Chemical Engineering
Communication

Biosci. Biotech. Res. Comm. 10(1): 143-150 (2017)

BBRC
Bioscience Biotechnology
Research Communications

Analysis of inflow performance relationship and reservoir characteristics using Saphir software

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ABSTRACT

Petroleum production from the reservoir is initially occurs by the natural energy of the reservoir itself. The reservoir pressure is usually high at the early stage of reservoir life, thus, it pumps crude oil to the surface. However, after some time of production, reservoir pressure starts to decline. In addition, penetration of solid particles into the pores causes plugging and results in formation permeability reduction. Hence, natural production from the reservoir starts to decrease after some time, depending on pressure drop rate and the degree of damage to the formation. Well testing is one of the practical methods for analysing the well. Pressure build up test is one of the most widely used well testing methods for analysing the well. In this study, a pressure build up test was conducted for 24 hours and then the pressure data were analysed using Saphir software. Finally, the well characteristics were used to analyse the inflow performance relationship (IPR) of the well. The well testing results showed that the well suffers from high skin, which hinders the effective production from the reservoir. In addition, IPR analysis using Vogel's and Darcy's method showed that the absolute open flow (AOF) is affected by the skin factor. The resulted AOF was always higher without the effect of skin factor included.

KEY WORDS: WELL TESTING, IPR, AOF, SAPHIR SOFTWARE, SKIN FACTOR

ARTICLE INFORMATION:

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Received 12th Dec, 2016
Accepted after revision 18th March, 2017
BBRC Print ISSN: 0974-6455
Online ISSN: 2321-4007 CODEN: USA BBRCBA
Thomson Reuters ISI ESC and Crossref Indexed Journal
NAAS Journal Score 2017: 4.31 Cosmos IF : 4.006
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Online Contents Available at: http//www.bbrc.in/

INTRODUCTION

Description of the dynamic behaviours of underground formation containing hydrocarbons are one of the most important challenges in oil and gas engineering. Thus, detailed information regarding the reservoirs is required to have a comprehensive knowledge about the current and future reservoir performance. Effective permeability of the reservoir, degree of the damage to the wellbore, skin effect, average reservoir pressure, and fault description are the importance reservoir characteristics, which should be identified for each well (Vaferi et al. 2009; Gringarten, 2012; Hills et al. 2014; Shahbazi et al. 2016).

Well testing analysis was first proposed in 1937 by Muskat to evaluate hydrocarbon reservoir performance. The general concept of the well testing is to create a flow disturbance in the well and analysing the pressure changes in the Bottomhole. Pressure build up and draw down test are two of the most widely used well testing methods to analyse well performance. During pressure build up test, the well is shut in for a period of time, thus, reservoir pressure starts to rise and build. In a draw down test, the well is produced at a constant flow rate for some time, during which reservoir pressure falls down. The pressure data versus time are recorded and analysed to predict the performance of the well. Appropriated well testing methods in which their main goal is to have the best match between the recorded pressure data and some ideal reservoir models can be used to evaluate well performance (SadeghiBoogar and Masihi, 2010; Onur and Kuchuk, 2012; Ghaffarian et al. 2014; Cho et al. 2013; Vaferi et al. 2015; Shahbazi et al. 2015).

Rosa and Horne (1997) investigated the discontinuities in permeability in the reservoir using a cyclic stimulation on an active well. The pulse was transmitted through a well and the response was received from another well. Different frequencies were generated as the results of different pulse signals, which allowed the possibility of investigating different extensions of the reservoir. The main result of their investigation was an equation to investigate the radius of cyclic influence for a given dimensionless frequency. Their study was later continued by Ahn and Horne (2010) in 2010 by focusing on different frequencies and phase data to analyse the generic interwell permeability profiles.

The reservoir heterogeneities of a gas filed and synthetic field was analysed by Fokker et al. (2012). They used different pulse testing through both attenuation and phase information, which last for several months. Their results showed that the well testing provide valuable information on the current status of the well. In addition, significant recommendations for improving the overall performance of the well were made by analysing the well test results. Lin (2014) investigated a well using flow rate profile logging through pressure build up and falloff test analysis. In this method, the wellbore history was not used to investigate the reservoir permeability, skin factor, and formation pressure. Instead, the flow rate data was gained from the flow test during the production and using pressure build up and falloff tests. In conventional well testing analysis, type curve analysis, log-log plots and derivatives methods are used to obtain the results, however this method reduced the sequences of achieving final results. Thus, skin factor and reservoir permeability were achieved with high reliability.

Rosario et al. (2016) used field testing of conventional and deconvolution methods to analyse pressure build up tests. They mainly tested real-time sand face rate measurements during the after flow periods. Their analysis showed that deconvolution methods provide much stronger results than the conventional methods. However, real-time data acquisition quality was the main factor affecting their reliability. In addition, they concluded that to have a comprehensive and accurate description of the reservoir, deconvolution methods cannot be used solely and conventional methods are required to be applied. In addition, the reliability of the matching, permeability and skin factor determination are improved using their techniques.

In this study, reservoir characteristics and performance of an oil reservoir in west of Iran was studied and analysed using rock and fluid properties as well pressure build up test. Since bubble point pressure of the reservoir was close to the initial reservoir pressure of the reservoir, Vogel's method was used to analyse reservoir performance. The results were then compared with the results achieved using Darcy's method. Well testing analysis was done using Saphir software.

MATERIALS AND METHODS

DESCRIPTION OF THE RESERVOIR MODEL

An oil reservoir located in west Iran was analysed suing pressure build up test for 24 hours. Porosity of the reservoir is 35% and net thickness of the productive layer is about 65 ft. In addition, formation rock compressibility is 2.7×10^{-5} psi^{-1} and total compressibility is about 9.9×10^{-6} psi^{-1}. Table 1 represents other reservoir properties.

WELL TESTING ANALYSIS

A pressure build up test was conducted on well number 1 for 24 hours. Then, the results of pressure data versus time as well as flow rates were used as an input to be used in Saphir software. Other reservoir properties

Table 1. Reservoir properties

Properties	Value
Connate water saturation	35%
Oil saturation	75%
Bubble point pressure (psi)	1399
Reservoir temperature (F)	130
Well radius (ft)	0.5
Oil viscosity (cP)	3
Oil formation volume factor (bbl/STB)	1.2

including well radius, productive layer thickness, porosity, type of fluid, total compressibility, oil viscosity, and reservoir temperature were added to the model. After running the model, pressure and pressure derivative figures on log-log scale and semi-log scale were produced as the results of well testing analysis. The figures were then analysed to determine the values of skin factor, reservoir permeability, and initial reservoir pressure. After determining the reservoir parameters, then reservoir performance was analysed sing IPR/AOF section of the software. The reservoir parameters and flow test results were used to determine inflow performance relationship (IPR) of the well. Finally, the IPR curves were used to determine the absolute open flow (AOF) of the well using two different methods of Darcy and Vogel.

RESULTS AND DISCUSSION

PRESSURE BUILD UP TEST ANALYSIS

Figures 1 to 3 represent the log-log plot of pressure data, semi-log plot of pressure data, and production history of the well, respectively. As shown in these figures, perfect matches have taken from experimental results, which prove the reliability of the simulation results. The simulation results showed that the reservoir model in this study is a homogenous reservoir with a fault at the boundary of the reservoir. The presence of this fault in the reservoir results in additional pressure drop in the reservoir.

Table 2 represents the reservoir properties gained from simulation results. As shown in this table, initial reservoir pressure is about 1078 psi, which is below the bubble point pressure of the reservoir (1399 psi). Thus, this reservoir is a saturated oil reservoir with gas existed in the reservoir. On the other hand, the reservoir productivity is about 15100 mD.ft and reservoir permeability is about 233 mD and skin factor of the reservoir is 22. The simulation results show that reservoir permeability is high enough to deliver the fluid from reservoir to the wellbore, however on the other hand, the current condition of the well is not favourable in terms of production since a high value of skin factor is achieved. A solution to this problem could be acidizing of the well or hydrau-

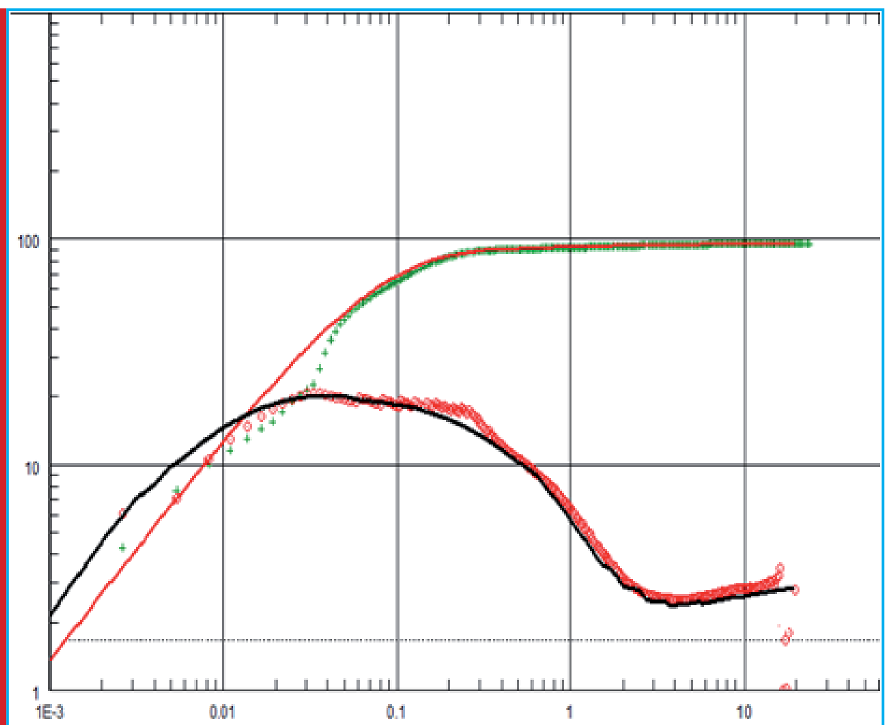

FIGURE 1. Log-log plot of pressure build up data.

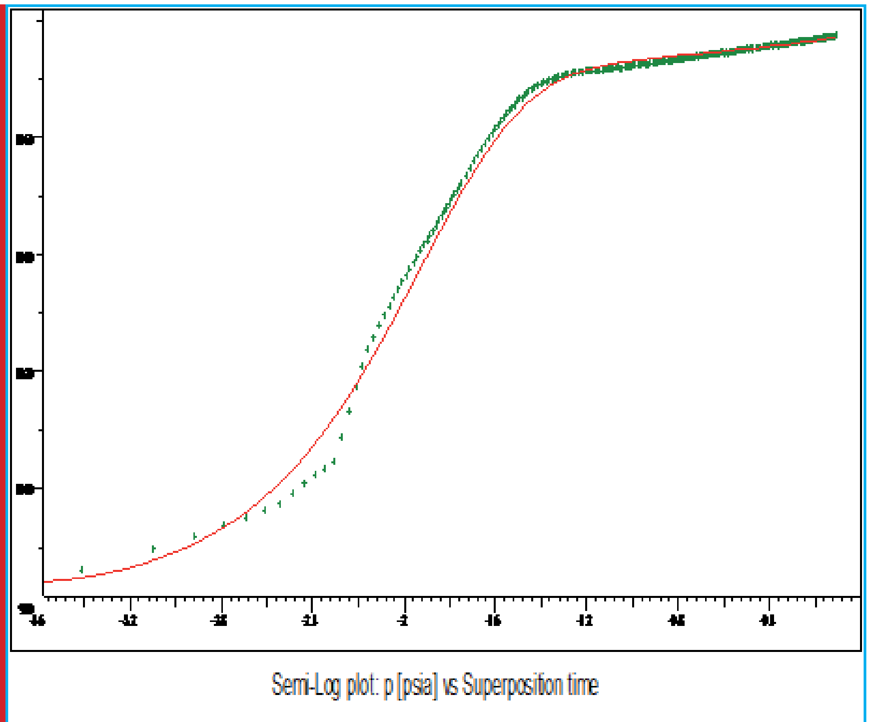

FIGURE 2. Semi-log plot of pressure build up data.

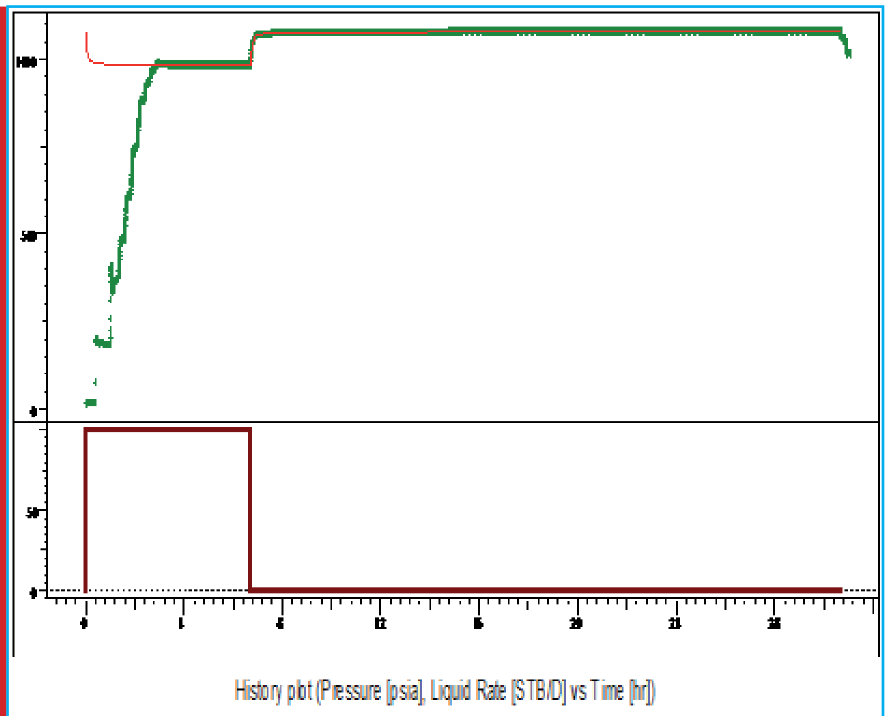

FIGURE 3. History plot of production rate and reservoir pressure in well number one.

Table 2. Reservoir simulation results from Saphir software	
Properties	**Value**
Pi	1078 psi
kh	15100 mD.ft
k	233 mD
Skin	22

lic fracturing to remove the scales inhibiting the fluid flow to the surface (Guo et al. 2014, Ghommem et al. 2015 and Zhou et al. 2016).

INFLOW PERFORMANCE RELATIONSHIP (IPR) OF THE WELL USING DARCY METHOD

A flow test with flow rate of 1600 STB/day and Bottom-hole flowing pressure of 450 psi was conducted on well number one. Initially, the IPR curve is assumed to be linear, where the slope is productivity index (PI) inverse. Then, IPR curve was analysed in two different cases of skin factor of 22 and 0. Figures 4 and 5 represent the IPR curves when skin factor is 22 and 0, respectively.

As shown in these figures, there is a big difference between the maximum producing flow rates with and without skin factor. Table 3 summarizes the

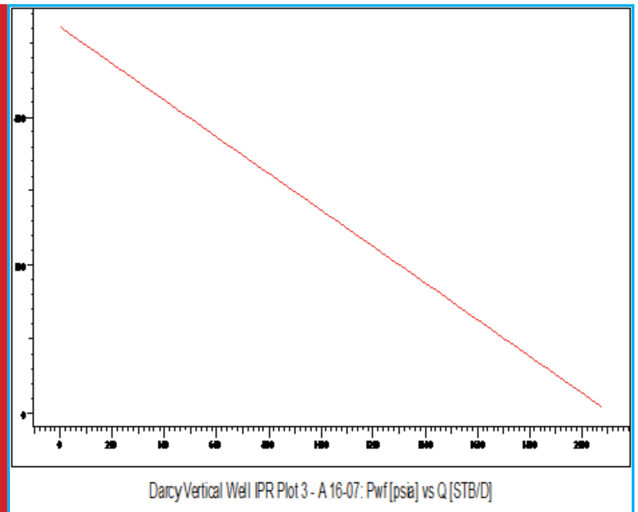

FIGURE 4. IPR plot of well number one with skin factor included using Darcy's method.

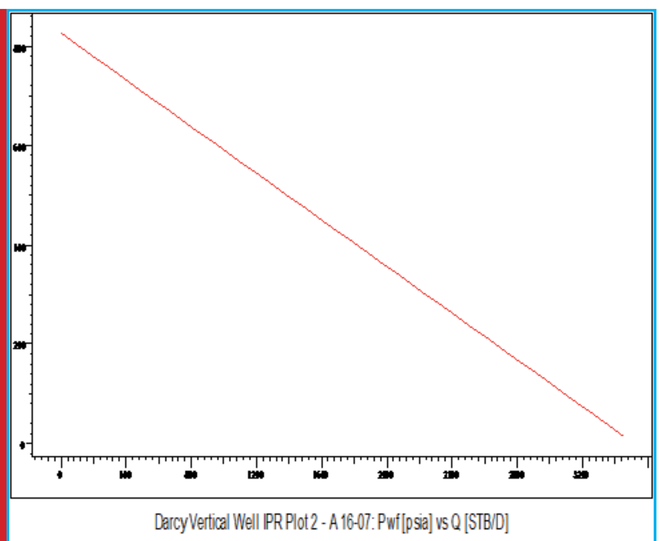

FIGURE 5. IPR plot of well number one without the effect of skin factor using Darcy's method.

Table 3. IPR results with and without skin factor		
Parameter	Value	Skin factor
AOFP	2081 STB/day	22
AOFP	3454 STB/day	0
Productivity index (PI)	1.02 STB/day/psi	22
Productivity index (PI)	4.25 STB/day/psi	0

IPR results achieved with and without skin factor in this study. As shown in this table, the maximum producing flow rate (AOFP) with skin is about 2081 STB/day while the value is 3454 STB/day without the effect of skin factor. On the other hand, productivity index o0f the well is 1.02 and 4.25 STB/day/psi with and without skin factor, respectively. This suggest that skin factor has a detrimental impact on producing flow rate and productivity of the well, which must be solved for high production rates (Mahdiyar et al. 2011; Luo et al. 2016).

INFLOW PERFORMANCE RELATIONSHIP (IPR) OF THE WELL USING VOGEL METHOD

Since reservoir pressure is close to the bubble point pressure of the reservoir and reservoir is saturated, Darcy's method cannot be used for analysing the well perfor-

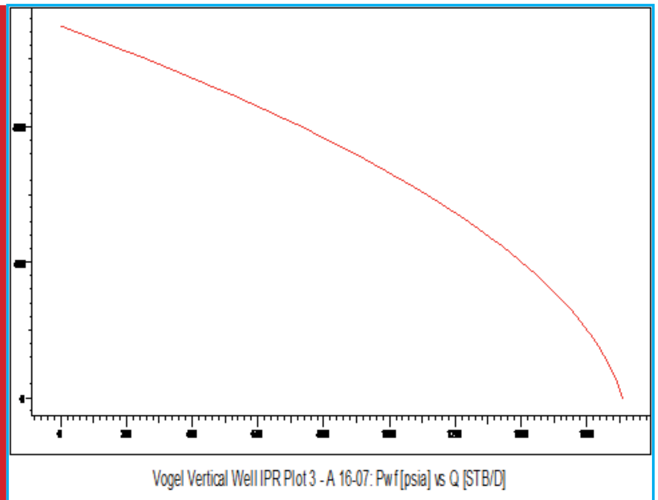

FIGURE 6. IPR plot of well number one with skin factor included using Vogel's method.

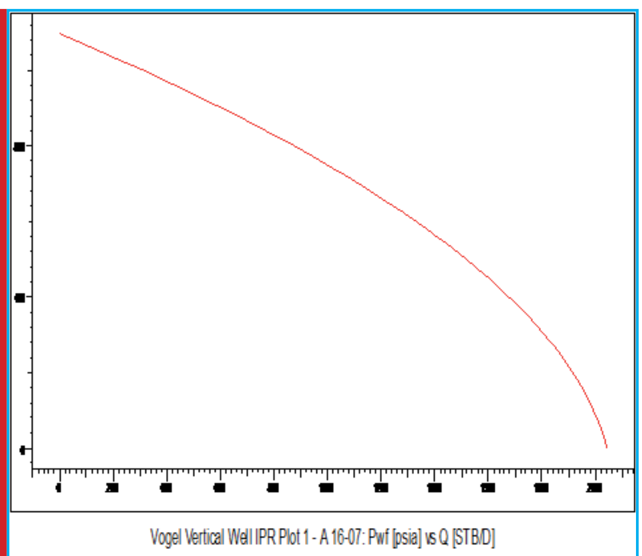

FIGURE 7. IPR plot of well number one without the effect of skin factor using Vogel's method.

mance. Thus, Vogel's method should be skin effect. These results suggest that skin factor has negative effect on production rate, which reduces it significantly. Thus, methods of skin removal such as acidizing and hydraulic fracturing are of great importance (Dehghan et al. 2015 Yegin et al. 2016 and Sobhaniaragh et al. 2016).

CONCLUSION

The well testing analysed through pressure build up test showed that the reservoir is a homogenous reservoir bounded with an impermeable fault. The value of skin factor in this reservoir is too high, which impeded the natural production from the well. This negative impact of skin factor could be solved through acidizing of hydraulic fracturing of the well. The reservoir permeability is high enough to deliver sufficient fluid from the reservoir to the wellbore, however the lift to the surface requires addition support by skin removal. Darcy's method can be used when bubble point pressure and reservoir pressure are not close, which results in linear IPR. However, when the values of pressures are close to each other, then Vogel's method should be used to analyse the well performance. In this case, the IPR is no longer linear and it is curvature.

ACKNOWLEDGEMENTS

The authors would like to appreciate the Department of Petroleum Engineering, Marvdasht Branch, Islamic Azad University, Marvdasht, Iran for the provision of the laboratory facilities necessary for completing this work.

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