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Elimination of formation damage in the wellbore area and expansion of the well drainage area

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Abstract

The exploration of unconventional oil and gas reservoirs is a prominent global trend today. Achieving cost-effective and efficient hydrocarbon production from these reservoirs necessitates advanced technologies. One such technology that has been employed in the oil and gas industry for many decades is hydraulic fracturing. It is used to create highly conductive channels within formations characterized by extremely low permeability values. The successful implementation of hydraulic fracturing hinges on the development of an effective fracturing design. This design is crucial to achieving the anticipated production outcomes from unconventional reservoirs, including tight gas, shale gas, coal bed methane, and reservoirs with very low permeability. Key parameters for the success of hydraulic fracturing operations include the determination of the optimal fracturing rate, fracture height, and the selection of propping agents. These factors collectively contribute to the efficiency and productivity of hydraulic fracturing activities in unconventional reservoirs.

Keywords: Formation damage, well stimulation, hydraulic fracturing, drainage area, tubing diameter, skin factor

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1. Introduction.

Formation damage refers to the phenomenon in which the permeability of the subsurface formation near the wellbore decreases. There are various factors that can lead to formation damage, which will be explored later. The decrease in permeability in the wellbore region has a direct impact on the overall productivity of the well. This reduction is often attributed to the blocking of pore throats in the vicinity of the wellbore, causing a decrease in the available flow area.

Turbulent flow in the well is another factor contributing to the reduction in the flow area. When turbulent flow occurs, it leads to a significant pressure drop in comparison to laminar or Darcy flow. The pressure drop associated with turbulent flow is notably higher, which results in a further

reduction in wellbore permeability. This complex interplay of factors underscores the importance of understanding and managing formation damage in well operations.

2. The Skin factor.

The skin factor is a crucial measure of the impact of formation damage on well performance. Formation damage typically results in a reduction in permeability around the wellbore. The accompanying figure illustrates the ideal pressure profile of a well, highlighting the influence of formation damage (represented by the yellow line) on creating an additional pressure drop.

The skin factor (s) can take on various values, and its interpretation is as follows:

Positive skin factor, $s > 0$: When a damaged zone near the well leads to a reduced permeability (k_{skin}) compared to the formation's original permeability (k), the skin factor is positive. The magnitude of the skin factor increases as the damaged zone's permeability (k_{skin}) decreases and as the depth of the damage (r_{skin}) increases.

Negative skin factor, $s < 0$: When the permeability around the well (k_{skin}) is higher than that of the formation (k), a negative skin factor is indicated. This negative skin factor suggests an improved wellbore condition, often associated with measures to enhance permeability near the well.

Zero skin factor, $s = 0$: A skin factor of zero signifies that no alteration in permeability around the wellbore is observed, implying that k_{skin} equals the formation's original permeability (k).

The skin factor is a valuable metric for evaluating the influence of formation damage on well performance and is a critical parameter in wellbore management and optimization.

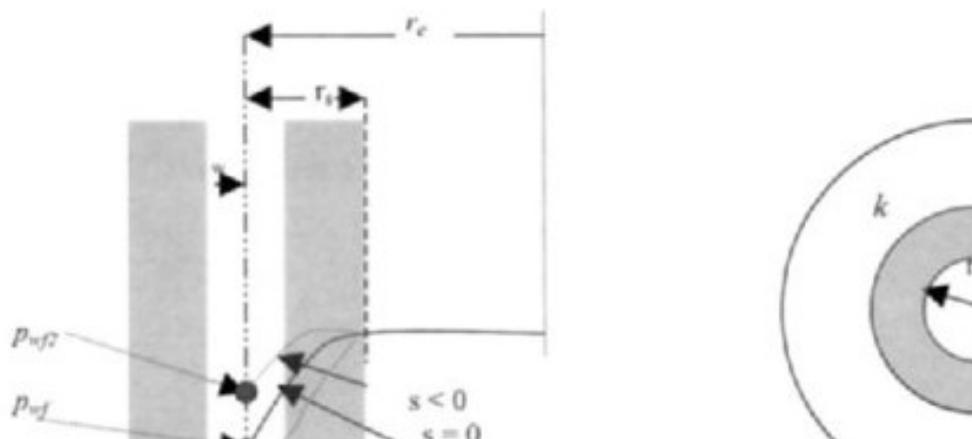


Figure1: Effect of the skin on pressure profile around wellbore

$$S_d = \frac{2\pi k_o h \Delta P_d}{q_o \mu_o} = \left(\frac{k_o}{k_d} - 1 \right) \ln \left(\frac{r_d}{r_w} \right).$$

h - formation height

q_o - oil flow rate

μ_o - oil viscosity

S_d - formation damage skin

k_o - formation permeability to oil

k_d - damaged permeability to oil

ΔP_d - extra pressure drop due to formation damage

Formation damage skin is directly related to the ratio of the original permeability to the damaged permeability. As this ratio increases, the skin factor also increases, signifying greater formation damage.

Stimulation in the context of oil wells refers to a set of operations carried out to optimize productivity. This technique is of paramount importance in the production process, as it encourages the flow of hydrocarbons from the reservoir rocks to the wellbore, given that the hydrocarbons are situated within the pores of the reservoir rock. Stimulation also encompasses methods aimed at improving the natural permeability of undisturbed rock formations housing the reservoir, making it economically viable for oil production. Permeability is the rock's ability to conduct fluids, including oil and water. Stimulation technologies can be applied to increase the reservoir's permeability to a level that allows for enhanced oil production rates.

One of the well stimulation techniques is hydraulic fracturing, which is employed to boost well productivity. In hydraulic fracturing, a fracturing fluid or pumping fluid, typically composed of a mixture of water and sand, is injected into the formation under high pressure.

This article delves into the influence of hydraulic fracturing on well productivity, with reference to a real well example using the Prosper model. The project explores how oil and gas production behavior is affected in various scenarios, including the base case, a 30-degree deviation angle, and a 45-degree deviation angle. Furthermore, the study investigates how different parameters, such as tubing diameters and skin factor, impact oil and gas production, aiming to determine the optimal well production rates. In practice, the well in question is somewhat deviated, and the study conducts a sensitivity analysis to identify optimal parameters for future wells and to assess production outcomes under different trajectories.

PVT parameters are as following in this well:

PVT - INPUT DATA (GUN_287_30_hydraulic-fracturing.Out) (Oil - Black Oil matched)

Done	Cancel	Tables	Match Data	Regression	Correlations	Calculate	Save	Open	Composit
<input type="checkbox"/> Use Tables									
Input Parameters					Correlations				
Solution GOR	119	Sm3/Sm3	Pb, Rs, Bo		Glaso				
Oil Gravity	838.369	Kg/m3	Oil Viscosity		Beal et al				
Gas Gravity	0.81328	kg/m3							
Water Salinity	0	ppm							
Impurities									
Mole Percent H2S	0	percent							
Mole Percent CO2	0	percent							
Mole Percent N2	0	percent							

Figure 2: PVT parameters for the well-reservoir model

PVT - Match Data (GUN_287_30_hydraulic-fracturing.Out) (Oil - Black Oil matched)



Figure 3: PVT test results for the well-reservoir model

The initial reservoir conditions for this well include a reservoir pressure of 350 bar and a reservoir temperature of 68°C.

To enhance the permeability around the wellbore, hydraulic fracturing has been employed. The following are the relevant reservoir and technical parameters for the hydraulic fracturing operation.

Inflow Performance Relation (IPR) - Input Data

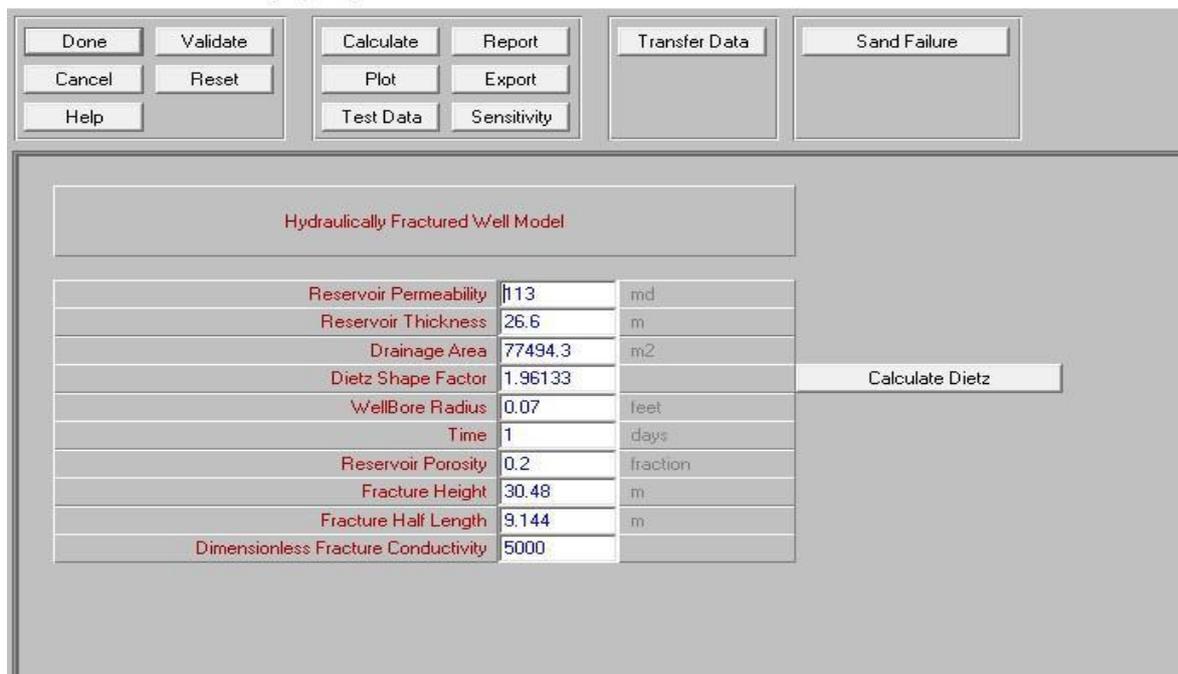


Figure 4: Input parameters for the hydraulic fracturing model in Prosper

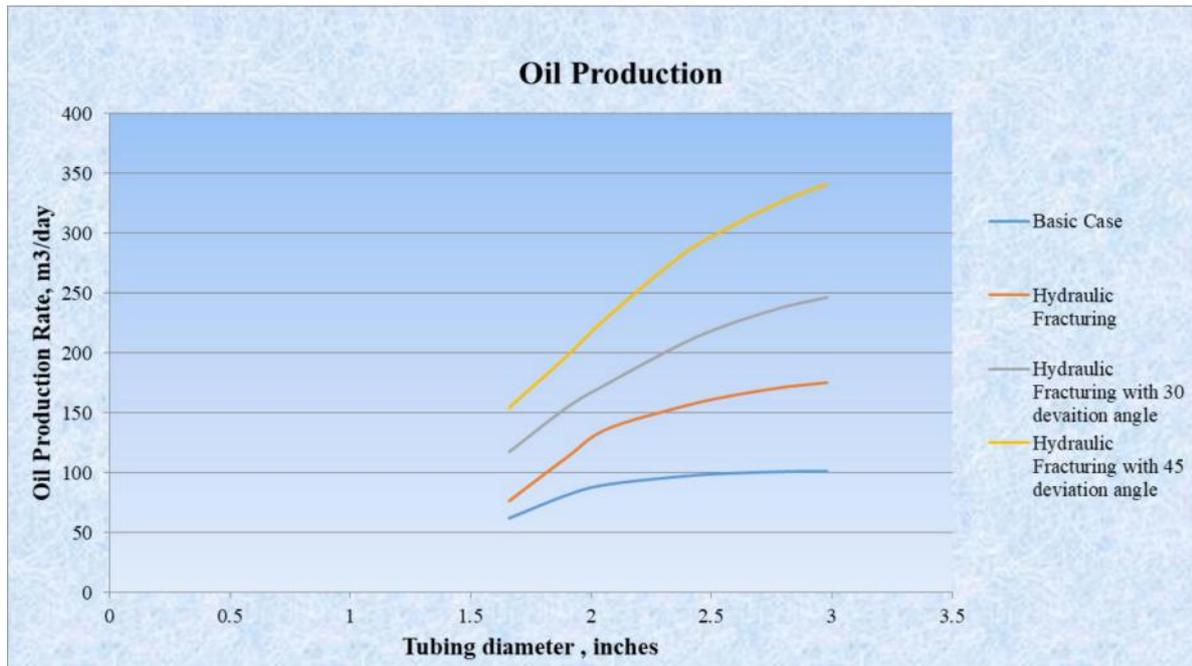


Figure 5: The daily oil production rate varies depending on the chosen tubing diameter.

Different tubing diameters can significantly impact the rate at which oil is produced from a well. This variation is a critical consideration in well optimization and reservoir management. It demonstrates that when a tubing diameter of 2.98 inches is selected, the daily oil production rate significantly increases to 340.8 cubic meters per day (m3/day) when employing the hydraulic fracturing method in the case of a 45-degree deviation angle. In contrast, the base case yielded a daily oil production rate of 101.4 m3/day. This comparison highlights the substantial improvement in oil production achieved through hydraulic fracturing with the specified tubing diameter under the given conditions.

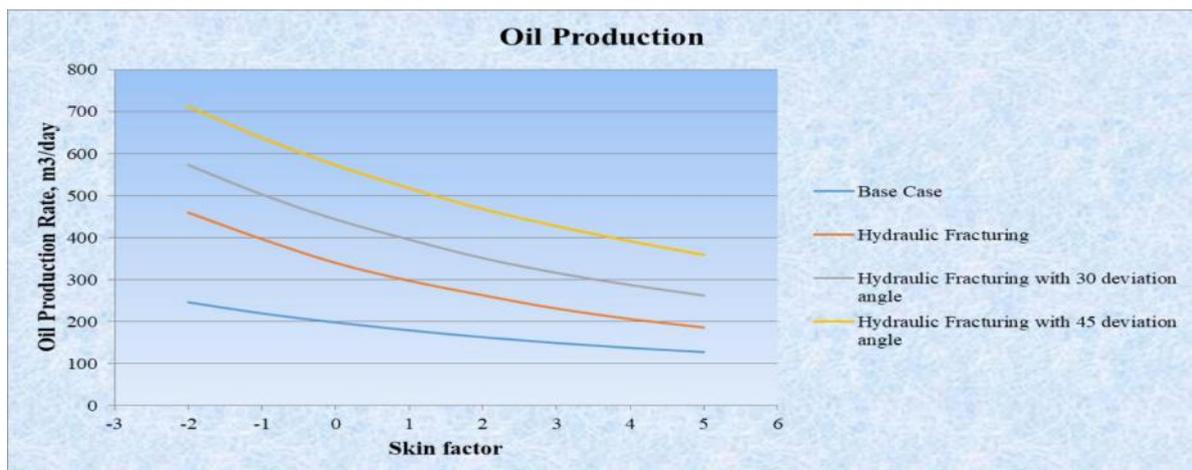


Figure 6: The daily oil production rate varies with different skin factors.

The skin factor is a key parameter that can influence the productivity of a well. Changes in skin factor can have a notable impact on the rate at which oil is produced from a well. Understanding

how different skin factors affect oil production is essential for well management and reservoir optimization.

Figure 6 depicts that when a negative skin factor of -2 is selected, the daily oil production rate significantly increases to 711.6 cubic meters per day (m³/day) when employing the hydraulic fracturing method in the case of a 45-degree deviation angle. In contrast, the base case yielded a daily oil production rate of 245.8 m³/day. This comparison highlights the substantial improvement in oil production achieved through hydraulic fracturing with a negative skin factor under the given conditions.

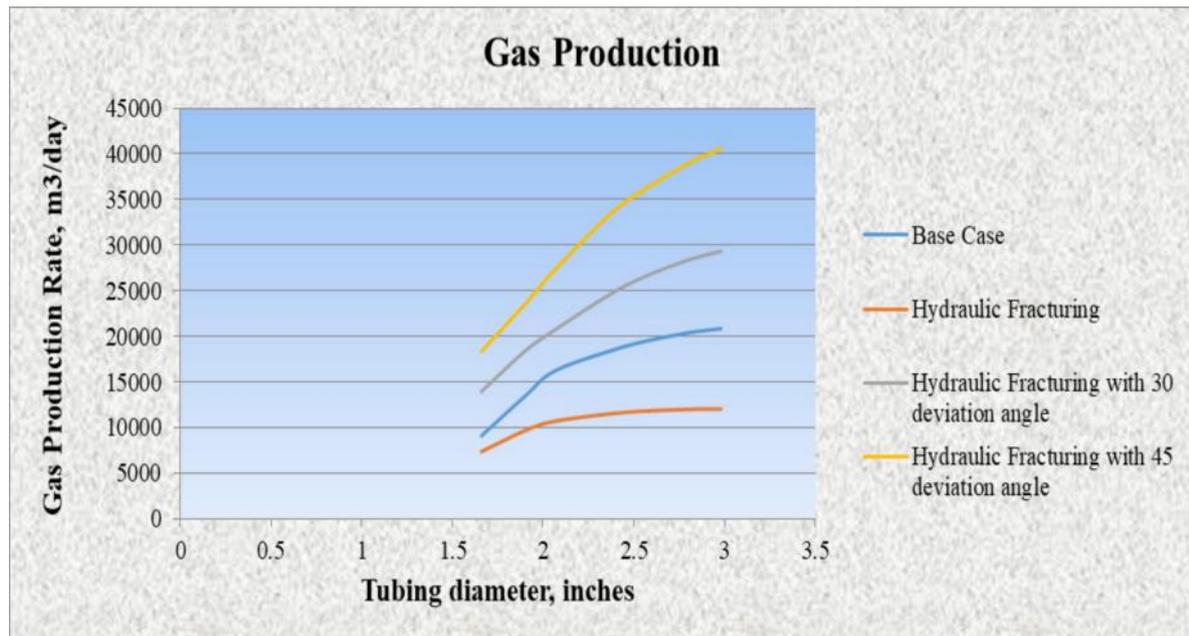


Figure 7: The daily gas production rate can vary depending on the choice of tubing diameter.

Different tubing diameters can have a significant impact on the rate at which natural gas is produced from a well. This variation is an important consideration in optimizing well performance and reservoir management, especially when aiming to maximize gas production.

Figure 7 illustrates that when a tubing diameter of 2.98 inches is chosen, the daily gas production rate significantly increases to 18,388 cubic meters per day (m³/day) when employing the hydraulic fracturing method in the case of a 45-degree deviation angle. In contrast, the base case yielded a daily gas production rate of 7,398.5 m³/day. This comparison underscores the substantial improvement in gas production achieved through hydraulic fracturing with the specified tubing diameter under the given conditions.

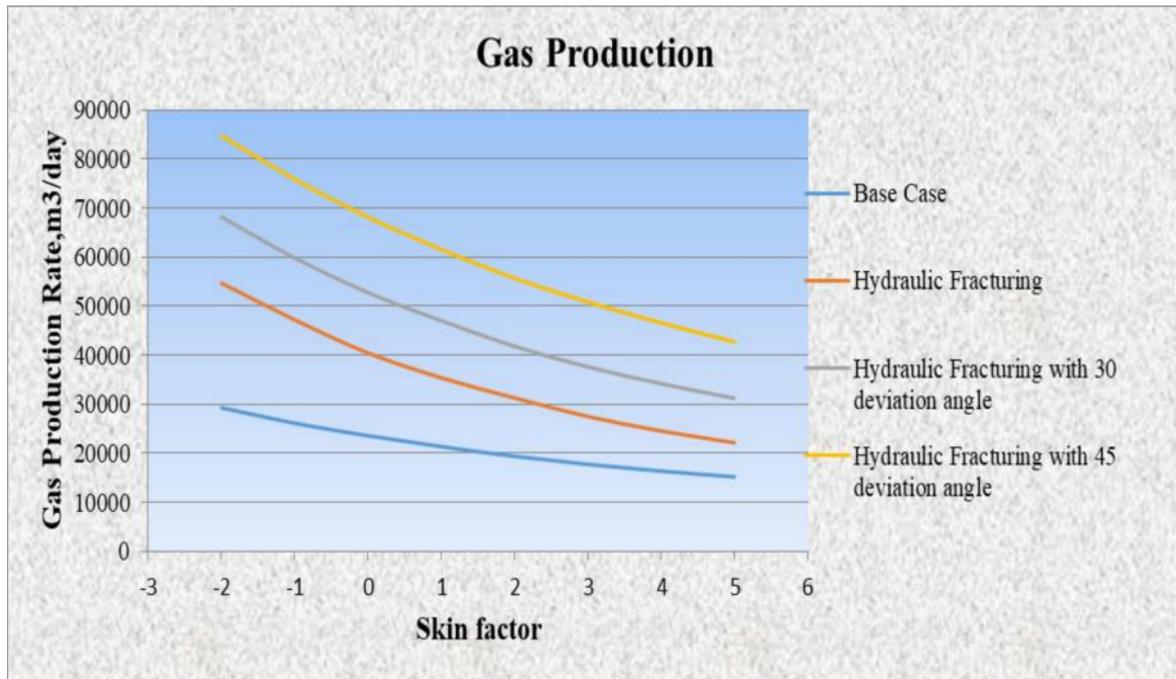


Figure 8: The daily gas production rate can vary with different skin factors.

Figure 8 demonstrates that when a negative skin factor of -2 is selected, the daily gas production rate significantly increases to 84,681.9 cubic meters per day (m³/day) when employing the hydraulic fracturing method in the case of a 45-degree deviation angle. In contrast, the base case yielded a daily gas production rate of 29,245.8 m³/day. This comparison highlights the substantial improvement in gas production achieved through hydraulic fracturing with a negative skin factor under the given conditions.

3. Conclusion

In conclusion, hydraulic fracturing proves to be an effective method for creating fractures in the rock formation, which stimulates the flow of natural gas or oil and increases the recoverable volumes. Choosing a deviation angle in well completion allows for a more extensive coverage of the drainage area compared to a vertical well. Additionally, in a deviated well, the pressure around the wellbore is higher than in a vertical well. The selection of a larger tubing diameter further enhances the extraction of oil and gas from the well. Through sensitivity analysis, the research has successfully determined the optimal tubing diameter and the targeted skin factor around the wellbore, which are critical factors in maximizing production.

Conflict of interest

The authors declare that they have no conflict of interest in relation to this research.

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About one of methods for determining the true parameters of the gas-liquid flow in risers

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Annotation.

In oil and gas production, multiphase gas-liquid flows are very typical for risers of fountain and gas lift wells. In the article, a new approach for estimating the real parameters of multiphase flows is proposed, taking into account the phase shift, and the possibility of their determination based on the macroscopic parameters is shown.

Keywords: multiphase flow, gas lift riser, flow parameters, structural mode, phase shift.

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1. Introduction.

It is very important to correctly assess the true characteristics of those flows in order to solve engineering problems related to multiphase flows, to perform hydrodynamic calculations in accordance with thermo-baric conditions in the viewed (researched) section of the lifting pipes. The analysis shows that important parameters such as the real density of the mixture, the real volume capacity of the phases, which characterize such flows, depend to a great extent on the slippage (relative speed) of individual phases, as well as the cross-sectional migration [1-6].

2. Formulation of the problem and solving methods.

In general, the study and determination of the true gas capacity parameter for gas-liquid mixtures has been the subject of research by many scientists, but in many cases, it has concluded with contradictory results. Thus, a number of researchers have emphasized that the real gas capacity (φ) increases with the increase of the relative velocity of the gas phase (displacement relative to the liquid), and some of them have emphasized the decrease of the φ parameter with the increase of the relative velocity of the gas. There were also scientists who claimed that the mentioned dependence