ASPECTS REGARDING INFLUENCE OF IPR AND OPR CURVES ON GAS LIFT PERFORMANCE

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ABSTRACT

Gas lift performance curve describes the relationship between the gas injection rates and liquid rates produced by a gas lift well and represents the input of the gas lift optimization process. This curve can be obtained by simulation, based on nodal analysis or can be built on the basis of gas injection rates and liquid rates measured in field.

To perform nodal analysis, when the nodal point is chosen at the middle of perforations it is necessary to build the IPR (Inflow Performance Relationships) curves which characterize the flow performances of fluid from reservoir into borehole and the OPR (Outflow Performance Relationships) curves, which characterize the upward two-phase flow through tubing. From nodal analysis result the coordinates of the operating points (flowing pressure, liquid rate) for each considered value of gas injection rate.

Therefore, we can build the gas lift performance curve by simply plotting the liquid rates as a function of the gas injection rates; these being obtained from nodal analysis.

If we study all the steps in the building process of gas lift performance curve, starting with the IPR curves, several errors generated by the bad calibrations may occur and lead to inaccurate results. In our paper we study some methods to build the IPR curves and also we investigate how much these curves influence the gas lift performance curve. From our sensitivity study it resulted that the gas lift performance curve is influenced by the methods used to build the IPR and OPR curves. It is also important to have a good calibration of IPR curves based on more than one test data and of OPR curves based on measured pressures data.

Keywords: Gas lift, IPR, OPR, gas-lift performance curve, nodal analysis.

INTRODUCTION

Gas lift performance curve describes the relationship between the gas injection rates and liquid rates produced by a gas lift well. This curve can be obtained by simulation, based on nodal analysis or can be built on the basis of gas injection rates and liquid flow rates measured in field. In both cases there may be errors that lead to the building of an inaccurate performance curve. Therefore, in the case of measurements in field, errors may occur due to malfunction of measuring devices.

Hence, in the case of nodal analysis, starting with the IPR curves, several errors generated by the bad calibrations may occur and lead to inaccurate results.

On the other hand, the gas lift performance curve is dynamic, being influenced by many factors such as: reservoir pressure, gas source capacity, PVT fluids, wellhead pressure, etc.

The efforts to build an accurate gas lift performance curve are motivated by the fact that this curve is very important in the production optimization and gas allocation process. In the case of an oil reservoir which produces through several gas lift wells and a gas source with limited capacity, the gas lift performance curve of each well represents the input of the production optimization process and gas allocation on that field.

PERFORMANCE OF GAS LIFT WELLS

Performance of gas-lift wells can be investigated using nodal analysis. To perform nodal analysis it is necessary to define the components of the production system, to choose the nodal point which divides the production system in two sections and to establish the flow performances of inflow section (upstream of nodal points) and the outflow section (downstream of nodal points) [1] [2].

Therefore, nodal analysis for a gas-lift well has the following steps:

- defining the components of the production system;
- choosing the nodal point and establishing which is the inflow section, respectively the outflow section;
- defining the gas source capacity;
- selection and calibration of the upward two-phase flow correlation in order to build the OPR curves;
- building the tubing performance curves or outflow performance relationships(OPR) curves based on upward two-phase flow correlation;
- building the inflow performance relationships (IPR) curves;
- finding the coordinates of the operating points .

If the production system is considered up to christmastree, usually the nodal point is chosen at the middle of perforations. In this case, the flow performances of inflow section are described by IPR (Inflow Performance Relationships) curves. These curves have different allures depending on the type of flow (homogeneous, heterogeneous or mixed).

In the case of heterogeneous flow, many researchers proposed several methods to build the IPR curves. Some of these methods are applied for two-phase flow and the other for three- phase flow. Moreover, these methods are developed for different trajectories of wells (vertical, deviated, horizontal, and multilaterals) and based on different hypotheses.

The performance of the fluid flow in the outflow section is determined by the characteristics of the upward two-phase flow through the tubing string and depends on the following parameters: wellhead pressure, gas injection rates, liquid rates, surface gas injection pressure in casing and PVT properties of the fluids.

To build the outflow performance relationships curves it is necessary to use an upward two-phase flow correlation in order to determine the gradients curves, injection points and flowing pressure for the liquid rates and gas injection rates considered.

Once the OPR and IPR curves have been built, nodal analysis can be performed. The coordinates of operating points (liquid rates and gas injection rates) resulted from nodal analysis are used to build the gas lift performance curve(GLPC).

Therefore, parameters that influence the performances of the gas-lift wells are related to the characteristic of the system components, the reservoir fluids and gas injection PVT properties, the capacity of the gas source and system boundary conditions.

On the other hand, the prediction of gas lift well performance depends on the methods used to build the IPR curve, to estimate the PVT properties of reservoir fluids and injection gases (when measured data are not available) and to model the upward two-phase flow through tubing string.

In the following we will focus only on the methods used to build IPR curves and on the upward two-phase flow correlations used to build the OPR curves.

INFLUENCE OF IPR METHODS AND UPWARD TWO-PHASE FLOW CORRELATIONS ON GAS LIFT WELL PERFORMANCES

In the case of our study we define the production system which has the following components: reservoir, casing perforations, tubing string and wellhead. We choose the nodal point al the middle of the perforated interval. Therefore, the reservoir and casing perforations are the inflow section and tubing string up to wellhead is the outflow section. In the case of this model, the boundary conditions are: reservoir pressure and wellhead pressures which in our study remain constant.

To perform this study we consider well data shown in table 1 and well trajectory shown in figure 1.

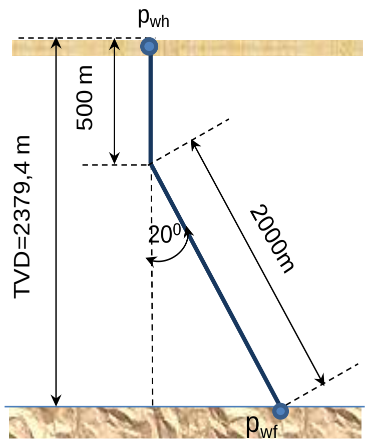

Figure 1. Well trajectory.

Table1. Reservoir, completion and PVT reservoir fluids data.

Parameter	Measurement Units	Value
Static pressure, p_{ws}	bar	106
Reservoir temperature, t_R	ºC	95
Bottom hole flowing pressure, p_{wf}	bar	76
Gas liquid ratio, GLR	sm^3/m^3	150
Liquid flow rate, Q	m^3/d	60
Gas injection rate, Q_{inj}	sm^3/d	20000
Water cut, i	%	10
Measured depth of middle perforations	m	2500
Thru vertical depth of middle perforations	m	2379,4
Measured lengtht of tubing string,	m	2450
Tubing inner diameter, d	in	3
Casing inner diameter, D	in	7
Wellhead pressure, p_{wh}	bar	15
Oil density, ρ_o	kg/m^3	850
Water density, ρ_w	kg/m^3	1050
Relative density of gas, ρ_{rg}	-	0,65
Oil Viscosity, μ_o	cP	2cP at 95ºC
Gas viscosity, μ_g	cP	0,02
Bubble points pressure,p_b	bar	294,4

We have considered two upward two-phase flow correlations developed by Orkiszewski [7] and Mukherjee and Brill[6] in order to build the OPR curves. Both correlations are widely used and take into account the flow pattern along the tubing string. These correlations also allow the prediction of the flow pattern as well as the determination of the liquid holdup and the two-phase friction factor.

Orkiszewski flow correlation [7] was developed for vertical well, but it has a discontinuity in its method calculation [3]. On the other hand, Mukherjee and Brill correlation [6] was developed for the case of inclined two-phase flow.

To build the IPR curves we considered several methods used in the case of heterogeneous flow as: Vogel [8], Fattah et. al. [4], Fetkovich [5] and Wiggins [9]. All of these methods, excepting Fattah et al. [4] method, are based on second degree equations with different coefficients that allow the building of IPR curve. Instead, Fattah et al. [4] develop a logarithmic equation to build the IPR curve.

We have chosen these equations because some of them like Vogel method [8] and Fetkovich method [5] are most used, often without take into account their hypotheses.

The Wiggins method [9] and Fattah et al. method [4] were chosen because one of them was developed for wells that produce with water cut and the other is based on logarithmic equation.

In the table 2 we show the equations of the methods developed by Vogel [8], Fattah et. al. [4], Fetkovich [5] and Wiggins [9] in order to build the IPR curves.

Using the equations from table 2 and data from table 1 we build the IPR curves which are shown in figure 2.

Table 2 Methods and equations used to build IPR curves.

Methods	**Equations**
Vogel [8]	$\frac{Q}{Q_{max}} = 1 - 0{,}2\frac{p_{wf}}{p_{ws}} - 0{,}8\left(\frac{p_{wf}}{p_{ws}}\right)^2$
Fattah et al. [4]	$\frac{Q}{Q_{max}} = 1 - \frac{\ln(\alpha \cdot p_{wf} + 1)}{\ln(\alpha \cdot p_{ws} + 1)}$ for p_{ws}<110 bar $\alpha = \frac{14{,}504}{-14{,}228 \cdot p_{ws} - 152{,}585}$
Fetkovich [5]	$Q_{max} = \frac{Q}{\left[1 - \left(\frac{p_{wf}}{p_{ws}}\right)^2\right]}$
Wiggins [9]	$\frac{Q_o}{Q_{omax}} = 1 - 0{,}52\frac{p_{wf}}{p_{ws}} - 0{,}48\left(\frac{p_{wf}}{p_{ws}}\right)^2$ $\frac{Q_w}{Q_{wmax}} = 1 - 0{,}72\frac{p_{wf}}{p_{ws}} - 0{,}28\left(\frac{p_{wf}}{p_{ws}}\right)^2$

In the table above: Q_{max}, Q_{omax}, Q_{wmax} are the maximum liquid flow rate, maximum oil flow rate and maximum water flow rate, m^3/d;

Q –liquid flow rate, m^3/d;

p_{wf} –bottom hole flowing pressure, bar;

p_{ws} –bottom hole static pressure, bar.

From figure 2, the following observations result:

- Vogel, Fetkovich and Wiggins methods[8], [5], [9] lead to similar results for the pressures bigger than test flowing pressure and Fattah et al.[4] method lead to slightly bigger results on the same pressures interval.
- Because in the case of all methods, the test point data are used to determine the maximum liquid flow rate, it is obvious that all methods lead to identical values in this point.

- For pressures lower than test flowing pressure, the flow rates calculated with methods mentioned above are very different, especially in the case of Fattah et al.[4] method and Wiggins method[9].

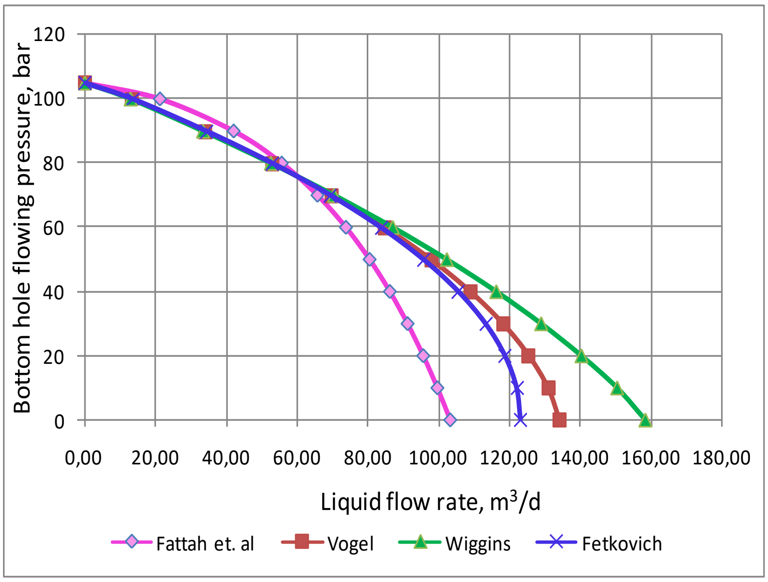

Figure 2 IPR curves built with methods developed by Fattah et al. [4], Vogel [5], Wiggins [9] and Fetkovich [5].

Therefore, for the pressures smaller than test flowing pressure it is very difficult to choose one method if we haven't at least one test point in this pressures interval.

Further we consider the upward two-phase flow correlation developed by Orkiszewski [7] in order to build the OPR curves for several values of gas injection rate between 3000 sm^3/d and 120000 sm^3/d (considering gas source capacity limited at 120000 sm^3/d). OPR curves obtained in this case are shown in the figures 3 with dotted lines. Once the IPR and OPR curves are built, the nodal analysis can be performed (figure 3).

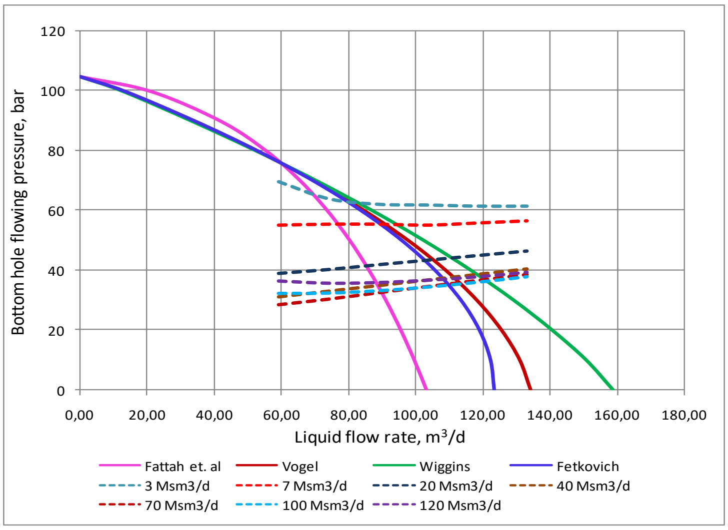

Figure 3 Nodal analysis considering IPR curves built with different methods and OPR curves built on the basis of upward two-phase flow correlation developed by Orkiszewski [7].

The coordinates of operating points for each considered value of gas injection rate result from the figure 3. If we graphically represent on a diagram the value pairs of gas injection rate and liquid flow rates, we obtain the gas lift performance curves (figure 4) in the hypothesis that IPR curves are built with different methods (Vogel [8], Fattah et. al. [4], Fetkovich [5] and Wiggins [9]) and for building of OPR curves is used the upward flow correlation developed by Orkiszewski [7].

Figure 4 shows how important the method chosen for building the IPR curves is. We observe that IPR curve built with Fattah et al method[4] lead to the smallest values of liquid flow rate and the one built with Wiggins method[9] lead to the biggest values of liquid flow rate.

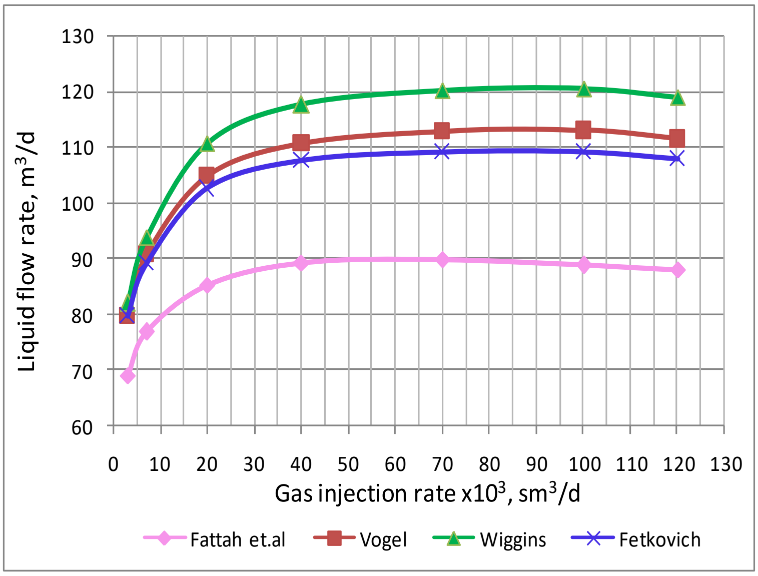

Figure 4 Influence of IPR curves built with different method and OPR curves built with Orkiszewski [7] two-phase flow correlation on gas lift performance curves.

Also from figure 4, we observe that the difference between the values of maximum flow rates from the two curves is about 30m^3/d. This difference is huge and leads to large errors in production optimization process. Consequently, it is necessary to calibrate the IPR curve on the basis of more than one test data point.

After that the OPR curves are built using the upward two-phase flow correlations developed by Mukherjee – Brill [6]. To perform nodal analysis in this case we use the same methods to build the IPR curves as in previous case (figure 5). The results will be compared with those resulted from the method developed by Orkiszewski [7].

The OPR curves built with Orkiszewski [7] and Mukherjee and Brill upward two-phase flow correlations are shown in figure 3 and 5 with dotted lines. If we compare the figure 3 with figure 5 we can observe that the OPR curves are different and lead to different values of operating points coordinates. Hence, Mukherjee and Brill correlation [6] moves the operating points to smaller liquid flow rates and bigger bottom hole flowing pressures. On the other hand, the Orkiszewski correlation [7] leads to the displacement of the operating points in the area of lower pressures, respectively higher rates.

We can see, also that for gas injection rate of 20000 sm^3/d operating point has approximately the same coordinates as test data point. That means the upward two-phase flow correlation developed by Mukherjee and Brill [6] is suitable in this case.

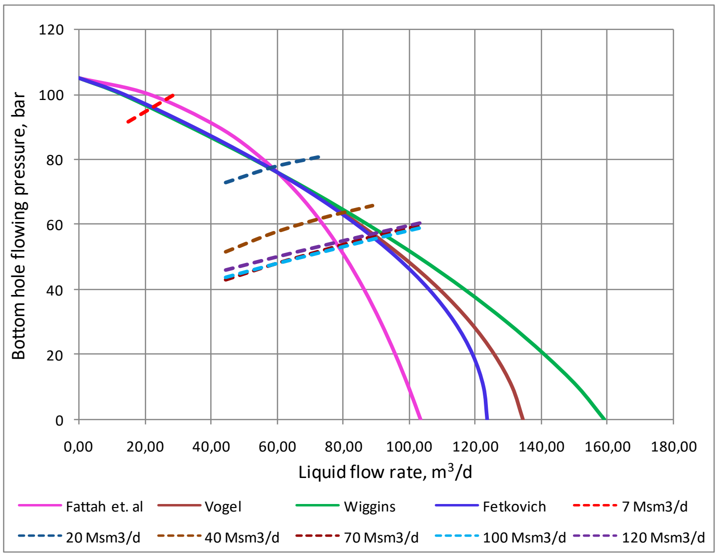

Figure 5 Nodal analysis considering IPR curves built with different methods and OPR curves built on the basis of upward two-phase flow correlation developed by Mukherjee and Brill [6].

As in the case shown above for building the gas lift performance curves, the value pairs of gas injection rate and liquid flow rates(operating points resulted from figure 5) are represented graphically on a diagram (figure 6). In this case IPR curves are built with different methods as: Vogel [8], Fattah et. al. [4], Fetkovich [5] and Wiggins [9] and OPR curves are built with the upward two-phase flow correlation developed by Mukherjee and Brill [6].

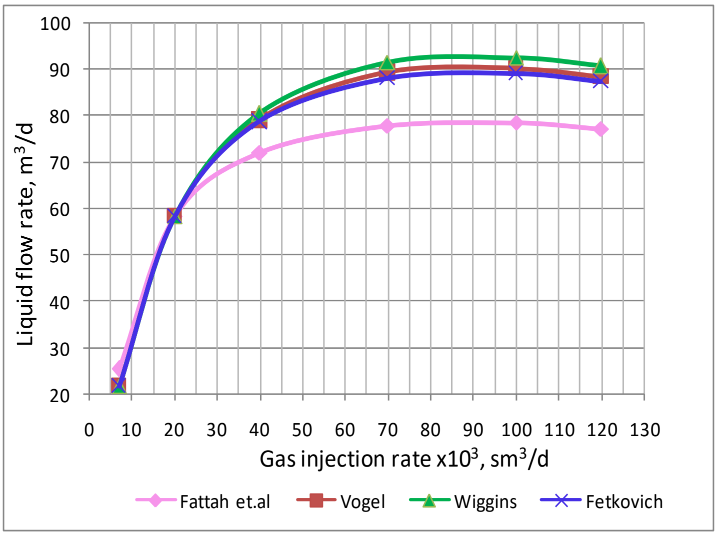

Figure 6 Gas lift performance curves considering the IPR curves built with different methods and OPR curves built with Mukherjee- Brill [6] two-phase flow correlation.

As can be seen from figures 4 and 6 in addition to the IPR curves, a major influence on the gas lift performance curves has the upward two-phase flow correlations used to build the OPR curves.

Figures 6 show us that IPR built with Fattah et al.[4] method leads to the most pessimistic results and IPR built with Wiggins method[9] leads to the most optimistic results, but the difference between the values of maximum flow rates is almost half (about 14m^3/d) compared with that from figure 4 (about 30m^3/d). Also, except for the gas lift performance curve built on the method of Fattah et al. [4], the others have similar values, the differences being less than 5sm^3/d.

This small difference is obtained because the upward two-phase flow correlation developed by Mukherjee and Brill [6] is more appropriate for the well production data in this study, and the OPR curves are concentrated near the test point, where the differences between the IPR curves built with several methods are smaller.

CONCLUSION

Gas lift performance curve is very important in production optimization process; being the base of this process. This curve shows the liquid flow rate produced for some value of gas injection rate, as well as the maximum value of liquid flow rate that can be produced and corresponding gas injection rate.

Gas lift performance curve is influenced by many factors like: characteristic of the system components, the reservoir fluids and gas injection PVT properties, the capacity of the gas source and system boundary conditions.

The prediction of gas lift well performance depends on the methods used to build the IPR curve, to estimate the PVT properties of reservoir fluids and injection gases and to model the upward two-phase flow through tubing string. In this study we investigated how IPR curve building methods and the upward two-phase flow correlations influence the gas lift performance curve.

Generally, the methods used to build the IPR curves have almost similar values for pressures bigger than test bottom hole flowing pressure. Obviously, in the test data point the values are identically for the all IPR methods considered. The IPR curves have different values for pressures lower than the test bottom hole flowing pressure. Consequently, it is necessary more than one test data point in order to calibrate the IPR curve. Without calibration of IPR curve, the performances of gas lift well could be predicted inaccurately, in optimistic or in pessimistic way.

The upward two-phase flow correlation has a large influence on gas lift performance curve. If this correlation is not calibrated, the OPR curves for same values of gas injection rate lead to operating points with different coordinates. Therefore, it is necessary to calibrate also the upward two-phase flow correlation on the production data. A good calibration lead to minimizing errors and permit to obtain an accurate prediction of the gas lift well performances.

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