REVISITING THE EFFECT OF RESERVOIR PARAMETERS: PERMEABILITY, SKIN AND THICKNESS ON FLOWRATE AND PRODUCTIVITY OF A WELL

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ABSTRACT: Formation permeability and thickness bear a direct relation with production rate whereas skin has inverse relationship with it. Additionally the value of skin assorts between positive (damaged well) to negative (stimulated well) values. In this study, case studies have been conducted by varying two parameters at a time and keeping the third parameter as constant. The diversification in skin factor and its resulting effects, while, considering the disparity in thickness and formation permeability upon flow rate have been scrutinized. Furthermore, for in depth investigation this study has been conducted to inspect the outcome of negative and positive skin on reservoir production while integrating it with variations in other two above mentioned parameters. This research show that the increase in flow rate when the skin is changed from zero to negative values is more as compared to the case when skin varies from positive value to zero. Further, the permeability and formation thickness have direct influence on well productivity, surface facilities (which in-turn can also effect the environment), regardless of the skin value.

Key words: well productivity, permeability, skin, hydraulic fracturing.

INTRODUCTION

Flow within a reservoir can be characterized by different types of flow regimes. But in any kind of flow regime, production of a well is strongly influenced by reservoir parameters, namely; formation permeability, thickness and skin near the wellbore (Economides and Nolte, 2000).

Owing to the permeability and production rate petroleum reservoirs are classified as conventional and unconventional (Alam, 2010). Permeability (*k*), the characteristic property of every petroleum reservoir or porous medium, is the ability of rock to transmit fluids through it, hence, greater the permeability, greater the production rate against the same drawdown pressure applied (Gatlin, 1960). A permeability value less than 0.01 md characterizes unconventional reservoirs (Alam, 2010).Such less value of permeability yields unattractive production rate as a result of natural depletion. Whereas, conventional reservoirs are characterized by good permeability, hence resulting into attractive production rates.

Every petroleum reservoir is unique and characterized by its own properties (Gatlin, 1960). While determining the amount of reserves, the thickness (*h*) of a reservoir in addition to reservoir extent, area and porosity plays a key role. The amount of reserves is directly dependent upon thickness of formation (assuming same oil saturation and porosity). Reservoirs characterized by large thickness value and good permeability have shown commercial production rates (Economides et. al, 1994, Brown 1984).

Capacity of the Formation: Permeability (*k*) and thickness (*h*) play a key role in determining production rate and future forecasts of the development of a reservoir. Capacity of formation, one of the major properties pertaining to a reservoir, is the product of permeability and thickness "*kh*". The producing potential of a reservoir is determined through the capacity of formation and has a direct relationship with it (Ahmed, 2006).

Causes and Effects of Skin: Thousands and millions of years ago, petroleum reservoirs were deposited deep beneath the earth's surface. To produce from such deep reservoirs, it is necessary that a conduit or a path should be provided to petroleum fluids. Drilling engineering with all its advancements has provided mankind to reach out to the petroleum reservoirs and safely produce the fluids to the surface. The fluids flow up to the surface due to the natural driving forces present in the reservoir.

Drilling involves a number of complex systems working simultaneously. One of the systems is mud circulation, which due to its significance occupies a key role in drilling operations. Water-based, oil-based, emulsion and foam can be used as drilling mud and its type depends upon the formation encountered. A number of additives are also added to the drilling mud to encounter the formations being drilled. The drilling mud, when circulated, becomes in contact with the formation at very high pressure and tends to damage it apart, in-addition to controlling the formation pressure (Gatlin, 1960). Due to the damage caused by drilling mud, permeability is reduced in the near well bore zone (flushed zone). The damage caused by drilling mud, partial completion of producing interval, turbulence due to increased flow rate, is the reason for extra pressure drop in the near wellbore zone, which can have significant effect on well productivity. This extra pressure drop due to damaged well bore can be reduced with the help of stimulation. The damage as well as improved wellbore conditions can be described with the help of skin factor. A value of positive skin represents damaged wellbore, whereas, negative value of skin depicts improved wellbore conditions.

MATERIALS AND METHODS

The influence of above discussed reservoir parameters under consideration, on flow rate can be calculated with the help of following equation (Beggs, 2003):

$$q_o = \frac{kh\Delta P}{\mu_o \beta_o \left(\ln \frac{r_e}{r_w} - s \right)} \quad (1)$$

The following form of equation (1) was utilized to make the plots in this research paper for unit pressure drop:

$$q_o = \frac{kh}{\mu_o \beta_o \left(\ln \frac{r_e}{r_w} - s \right)} \quad (2)$$

Hydraulic Fracturing: Hydraulic fracturing, a stimulation technique, is a widely applied technique (Economides and Nolte, 2000). Even in the case of unconventional reservoirs, the productivity can be improved to a level resulting into commercial production owing to a good fracture treatment design. The hydraulic fracture can be designed with the help of fracturing models; PKN and KGD are among the most widely used models. PKN model is used where fracture half length is more than fracture height, whereas, KGD model is used where more fracture height is required compared to fracture width (Economides and Nolte, 2000; Valko and Economides, 1995).

Case Studies: The range of values for reservoir parameters have been taken from different reservoirs and the further details are given below.

RESULTS AND DISCUSSION

Analyzing the Effect of Skin for Varying Permeabilities Upon Flow rate: Considering a reservoir having thickness of 50 ft, external and internal radius of 1000 and 0.5 ft respectively, formation volume factor of 1.06 and viscosity of 1.03 cp. The effect of variations in skin and formation permeability on flow rate have been shown in figure 1, which presents six cases considering different formation permeabilities (ranging from 50 to 500 md) for each value of skin. Apart from permeability rest of the properties were assumed constant. It is presented in figure 1 that production rates were more for high capacity formations (having more permeability).The flow rate has shown an increasing trend with the variations in skin values from positive to negative, for example, 62 STB/Day for a skin of -5 and 12 STB/Day for a skin value of +5 (in case of k = 500 md) showing an increment of more than five times, it could be readily observed that the value of flow rate for improved well (negative skin) was more than damaged well (positive skin).Vigilant inspection of the figure 1 brings another valuable inference that the formations having more original permeability offered more productivity increase than the less permeability formations, while comparing the results for same skin values formation capacity being the major reason behind this behavior. When the damage was removed through stimulation, the increase in production rate of the more permeability formations was much more compared to low permeability formations.

While studying figure 2, it was observed that it had similar findings except the permeability range which was different in this case; i.e., from 5 to 50 md.

Analyzing the Effect of Skin with Varying Formation Thickness: Figure 3 and 4 showed the variations in skin and formation thickness and their resultant effect upon flow rate. For this analysis the permeability of formation was assumed constant, i.e., 50 md and the formation thickness varied from 20 to 130 ft.

Figure 3 and 4 were similar in spirit to figure1and 2, the differentiating parameter in this case was formation thickness which was varying and rest of the parameters were assumed constant. The obtained results showed that, as the thickness of formation increased, the flow rate also increased. Careful examination of the plots revealed that the effect of variations in skin; a flow rate of 6.2 STB/Day for a skin value of -5 and 1.2 STB/Day for a skin value of 5 for the case of 50ft thick formation was obtained(figure 3). Similarly, as in previous case, capacity of formation being the major factor; the increase in production rate of the formation having more thickness was more compared to formations having less thickness for variations in skin values from positive to negative values.

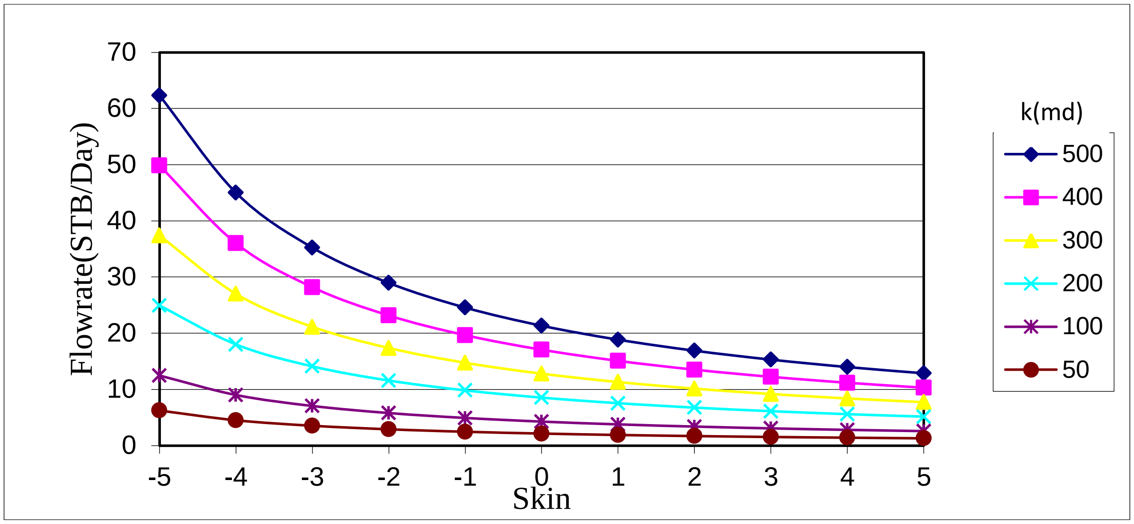

Figure 1: showing the variations in skin and formation permeabilities coupled with their effects upon flow rate

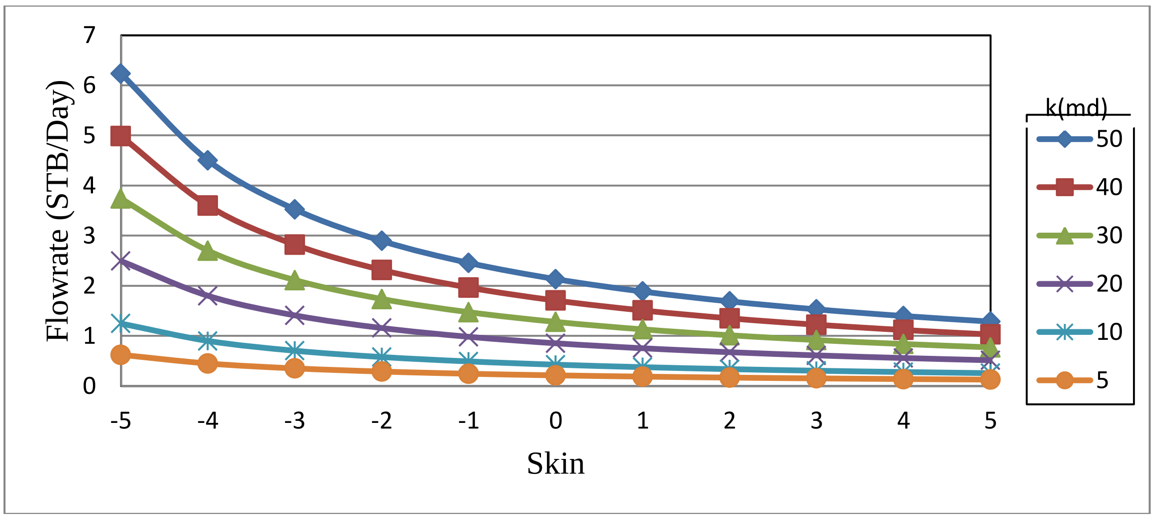

Figure 2:showing the variations in skin and formation permeabilities coupled with their effects upon flow rate

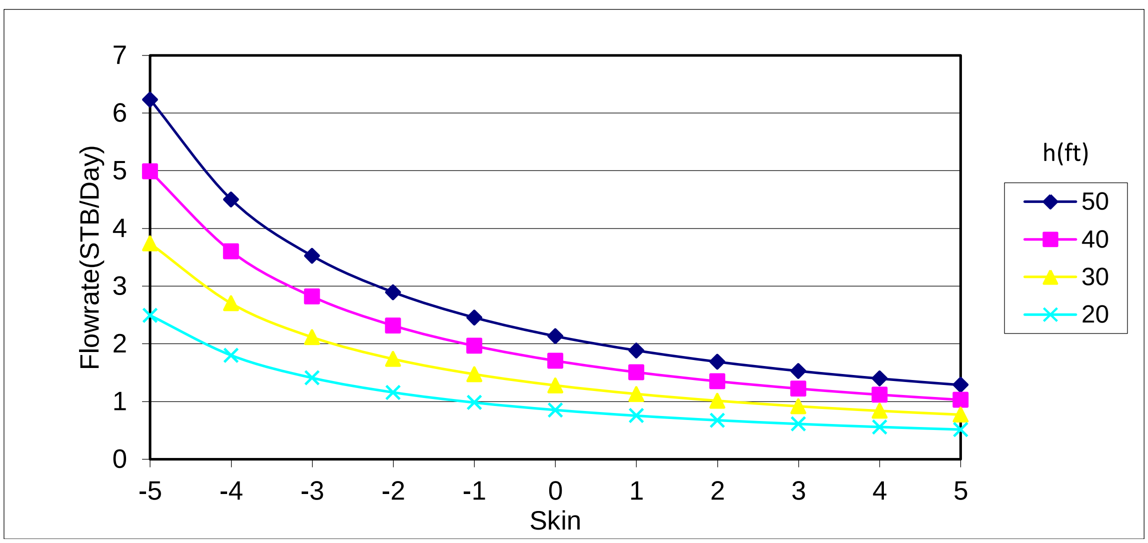

Figure 3: showing the variations in skin and formation thickness coupled with their effects upon flowrate

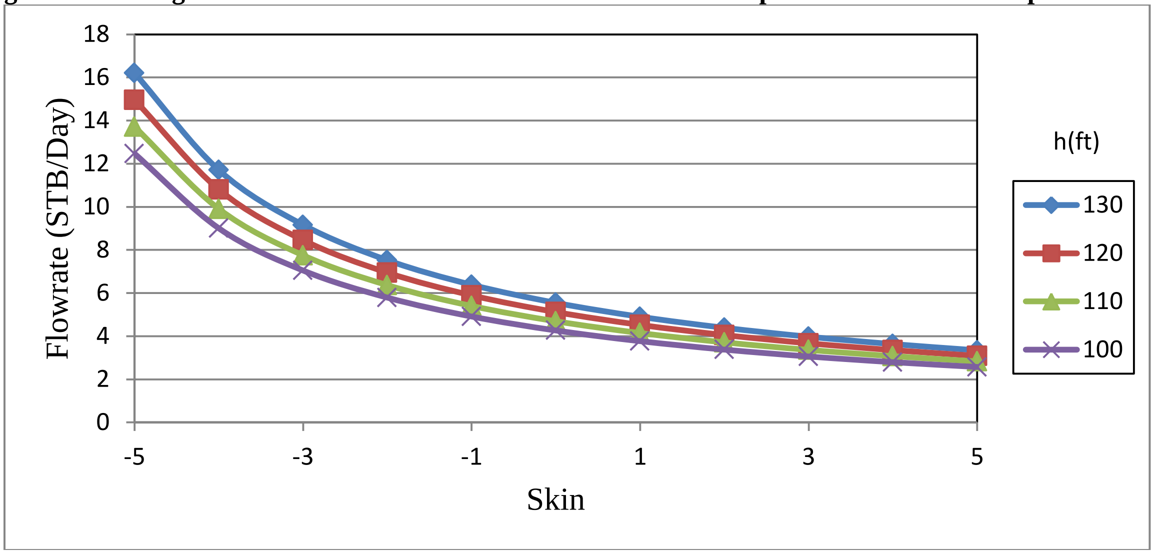

Figure 4:showing the variations in skin and formation thickness coupled with their effects upon flowrate

Nomenclature

h	Thickness of formation	k	Permeability of formation
q_o	Oil flow rate	r_e	External radius of reservoir/ drainage radius
r_w	Wellbore radius	s	Skin
β_o	Formation volume factor	μ_o	Viscosity of producing fluid
ΔP	Pressure differential		

Conclusion: The results obtained from above discussion and plots infer that stimulation changes the skin from positive to negative value, thereby reducing the pressure drop in the near wellbore zone and increasing the well productivity. The ultimate recovery from a reservoir is dependent upon the productivity of wells present in the reservoir, so the increased well productivity, increases recovery in the primary phase. The damaged skin can be improved with the help of stimulation and as the damage is removed and skin goes to its negative value, the increase in productivity is more compared to the increase when the skin is changed from positive value to zero. The reason for this behavior is that as the skin is improved beyond zero, the flow of fluid is enhanced beyond the natural capability of the formation to conduct the fluid.

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