Modify Chock Performance Equation for Tertiary Reservoir Wells in Khabaz Oil Field.

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Abstract. Gilbert correlation has been modified to determine the performance of multiphase fluid-flow through the wellhead and choke. The modification present two sets of new correlations based on statistical analysis of 33 production tests data from 12 wells produce from Tertiary Reservoir in Khabaz oil field, first correlation is modified of Gilbert equation to predict liquid flow rates as a function of wellhead flowing pressure, gas-liquid ratio and choke size, the second correlation takes the effect of water cut and sediment (BS & W) as an effective parameter to minimize error. A comparison between the results of each correlation with measured date has been made to select the best correlation to predict flow rate in newly drilled wells. The oil flow rates predicted by the new correlations show excellent agreement with the measured rates and the second modified Gilbert correlation are found to be closest to all ranges of flow rate variables with an average error of 10 % and R2=0.9493.

1. Introduction
Pressure is an important energy in the Oil and gas production system, either choke performance to control the flow rate. Thus, different studies have been published tacking present theories and correlations to introduce simultaneous liquid and gas flow through an orifice. The first relationship was present by Gilbert in 1954 based on field data collected from the Ten Section field of California [1], Ros 1960 have also presented relationships that are often used [2]. Gilbert’s approach was widely used by petroleum engineers more than any other approach. The goal of this paper is a recalculation of observed available data to modify Gilbert correlation parameters correspond to the tertiary Khabaz oil field, then calculate flow rate by using modified parameters and compare the results with a flow rate estimated from original Gilbert approach Therefore, production data from 12 oil wells in the Khabaz oil field as in Table (1) were used to check correlations.

1.1 Area of Study
The Khabaz oil field is multi-pay zones Carbonate oil fields like most of the carbonate oil fields in the north of Iraq. It is located in North West of Kirkuk city and far about 12 km from Kirkuk city centre as shown in Figure. 1.
The field is about 18 km length and its width is about 4 km. It consists of single small subsurface asymmetrical anticline dome sweeping to south direction with depth. Its northeast flange dipper than the southwest flange with general axis extends from northwest to southeast and parallel with the Kirkuk oil field axis in Cotton –Kushkai region. First well (Kz-1) has been drilled in August 1976, since that time, drilling operations have continued.

As shown in Figure 2.

**Figure 1.** Khabaz oil field location.

The Khabaz oil field consists of three main hydrocarbon reservoirs.

1. Tertiary Reservoir.
2. Cretaceous Upper Qamchuqa (Mauddud) Reservoir.
3. Cretaceous Lower Qamchuqa (Shuaiba) Reservoir.

As shown in Figure 2.
All the 12 wells which have been selected in this paper are produce from the Tertiary Reservoir; the important reservoirs in Khabaz field, so the paper confines only to tertiary producer wells.

1.2 Basic Equations

To estimate the relationship between the production rate and wellhead flowing pressure for two-phase critical flow, an empirical correlation has been developed. These correlations are presented in a similar form to eq.1.

$$PWF = c \frac{GOR^{a+Q}}{D^b}$$

(1)

Where

PWF = tubing-head pressure, (psi)
R = gas/liquid ratio, (Scf/STB)
Q = gross liquid rate, (BBL/D)
D = chock size. (Inch)
a, b and c = constants,

Gilbert's Approach based on the assumption of a knife-edge chokes and simplifying some assumptions that related to the pressure and flow characteristics of the oil and gas through the chock. Theoretically Gilbert's equation assumes that the actual mixture of fluid velocities through the bean should be passed the sound speed; in order to the downstream, flow line pressure, no effect on the rate and pressure of upstream. The fluid velocity reaches the sound speed when the upstream pressure is at least twice greater than the downstream pressure. However, Gilbert, renowned, that his equation works well when the downstream pressure is less than 70% of the upstream pressure. Ross's (1960) and Baxendell (1958)
developed another correlations similar to that of Gilbert (1954) correlation but with different correlating parameters. The parameters of each equation are given in the table (1).

**Table 1. Correlation Parameters**

| Correlation      | a         | b     | c  |
|------------------|-----------|-------|----|
| Gilbert (1954)   | $3.86\times10^{-3}$ | 0.546 | 1.89 |
| Baxendell (1958)| $3.12\times10^{-3}$ | 0.546 | 1.93 |
| Rose (1960)      | $4.26\times10^{-3}$ | 0.5   | 2   |

1.3 Nonlinear Regression
The Nonlinear regression: is a type of regression analysis of observational data that integrated by a function which is a nonlinear grouping of the model parameters and depends on one or more independent variables. The data is close-fitting by a method of successive approximations [3].

1.4 Correlation Coefficient
A correlation coefficient has measured the strength and what of a linear association between two variables. It ranges from 1 to 0. The stronger relationship is close to the absolute value of 1, and A zero correlation coefficient specifies that there is no linear relationship between the variables. The coefficient can be either negative or positive [4].

1.5 Data acquisition
Recently, the total number of wells in tertiary reservoir reached 26 wells, divided into working, new drilled not connected to Degas station observation, and water injection wells. Although the number of wells selected is 12, but they represent most of the working well and provided data from all parts of the reservoir. It can be adapted to modify the correlation depending on estimate surface flow rates in newly drilled wells as shown in the figure 3.
2. Results and Discussion
33 test data of production are gathered from 12 wells, including the flow rates, gas-liquid ratio, choke size, upstream pressure, downstream pressure, and water cut, lay within the range 400–2900 (STB/day), 847–2595 (SCF/STB), 16–42 (1/64th-inch), 445–1854 (Psi), and (0–4.7) % respectively as shown in Table 2.
Table 2. Production Test Data.

| No | DATE     | Choke size in | Pressure psi | Q bbl/d | GOR scf/bbl | WT % | flow path |
|----|----------|---------------|--------------|---------|-------------|------|-----------|
| 1  | 15/07/2000 | 0.438         | 446.5        | 1000    | 1112        | 1    | Tubing    |
| 2  | 05/05/2002 | 0.375         | 445          | 850     | 873         | 0.5  | Tubing    |
| 3  | 22/07/2000 | 0.375         | 1102         | 1300    | 913         | 1.3  | Tubing    |
| 4  | 01/05/2002 | 0.375         | 1233         | 1150    | 1290        | 2.3  | Tubing    |
| 5  | 03/09/2000 | 0.250         | 1711         | 400     | 2595        | 0    | Tubing    |
| 6  | 16/10/2001 | 0.313         | 1377.5       | 450     | 1976        | 0    | Tubing    |
| 7  | 17/08/2002 | 0.250         | 1850         | 400     | 2500        | 0    | Tubing    |
| 10 | 15/10/2001 | 0.375         | 1116.5       | 1600    | 927         | 4.5  | Tubing    |
| 11 | 04/05/2002 | 0.375         | 1130         | 1250    | 949         | 4.7  | Tubing    |
| 12 | 18/07/2000 | 0.375         | 1203.5       | 1200    | 1174        | 0.2  | Tubing    |
| 13 | 21/07/2000 | 0.313         | 1232.5       | 850     | 1221        | 0.3  | Tubing    |
| 14 | 05/09/2001 | 0.313         | 1261.5       | 1100    | 1078        | 0.9  | Tubing    |
| 15 | 20/10/2001 | 0.250         | 1305         | 750     | 989         | 0.8  | Tubing    |
| 16 | 10/10/2001 | 0.563         | 1102         | 2600    | 1027        | 1.2  | Tub.      |
| 17 | 07/07/2000 | 0.250         | 1450         | 500     | 1780        | 0    | Tubing    |
| 18 | 10/05/2002 | 0.250         | 1855         | 450     | 1976        | 0    | Tubing    |
| 19 | 16/07/2000 | 0.500         | 1160         | 2250    | 1121        | 0    | Tubing    |
| 20 | 20/07/2000 | 0.438         | 1189         | 1700    | 1047        | 0    | Tubing    |
| 21 | 21/05/2002 | 0.438         | 1090         | 1700    | 1134        | 0    | Tubing    |
| 23 | 04/08/2002 | 0.500         | 1190         | 2200    | 1079        | 0    | Tubing    |
| 24 | 27/10/2001 | 0.375         | 1276         | 1100    | 1483        | 0    | Tubing    |
| 25 | 08/05/2002 | 0.375         | 1275         | 1000    | 1483        | 0    | Tubing    |
| 26 | 29/06/2000 | 0.656         | 783          | 2900    | 921         | 0    | Tubing    |
| 27 | 01/07/2000 | 0.563         | 899          | 2150    | 966         | 0    | Tubing    |
| 28 | 03/07/2000 | 0.500         | 928          | 1550    | 957         | 0    | Tubing    |
| 29 | 23/10/2001 | 0.250         | 1363         | 650     | 1369        | 0    | Tubing    |
| 30 | 24/08/2002 | 0.250         | 1025         | 700     | 847         | 0    | Tubing    |
| 31 | 23/07/2000 | 0.297         | 1232.5       | 950     | 1249        | 0.8  | Tubing    |
| 32 | 17/09/2001 | 0.297         | 1322         | 1250    | 1068        | 0    | Tubing    |
| 33 | 22/10/2001 | 0.266         | 1421         | 850     | 1134        | 0    | Tubing    |

The first correlation for Khabaz field is Gilbert modified equation based on regression analysis of equation (1) as flowing:

\[ Q = \frac{PWF}{c \cdot GOR^b} \]  

(2)

Where, 
\[ a = 0.000275, \quad b = 0.9058, \quad c = 1.7634 \]

The second correlation has been developed considering a parameter which has not been covered in the previous correlations; water cut (Wct.) measured volume percentage of the production stream, in addition to other parameters which had been added to the correlation, in order to reduce error in the field condition to a minimum, as represented in the following form.

\[ Q = \frac{PWF}{c \cdot GOR^b} \cdot \left(1 - \frac{Wct\%}{100}\right)^d \]  

(3)

Where, 
\[ a = 0.0000486, \quad b = 1.159, \quad c = 1.733 \quad \text{and} \quad d = 1.3936 \]
These new correlations applied to estimate flow rate and compared with Gilbert correlation which is recently used to estimate flow rate in the Khabaz oil field. The results show that flow rate estimated by new correlations is closer to the actual rate in tests than Gilbert correlation as shown in the figure 4.

![Figure 4](image.png)

**Figure 4.** Compares estimated flow rate by correlations with actual rates.

Also, R2 and absolute error techniques are used for the comparison between correlations to predict the stronger correlation that can be applied and guess how far to estimate the flow rates from actual test flow rate data. The absolute errors are calculated using the following equation:

$$E_{ABS} = \left| \frac{Q_{est} - Q_e}{Q_{est}} \right| \times 100$$

According to the results the absolute average errors of the three correlations, Gilbert first modified Gilbert and second modified Gilbert equation, (21%), (12%) and (10%) respectively as tabulated in Table 3. A good match between the measured and the predicted data is estimated by second modify Gilbert. With a high accuracy of predicted production rates of (R2) 0.9493 obtained. As evident from Figure 5.

**Table 3.** Results in the average absolute errors of the three correlations.

| Correlation                  | Absolute Error% |
|------------------------------|-----------------|
| Gilbert                      | 21              |
| First Modify Gilbert         | 12              |
| Second Modify Gilbert        | 10              |
3. Conclusions
Depending on 33 real production tests data and two sets of newly-established choke performance correlations for the tertiary reservoir of Khabaz field in Iraq. The following conclusions are drawn:

1. The first predicted correlation; the modified Gilbert equation, has given an average error of 12 %, while original Gilbert correlation is giving average errors of 20%.

2. In order to minimize the error of field condition, a new parameter was added to Gilbert correlation; (free water and sediment (BS & W)), which was not included in the previous Gilbert correlation and other published correlations. This addition of new parameters in this work; the newly predicted correlations (the second modify Gilbert equation) minimizes the average error to 10 %.

References
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