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Application of Chan Plot in Water Control Diagnostics for Field Optimization: Water/Gas Coning and Cusping

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Abstract

A major problem in hydrocarbon depletion is the accompanying water production. Water production, especially in a deep offshore aquifer driven reservoir, is inevitable. In the petroleum industry, most active bottom-water drive reservoirs are completed strategically to handle produced water problems that may arise during the production of oil & gas. Water production may come in the form of a tongue, cone, cusp or a combination of all depending on the location, magnitude and direction of water movement. Some of the drawbacks include: decrease in oil flow rate, increase in the volume of water to be handled thereby increasing the cost of surface installations, reduced efficiency in the depletion mechanism, increase in water disposal cost because produced water is corrosive, early abandonment of affected well & loss of field total overall recovery. The situation is not different in a monocline reservoir. Edge water coning presents huge challenges especially when it is unanticipated. Edge water coning is different from bottom water coning because water encroaches in a sloping bed. Some of the challenges encountered in a monocline reservoir includes: difficulty in predicting water breakthrough time and Water Oil ratio (WOR) performance after breakthrough. Thus, several attenuation methods have been developed to circumvent excessive water production as a result of water coning. Among these methods are: selective water plugging, chemical shut-off, horizontal wells, down hole oil-water separation (DOWS) technology etc. This research work deals with the production optimization in a brown XYZ field which is at primary recovery stage having a number of producing wells. The main objective of this research is to optimize XYZ field by understanding the mechanism involved in the water coning process and presenting a remedy to the coning problem. With the use of a production plot software, under the direct optimization technique under the global method. Origin production plot tool was used for analysis of the brown field. The field is made up of eleven producing wells and optimization was done on the field 10 years after production started.

1. Introduction

Prior to the production of oil and gas, the oil-water contact is supposedly flat, stable and practically distant away from the wellbore perforations. Hence, the forces acting on the interface of the oil-water contact are at equilibrium. During oil production, the steady-state flow condition is prevalent as flow rate and pressure at the outer boundaries are constant which in turn leads to a constant pressure drawdown at every point within the reservoir boundaries [1,2,3]. Thus, there is a dynamic flow of oil towards the perforated interval aided by the break in equilibrium between the viscous forces and gravitational force. This imbalance in equilibrium between these forces favors the viscous force which leads to a sharp increase in flow rate and ultimately forming a cone-like shape. [4,5,6].

Therefore, an increase in production rate initiates an increase in the height of the cone as it moves towards instability and results in water breakthrough. This instability of the cone is as a result of the strong upward dynamic force caused by high pressure drawdown which cannot be equaled by the weight of water. Some authors have alluded that water breakthrough occurs at a point above which the dynamic pressure gradient is greater than the hydrostatic pressure gradient [7, 8].

In the exploration of hydrocarbons, reservoirs generally are considered alongside with the aquifers; which are usually beneath them. The presence of aquifer beneath hydrocarbon reservoirs serves as a two-edged sword with both positive and negative benefits. One major advantage of this water bearing body is that it serves as the drive mechanism (i.e. energy source) of the reservoir; which in turn increases the oil recovery potential of the reservoir [9,10]. However, this water drive potential from aquifer becomes disadvantageous at a later production stage of the hydrocarbon reservoirs. The disadvantage comes in the form of production of water alongside oil; which to a large extent, cannot be avoided; especially in bottom-water drive reservoirs [11,12,13]. If this oil production challenge is not mitigated, it can lead to less oil recovery and ultimately result in early abandonment of the hydrocarbon field(s) and/or well(s). Water production is a necessary evil in oil production, whose negative impact comes in several forms, one of which is water coning. Coning is a near-wellbore and rate-sensitive phenomenon which depends on production rates.

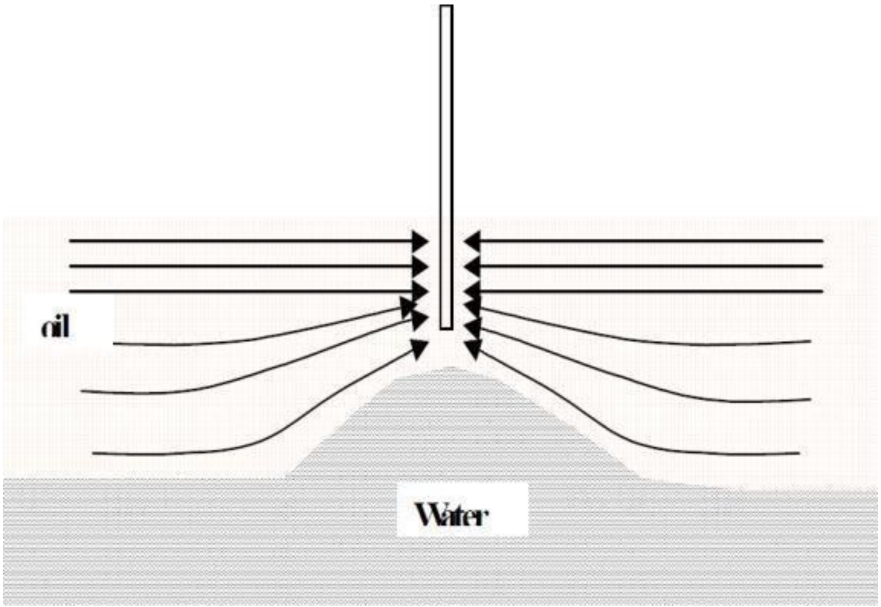

Fig.1. The physics of water coning

A major problem in hydrocarbon depletion is the accompanying water production. In the petroleum industry, most active bottom-water drive reservoirs are completed strategically to handle produced water problems that may arise during the production of oil & gas. Water production may come in the form of a tongue, cusp, cone or a combination of all depending on:

- Location
- Magnitude
- Direction of Water Movement

Some of the drawbacks include:

- Decreased oil flow rate
- Increased volume of water to be handled thereby increasing the cost of surface installations
- Increase in water disposal cost (because produced water is corrosive)
- Early abandonment of afflicted well ➢ Loss of field total overall recovery.

This research seeks to address the following:

1. To determine excessive water and gas production mechanisms using a new technique that has proved to be effective in the industry; **the Chan Plot**.
2. To determine the effects of water coning and cresting in bottom water drive reservoirs.
3. To give remedial solutions to solve the problem of water coning.

2. Methodology

The methodology involved the acquisition of BWPD (barrels of water per day) and BTFPD (barrels of total field production per day) together with GOR (gas-oil ratio). The Chan diagnostic plots were plotted using available data by initially creating a plot of gas-oil ratio and percentage water cut with time. The percentage water cut is derived from the relationship.

$$\%water\ cut = \frac{BWPD}{BTFPD} \dots\dots\dots\dots\dots (1)$$

There are essentially three types of production data that must be recorded in order to perform reliable reservoir calculations. These are:

1) Oil production data, even for properties not of interest, can usually be obtained from various sources and is fairly reliable.
2) Gas production data is becoming more available and reliable as the market value of this commodity increases; unfortunately, this data will often be more questionable where gas is flared.
3) The water production term need represent only the net withdrawals of water; therefore, where subsurface disposal of produced brine is to the same source formation, most of the error due to poor data will be eliminated.

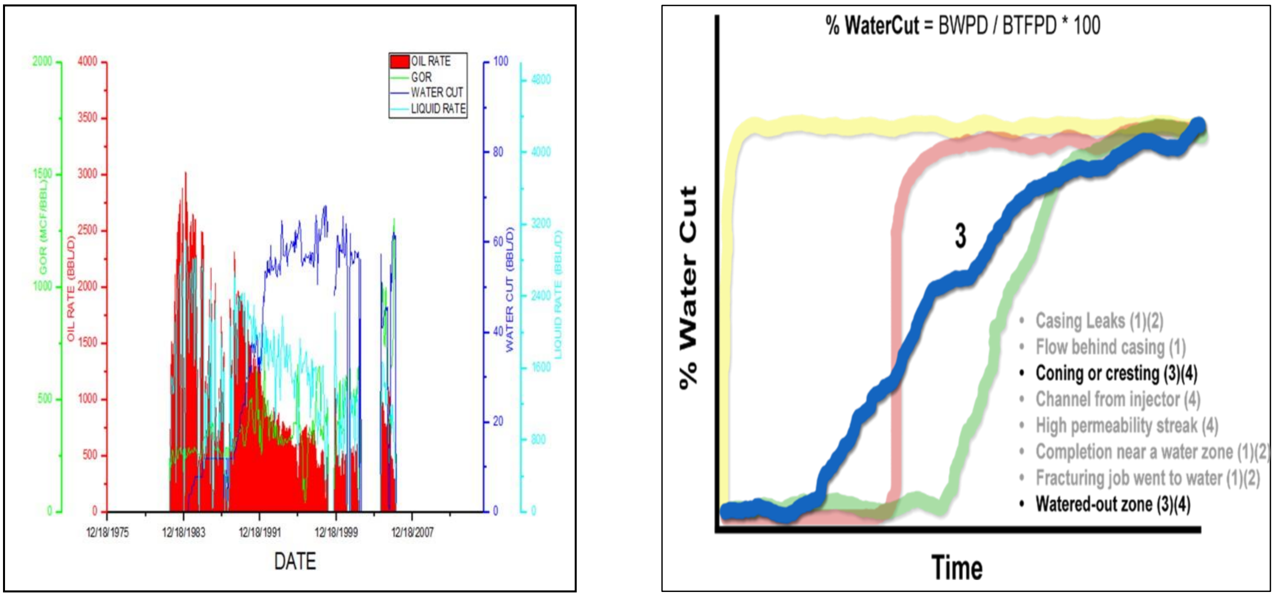

Fig.2 XYZ-32T:D3000E Analysis

From the Fig.2, the following was noted:

1. Early breakthrough and continuous increase in WOR displays a coning type 3 behavior.
2. Oil production rate continues to decline steadily as water production increases.
3. Coning analysis would be performed on this well to predict a critical production rate.

As can be observed in Fig. 2, the water-cut trend for XYZ-32T follows the behavior of the **Type 3** behavior plot. The interpretation plot Type 3 indicates **Coning/Cresting and/or watered-out zones**. A water coning analysis will be carried out on XYZ-32T to predict the desired critical production rate. The coning analysis was carried out by simply applying the Meyer, Gardner and Pirson conning model and inputting the independent variables.

Meyer, Gardner and Pirson (1977)

$$q_o = \frac{\pi k_h \Delta \rho g}{B_o \mu_o \ln\left(\frac{r_e}{r_w}\right)}(h^2 - h_p^2) \tag{2}$$

3. Results

3.1 Chan Plot

A new technique to determine excessive water and gas production mechanisms as seen in petroleum production wells has been developed and verified. Creating Chan water control diagnostic plots is a common well surveillance activity to search for signatures that distinguish and explain mechanisms behind excessive water production in oil wells.

3.2 Chan Plot Comparison

After running the Chan plot using the appropriate software, it is important to cross check with the standard plots by a means of comparison to know the particular well problem you are dealing with. For the reservoir under study in this research work (D3000E), The Chan plot is shown in Fig.3.

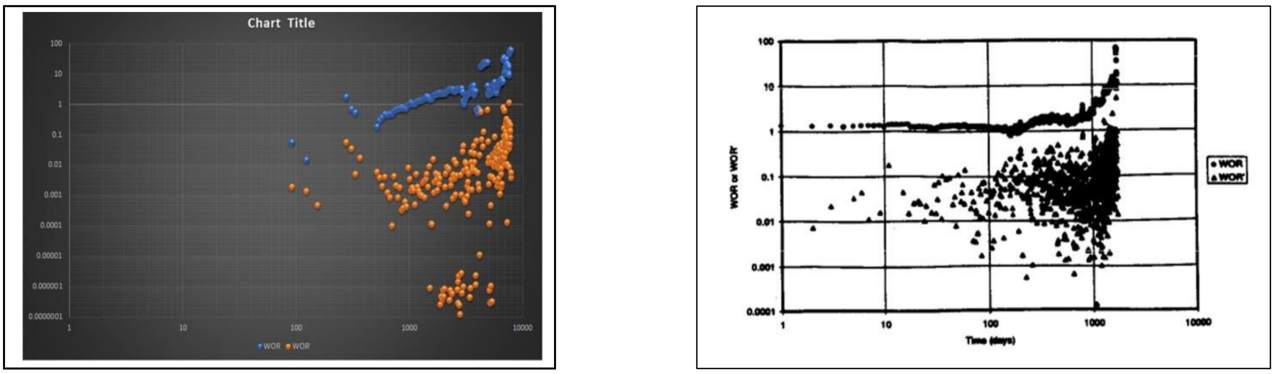

Fig. 3 Chan Plots indicating a coning/cresting/cusping problem

3.3. Discussion

After a thorough well-by-well analysis of the historical production and its effect on water production, several points can be noted:

- Wells under coning effect are mostly are result of high initial production rates.
- XYZ wells are much more susceptible to coning and should be produced below the critical coning rate.
- Abrupt changes to choke sizes (draw-down) encourage water production.
- Well recompletion is necessary for water production control.
- Wells needs to be closed in for cone height to recede.

One of the primary objectives of this study was to investigate upon the causes of the sudden water breakthrough into wells and recommend remedial action. Excessive water production has been an object of concern and intensive research in the petroleum industry over the years. Water production has been a major inhibitor in achieving a well's oil recovery potential. High water-cut can be attributed to many related causes. Possible causes of excessive water production include: Casing leaks, Flow behind casing, Coning and cresting, Channel from injector, High permeability streak, Completion near water zone, Fracturing job went to water, Watered-out zone

A historical plot of a well water-cut shows a graphical pattern that is attributable to the possible causes of the excessive water production.

4. Conclusion

One major production related problem in oil and gas production that has received a lot of attention is water coning; especially in bottom-water drive reservoirs. The developed correlations available in the literature to predict water coning parameters are adequately prolific to establish its occurrence and severity in the reservoir during oil production. Notwithstanding, these correlations' prediction provides a window of operation to avert early occurrence of water coning. However, most predicted water coning parameters; especially critical rate, if implemented would be uneconomical for any company to operate. Therefore, water coning control methods that would suppress or mitigate coning tendency and improve oil recovery is a consideration. There are several water coning control methods in the literature, however, downhole water sink (DWS) and downhole water loop (DWL) completions handle the challenge of water coning and improve oil recovery as well. Thus, this paper reviewed the water coning problems and the following conclusions were drawn:

i. The Chan Plot is a very good and accurate predictive tool for the determination of water coning and cresting problem in a well.
ii. Water coning, cresting or cusping in oil wells is a major cause of water production problems and as such should be eliminated or reduced to the barest minimum as it usually impacts negatively on well productivity in a field optimization program.
iii. With the little research done on the DWS and DWL technologies, theoretically, DWL technology seems more promising than the DWS technology because DWL technology is effective in reservoirs with large and small aquifer while DWS deals with reservoirs with large and active aquifer; however, it requires field(s) case application to support its robustness as water coning control approach over DWS technology.

The following recommendations can be made based on this research work carried out.

1. Since this research work was more of an extensive study of water coning and cusping in oil wells, efforts could be made to use other predictive tools that would determine the type of water production problem in a well.
2. This research work doesn't place much emphasis on the control of water coning problems, it is important to whoever would pick up this work for future reference to try and look more into the water coning control techniques such as: selective water plugging, DWS and DWL.

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