Analyzing the Production of Horizontal and Vertical Well After Applying Proposed Stimulation

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Abstract: Most of the wells in oil and gas industry are vertical. These wells have low risk in terms of its construction and maintenance and easy to drill as compare to horizontal drilling. Horizontal wells are drilled to enhance production and performance of well by providing wide range of well bore (contact area) with reservoir that's why horizontal drilling is very popular. Horizontal and vertical wells though have number of advantages but there are some disadvantages and one of them is skin. Skin is basically the measure of amount of damage around the well bore in reservoir. Damage near well bore may cause by fine migration, wettability reverse, solid plugging, drilling fluid etc. Intensity of positive skin ranges from 0 to 50 indicates damaged reservoir and intensity of negative skin ranges from -0 to -5 indicates improved reservoir after implementing stimulation job. It is estimated that production from two third of horizontal and vertical wells are reduced because of skin. For minimizing formation damage reactive solution of chemicals either Hydro Caloric Acid or Hydro Fluoric Acid are used known as acidizing. The research methodology is to first collect information/data from fields regarding formation damage in vertical well and horizontal well having the same reservoir then by using simulation software analysis take place between horizontal well and vertical well in terms of production. In case of horizontal well formation damage caused to reduce the production from 15 MMSCFD to 10 MMSCFD. By applying proposed treatment job the production increase to 18.364 MMSCFD while in case of vertical well formation damage caused to reduce the production from 5 MMSCF/D to 3 MMSCF/D. By applying appropriate treatment job the production increase to 4.618 MMSCF/D.

Keywords: *skin Damage, wettability alteration, Stimulation job, Solid Plugging, Draw down Pressure.*

1. Introduction

Horizontal drilling is very popular in oil and gas industry. Horizontal wells are drilled to enhance production and performance of well by providing wide range of well bore with reservoir. Horizontal wells was inactive before 1985, but after wards there was man named Austin Chalk who make boom of Horizontal Drilling in oil and gas Industry[2]. There are number of application of horizontal drilling like it reduce pressure drop around the well bore, reduce fluid viscosity around well bore, reduces water and gas conning due to large drainage area and drawdown in the reservoir etc.

In last few year number of horizontal wells have drilled throughout the world. Horizontal well is drilled parallel to the reservoir bedding planes. Horizontal drilling has excellent wellbore thickness due to which enhancement in reservoir contact and thereby enhances wellbore productivity.

1.1 Formation Damage

Formation damage or skin can be defined as any type of process which cause to reduction in flow capacity or production in oil and gas formation. It is called the zone of reduced permeability due to foreign fluid or solid invasion into the rocks. The concept of skin damage was introduced by Van Everdingen and Hurst in petroleum industry for to better understand the concept of formation damage. After applying different experimental procedures it was concluded that in practically at given flow rate the bottom-hole flowing pressure is less than that calculated theoretically which indicated that there was an additional pressure drop due to permeability reduction. He named that zone skin damage. In general the skin factor can vary from +1 to +10 and even higher values are possible for serious formation damage **[2].**

1.1.1 Causes of Formation Damage

There are number of causes of formation damage. Formation damage can be happen at any time of petroleum processes. Following are some causes of formation damage **[1].**

1.1.1.1 Fluid-Fluid Incompatibility

Most of the problems of formation damage cause by incompatibility of fluids which can arise emulsion blockage by mixing mud acids and some crude oils. Once it is formed it can be controlled by careful treatment design. It can be controlled by introducing pre-flush/after flush techniques.

1.1.1.2 Solid Plugging

Drilling fluid is composed of liquid and solid mixtures. During circulation of drilling fluid liquid part clean drilling

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cutting while solid part form mud cakes around well bore. Excessive of mud cake cause solid plugging which reduces permeability.

1.1.1.3 Fine Migration

This type of formation damage mostly occurs in clastic formation because they have high content of transport material within the rock. The movement of naturally existing fine grains particles in the pore system that reduce permeability is known as process of fine migration. This can be reducing by reducing production rate, increasing flow area by adding extra perforation tunnels.

1.1.1.4 Phase Trapping and Blocking

This type of formation damage is caused by drilling fluid incompatibility to formation and cause water saturation. This can be reducing by designing proper drilling fluid which compatible to formation.

1.1.1.5 Clay Swelling

Clay swelling cause by reacting of hydrophilic material into formation (i-e Reactive smectite) with fresh or low salinity water which cause to expand and reduce Rock permeability. This can be reduce by high salinity drilling fluid or add glycols and other chemical inhibitors to keep reactive clays from becoming hydrated.

1.1.1.6 Clay Deflocculation

This type of formation damage is cause by rapid change in pH salinity of fluid. This happens when clay particles changes from flocculated state into deflocculated state. This can be inhabitate by avoiding cationic and pH shocks.

1.1.1.7 Wettability Alteration

This is major formation damage concern in oil and gas industry. This type of formation damage cause by treating additives to near well bore region which alter water –wet formation to oil-wet formation which cause increase in permeability of water while decreasing in oil permeability or increase in produced water and decrease in oil/water ratio. Wettability alteration can be reduced by addition of surfactants and solids to drilling fluid.

2. Problem Statement

As horizontal drilling is very popular in oil and gas industry but production result from many horizontal wells are very disappointing due to formation damage. It is estimated that production from two third of horizontal wells are reduced because of skin damage **[2].** Vertical wells are also affected with formation damage during drilling and production phase. For to minimize formation damage or to improve permeability of damage zone, stimulation techniques are used. Acidizing job is very beneficial for damage zone. Acidizing job is basically Stimulation technique in which permeability and production of well is improve by pumping reactive solution of chemicals either HCL or HFL acid. Acidizing process is different for different formation like in sandstone the acids help to enlarge the pores while in Carbonate reservoir acids dissolved in formation and increase permeability

3. Objectives

The main objectives of this thesis are below:

- Estimate Skin Damage in Horizontal and vertical well by modeling of reservoir using prospers software.
- To predict recovery factor from horizontal well and vertical well.
- What percentage acidizing job required in each well i-e horizontal well and vertical well**.**

4. Methodology

The Research methodology of this is to first collect information/data from fields regarding formation damage in vertical well and horizontal well of same reservoir. After that by using simulation software analysis is done for formation damage and this simulation process is continuously repeated until and unless satisfied result is obtained.

5. Related Work

Formation damage is considered as most important factor in term of reducing natural permeability. It is very undesirable and economic problem that can occur at any phase of oil and gas recovery including drilling, production, and work over, hydraulic fracturing etc. The formation damage can be cause by mechanical damage, biological damage and physical damage. Assessment of formation damage and their control as well as remediation is big problem in oil and gas industry that can be observed by indicators like permeability reduction and decrease in well performance **[3].**

Following are some research papers which based on formation damage and their solutions in different fields around the world.

In this research paper Author described that horizontal well has open hole completion that's why formation damage is more severe than vertical wells. Further defines that stimulation techniques are very costly and ratio of success is very low that's why prior laboratory test can shows that whether the stimulation technique can be beneficial or not. The laboratory tests like leak off test to be conducted prior expenditure and risk of implementing them to reservoir **[1].**

This Research paper is based on optimization of drilling fluid in horizontal well. In this paper author describe that the optimization of drilling fluid is a main concern of reducing the chance of drilling fluid. The interaction of foreign fluid into wellbore cause that leads to inadequate parameters to formation can cause of poor well performance and non-viable economics for horizontal drilling system. An increased understanding various damage mechanism associated with horizontal drilling can leads to better developments of improved drilling of horizontal drilling without formation damage **[2].**

In this Paper Author describe that underbalanced drilling can be reduce formation damage due to whole mud filtrate, invasion into high permeability and fractured formation. This paper elaborate the damage scenario based on the laboratory results which is designed to evaluate and

prescreen fluids and procedures prior to implement costly underbalanced drilling**[3].**

In this Paper Author describe that critical situation is created near wellbore formation damage in terms of marginal flow of performance which reduce economic production of oil and gas. Several flow calculations were analyzed to find productivity ratio in horizontal and vertical well. And it was concluded that in horizontal well skin increases in terms of vertical to horizontal permeability. This can be removed by underbalanced drilling if it is properly applied to well **[4].**

This Paper describes the solution of formation damage in horizontal drilling and extended reach drilling. According to research paper from six ways we can overcome the formation damage. Following are mentioned**[5]:**

1. **Acid Cleanup:** The circulation of low and high concentration of fluid (hydrochloric, hydrofluoric, formic etc) can lead to best recovery of formation permeability.
2. **Acid Fracturing:** This method done by using two fluids having different viscosities. A high viscosity fluid known as pre-flush is used initially followed by the low viscosity fluid that keeps the channels open to increase permeability.
3. **Drill in Fluid:** This is latest solution that allows most of the operators use in order to minimize formation damage. These types of fluids have various type and concentrations of salt to minimize fluid loss into the formation.
4. **Breaker Fluids**: The breaker fluid has a capability to dissolve in the mud cake and remove it without releasing fines to the formation. But these fluids have mostly problem of losing fines and completion fluid when there is over-balanced condition created.
5. **Filter Cake Liftoff**: Research has shown that chemical and dissolution of filter cake have ability to exhibit the flow of production to the wellbore.
6. **Under Balanced Drilling:** This type of drilling contains many well control risks and continuous to be one of the most preventive measures of formation damage**.**

In this paper it was analyzed that horizontal well productivity consist much higher than that for vertical well in same reservoir. By using three low damaging mud during drilling it was observed that it provide excellent formation protection with lower skin damage and much larger regained of permeability as compared to other drilling fluids. The analysis shows that the oil production of horizontal well three to five times greater than the production of vertical wells that also great prevention of formation damage**[6].**

This paper based on formation damage, types, mechanism and their indications. The summary of this paper is that some reservoir has the potential to damage formation itself. The proper integration of available fields and laboratory analysis of rock, fluids and specific practices can leads to better results in terms of formation damage. These things allow the operators to make s informed decisions as to best practices to drill, complete and produce wells**[7].**

In this Paper Author describe that the production of horizontal well did not always up to expectation like in the middle east where vertical well are commonly naturally prolific. Due to large contact area in horizontal wells the wells are almost suspect to the formation damage. Further he describes that it is very important to estimate the real contribution of each section of horizontal well to the total production and formation damage and role of friction in the overall performance of the well. A semi analytical approach is used to study the simultaneous effect of the perforation distribution near the well bore formation and friction losses occurs in horizontal wells. The experimental result shows that for short horizontal reservoir formation damage does not significantly panelized, for medium formation damage moderately effect the production while for long horizontal well the production loss due to formation damage is still not excessive**[8].**

This paper based on productivity index in horizontal well. In this research paper author defines that production of horizontal drilling is directly dependent to pressure difference at the reservoir and the wellbore. The constant of proportionality is being the productivity index. After did lots of research He concluded that if the wells are properly perforated at an equal interval than there is high ratio of reducing formation damage or skin problems in oil and gas reservoir which also create high productivity index in reservoir**[9].**

In this Paper Author mentioned that permeability impairment increase as differential pressure increase. This research was carried out the investigation of formation damage caused by oil base mud on the Barea Stone core in simulated vertical and horizontal well which is based on measuring condition s at various differential pressure. Experimental result showed that horizontal condition experienced more severe damage as compared to vertical condition**[10].**

This paper based on irregular distribution of formation damage along their lengths in horizontal wells which creates challenging problems in the interpretations. The authors generate the synthetic pressure transient responses for different irregular distribution of formation damage and make comparative analysis with the known formation damage distribution and find the pressure drop **[11].**

In this Paper Authors describe that primary cause of formation damage is deposition of calcium carbonate, calcium sulphate and strontium sulphate in perforation tunnel or in the formation sandstone near wellbore. According to research author suggests that by using Ethylene diamine tetra acetic acid (EDTA) we can remove the scale deposit in formation. This EDTA treatment can effectively dissolve and remove the dissolved metal ions **[12].**

This research paper is based on modernizing of existing technologies for better sweep efficiency that cause plugging of highly permeable channels and layers by injection of fine particles by applying three improved water flooding methods **[13].**

1. Injection of raw or poorly treated water
2. Injection of high saline water
3. Injection of sweet water

These above three methods were modeled on Eclipse in black Oil model with different options. By applying above three methods it was found that production increase to 3-15 % and 2-3 times decrease in amount of injected water**[14].**

This research paper is based on experimental study of formation damage in fractured carbonate reservoir. This study was done on core sample of carbonate reservoir at underbalanced drilling condition. One major concern during testing of core sample is maintaining of loss underbalanced pressure condition. The core sample test was conducted with four underbalanced drilling fluids i-e lab oil, brine (3% KCL), water based mud and fresh water in order to examine or measure permeability at initial level and return permeability at both pressure underbalanced and overbalanced. The results shows that a short overbalanced pressure provide a significant reduction in permeability of fractured formation**[15].**

This paper is basically thesis of author in which He describe that horizontal drilling is now very common in oil and gas industries in order to increase production rate and improve recovery. If well completion for horizontal well is properly designed and selected then it can gain high production ratio. In his further describe the designing procedure and methodology of selecting the best completion for horizontal well in order to gain popularity in terms of production**[16].**

This paper based on Research on Triassic high permeable oil reservoir in the Tarim Basin of north west China to analyze horizontal drilling results. In high over balanced pressure and longer exposure to drilling fluid can result in extensive formation damage. Permeability heterogeneities, anisotropy mud cake filtration can cause severe formation damage than vertical well. According to author the solution of formation damage which He concluded after applying several techniques to Tarim Basin reservoir that non-invasive or ultra-low invasion fluid one properly formulated can reduce the risk of formation damage. These fluid forms a plugging zone with ultralow to zero near the wellbore that helps to prevent the solids and liquids into too deeply invasion**[17].**

In this Research paper authors describe that horizontal drilling has gained popularity in oil and gas industries regarding high production ratio, multiple zone of production, high contact area, reducing drawdown to minimize gas coning problems but there is also high ratio of formation damage that can be compare to the total production of vertical well. Formation damage effects are very disappointing in terms of marginal flow performance. In this research paper the detailed information of formation damage included and simulation based model is added to find the production rate at different parameters to attain the maximum value of production which damage during formation damage. And also compare with vertical well production ratio**[18].**

This research paper is based on model that describes mechanism and process of filtration into a formation through a compressible filter cake during drilling of horizontal wells. After applying the Goodman's integration techniques it was resulted that the rapid decline in solid pressure may cause more damage in horizontal well compare to vertical well. Control of volume of filtrate in formation is achievable by controlling viscosity of mud, specific mud cake volume and other specific properties of mud cake. By estimating the thickness of mud cake it is being observed the effect of length of horizontal section of well. The model is easily applicable to know the important values needed to know the status of formation during the drilling of horizontal wells**[19].**

6. Well Descriptions

Case-1 Formation Damage In Horizontal Well

The horizontal well is drilled at depth of (TD) of 1,671 m MD. The well has been completed barefoot as a single string producer from Limestone (L) and completed with 9-5/8" packer and 4.5" completion equipments. During completion integrity test (CIT), well flowed at 10MMscfd gas. However throughout well clean-up, drilling mud containing asphaltic components observed at surface.

According to latest surface well test, the well is flowing at ~10 MMscfd gas. Adjacent horizontal wells are producing at a much improved rate of 18-22MMscfd. In view of adjacent wells' performance, and with 8-1/2" open-hole reservoir section, it appears that formation has been damaged because of incompatible drilling mud.

CASE: 2 Formation Damage In Vertical Well

Vertical wellhas been completed barefoot as a single string producer from Limestone (L) and completed with 9-5/8" packer and 4 ½" completion equipments. The thickness of well is 27 m which is fully perforated. The well is fully cased. During completion integrity test (CIT), well flowed at 5 MMscfd gas. But after some time this well flow at 3 MMscfd gas due to formation damage.

7. Results

Case-1 Formation Damage In Horizontal Well

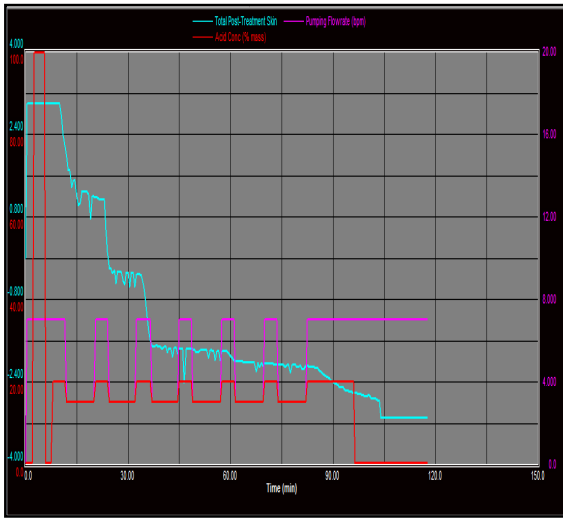

Figure 1.1 Acid concentrations and pumping flow rate of Horizontal well

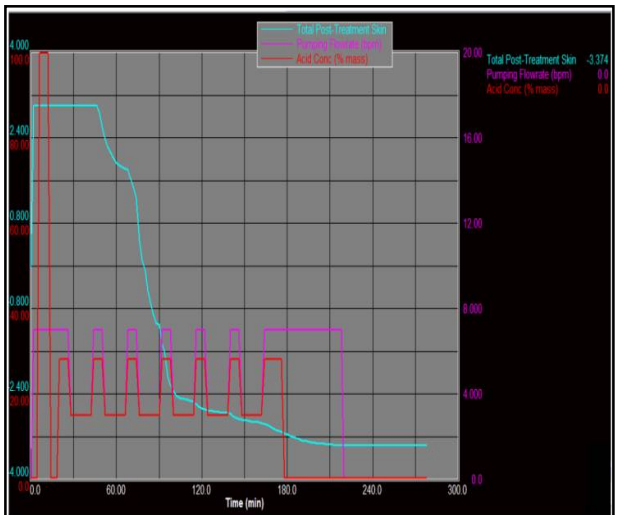

Figure 1.2 Absolute Open Flow Rate of Horizontal well

Treatment Fluids

- Acid Pre-Flush = 100 bbl.
- Main Acid (SRA-28) = 400 bbl
- Divert Acid = 300 bbl
- Acid Post Flush = 100 bbl
- Displacement = 200 bbl

The above data was put in acidizing simulation software which shows following results

Skin limited or reduced to -3.374. Which put into prosper software the production increase to 18.3648 MMSCFD.

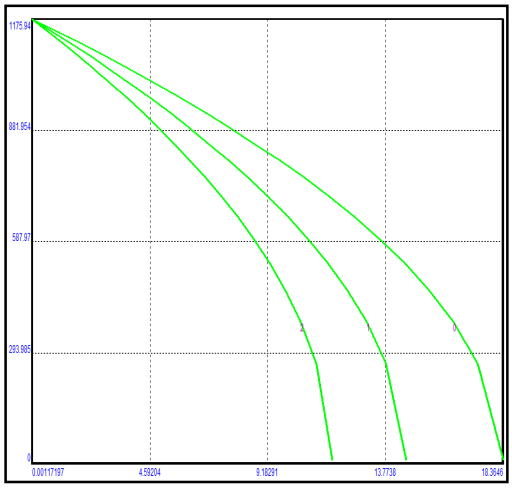

Figure 1.3 Absolute Open Flow Rate of Horizontal Well

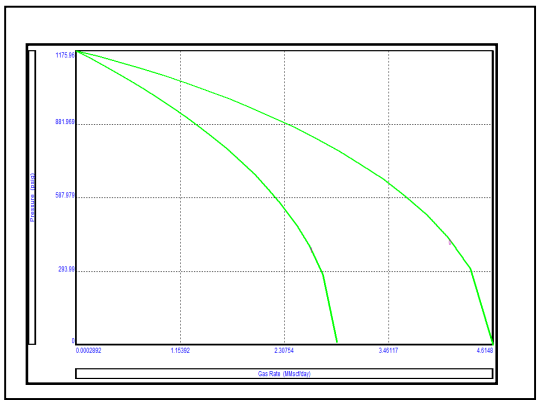

Figure 2.4 Absolute Open Flow Rate of Vertical Well

Case: 2 Formation Damage in Vertical Well

- Acid Pre-Flush = 50 bbl.
- Main Acid (SRA-28) = 200 bbl
- Divert Acid = 150bbl
- Acid Post Flush = 50bbl
- Displacement = 100bbl

The above data was put in acidizing simulation software which shows following results. Skin reduced to -2.4 which increase production to 4.614 mmscfd

8. Conclusion

The findings are concluded as follows:

In case of horizontal well formation damage caused to reduce the production from 15 MMSCFD to 10 MMSCFD. By applying appropriate treatment job the production increase to 18.3648 MMSCFD, indicates production increased by 83%.

In case of vertical well formation damage caused to reduce the production from 5 MMSCF/D to 3 MMSCF/D. By applying appropriate treatment job the production increase to 4.614 MMSCF/D, indicates production increased by 54%.

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