Evaluation of Correlations for Libyan Natural Gas Compressibility Factor

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Abstract:

The compressibility factor (Z-factor) of natural gases is necessary in many gas reservoir engineering calculations. Knowledge of the pressure – volume - temperature (PVT) behavior of natural gases is necessary to solve many petroleum engineering problems such as gas reserves, gas metering, gas pressure gradients, pipeline flow and compression of gases. However, the value of compressibility factor should be computed when PVT data are not available. For this purpose some developed empirical correlation for the Libyan natural gases were tested to find out they are applicable or not. Six empirical correlations were tested for estimating the (Z-factor). Estimated Z-factor values by these empirical correlations are also compared with a large of lab z-factor measurement consisting about 90 sample from two Libyan oil Field are (ten wells from Amal oilfield and five wells from Tibiste oilfield). The results obtained shows that some of those correlations are valid for the Libyan natural gases, and some of them are not applicable due to their high average absolute error.

***Keywords*:** Libyan natural gases, gas Compressibility factor, Evaluation, Average absolute error.

1. Introduction:

Natural gas is a subcategory of petroleum that is a naturally occurring, complex mixture of hydrocarbons, with a minor amount of inorganic compounds [1]. There are two terms frequently used to express natural gas reserves proved reserves and potential resources. The proved reserves are those quantities of gas that have been found by the drill. They can be proved by known reservoir characteristics such as production data, pressure relationships, and PVT data. The volumes of gas can be determined with reasonable accuracy [1]. Many correlations for calculating thermodynamic properties of natural gas such as compressibility factor, density and viscosity, has been presented [2]. In each of these correlations, each property is a functional of reduced properties such as reduced pressure, reduced volume, and reduced temperature.

For estimation of compressibility factor of natural gas, the most widely accepted correlation has been presented by the Standing and Katz (S-K) (Standing and Katz, 1942) z-factor chart. The S-K chart was developed using data for binary mixtures of methane with propane, ethane, butane, and natural gases having a wide range of composition. None of the gas mixtures molecular weights exceed 40 gm/mole [3] .

In recent years, most studies for calculating compressibility factor of natural gas have been done by employing correlations. Elsharkawy et al. (2001) presented a new model for calculating gas compressibility factor based on compositional analysis of 1200 compositions of gas condensates [2]. Also Elsharkawy (2004) presented efficient methods for calculating compressibility factor, density and viscosity of natural gases. This model is derived from 2400 measurements of compressibility and density of various gases. (Papay 1985) Correlation, (Najim,1995), Shell Oil Company Correlation (Kumar, 2004) and (Beggs and Brill, 1973) Correlation are direct relations and (Hall-Yarborough, 1975) Correlation, (Dranchuk and Abou-Kassem, 1975) Correlation are iterative relations for calculating compressibility factor of natural gas. New correlation for compressibility factor of natural gas has been presented by Heidaryan et al.(2010) and

Azizi et al (2010) . Heidaryan et al.(2010) correlation has 1.660 of average absolute percent deviation (*AAPD*) versus Standing and Katz (1942) chart[3].

Kingdom et al. (2012) used various correlations available for the calculation of gas compressibility factors. The correlations or equations of state considered for such purpose are Standing & Katz, Hall and Yarborough, Beggs and Brill, and Dranchuk and Abou-Kassem. This correlation resulted in z factors which fitted the data base with an average absolute Error of 0.6792% percent and a maximum error of 4.2% percent[4].

Obuba et al. (2013) selected twenty-two (22) laboratory gas PVT reports from Niger Delta gas fields. They developed methods that allow accurate determination of Z-factor values both for pure components and gas mixtures including significant amounts of non-hydrocarbon components. Their correlation also showed high correlation coefficient of: 93.39%, for dry gas; 89.24% for solution gas; 83.56% for rich CO_2 and 83.34% for rich condensate gas reservoirs [5]. Fayazi et al. (2014) developed the new model and tested using a large database consisting of more than 2200 samples of sour and sweet gas compositions. The developed model can predict the natural gas compressibility factor as a function of the gas composition (mole percent of C_1,C_7, H_2S, CO_2, and N_2), molecular weight of the C_7, pressure and temperature. The calculated Z-factor values by developed intelligent model are also compared with predictions of other well-known empirical correlations [6]. Statistical error analysis shows that the developed model out performs all existing predictive models with average absolute relative error of 0.19% and correlation coefficient of 0.999.

This work is focused on the selection of the most accurate correlations to predict compressibility factor for Libyan natural gas . The most accurate correlations is based on the lowest Absolute Relative Error (ARE%) and highest correlation coefficient (R^2). The correlations which are used in this study as follows :-

- Niger Delta correlation [5] .
- Hall-Yarborough, correlation [10].
- Brill and Beggs correlation [11].
- Papay correlation [13] .
- Dranchuk-Abu-Kassem, correlation [16] .
- Shell Oil Company correlation [17] .

2. Pseudo Critical Properties Correlations:

The pseudo critical properties provide a means to correlate the physical properties of mixtures with the principle of corresponding states[1]. The values of critical pressure and critical temperature can be estimated from its specific gravity if the composition of the gas and the critical properties of the individual components are not known. There are several different correlations available. The most common correlations are proposed by Sutton method [7-8].

2.1Sutton Method :

The most common is the one proposed by Sutton , which is based on the basis of 264 different gas samples [8]. Sutton developed correlation when the gas gravity is available to estimate the pseudo critical pressure and temperature as the function of gas gravity. Sutton correlation are based on larger data base and consequently differ significantly and fit the raw data with quadrate equation and obtained the following empirical [9]. Equation relating pseudo critical properties of the hydrocarbons to the specific gravity are described below :-

$$P_{pch} = 756.8 - 131.0\gamma_h - 3.6{\gamma^2}_h \qquad (2\text{-}1)$$

$$T_{pch} = 756.8 - 131.0\gamma_h - 3.6{\gamma^2}_h \qquad (2\text{-}2)$$

Where:-

P_{pch} = pseudo critical pressure of hydrocarbon component.

T_{pch} = pseudo critical temperature of hydrocarbon component.

γ_h = gas gravity of hydrocarbon component

These equations can be applied when the γ_g range is from 0.57 to1.68 ($0.57<\gamma_g<1.68$) and the gas contains less than 12% moles from CO_2 , 3% moles of nitrogen and no moles from H_2S. However if the gas contains more than 12% moles from CO_2 3% moles of nitrogen or any moles from H_2S then the γ_g hydrocarbon should be calculated by the following equation:-

$$\gamma_h = \frac{\gamma_w - 1.1767 y_{H2S} - 1.5196 y_{CO2} - 0.9672 y_{N2} - 0.662 y_{H2O}}{1 - y_{H2S} - y_{CO2} - y_{N2} - y_{H2O}} \qquad (2\text{-}3)$$

Where:-

y_{H2S} = mole fraction of H_2S in the gas mixture

y_{CO2}= mole fraction of CO_2 in the gas mixture

y_{N2}= mole fraction of N_2 in the gas mixture

y_{H2O} = mole fraction of H_2Oin the gas mixture

Then the pseudo critical pressure and temperature described by the following equation

$$T''_{pc} = \left(\frac{T'_{pc} - 227.2 y_{N2} - 1.165\, y_{H2O}}{(1 - y_{N2} - y_{H2O})}\right) + T_{pc}, cor \qquad (2\text{-}4)$$

$$P''_{pc} = \left(\frac{P'_{pc} - 493.1 y_{N2} - 3200\, y_{H2O}}{(1 - y_{N2} - y_{H2O})}\right) + P_{pc}, cor \qquad (2\text{-}5)$$

Where:

Tpc = Pseudo-critical temperature, ^{0}R

Ppc = Pseudo-critical pressure psia

$T''pc$ = The adjusted pseudo-critical temperature, ^0R

$P''pc$ = The adjusted pseudo-critical pressure, psia

Calculating Pseudo reduced (Ppr & Tpr) using equation:

$$T_{pr} = \frac{T}{T''_{pc}} \quad (2\text{-}6)$$

$$P_{pr} = \frac{P}{P''_{pc}} \quad (2\text{-}7)$$

Where:

P = Pressure system, psia

T= Temperature system ,^0R

Tpr = Pseudo-reduced temperature, dimensionless

Ppr = Pseudo-reduced pressure, dimensionless

3. Gas Compressibility Factor (Z):

It is defined as the ratio of the actual volume of number of moles of gas at temperature and pressure to the volume of the same number of moles at the same ideal temperature and pressure. The compressibility factor at a given pressure and temperature can be obtained by using either the correlations or experimental chart [6].

3.1Direct Calculation Of Compressibility Factor:

The principle of corresponding states suggests that pure but similar gases have the same gas deviation or Z factor at the same values of reduced pressure and temperature. After decades of existence, the Standing-Katz Z-factor chart, it is still widely used as a practical source of natural gas compressibility factors. As a result, there was an apparent need for a simple mathematical description of that chart. Several empirical correlations for calculating (Z-factors) have been later developed.

Numerous rigorous mathematical expressions have been proposed to accurately reproduce the Standing and Katz (Z-factor) chart. Most of this expressions are designed to solve for the gas compressibility factor at any (P_{pr}) and (T_{pr}) iteratively [12,13]. Six of these empirical correlations are selected in this work as mentioned before.

3.1.1. Hall-Yarborough's Correlations [10]:

Hall and Yarborough presented an equation of state that accurately represents the Standing and Katz (Z-factor) chart. The proposed expression is based on the Starling- Carnahan equation of state.

The coefficients of the correlation were determined by fitting them to data taken from the Standing and Katz (Z-factor) chart. Hall and Yarborough proposed the following mathematical form[10]:-

$$Z=\left[\frac{0.06125tP_{Pr}}{Y}\right]\exp[-1.2(1-t)^2] \qquad (3\text{-}1)$$

Where:-

Ppr = pseudo-reduced pressure

t = reciprocal of the pseudo-reduced temperature (i.e., Tpc/T)

Y = the reduced density, which can be obtained as the solution of the following equation:-

$$F(Y) = X_1 + \frac{Y + Y^2 + Y^3 + Y^4}{(1-Y)} - (X_2)Y^2 + (X_3)Y^{X_4} = 0 \qquad (3\text{-}2)$$

Where:-

$X_1 = -0.0612p_{pr}t \exp[-1.2(1-t)^2]$, $X_2 = (14.76t - 9.76t^2 + 4.58t^3)$

$X_3 = (90.7t - 242.2t^2 + 42.4t^3)$, $X_4 = (2.18 + 2.82t)$

Hall and Yarborough pointed out that the method is not recommended for application if the pseudo-reduced temperature is less than one (Tpr<1.0).

3.1.2. Brill And Beggs Z-Factor Correlation [11]:

Brill and Beggs have suggested the following correlation:

$$Z = A + \frac{1-A}{e^B} + c.P_r^D \qquad (3\text{-}3)$$

Where:-

$A=1.39\,(T_r - 0.92)^{0.5} - 0.36T_r - 0.101$, $B=(0.62-0.23T_r)\,P_r + \left(\frac{0.066}{T_r-0.86} - 0.037\right)P^2{}_r + \frac{0.32P^6{}_r}{10^{(9T_r-9)}}$, $C= (0.132 - 0.32\log T_r)$, $D=\text{Anti}\log(0.3106 - 0.49T_r + 0.1824T^2{}_r)$.

Where:

Tr = reduced temperature, dimensionless

Pr = reduced pressure, dimensionless

This method is not suggested to be used for reduced temperature (Tpr) values less than 0.92.

3.1.3.Dranchuk And Abu-Kassem's Correlation [16]:

Dranchuk and Abu-Kassem derived an analytical expression for calculating the reduced gas density that can be used to estimate the gas compressibility factor. The reduced gas density (ρ_r) is defined as the ratio of the gas density at a specified pressure and temperature to that of the gas at its critical pressure or temperature :-

$$\rho_r = \frac{\rho}{\rho_c} = \frac{[pM_a(ZRT)]}{[p_c M_a(Z_c RT_c)]} = \frac{[p/(ZT)]}{[p_c/(Z_c T_c)]}$$

(3-4)

Where:

ρ_r= Reduced gas density

ρ_c= Critical gas density

ρ= Gas density

R= Gas constant

Zc= Critical gas compressibility factor

The critical gas compressibility factor (Z_c) is approximately 0.27, which leads to the following simplified expression for the reduced gas density as expressed in terms of the reduced temperature (T_r) and reduced pressure (P_r) :-

$$\rho_r = \frac{0.27P_{Pr}}{ZT_{Pr}} \qquad (3\text{-}5)$$

The authors proposed the following 11-constant equation of state for calculating the reduced gas density:-

$$f(\rho_r) = (R_1)\rho_r - \frac{R_2}{\rho_r} + (R_3)\rho_r^{\ 2} - (R_4)\rho_r^{\ 5} + (R_5)(1 + A_{11}\rho^2{}_r)\rho_r^{\ 2}\exp[-A_{11}\rho^2{}_r] + 1 = 0$$

The proposed correlation was reported to duplicate compressibility factors from the Standing and Katz chart with an average absolute error of 0.585% and is applicable over the ranges[16]:-

$0.2 \leq P_{Pr} < 30,\ 1.0 < T_{Pr} \leq 3.0$

3.1.4. Papay Correlation [13]:

Papay correlations proposed a simple expression for calculating the gas compressibility factor explicitly. correlated the (Z- factor) with pseudo-reduced pressure (P_{pr}) and Temperature (T_{pr}) as expressed next:-

$$Z = 1 - \frac{3.53P_{Pr}}{10^{0.9813T_{Pr}}} + \frac{0.274P^2{}_{Pr}}{10^{0.8157T_{Pr}}} \qquad (3\text{-}6)$$

Where:-

Tpr = Pseudo-reduced temperature, dimensionless

Ppr = Pseudo-reduced pressure, dimensionless

3.1.5. Shell Oil Company Correlation [17]:

Kumar proposed shell company model for estimation of Z-factor as:

$$Z=A + BP_{pr} + (1-A)\exp^{(-C)} - D\left(\frac{P_{pr}}{10}\right)^4 \qquad (3\text{-}7)$$

Where:-

$A= -0.101 -0.361T_{pr} + 1.3868\sqrt{T_{pr} - 0.919}$, $B= 0.21+\frac{0.04275}{T_{pr}-0.65}$, $C = P_{pr}(E+ FP_{pr} +GP_{pr}{}^4)$,

$D= 0.122\exp(-11.3(T_{pr}-1))$, $E=0.6222-0.224T_{pr}$, $F=\frac{0.0657}{T_{pr}-0.85} - 0.037$,

$C = 0.32\exp(-19.53(T_{pr}-1))$

3.1.6. Niger Delta Correlation [5]

This correlation is a function of pseudo-reduced pressure and temperature. Their proposed equation is as follow:

$$Z = 6.41824 - 0.013363P_{pr} -3.351293T_{pr} \qquad (3\text{-}8)$$

4. Statistical Error Analysis:

There are four main statistical parameters that are being considered in this study. These parameters help to evaluate the accuracy of the predicted any fluid properties obtained from the correlations.

4.1. Average Absolute Percent Relative Error(AAPRE):

This Parameter is to measure the average value of the Absolute Relative deviation of the measured value from the experimental data. The value of AAPRE is Expressed in Percent. The parameter can be defined as:-

$$E_a = \left(\frac{1}{nd}\right) \sum_{i=1}^{nd} Ei \qquad (4\text{-}1)$$

E_i is the relative deviation in percent of an estimated value from an experimental value and is defined by :-

$$Ei = \left|\frac{X_{est} - X_{exp}}{X_{exp}}\right| i \times 100 \,, \qquad i = 1,2,\ldots\ldots \qquad (4\text{-}2)$$

Where x_{est} and x_{exp} represent the estimated and experimental values, respectively and indicate the relative absolute deviation in percent from the experimental values. A lower value of AAPRE implies better agreement between the estimated and experimental values [15].

4.2. Coefficient (R^2)

To select the most accurate method to estimate Z-factor correlation coefficient (R^2) is used. The maximum (R^2)is the best method. The following equation was used to calculate (R^2) :-

$$R^2 = 1 - \frac{\sum(f_i - y_i)^2}{\sum(y_i - \bar{y})^2} \qquad (4\text{-}3)$$

Note; the all calculations were made by excel software.

4.3. Cross Plot:

In this technique, all the estimated values are plotted against the experimental values, and thus a cross plot is formed. A 45° [0.79-rad] straight line is drawn on the cross plot on which the estimated value is equal to the experimental value [17].

5. Results And Discussion:

5.1. Collecting PVT Data:

In this study the fifteen wells were selected from two Libyan oil Field are (ten well from Amal field and five well from Tibiste field). Lab z-factor data was gathered from Amal oilfield and Tibiste oilfield. The Z-Factor was estimated using different correlations. The input parameters , pseudo-reduced temperature (T_{pr}) and pseudo-reduced pressure (P_{pr}) was obtained by Sutton method. 540 points were obtained and compared with 90 points at different conditions of the lab Z-factor measurement. However, the results were divided in two parts, the first one studied each well separately with different well pressures , and the second one studied the wells comprehensively.

5.2. Study Of Each Well Separately:

In this section, the gas compressibility factor as a function of changing pressure has been investigated for the all wells separately . Also the ability of the correlations for calculating the gas compressibility factor as a function of changing pressure has been investigated. Calculated Z-factor by different correlations with Sutton method

- Amal field, the wells (B3-12 ,B4-12 , B7-12, B11-12, B12-12, B46-12 , B51-12 , E1-12 , N11-12 and R1-12)
- Tibisti field, the wells (I8-13 ,I9-13 ,I10-13 , I13-13 and O1-13)

Table 1 to 4 show the comparison between the experimental and predicted Z-factor by all correlations considered in this study for some wells "Well B**7**-12 AMAL field , Well B1**1**-12 AMAL Field**,** Well E1-12 AMAL Field and Well O1-13 TIBISTI Field "

It can be noticed from of these tables that Brill and Beggs, Dranchuk - Abu-Kassem and papay correlations have estimated data which is closest to the lab data , while the Hall-Yarborough, Shell Oil Company, Niger Delta correlations calculated data far from the lab data. It is interesting to note that , due to high error values which are obtained from (Hall-Yarborough, Shell Oil Company and Niger Delta correlations) as shown in results , those correlations are canceled out from the screen analyzed and plots.

Table 1 Experimental and predicted compressibility factor for well B7-12 AMAL Field

Correlations	Temperature 228F^0						AARE%
Pressure (Psia)	1112.7	919.7	718.7	512.7	309.7	168.7	
Specific gravity	0.814	0.828	0.851	0.891	0.988	1.154	--
Z-lap	0.914	0.921	0.928	0.942	0.955	0.97	--_
Hall-Yarborough	1.1149	0.4096	0.7254	0.3381	0.2083	0.1175	54.91
Brill and Beggs	0.9071	0.9191	0.9327	0.9477	0.9627	0.9745	0.805
Abu-Kassem	0.8953	0.9056	0.9183	0.9336	0.9501	0.9641	1.36
Papay	0.9049	0.9126	0.9252	0.9387	0.9532	0.9657	0.74
Shell Oil Company	0.9068	0.9177	0.9091	0.5399	0.4853	0.4701	24.42
Niger Delta	0.6754	0.7217	0.7933	0.9089	1.1546	1.1576	14.50

Table 2 Experimental and predicted compressibility factor for well B11-12 AMAL Field

Correlations	Temperature 231F^0						AARE%
Pressure (Psia)	1313.7	1112.7	916.7	714.7	515.7	312.7	
Specific gravity	0.823	0.829	0.838	0.865	0.905	1.005	--
Z-lap	0.904	0.911	0.916	0.927	0.939	0.955	_
Hall-Yarborough	0.8546	0.7247	0.5971	0.4628	0.3223	0.1996	42.5714
Brill and Beggs	0.8928	0.9054	0.9189	0.9323	0.9468	0.9618	0.7141
Abu-Kassem	0.8838	0.8937	0.9054	0.9177	0.9326	0.9491	1.2644
Papay	0.8944	0.9033	0.9138	0.9246	0.9377	0.9521	0.4703
Shell Oil Company	0.8932	0.9049	0.9174	0.9077	0.5404	0.4836	15.9300
Niger Delta	0.6718	0.6941	0.7249	0.8073	0.9210	1.1696	12.9075

Table 3 Experimental and predicted compressibility factor for well E1-12 AMAL Field

Correlations	Temperature 234 F^0						AARE%
Pressure (Psia)	1458.7	1214.7	965.7	710.7	457.7	215.7	
Specific gravity	0.790	0.807	0.824	0.857	0.924	1.100	--
Z-lap	0.895	0.907	0.914	0.93	0.947	0.974	_
Hall-Yarborough	0.5693	0.4807	0.3905	0.2993	0.2082	0.1167	62.4127
Brill and Beggs	0.8935	0.9048	0.9183	0.9332	0.9495	0.9676	0.3576
Abu-Kassem	0.8857	0.8938	0.9050	0.9188	0.9354	0.9554	1.2988
Papay	0.8965	0.9038	0.9136	0.9255	0.9397	0.9575	0.5832
Shell Oil Company	0.8958	0.9055	0.9173	0.8957	0.5141	0.4212	17.6410
Niger Delta	0.5846	0.6319	0.7007	0.8236	1.0457	1.5065	23.3365

Table 4 Experimental and predicted compressibility factor for well O1-13 TIBISTI Field

Correlations	Temperature 168 F^0						AARE%
Pressure (Psia)	854.7	657.7	462.7	264.7	158.7	106.7	
Specific gravity	0.860	0.937	1.033	1.180	1.330	1.475	--
Z-lap	0.936	0.946	0.958	0.97	0.986	0.988	--_
Hall-Yarborough	0.3474	0.2823	0.2191	0.1428	0.0987	0.0704	79.7157
Brill and Beggs	0.9271	0.9362	0.9449	0.9603	0.9715	0.978	1.1394
Abu-Kassem	0.9132	0.9217	0.9303	0.9468	0.9600	0.9680	2.4889
Papay	0.9210	0.9280	0.9347	0.9494	0.9618	0.9695	2.0605
Shell Oil Company	0.9250	0.8407	0.5042	0.4335	0.3756	0.3307	47.3677
Niger Delta	0.6958	0.8550	1.1280	1.4669	1.7320	1.9290	34.1020

Table 5 demonstrates the absolute average relative error (AARE%) for the empirical correlations presented in this study for all wells. It can be seen from the observation results in table 5 that, Brill and Beggs correlation offers the lowest AARE for the wells B3-12, B4-12, B12-12, B46-12 , B51-12, N11-12, E1-12, R1-12, I8-13, I9-13 and O1-13. Moreover, Papay correlation gives the lowest AARE for wells B7-12, B11-12 and I13-13. Furthermore the Dranchuk - Abu - Kassem correlation presents the lowest AARE for well I10-13. On the other hand, the Dranchuk - Abu - Kassem correlation gives the highest AARE for the most wells.

Table 5 summary of Average Absolute Relative Error(AARE%) for all wells

Average Absolute Relative Error (AARE%)for the correlations			
Well	**Papay**	**Dranchuk - Abu -Kassem**	**Brilland Beggs**
B3-12	1.8594	2.6381	1.3055
B4-12	2.1141	2.8047	1.6976
B7-12	0.5008	1.1245	0.5571
B11-12	0.4703	1.2644	0.7141
B12-12	1.0548	1.8925	0.3738
B46-12	2.8730	3.7684	2.6391
B51-12	1.6887	2.2903	0.9849
E1-12	0.4405	1.1149	0.3894

Average Absolute Relative Error (AARE%)for the correlations			
Well	**Papay**	**Dranchuk - Abu -Kassem**	**Brilland Beggs**
N11-12	1.7936	2.4848	1.2893
R1-12	1.9378	2.7092	1.4403
I8-13	0.6113	1.2010	0.3786
I9-13	0.6171	1.1447	0.4800
I10-13	0.4787	0.3794	1.3996
I13-13	0.3585	0.6641	1.0344
O1-13	1.8088	2.2372	0.9406

5.3. Comprehensive Study For The All Wells Together:

A comprehensive study was performed to compare between the targeted empirical correlations. Another method we applied for selection of best correlation is called cross plots parity line as shown in figure 1. This method illustrates how most data points fall on the angle of 45^o parity line, and also it indicates how perfect data distribution at the centre of chart. Figure 1 illustrates this for the correlations. This results show a remarkable good performance for that of Brill and Beggs correlation with Sutton method when compared with other correlation used for the comparisons and can be used to predict Z-factor calculation for natural gas reservoirs in Libya.

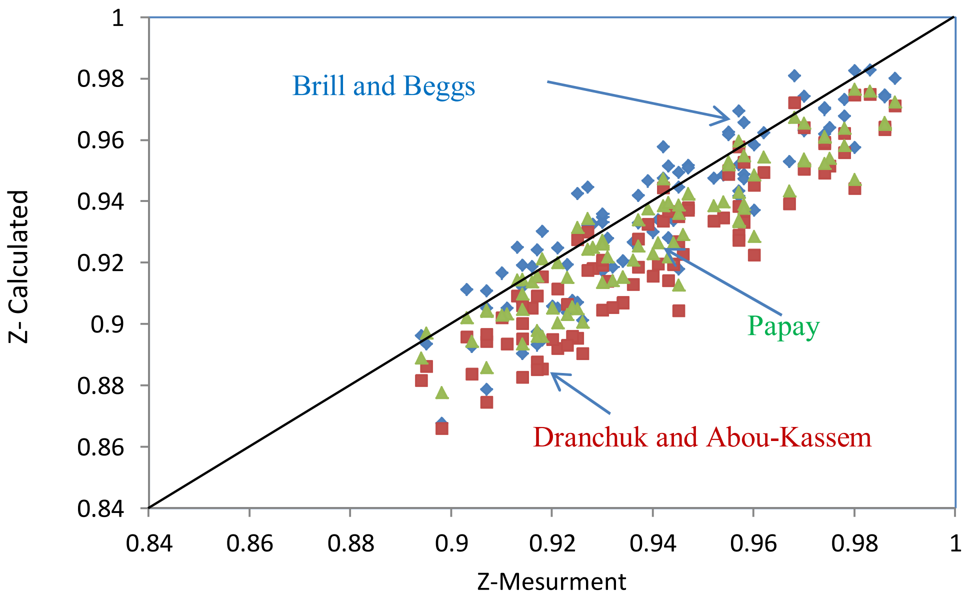

Figure 1 Z predicted (correlations) versus *Z* measured (experimental)

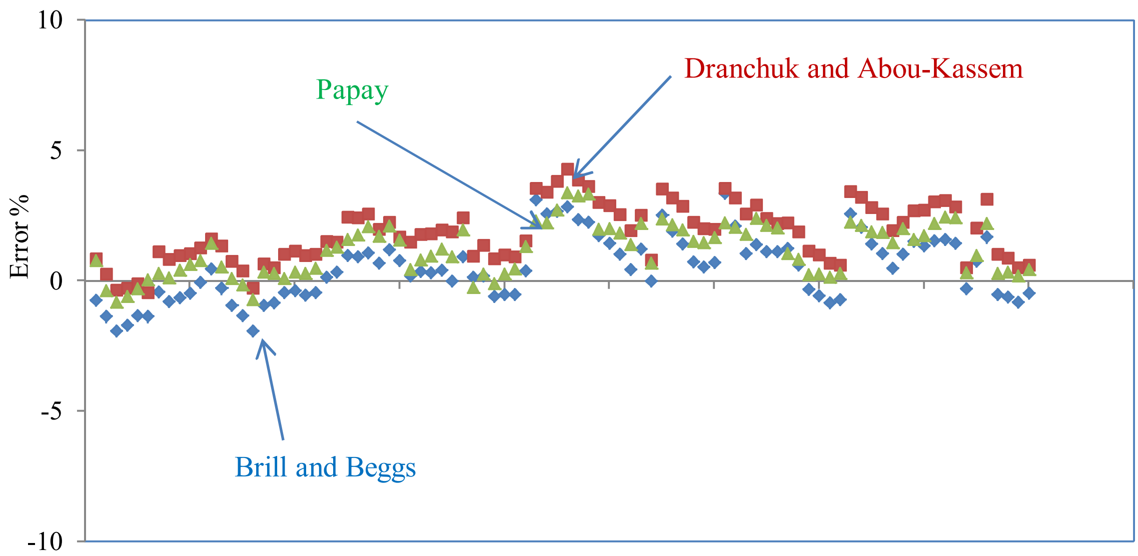

Figure 2 Error percent in *Z* factor calculations

Figure 2 shows error percent for compressibility factor calculation by three correlations. According to Figure 2 the error percent generally is in the range of -1.5% to +3.7%. for 540 points. The results show that the Brill and Beggs correlation with Sutton method for compressibility factor (*Z* factor) has a good accuracy in comparison with the other correlations .

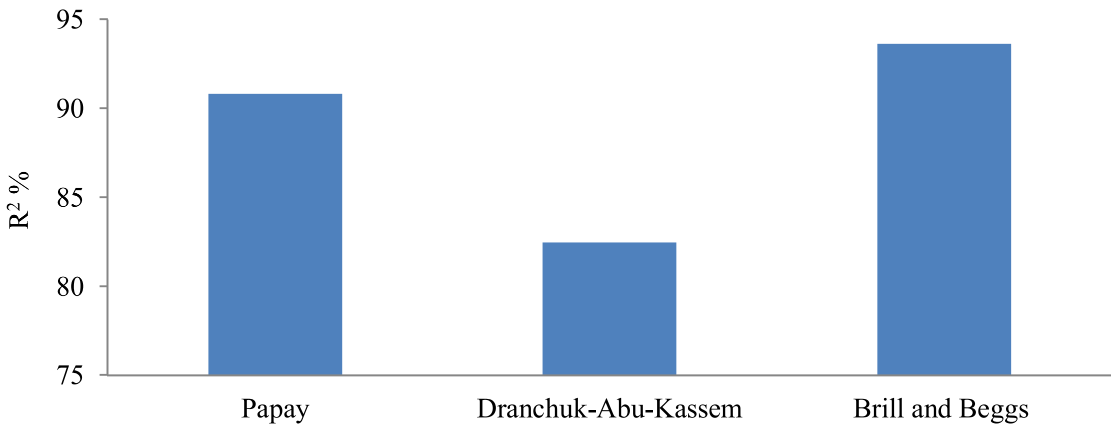

Figure 3 Regression Factor R^2 % Cofficient

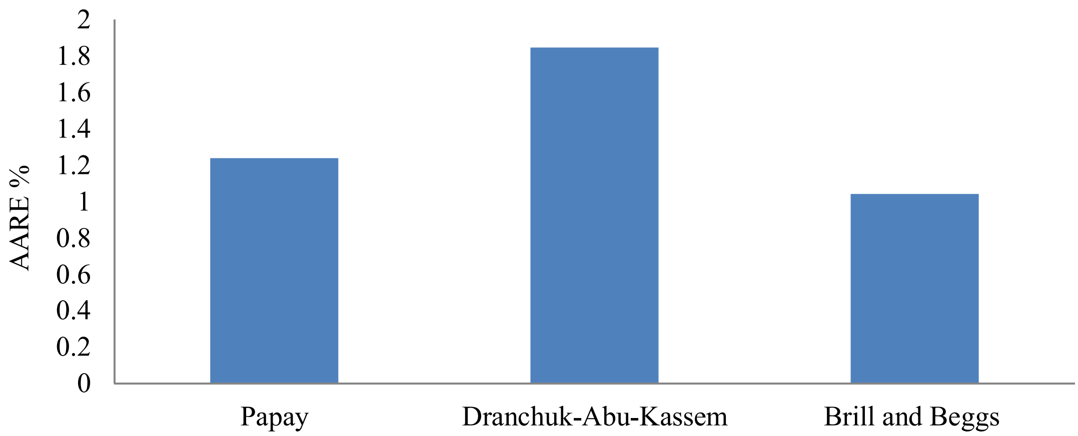

Figure 4 Absolute Relative Error (AARE%)

Results obtained from the figures 3 and 4 are analyzed to ascertain correlations level of accuracy. The results show that Beggs and Brills has the highest regression factor R^2 of 93.642 % with lowest AARE of 1.0416% followed by Papay has R^2 of 90.83 % with AARE of 1.24%. While Dranchuk and Abou-Kassem have the lowest $R^2$of 80.704 % with highest AARE of 1.9186 %. This therefore, means that Beggs and Brills correlation shows best correlation performance for two Libyan field AMAL and TIBISTI.

6. Conclusion:

This work was focused on the selection of the most accurate correlations to estimate pseudo-reduced temperature (T_{pr}) and pseudo-reduced pressure (P_{pr}) and predict compressibility factor for Libyan natural gas. Fifteen well were selected from two oil fields (Amal and Tibisti) to utilize in this study. A total of 90 points of laboratory Z-factor were used in this study with 6 correlations to estimate Z-factor. The input parameter Tpr and Ppr is obtained by Sutton method. Some of correlations are not applicable due to their high Average Absolute Relative Error, such as Hall-Yarborough correlation, Shell Oil Company correlation and Niger Delta correlation for predicting the Z-factor of Libyan natural gas. On the other hand, the other correlations (Papay, Brill and Beggs and Dranchuk-Abu -Kassem) have a remarkable good performance with error percent generally was in the range of (-1.5% to 3.7%). Moreover, Graphically, the Brill and Beggs correlation shows the best trends performance in the two reservoirs system. However, the average absolute relative error (AARE) and coefficient of determination (R^2) between the Brill-Beggs correlation predictions and the relevant experimental data were found to be 1.0416 % and 93.64271 % respectively.

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