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The Efficient Use of Surface Choke to Optimize Oil Production in Niger Delta.

Ehirim O. Emmanuel
Department of Chemical/Petrochemical and Petroleum Engineering Rivers State University
Port Harcourt, Nigeria

ABSTRACT*: When a well is brought into production, the rate at which the well is produced has a great effect on the life of the well and the total cumulative recovery. High production rate can result to the damage of the reservoir formation, resulting in lower recovery. Also, high sand production can occur which can result to tubing and casing collapse. The above situations can be quelled by the installation of a surface choke which controls the flow rate and provokes optimal production. Selection of optimal surface choke size for this work was done using the Gilbert's correlation. Three wells and three different choke sizes used for each of the wells were considered for demonstration. Analysis of the results shows that the optimal choke sizes for optimal production rate for each of the wells are 41.81/64'', 25.16/64'' and 28.55/64'' respectively.*

***KEY WORDS** - Surface Choke, Production Rate, and Wellbore*

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I. INTRODUCTION

When wells are drilled and completed the size of the production tubing remains constant. As such, the rate of production from the well to the surface would be highly dependent on the tubing size. In order to control the flow rate of the well at the surface, a surface choke can be installed to control the flow rate of the well. Although a choke device is used for a number of purposes at the surface or downhole, its principal use is to control flow rate and pressure of the produced hydrocarbon at the wellhead.

It has been shown by practical experiences that a certain flow rate exists above or below the critical rate under a given well conditions for which a well begins to develop problems. Therefore a maximum efficient rate (MER) which is the rate at which a well may be produced optimally without developing much problem, is strongly recommended for any given well. MER is achieved by selecting the right choke size for a particular well at any given well conditions and also by ensuring that critical flow is maintained across the choke i.e. Pressure fluctuations downstream does not affect upstream pressure.

The higher the quantity of crude oil a company can produce, the higher the return the company gets from the sales. This drive to make more profit can instigate some firms to producing a well above the critical flow rate, way above the MER of the well. If the fluid flow through well including the wellbore, is allowed at too great a flow rate, then sand from the producing formation can invade and damage the well. Apart from the damaging of the well, also, excessive sand production has the potentials of damaging or destroying the internals of surface equipment.

It is important to control the rate of fluid flow through a wellhead on a hydrocarbon producing well which is not on artificial lift as stated by Ken Arnold[1] in order to ensure that the well optimally produces without inducing any damage on itself or the life of the reserve. The size of a choke selected to restrict flow should be an optimal choke size that promotes highest recovery efficiency without formation damage. If the fluid flow through well including the wellbore is allowed to flow at excessive rate, then sand from producing formation can invade and damage the well, Scott Jessie[2]. This occurs because the pressure differential between the producing formation or formations and the wellbore of the well can induce sand to flow into the wellbore. Apart from excessive sand production, producing a well at a flow rate too great can also result to the following effects: Gas and/or water coning, Formation Damages, Tubing or casing collapse, etc. In order to take measure over the adverse effects of these factors on the life of the well and the reserve, the surface choke provides us with a better control over the well.

A typical well production system, a gas well or an oil well,consists of several components including:Flow through porous medium, Flow through vertical or directional wellbore, Flow through choke, and Flow through surface line

There are different types of choke: Fixed choke (also called positive choke), Needle and seat choke, Plug and cage choke (or adjustable choke). The most commonly used are the adjustable and positive choke.

Positive chokes (Fig.1) consists of a removable flow bean with a circular orifice of fixed dimensions. The dimension is usually specified in diametric increments of 1/64 inch. Positive chokes are used both in oil, gas and water services.

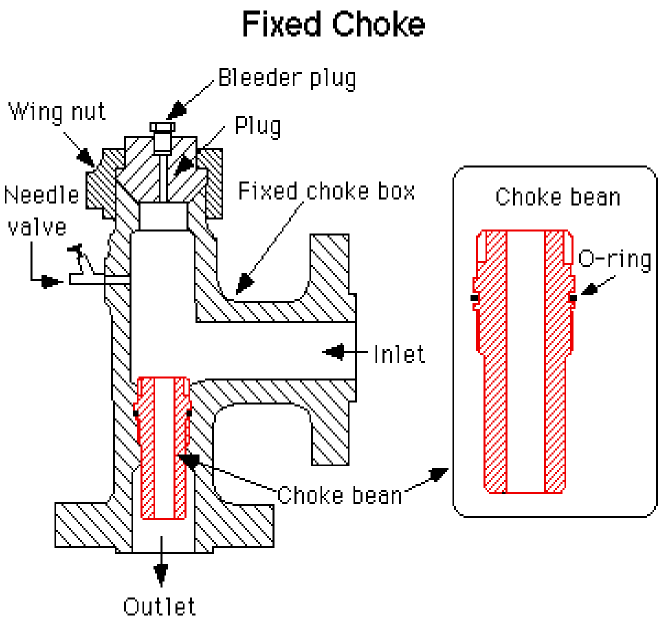
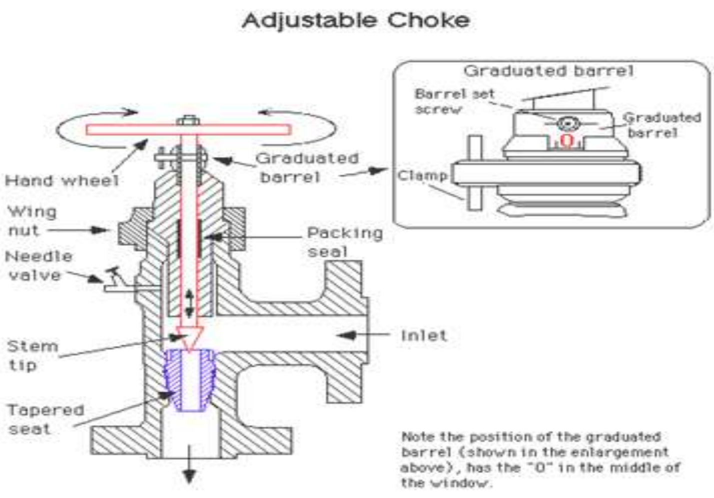


Fig. 1: Fixed Choke (Courtesy of Beijing Oilfield Service)

Adjustable choke (Fig. 2) have an externally controlled variable orifice and a visible area indication mechanism. This mechanism called the barrel or stem is calibrated in terms of diameters of equivalent circular orifices in increments of 1/64 inch. The adjustable choke allows the size of the orifices that fluids flow through to be changed.



outlet

Fig. 2: Adjustable choke (Courtesy of Beijing oilfield service)

The listed chokes above work on the same principle of dissipating large amounts of potential energy over a short distance. This is done by causing the fluid to pass through a short rapid contraction. This restriction has the effects of forcing the fluid into a narrow jet, creating eddies on both inlet and exit of the choke and increasing the turbulence of the flow, thus dissipating energy and reducing the flow rate. This implies that for a given mass of fluid flowing through choke, there is usually a large pressure drop.

In order to convey the fluid in the wellbore to surface, some forms of pressure losses are experienced in the tubing. These various pressure drops account for the vertical flow performance. In most wells, the tubing contributes as much as 80% to the total pressure drops in a producing well, [3]. The energy relationship for a fluid flowing through tubing may be obtained by an energy balance. The flowing fluid possesses some form of energy and also gains energy from the surrounding or transfers energy to the surrounding. The theoretical basis for most fluid flow equation is the general energy equation which is an expression of the conservation of energy between two points in a system.

The Impact of Multi-phase flow cannot be overlooked in the design of an optimum choke for optimum production rate. Multi-phase flow is a complex phenomenon that is common in all facets of hydrocarbon production systems compared to a single-phase flow. Multi-phase flow occurs in the reservoir, in the production string, in the surface pipeline, and through the refining process. Multi-phase flow analysis is used primarily to model the pressure loss that occurs over a segment of conduit. However, it is also used in the design of phase separation facilities to predict liquid slug sizes that the facilities must be able to accommodate.

The flow of multi-phase mixture is much more difficult to model than single-phase flow. Whereas single-phase flow may be characterized by laminar or turbulent flow, multi-phase flow analysis must consider the quantity of the phases, the flow pattern of the phases, the interfacial tension between the phases, stratification between the phases, and the different velocities of the phases. Typically the phase will move at different velocities due to variation in phase densities and velocities. The disparity in the phase velocity is referred to as the slip velocity. Due to the phases slipping past each another, the relative concentration of the phases inside the system are distinct from the rates the phases are crossing the system's boundaries. Since the phases are not moving in tandem, the phase volume inside the system cannot be directly inferred from the phase flowrates. The difference between the in-situ concentrations inside the system and the concentration of the phases flowing through the system is known as the hold-up phenomenon.

The purpose of the tubing in a well is to convey the produced fluids from the producing zone to the surface or to convey fluids from the surface to the producing zone. It should be able to do this safely and economically for the life of the well,[4]. At very high production rates, especially from unconsolidated formations, the formation may cave into the wellbore resulting to the collapse of the casing. More so, tubing pressure may exceed annular pressure, leading to tubing collapse. Sand production may also cause the abrasive wear of the tubing thereby lowering its capacity to resist collapsing.

Production of fluids from a collection of wells may have limits due to the shearing of surface facilities which have limited capacities such as for separating gas, oil and water. The different wells may produce different relative percentages of gas, oil and water. Therefore, production from the individual wells is controlled by adjusting the respective opening size of their chokes. The aim of this research is to determine the optimum choke size for optimum production rate using the Gilbert model.

II. MATHEMATICAL MODELLING

Several models have been developed to describe or model flow through surface choke. The adopted approach for the purpose of this research is the choke model as proposed by [5].

Obtained field data from different case study wells are analysed using the Gilbert and Vogel [6] correlations in order to determine a model choke size and to generate the choke performance curve and wellhead performance curve for each of the wells in order to obtain an optimal choke size for the well.

2.1 BASIC ASSUMPTIONS

1. Flow through the surface choke is at critical condition
2. The liquid rate equals the oil rate for two-phase flow.
3. The performance of the well is considered at the wellhead/surface conditions.

For critical flow conditions, based on daily production data of a California oil field, Gilbert established an empirical relation for the tubing head pressure which related the liquid flow rate, the gas-liquid ratio and the choke size by:

$$P_{wh} = K \; Q_L \tag{1}$$

Where

$$K = \frac{AR^{B}}{d^{c}} \tag{2}$$

and

P_{wh}= wellhead flowing pressure (Psi)
Q = gross liquid flowrate (STB/D)
R = gass-liquid ratio (Mscf/STB)
D = surface choke diameter ($^{1}/_{64}$")
A,B,C = correlating constants

Gilbert developed the constants for equation (2) as:
A = 435
B = 0.546
C = 1.89
Making substitution of equation (2) with the constant term values into equation (1) yields:

$$P_{wh} = \frac{435\ R^{0.546} Q_L}{d^{1.89}} \tag{3}$$

Solving for **d** in equation (3) yields:

$$d = \left[\frac{435\ R^{0.546} Q_L}{P_{wh}}\right]^{1/1.89} \tag{4}$$

Equation (4) is the model equation used for this research. With given values of Q_L, R and P_{wh} for any given test well data, equation (4) will be used to predict the optimal choke size for the particular well under consideration.

Validation Of Model

For the purpose of illustration, the model is validated using MER test data from 3 production wells in the NIGERDELTA regions of Nigeria, hereafter referred to as wells 1, 2 and 3 of known surface choke sizes. Each of the wells is validated for three different surface choke sizes.

Data Presentation

Data for wells 1, 2 and 3 are presented for their different choke sizes respectively which shall be used for the generation of choke performance and wellhead performance curves for each case.

Choke Performance Curve

The defining equation for the generation of choke performance curve is equation (3) given below

$$P_{wh} = \frac{435\ R^{0.546} Q_L}{d^{1.89}} \tag{3}$$

For each predicted choke size, different values are assumed for Q_L in equation (3) to generate the curve.

Wellhead Performance Curve

The Vogel equation has been adopted for the generation of wellhead performance curve for each of wells.

$$Q_L = Q_{L(max)}\left[1 - 0.2\left(\frac{P_{fl}}{P_{wh}}\right) - 0.8\left(\frac{P_{fl}}{P_{wh}}\right)^2\right] \tag{5}$$

Where
P_{fl} is flowline pressure immediately after the wellhead
$Q_{L(max)}$ is maximum liquid rate for each well relative to the 3 choke sizes.

$$Q_{L(max)} = \sum_{i=1}^{n} Q_{Li} / 3 \tag{6}$$

$$P_{wh} = \sum_{i=1}^{n} P_{whi} / 3 \tag{7}$$

Where i = 1, 2, 3

Different values for P_{fl} are assumed to generate wellhead performance for each well using equation 5.

III. RESULTS AND DISCUSSION

TABLE 1: CHOKE SIZES FOR WELL 1

Q_L (STB/D)	R(Mscf/STB)	P_{wh} (Psi)	Calculated choke size ($^1/_{64}$")	Field choke ($^1/_{64}$")	BSW (%)
3762	3.56	2822	41.81	40	48.8
3174	1.26	2058	33.46	32	59
3612	0.51	1740	30.15	28	95

TABLE 2: CHOKE SIZES FOR WELL 2

Q_L (STB/D)	R(Mscf/STB)	P_{wh} (Psi)	Calculated choke size ($^1/_{64}$")	Field choke ($^1/_{64}$")	BSW (%)
889	1.05	1740	17.72	16	0.5
2289	0.748	1914	25.16	24	0.4
2635	0.7158	1740	28.15	28	40.7

TABLE 3: CHOKE SIZES FOR WELL 3

Q_L (STB/D)	R(Mscf/STB)	P_{wh} (Psi)	Calculated choke size ($^1/_{64}$")	Field choke ($^1/_{64}$")	BSW (%)
834	0.207	315	28.55	28	58
966	0.138	160	36.38	36	65.6
1116	0.326	203	44.25	40	63

4.3 Discussions

A comparison of calculated choke diameterswith field values are presented for each of the wells in tables 1 to 3. It can be quickly be verified that from tables 1,2 and 3, the predicted choke sizesare in fair agreement with the actual choke sizes. It can also be observed that the model predicts near accurate choke sizes for both high and low gas liquid ratio wells as shown in the table.

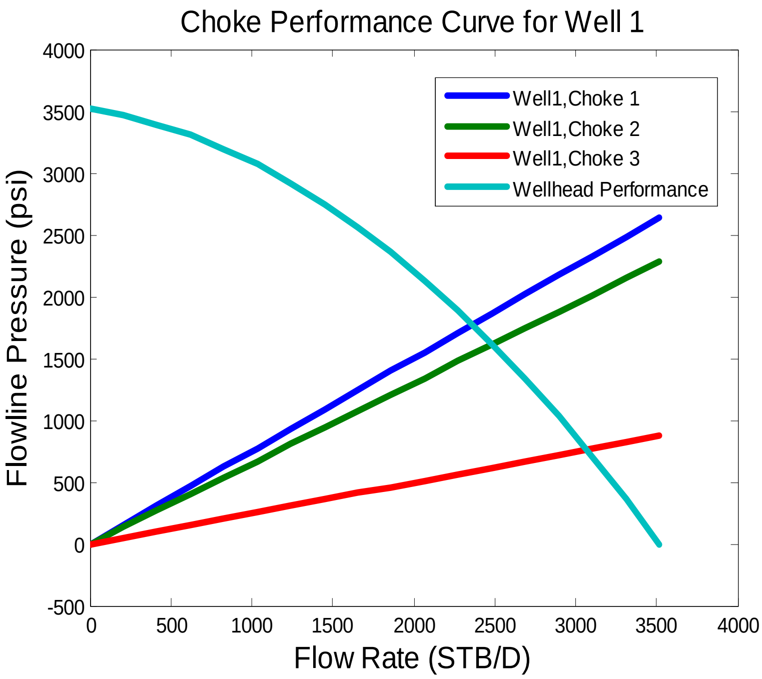


Fig. 3: Choke and Wellhead performance curves for well 1

Figures 3 through 5, illustrate graphically the choke and the wellhead performance curves for the three wells. Notice three points of intersections representing operational points for each of the cases considered. Fig.1 demonstrates that placing well 1 on choke size 30.15/64" will result to production rate of 2380 STB/D, and the production rate for choke size 33.46/64" is 2500 STB/D. While the production rate for choke size 41.81/64" is 3150 STB/D.

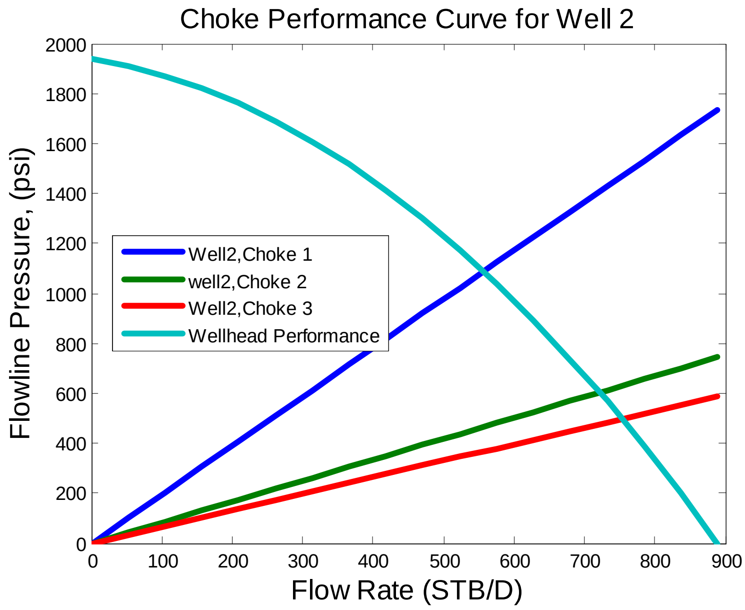


Fig.4: Choke and Wellhead performance curves for well 2

A comparison of the three choke sizes with BSW values given in Table 1 shows that choke size 41.81/64" has the lowest basic sediment and water (BSW) value of 41.8%. This means that to achieve an optimal production for well 1 it would be necessary to install a choke size of 41.81/64"

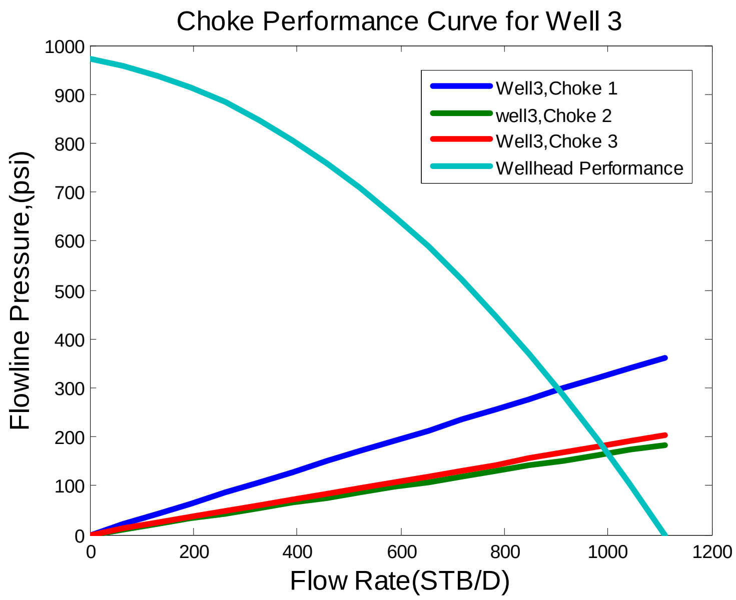


Fig. 5: Choke and Wellhead performance curves for well 3

With similar considerations for wells 2 and 3, the optimal choke size required for well 2 is 25.16/64" with production rate of 740 STB/D and BSW value of 0.4%. And that for well 3 is 28.55/64" with production rate of 890 STB/D and BSW value of 58% which is the barest minimum value of BSW obtainable for the well at the given conditions.

IV. CONCLUSION

The proposed model by Gilbert (1959), though developed with a Californian's oil wells characteristics, proved efficient when applied to oil wells in Niger Delta in Nigeria. The proposed model can be used to predict optimal surface choke size with direct computation of date such as the gas-liquid-ratio, wellhead pressure and the flow rate which are readily available. From the graphical representations, the optimal flow rate occurs where the plot of the choke performance crosses the wellhead performance curve taking into consideration the BSW value obtainable at the given conditions. This research also illustrates the universality of the proposed Gilbert model.

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