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Tuned Inflow Performance Relationship (IPR) For One of the Iranian Gas Solution Oil Field

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Summary

Inflow performance relationships, IPR, are measureable predictions of a reservoir. Researcher and engineers use this relationship for obtaining optimum production and some production operations like artificial lift, stimulation operations. Many researches have been studied in vertical, horizontal and deviated wells to calculating the IPR. Also many works have been done for estimating the IPR for oil and gas reservoir with various rock and fluid properties.

The goal of this work is to obtain a general Vogel type correlation for an oil reservoir in vertical wells. The data which is used in this paper is resulted from a multi rate well testing for heavy oil reservoir in one of the Iranian south reservoir. This test was done on 12 wells on the oil reservoir which all of these wells have heavy oil production. This general correlation that was obtained from Vogel equation, has new coefficients for this case. It must be noted it is easy to apply this relationship for an oil reservoir, because it only needs common known parameters of the field.

Introduction

The information of inflow performance of the reservoir is a very important factor to reach optimum point for production, artificial lift and surface equipment. The relation between bottom-hole pressure and production rate is defined as the inflow performance relationships (IPR).(Camacho et al., 1987) Many studies have been done on IPR for light and medium crude oil in vertical wells. According to this fact that a large number of reservoirs in the world are heavy oil, it is very important to obtain IPR correlation for heavy oil reservoirs. Also due to the rock and fluid properties which are different for any special reservoir, the IPR correlation will be different. So if we use the IPR correlation that belong to the related reservoir in our calculations, the error will be minimum and the obtained results are very high accurate.

Horizontal wells (and also inclined wells) have been utilized to calculate the inflow performance relationships. These wells apply for some cases and have great advantages compared to vertical wells. These wells have been applied in cases as fracture reservoirs; low permeability reservoirs; heavy oil reservoirs and for protect the well from water and gas coning. In some cases the vertical correlations are utilized for horizontal wells which is not true because the flow in tubing is a mixture of linear and radial streamlines. Anisotropy is another parameter that relate to the vertical and horizontal permeability which is different in vertical and horizontal wells.(Camacho and Velazquez, 1993)

In 1968, Vogel utilized a method to obtain inflow performance relationships curves of saturated oil reservoir in vertical wells. Vogel proposed his model based on dimensionless form and his model has good result and simple form in the industry. In 1973, Fetkovich proposed a new model to estimate the IPR equation based on multi rate tests. He obtained his approach from gas wells. When the gas saturation is more than critical gas saturation this equation may also be applied for oil wells. This model also is an applicable method in the industry.(Fawzi et al., 2000)

Wiggins et al., in 1992, utilized a new based computer modelling by using fluid properties and different relative permeability curves to proposed inflow performance relationships in vertical wells. He worked on three phase flow (oil, gas and water). It must be noted this proposed model is like the Vogel's equation depending on water cut and the data are obtained by stabilized flow test. This method based on saturated reservoirs and the effect of oil viscosity is not considered.(Gasbarri etal., 2009)(Elias et al., 2009)

Klins and Clark developed in 1993 an IPR equation similar to Vogel approach. They utilized a new exponent "d" to the Vogel equation instead exponent (2). This new exponent is related to the reservoir pressure and bubble point pressure. The parabolic coefficient is a little different from them in Vogel equation.(Guo et al., 2007) In this study a new correlation are proposed for heavy oil in vertical wells. These data are recorded by multi rate well testing in one of the Iranian oil reservoir.

Method and/or Theory

The under study reservoir is a solution gas drive type with heavy oil. Its multi-rate flow tests data is used that belongs to 12 oil wells to determine the related reservoir IPR equation. Because of close similarity of reservoir condition to the Vogel's relation assumptions, Vogel's equation is selected and rewritten according to the new condition of our reservoir. The Vogel's equation is shown in below.

$$q = q_{max}\left[1 - 0.2\left(\frac{P_{wf}}{P_{av}}\right) - 0.8\left(\frac{P_{wf}}{P_{av}}\right)^2\right] \tag{1}$$

That the q_{max} equals to $JP_b/1.8$. For tuning this equation first of all it must become in dimensionless form like eqation2.

$$\frac{q}{q_{max}} = \left[1 - 0.2\left(\frac{P_{wf}}{P_{av}}\right) - 0.8\left(\frac{P_{wf}}{P_{av}}\right)^2\right] \tag{2}$$

For tuning the equation, target parameters are the two constants, 0.2 and 0.8. Also the field data (well flow pressure related to flow rate of production fluid) from multi-rate flow tests should change to dimensionless parameters too as q/qmax and Pwf/Pav. By assuming (X = Pwf/Pav) and (Y = q/qmax) the field data must fit on the 2nd degree equation Y = 1- aX – bX2. In Figure1 the curve fitting of the data with the suitable curve is illustrated.

From the results of that, the reservoir IPR for prediction of reservoir behavior is obtained like below.

$$\frac{q}{q_{max}} = \left[1 - 0.3818\left(\frac{P_{wf}}{P_{av}}\right) - 0.6604\left(\frac{P_{wf}}{P_{av}}\right)^2\right]$$

(3)

$$R^2 = 0.96039$$

The quantity of q_{max} can be calculated like this:

$$\frac{q - q_b}{q_{max} - q_b} = \left[1 - 0.3818\left(\frac{P_{wf}}{P_{av}}\right) - 0.6604\left(\frac{P_{wf}}{P_{av}}\right)^2\right]$$
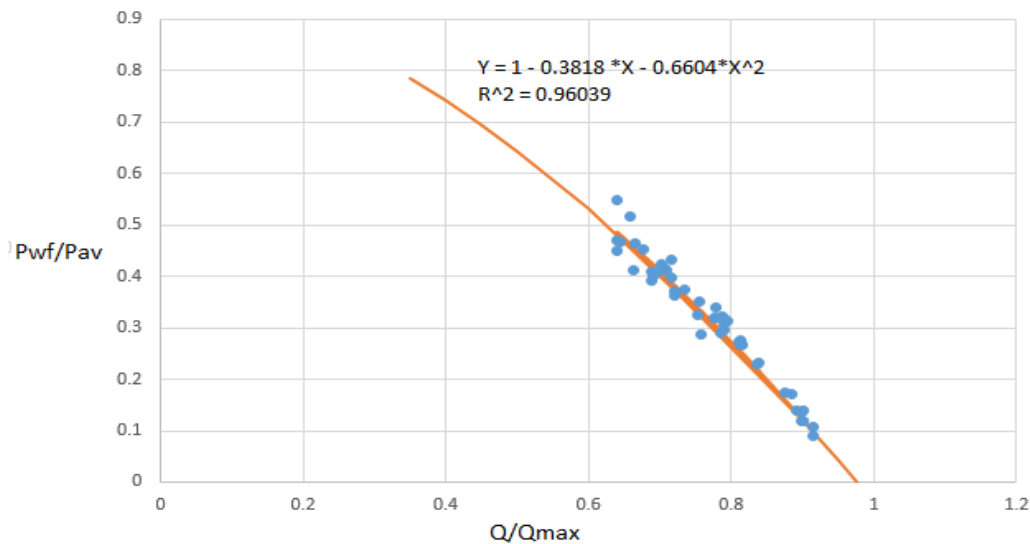
(4)

Figure 1 *Curve fitting with field data*

By rearranging, it can be written like:

$$\frac{q}{q_{max}} = q_b + (q_{max} - q_b)\left[1 - 0.3818\left(\frac{P_{wf}}{P_{av}}\right) - 0.6604\left(\frac{P_{wf}}{P_{av}}\right)^2\right]$$

(5)

By derivation by P_{wf} from both side of equation it become like:

$$\frac{dq}{dP_{wf}} = q_{max} - q_b\left[\frac{-0.3818}{P_b} - \frac{1.308 P_{wf}}{P_b^2}\right]$$

(6)

For when $P_{wf} = P_b$ we have:

$$\frac{-dq}{dP_{wf}} = \frac{-1.7026(q_{max} - q_b)}{q_b}$$

(7)

And J is equal to:

$$J = \frac{1.7026(q_{max} - q_b)}{q_b}$$

$$\text{(8)}$$

And the flow rate obtain from this:

$$q_{max} - q_b = \frac{JP_b}{1.7026}$$

$$\text{(9)}$$

Because of deviation of the curve from some part of field data, another IPR curve for finding a better match and comparing with first one can be developed. One of the possible solutions for that is to create an equation with extra term with higher degree. The basic form of this equation is like:

$$\frac{q}{q_{max}} = \left[1 - a\left(\frac{P_{wf}}{P_{av}}\right) - b\left(\frac{P_{wf}}{P_{av}}\right)^2 - c\left(\frac{P_{wf}}{P_{av}}\right)^3\right]$$

$$\text{(10)}$$

Example

By curve fitting of the field data with this new equation, three constants a, b and c become -0.4436, 2.787 and -1.355 respectively and finally the equation forms in this way.

$$\frac{q}{q_{max}} = \left[1 + 0.4436\left(\frac{P_{wf}}{P_{av}}\right) - 2.787\left(\frac{P_{wf}}{P_{av}}\right)^2 + 1.355\left(\frac{P_{wf}}{P_{av}}\right)^3\right]$$

$$\text{(11)}$$

All of the three curves (Vogel's, 2nd degree curve and 3rd degree curve) are illustrated in figure 2 and error of their revenue with comparing to each other are equal to 18.20, 6.35 and 7.29 respectively. So the 2nd degree curve has the lowest error and best performance and the Vogel's equation has the biggest error. Also the results show that adding a higher degree term couldn't cause more accuracy of curve and improving curve fitting necessarily.

Deviation of the Vogel's curve from the real data may cause from the type of drilling, completion, production operations and creating skin and damage around the wellbore. Also the nature and type of the reservoir fluid is an effective factor and has an important role in inflow performance relationship. By having the modified IPR equation it is so easier to predict the treatment of reservoir with facing the new drilled well in the reservoir.
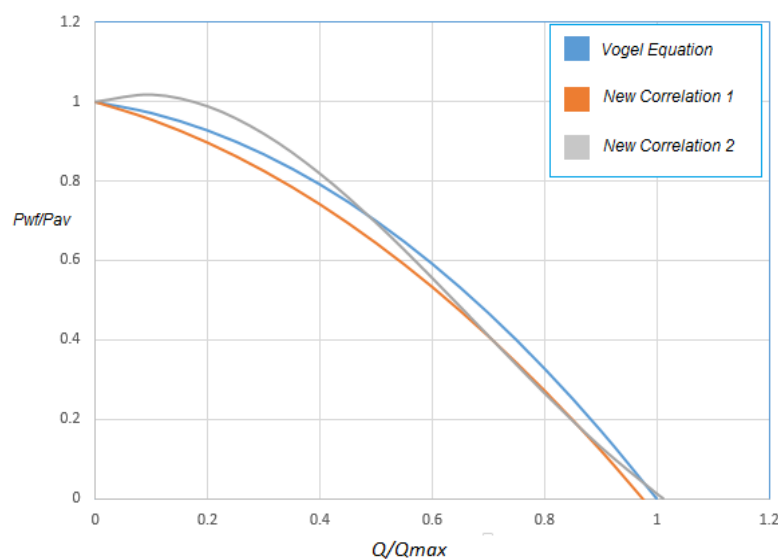

Figure 2 Comparison between Vogel's, 2nd degree curve and 3rd degree curve

For testing and validating the investigation of curves and their results, we examine the developed curves by a new well data which named well #13. This test will help us to see their accuracy of performance. The results of this test are shown in table 1.

The results of the investigation all three curves with pressure and related flow rate data show expected facts that the Vogel's equation has the greatest error and the 2nd degree equation has the lowest error and it is the most suitable equation for this specific reservoir. Also this study shows the 3rd degree equation has less accuracy than 2nd degree equation. This work is utilizable for other oil and gas reservoirs and it is possible to make tuned IPR equations for them and use.

#	P_{wf} / P_{av}	Q / Q_{max}	$[Q / Q_{max}]$ 2nd Degree	$[Q / Q_{max}]$ Vogel	$[Q / Q_{max}]$ 3rd Degree	error 2nd Degree Eq. %	error Vogel %	error 3rd Degree Eq. %
1	0.767298	0.339638	0.318237	0.375543	0.31165	6.301137	10.57146	8.240588
2	0.796447	0.288754	0.277007	0.333249	0.26999	4.068219	15.40923	6.498209
3	0.655955	0.439732	0.465402	0.524588	0.474238	5.837556	19.29711	7.847109
4	0.758212	0.305144	0.33086	0.388449	0.324761	8.427504	27.30021	6.428783
						ẽ = 6.15%	ẽ =18.14%	ẽ =7.25%

Table 1 *Testing the new developed correlation with well #13 data*

Conclusions

Using the empirical correlations has serious error because the nature of these equation are based on data from special fields, so they couldn't work for other fields properly. The best solution for using them is to modify and tuning them based on our conditions. Investigation on tuned equations shows that they have good accuracy and it is suitable to use them for new drilled well in the reservoir. This is an applicable and general solution for other oil and gas reservoirs.

The best correlation for tuning is Vogel's equation. Most of other correlations are complex or not easy to use, by the way the Vogel's equation is so easy to use and applicable for tuning. Adding more high-degree terms to the IPR equation doesn't fix the error necessarily.

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