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Determination of Performance of Models In Early Flow Period of A Horizontal Oil Well Using Wellbore Radius As Determinant

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ABSTRACT

There are some other two-phase IPR methods available in the literature that can be used to predict the performance of oil wells. Hence, in this study, the objective is to carry out a comparison using a wellbore radius as a determinant. The aim is to know how wellbore affects productivity and also to know which model is more reliable in predicting the future performance of a horizontal well. In this work, the IPR curve was developed and used to analyse wells deliverability by estimating the production rate for a given bottom-hole flowing pressure and wellbore radius were used as a determinant. The results show that Wiggin's method has a higher performance. The results have exposed the inflow performance relationship (IPR) of a horizontal oil well at the early flow time. It was observed also that wellbore radius affects productivity and from this, we can convincingly say that Wiggin's method is better in predicting the future performance of a horizontal well.

Keywords: Inflow, Performance, Deliverability, Determinant, Bottom-hole

INTRODUCTION

In the petroleum industry, a horizontal well is a relatively new technology in the oil and gas field development when compared with other methods; (Hawkings et al. 1990; Zhang et al. 2017; Kumar et al. 2018; Li et al. 2018; Ogbamikhumi and Adewole, 2020). Its main advantage is the high productivity per well (Joshi, 2003). The evaluation of the deliverability of the reservoir in the production engineering section is very important. With this, the Inflow Performance Relationship of a well is a connection between its producing bottom-hole pressures and its equivalent production rates under a certain reservoir situation. This shows the producing features of a well. Its results are used in defining the economics of producing a well. The flow of a liquid into a well can be determined by both characteristics of the reservoir and the sand face flowing pressure. By this relationship, a graph is plotted, the bottom-hole flowing pressure on the X-axis, and the production rates on the Y-axis. This is termed the inflow performance relationship curve or IPR curve (Vogel, 1968; Sajedian et al. 2012).

IPR curves are the curves that replicate the ability of the reservoir to deliver fluid to the wellbore. Therefore, IPR curves are important information to analyse the deliverability of wells. Well IPR curves can be built using reservoir parameters. These parameters define the factors (e.g., Productivity index) in the IPR model. The test points (production rate and flowing bottom-hole pressure) are commonly used for generating IPR curves (Al-Jawad et al. 2006).

For single-phase flow, the production rate into a well is directly proportional to the difference between bottom-hole flowing pressure and reservoir pressure, which is called drawdown. IPR curves for single-phase flow result in straight lines with a slope of one over a productivity index or PI. The productivity index is the extent of the gradient of the IPR curve (Tongwen et al. 2019).

Although the horizontal well is a relatively new technology, it is more advantageous as compared to vertical wells. The horizontal well has increased productivity per wells, can access unconventional resources, reduced numbers of well, and thus reducing operational cost (Furui, et al. 2003; Abdullah et al. 2015). The IPR is a correlation between the well bottom-hole flowing pressures and its equivalent flow rates. This indicates the producing characteristics of the well and is used to determine the reservoir deliverability. There has been various experimental correlations recommended predicting oil well performance under two-phase flow conditions. Some of the key methods are stated below and the first two techniques (Vogel's and Wiggins') will be a focus on in this field. These methods are (Ahmed Tarek, 2006);

(I) Vogel's method
(ii) Wiggins' method
(iii) Standing's method
(iv) Fetkovich's method
(v) The Kleins-Clark method.

Vogel was the first to present an easy-to-use technique for predicting the performance of oil wells. His experimental inflow performance relationship (IPR) is founded on computer simulation. There are some other two-phase IPR methods available in the literature and their method that can be used to predict the performance of oil wells.

Hence, in this study, the objective is to carry out a comparison using a wellbore radius as a determinant. The aim is to know how wellbore affects productivity and know which model is more reliable in predicting the future performance of a horizontal well**.**

MATERIALS AND METHODS

Vogel's inflow performance relationship

To use this relationship, the following steps are taken: Determination of (i) oil production rate (ii) flowing bottom hole pressure (iii) maximum oil production rate and (iv) production rates for other flowing bottom hole pressures at the current average reservoir pressure and data from previous work was used (Oloro, 2014).

$$\frac{Q_o}{(Q_0)max} = 1 - 0.2\left(\frac{P_{wf}}{P_r}\right) - 0.8\left(\frac{P_{wf}}{P_r}\right) \quad (1)$$

Q_o = oil flow rate at P_{wf}
$(Q_o)_{max}$ = maximum oil flow rate at zero wellbore pressure, i.e., AOF
P_r = present average reservoir pressure, psig
P_{wf} = wellbore pressure, psig
Future flow rate

$$(Q_{omax})f = (Q_{omax})p\left(\frac{(P_r)f}{(P_r)p}\right)\left(0.2 + 0.8\left(\frac{(P_r)f}{(P_r)p}\right)\right) \quad (2)$$

NOTE: In this study, the above method is used for saturated oil reservoir $P_r \leq P_b$

Wiggins' inflow performance relationship

Wiggins' extended his application to predict future performance by providing expressions for estimating future maximum flow rates. Wiggins' recommended expressions are comparable to that of Vogel's and are expressed as (Wiggins, 1994):

$$\frac{Q_o}{(Q_0)max} = 1 - 0.52\left(\frac{(P_{wf}}{(P_r}\right) - 0/48\left(\frac{(P_{wf}}{(P_r}\right)^2 \quad (3)$$

$$\frac{(Q_{omax})f}{(Q_{omax})p} = 0.15\,\frac{(P_r)f}{(P_r)p} + 0.84\left(\frac{(P_w)f}{(P_r)p}\right)^2 \quad (4)$$

$(P_r)_f$ = future average pressure
$(P_r)_p$ = current (present) average pressure
$(Q_{omax})_p$ = current maximum oil flow rate
$(Q_{omax})_f$ = future maximum oil flow rate

RESULTS AND DISCUSSION

The results from this work were obtained by solving for several ? P, which is the drawdown pressure, represented by:
(Pi-Pwf), Wellbore radius (rw), and flow rate (q) keeping the skin (s) constant and also $_{using}$ J approach, Vogel's, and Wiggins' methods to obtain the IPR curve. The IPR expected is produced by calculating (P_i-P_{wf}) for different flow rates used.
Table 1 is showing the values of wellbore radius, x in Ei(-x),and Ei(-x) .
As the wellbore radius increases the value of x in EI (-x) increases.

Table 1: Values for Wellbore radius, (rw), x in Ei(-x), and Ei (-x) (Oloro, 2014)

Wellbore radius (r_w	Values of x in Ei (-x)	Value of Ei (-x)
2.5	0.0444	2.550
2.875	0.0587	2.320
3.125	0.06943	2.160
4.5	0.143	1.521

Given μ=0.6cp B_o=1.2RB/STB, H=100ft ϕ=0.25 K=0.1 S=0 C_t=1. 5x 10^{-5}psi^{-1}. For r_w=2.5in, t

Table 2 is representing the values of flow rate, drawdown, and bottom-hole pressure when r_w=2.5 in.

From the table, as the flow rate increase, the bottom-hole pressure decreases while the initial pressure increases with wellbore radius of 2.5 in.

Table 2: Values of Flowrates, Drawdown, and Bottom-hole flowing pressure

Q(STB/day)	$P_i - P_{wfr}$	P_{wf}
50	161.976	2037.973
100	324.054	1875.95
200	648.108	1551.89
300	972	1228
400	1296	904
600	1944	256

Stabilized flow rate and wellbore pressure = 190STB/day and 1650psig

$(Q_o)_{max}$=475STB/day and 558.8STB/day for Vogel's and Wiggins' method respectively

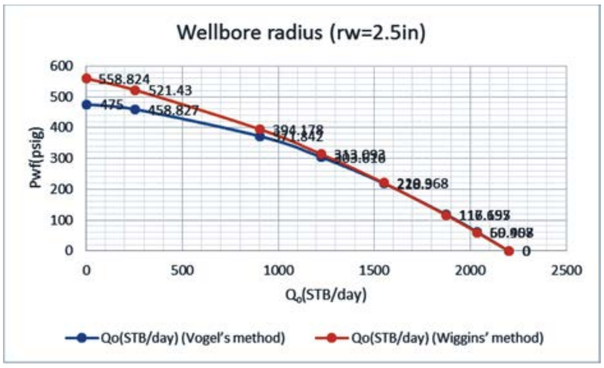

Fig. 1 Graph of (Pwf) against (Qo) at rw=2.5in

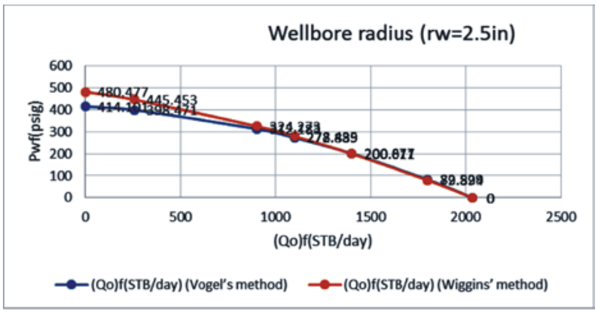

Fig. 2 Graph of (Pwf) against (Qo)f at rw=2.5

At the wellbore radius (r_w) of, 2.5in, the Absolute open flow potential (AOFP) at P_{wf}=0psig for Wiggins' method is higher than that of the Vogel's method. The increment started at P_{wf}=1227. 838psig as shown in figure 1. For the future flow rate, the absolute open flowing potential (AOFP) at P_{wf}=0psig for Wiggins' method is higher than that of the Vogel's method. The increment started at P_{wf}=1100psig as shown in figure 2.

Given Bo=1.2RB/STB, H=100ft ϕ=0.25

K=0.1 S=0 C_t=1.5x 10^{-5}psi^{-1} μ=0.6cp For r_w=2.875

Table 3 is representing the values of flow rate, drawdown, and bottom-hole pressure when r_w=2. 875in.From the table, as the flow rate increase, the bottom-hole pressure decreases while the initial pressure increases with a wellbore radius of 2.875 in.

TABLE 3: shows varying values of Flow rates, Drawdown and Bottom-hole flowing pressure

Q (STB/day)	$P_i - P_{wfr}$	P_{wf}
50	147.413	2052.587
100	294.826	1905.174
200	589.651	1610.349
300	884.477	1315.523
400	1179.302	1020.698
600	1768.954	431.046

Stabilized flow rate and wellbore pressure=180STB/day and 1700psig

$(Q_o)_{max}$=489.438STB/day and 577.718.8STB/day for Vogel's and Wiggins' method respectively

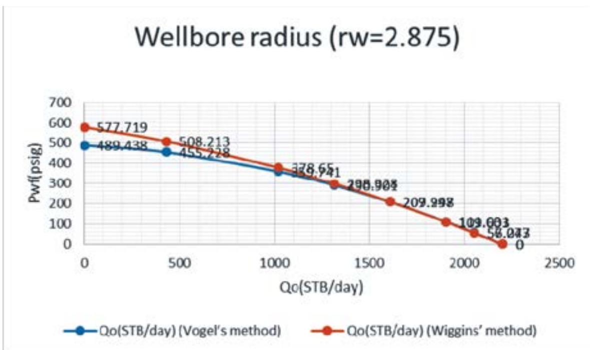

Fig. 3 Graph of (Pwf) against (Qo) at rw=2.875in

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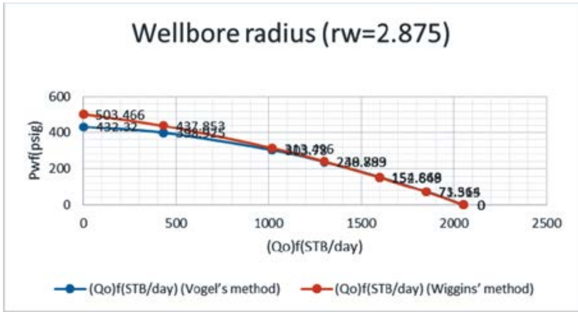

Fig. 4 Graph of (Pwf) against (Qo)f at rw=2.875in

At wellbore radius (r_w) of 2.875, the Absolute open flow potential (AOFP) at P_{wf}= 0 psig for Wiggins' method is higher than that of Vogel's method as shown in the figure. The increment started at P_{wf}=1610. 349psig as shown in figure 3. For the future flowrate, the absolute oil flowing potential (AOFP) at P_{wf}=0psig for Wiggins' method is higher than that of Vogel's method as shown in figure 4. The increment started at P_{wf}=1300psig.

Taken Bo=1.2RB/STB, H=100ft ϕ=0.25 K=0.1 S=0 C_t=1.5x $10^{-5}psi^{-1}$ μ=0.6cp for r_w=3.125in

Table 4 is representing the values of flow rate, drawdown, and bottom-hole pressure when r_w=3.125 in.

From the table, as the flow rate increase, the bottom-hole pressure decreases while the initial pressure increases with a wellbore radius of 3.125 in.

Table 4: shows varying values of Flowrates, Drawdown, and Bottom-hole flowing pressure

Q(STB/day)	$P_i - P_{wfr}$	P_{wf}
50	137.246	2062.754
100	274.493	1925.507
200	548.986	1651.014
300	823.478	1376.522
400	1097.971	1102.029
600	1646.957	553.043

Stabilized flow rate and wellbore pressure = 175STB/day and 1750psig

$(Q_o)_{max}$ =522.840STB/day and 619.153STB/day for Vogel's and Wiggins' method respectively

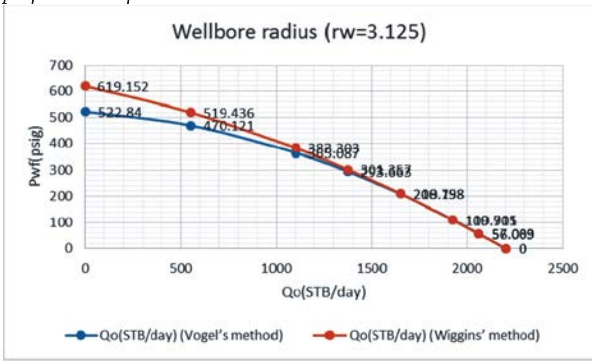

Fig. 5 Graph of (Pwf) against (Qo) at rw=3.125

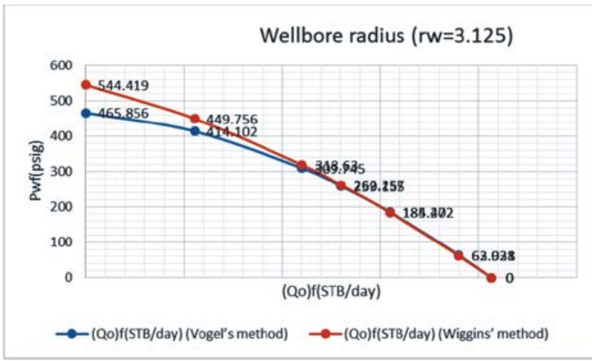

Fig. 6 Graph of (Pwf) against (Qo)f at rw=3.125in

At wellbore radius (r_w) of 3. 125in, the Absolute open flow potential (AOFP) at P_{wf}=0psig for Wiggins' method is higher than that of the Vogel's method. The increment started at P_{wf}=1376. 522 psig as shown in figure 5. For the future flow rate, the absolute oil flowing potential (AOFP) at P_{wf}=0psig for Wiggins' method is higher than that of the Vogel's method. The increment started at P_{wf}=1300psig as shown in figure 6.

Take B_o=1.2RB/STB, H=100ft ϕ=0.25 K=0.1 S=0 C_t=1. 5x $10^{-5}psi^{-1}$ μ=0.6cups of raw=4.5

Table 5 is representing the values of flow rate, drawdown, and bottom-hole pressure when r_w=4.5in.

From the table, as the flow rate increase, the bottom-hole pressure decreases while the initial pressure increases with a wellbore radius of 4.5 in.

Table 5: shows varying values of Flowrates, Drawdown, and Bottom-hole flowing pressure for r_w=4.5in

Q (STB/day)	Pi - Pwfr	Pwf
50	96.644	2103.356
100	196.289	2006.711
200	386.577	1813.423
300	579.8 66	1620.134
400	773.155	1426.845
600	1159.732	1040.268

Stabilized flow rate and wellbore pressure=170STB/day and 1800psig $(Q_o)_{max}$=565.109STB/day and 671.344STB/day for Vogel's and Wiggins' method respectively

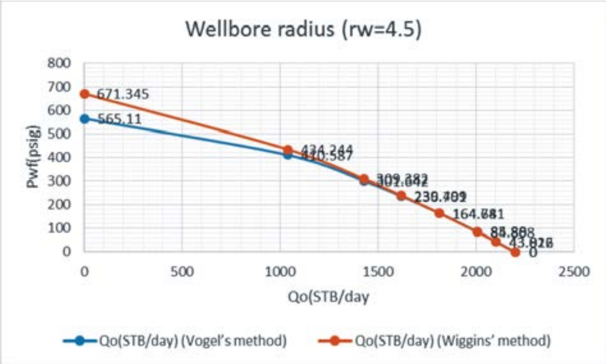

Fig. 7 Graph of (Pwf) against (Qo)f at rw=4.5

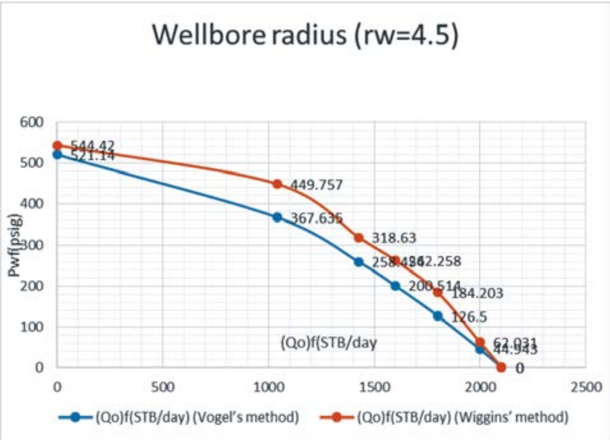

Fig. 8 Graph of (Pwf) against (Qo)f at rw=4.5

At the wellbore radius (r_w) of 4.5, the Absolute open flow potential (AOFP) at P_{wf}=0psig. The increment started at P_{wf}=1620. 134psig as indicated in figure 7. For the future flow rate, the absolute oil flowing potential (AOFP) at P_{wf}=0psig for Wiggins' method is higher than that of the Vogel's method. The increment started at P_{wf}=1800psig as shown in figure 8.

Inflow Performance Relationship (IPR) defines the performance of flow rate with flowing pressure, which is a significant tool in understanding the well productivity. Two models were used in this study and the results were presented as shown above. To validate this work, Ahmed, et al (2017) work was used. Their work shows that the Wiggins method is more reliable in predicting the future performance of a horizontal well.

CONCLUSION

Finally, it can be seen that the studies have exposed the inflow performance relationship of a horizontal well at the early flow time. We can see that the effect of the wellbore radius on productivity. When there is an increase in wellbore radius, there was an additional pressure drop. Also, we can convincingly say that Wiggins' method is better than Vogel's method. The future flow rate was also determined using both Wiggins' method and Vogel's method, and Wiggins' method is better than Vogel's method.

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