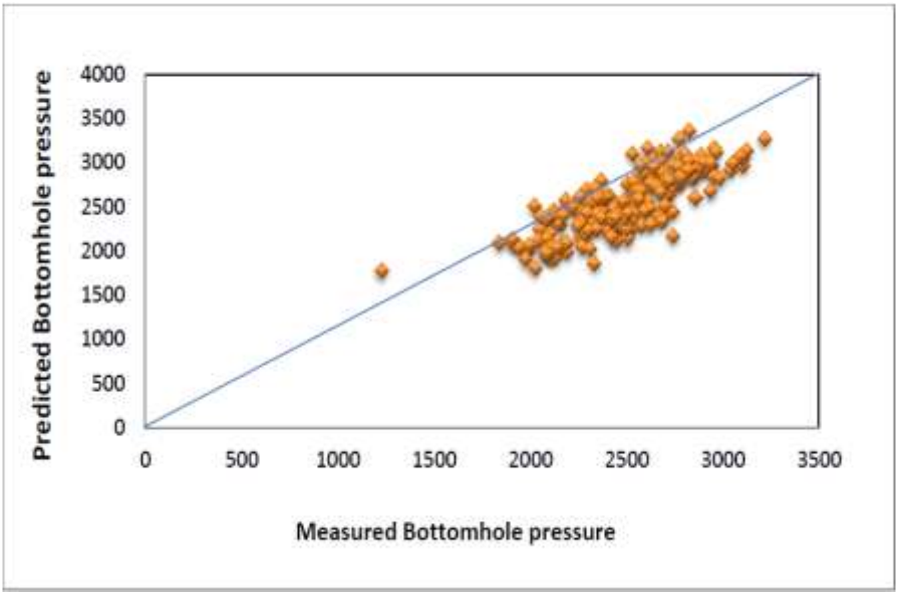

Figure 7: Cross plot of Observed vs. Calculated BHP for Duns and Ros-original correlation

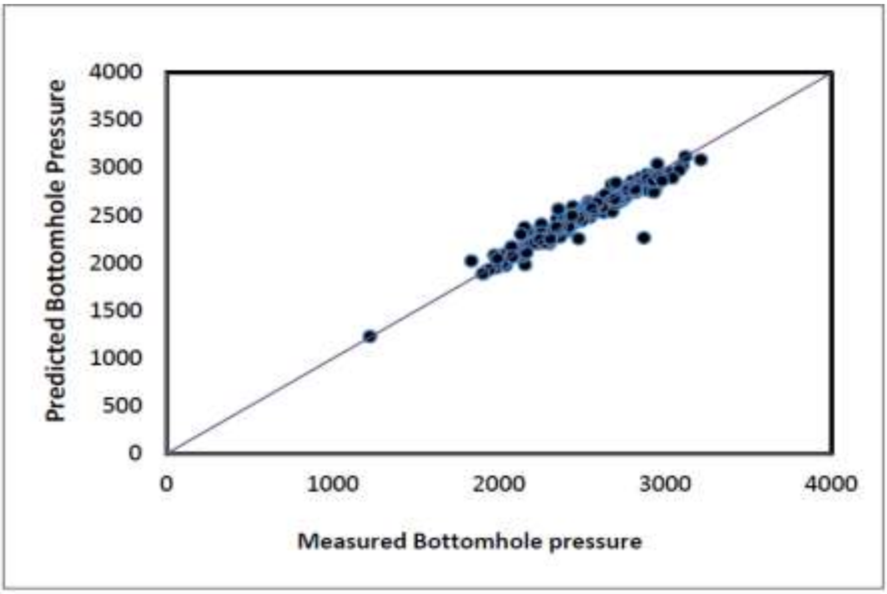

Figure 8: Cross plot of Observed vs. Calculated BHP for ANN model

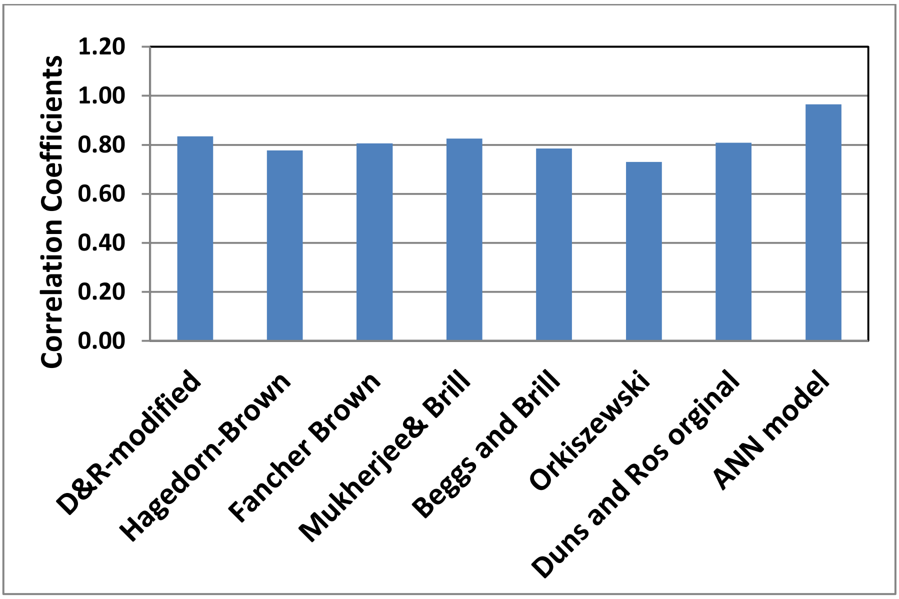

Figure 9: Comparisons of Correlation Coefficients for the Models

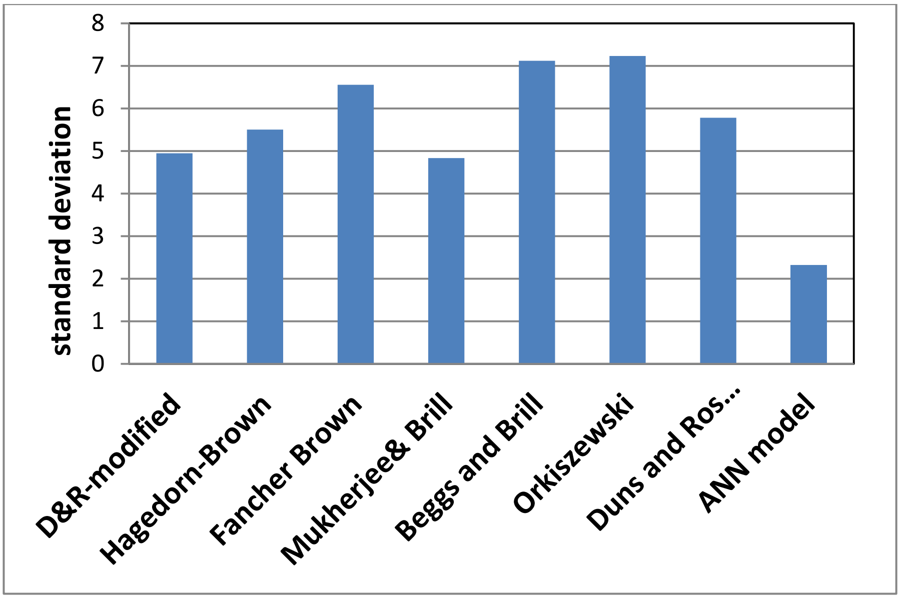

Figure 10: Comparison of standard deviation for the Models

The average absolute percent relative error is a significant sign of the accuracy of the models. Its value for ANN was 2.144%, while other correlations indicate high error values of 9.72% for Orkiszewski correlation, 8.87% for Beggs and Brill correlation, 8.81% for Fancher Brown correlation, 7.34% for Hagedorn and Brown correlation, 6.93%,for Duns and Ros original correlation, 6.26% for Duns and Ros modified correlation, 6.11% for Mukherjee and Brill correlation.

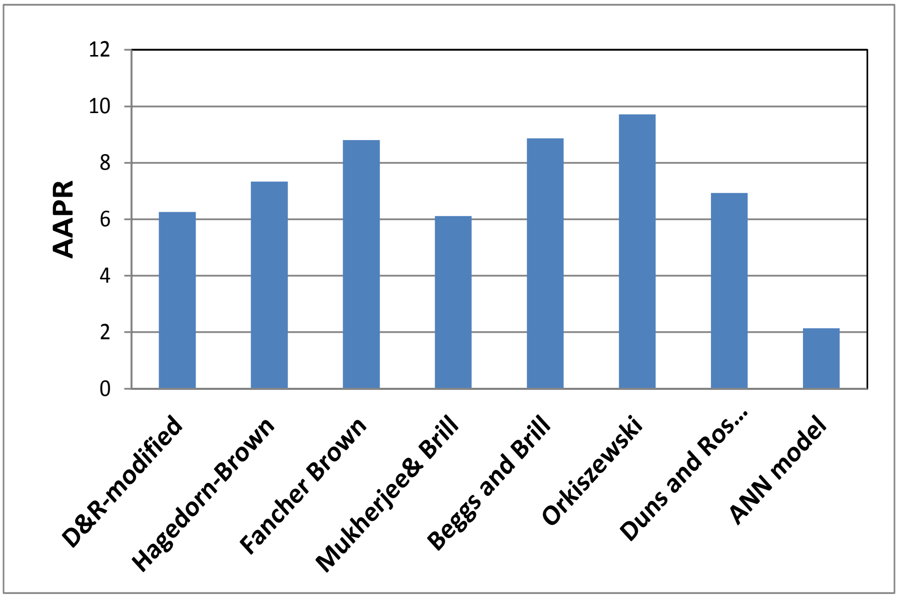

Figure 11: Comparison of AAPR for the Models

Residual Analysis

The relative frequency of deviations between estimated and actual values is depicted in figures 12 through 19 for the tested correlations. These figures showed the error distribution around the zero line to verify whether models and correlation have error trends. Analysis of residual (predicted BHP minus the measured BHP) is an effective tool to check model deficiencies. The Orkiszewski correlation shows the worst negative error performance with a value of -994.73 psia. While Beggs and Brill correlation showed the worst positive error performance (854.52 psia). Duns and Ros modified correlation showed the best error trend around zero (656.36 to -365.66).

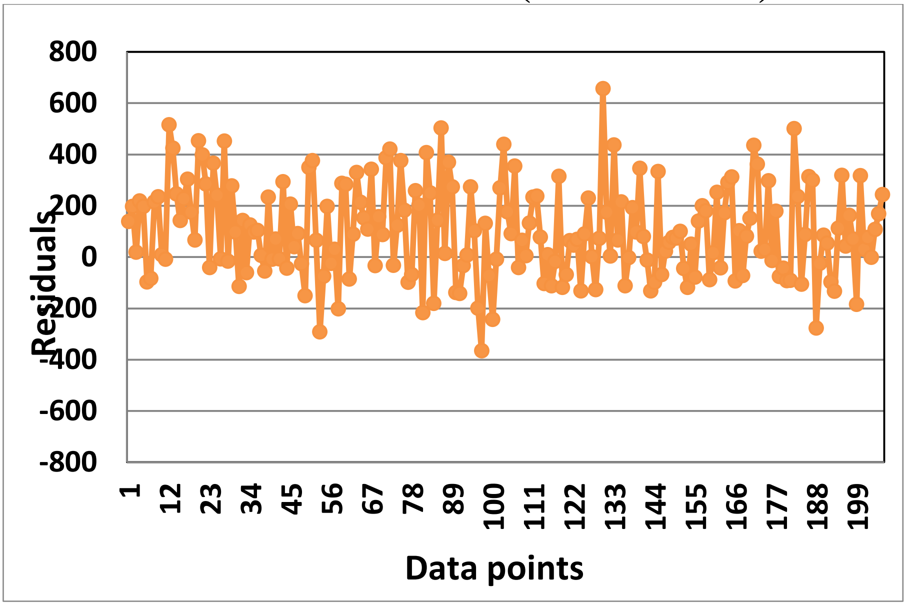

Figure 12: Residual Graph for Duns and Ross modified model

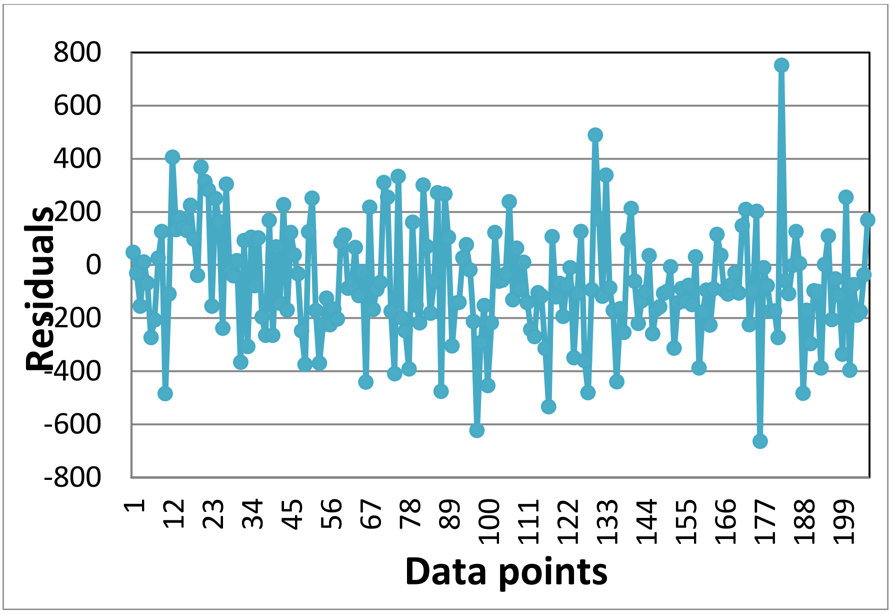

Figure 13: Residual Graph for Hagedorn and Brown model

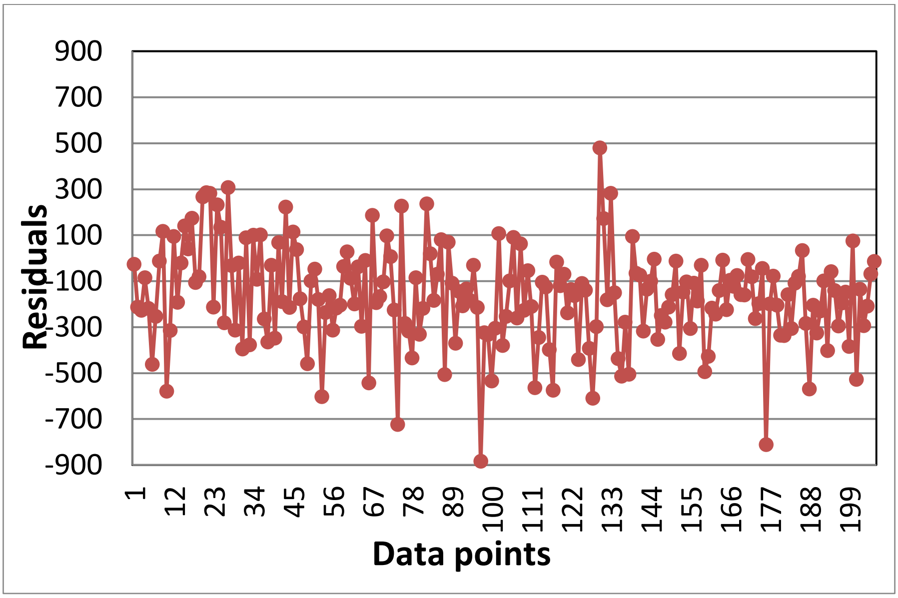

Figure 14: Residual Graph for Fancher Brown model

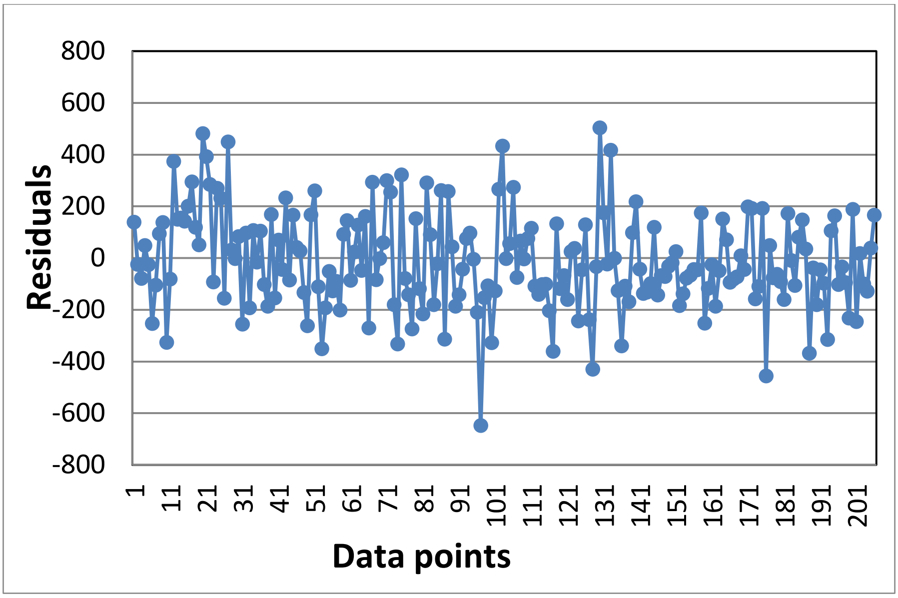

Figure 15: Residual Graph for Mukharjee and Brill model

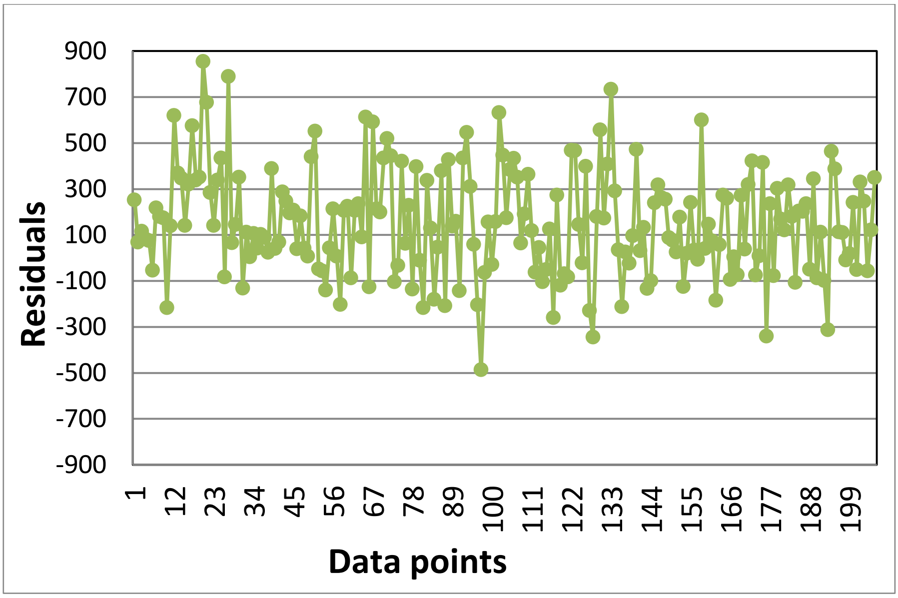

Figure 16: Residual Graph for Beggs and Brill model

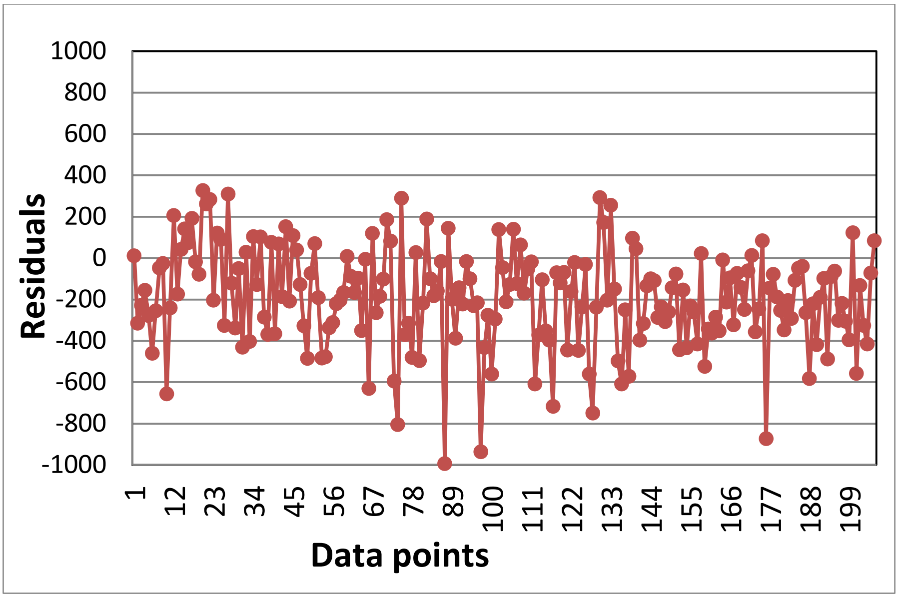

Figure 17: Residual Graph for Orkiszewski model

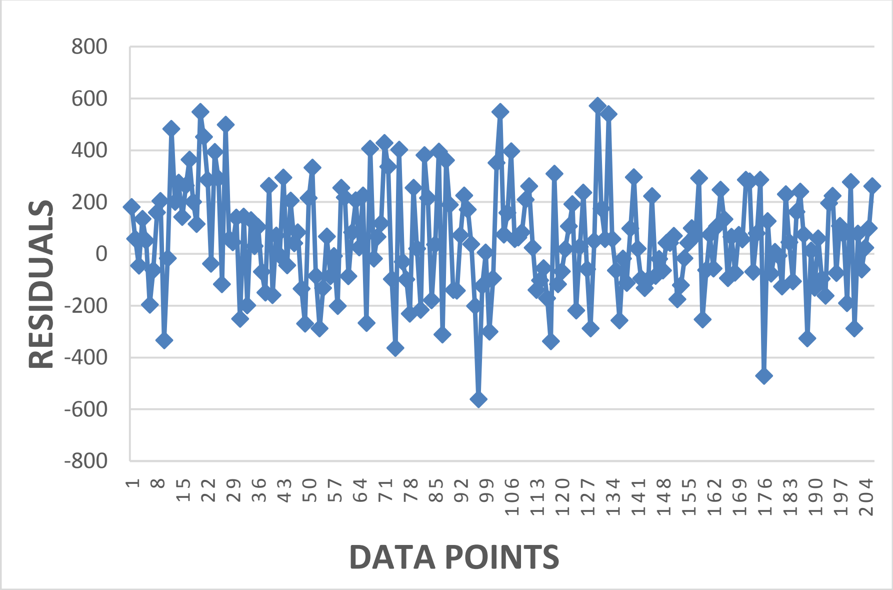

Figure 18: Residual Graph for Duns and Ros original model

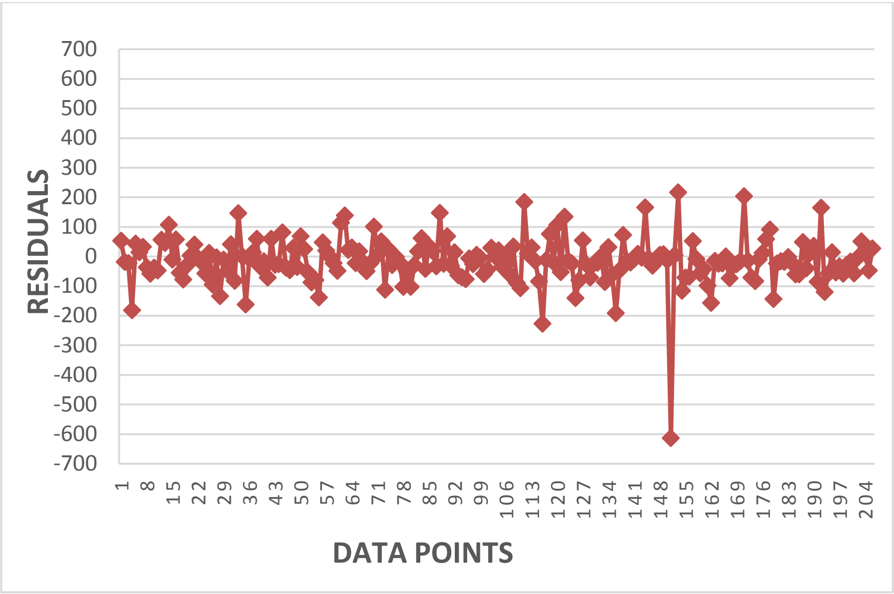

Figure 19: Residual Graph for ANN model

CONCLUSIONS

Based on the results obtained in this paper may be obtained the following conclusions:

- Of existing correlations in the literature, the best estimate of the flowing BHP in vertical wells examined in this study was found to be provided by Mukherjee and Brill correlation. The correlation achieved best correlation coefficient (0.83), the lowest maximum absolute relative error (-0.33%), the lowest standard error deviation (4.84), and the lowest average absolute percent error (6.11%).
- The developed Artificial Neural Network model outperformed the best available empirical correlations.
- The developed Artificial Neural Network model achieved best correlation coefficient (0.97), the lowest maximum absolute relative error, the lowest standard error deviation (2.32), and the lowest average absolute percent error (2.144%).
- A graphical analysis showed that the Duns and Ros modified models outperforms other correlations.□

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APPENDCES

Appendex A: Predicted Bottomhole pressure (Psia)

MBHP (Psia)	Duns and Ros modified	Hagedorn Brown	Fancher Brown	Mukerjee Brill	Beggs and Brill	Orkiszewski	Duns and Ros original
2641	2543.74	2367.64	2178.68	2387.15	2588.15	2179.2	2444
2565	2481.3	2357.91	2311.76	2459.5	2783.17	2309.3	2501.42
2615	2829.3	2640.35	2601.99	2708.51	2795	2566.42	2774.74
2888	3122.27	3012.84	3004.96	3024.88	3062.73	2860.52	3091.57
2449	2457.57	1964.53	1869.14	2122.43	2233.37	1790.93	2114.43
2403	2394.33	2293.73	2087.65	2320.41	2543.2	2161.62	2385.29
2023	2538	2428.43	2116.79	2396.51	2643.12	2227.46	2504.69
2049	2472.86	2181.24	1855.95	2198.44	2418.51	1874.25	2249.17
2353	2598.53	2530.68	2332.15	2506.82	2700.67	2394.32	2627.32
1932	2073.96	2071.82	2071.81	2073.96	2073.98	2071.82	2074.14

Appendix B: Predicted Bottomhole pressure by ANN model

Target	Output	AE	ARE	residuals
2641	2654.68	13.68	0.52	13.7
2565	2597.10	32.10	1.25	32.1
2615	2577.65	37.35	1.43	-37.3
2888	2829.53	58.47	2.02	-58.5
2449	2411.03	37.97	1.55	-38.0
2403	2354.63	48.37	2.01	-48.4
2023	2079.31	56.31	2.78	56.3
2049	2094.60	45.60	2.23	45.6
2353	2460.18	107.18	4.55	107.2
1932	1920.46	11.54	0.60	-11.5

Appendix B: Statistical Analysis Results of Empirical Correlations and ANN model

model	AAE	AAPR	max	min	R	STD
Duns and Ross modified	3.67	6.26	26.35	0.04	0.83	4.95
Hagedorn and Brown	-2.61	7.34	39.39	0.03	0.78	5.51
Fancher and Brown	-6.76	8.81	34.79	0.19	0.81	6.55
Mukherjee and Brill	-0.33	6.11	35.27	0.07	0.83	4.84
Beggs and Brill	6.31	8.87	36.44	0.17	0.79	7.12
Orkiszewski	-7.55	9.72	37.50	0.22	0.73	7.23
Duns and Ros original	2.25	6.93	44.63	0.15	0.81	5.78
ANN Model	53.85	2.14	21.35	0.01	0.97	2.32