2012 International Conference on Bioscience, Biochemistry and Bioinformatics
IPCBEE vol.31(2012) © (2012)IACSIT Press, Singapoore

Mechanism of Excessive Water Production in an Iranian Offshore Oilfield

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Abstract: Excessive water production is a complicated issue in the oil and gas industries and has economical and environmental impacts. Finding the reasons for water encroachment is very important in reaching the optimum solution for controlling and treatment of unwanted water. Water is often encroaching to the wellbore by either coning or channeling phenomena. Plots of water-oil ratio (WOR), together with the derivative plots of water-oil ratio (WOR') are efficient tools in distinguishing the mechanism of excess water in the production wells. In this work, an Iranian offshore oilfield, which produces unwanted water, has been studied. As the rate of water production in a number of offshore oil wells gradually increased, it was proposed to find a solution, but before that, it was decided to find the exact mechanism and the source of the excessive water. A number of water producing wells were selected and the history data was carefully studied. By analyzing and plotting the data and simulating and comparing the results with standard plots, the mechanism of each well was identified. As a result of this study, channeling is the main reason for water production in high permeability sandstone zone, which can be cured by appropriate methods.

Keywords: excessive water, water cut, water-oil ratio, channeling, sidetrack operation.

1. Introduction

The economics of unwanted water production is one of the most important problems in oil and gas industry. Managing the cycle of water production, down-hole or surface separation, and disposal involve a wide range of oilfield services which are costly. These include data acquisition and diagnostics using production logging, water analysis for detecting water problems and reservoir modeling to characterize the flow. Also, there are various technologies to eliminate water problems such as down-hole separation and injection, chemical and mechanical shut-offs, and surface water separation and production facilities. All of these operations from different logging like temperature and density logs to reservoir modeling for diagnosing water problems are costly for oil companies. Therefore, using a method that has low cost for diagnosing water problem is of interest to all.

One of these methods is diagnostic plots. A diagnostic log-log plot of WOR and derivative of WOR versus time was presented for the first time by Chan.[1]. A set of diagnostic plots are generated by conducting a series of systematic water-control numerical simulation studies using a black oil simulator. This three-dimensional, three phase simulator is capable of modeling the performance of reservoir flow under different drive mechanisms and water flood schemes. He discovered that derivatives of the WOR versus time can be used for differentiating whether excessive water production problem in a well is due to coning,

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channeling or uprising water-oil contact. In this article, we focus on the detection of excessive water production in a sandstone reservoir with high horizontal permeability in an offshore Iranian oilfield. First, we review the three basic different water breakthrough mechanisms, and then, describe the use of diagnostic plots to find the reasons for unwanted water production.[1]

2. Controlling Excessive Water

There are three stages for controlling the excess water production in the oil reservoirs, which are summarized in the following steps:

Step one: Obtain alternatively the value of water-oil ratio for analyzing the behavior of oil reservoir and draw production history plot in a defined period of time.

The value of water-oil ratio can be calculated in the laboratory. Also, when a reliable production history is available, it often contains a wealth of information that can help diagnose the location of water entry point and also the volume.

Step two: The production of unwanted water can occur for different reasons like tubing leak, flow behind casing, high permeability layer, etc, but various water breakthrough mechanisms can be classified into three basic types of problems as follows:

1- Channeling problems (open flow through faults, fractures, or channel flow behind casing)

2- Coning problems

3- Water-oil contact uprising (edge-water flow)

The method for differentiating and diagnosing the above water problems is by using the diagnostic plots, which is expressed as below:

First, the value of water/oil ratio(WOR) is calculated by using the actual oil and water production .

Then, the derivative value of water/oil ratio(WOR) is calculated by the following equation:

$$WOR' = \frac{d(WOR)}{dt} = \frac{(WOR_2 - WOR_1)}{(t_2 - t_1)} \quad (1)$$

Finally, the water problem is diagnosed with the help of table 1.

Table 1: different patterns source of producing water in the reservoir

WOR Slope	WOR' Slope	Reason for Water Production
positive	Positive	channeling
positive	negative	coning
positive linear slope	horizontal line	water/oil contact rising

The plots for the 3 water problems are illustrated in the following figures (1-3).

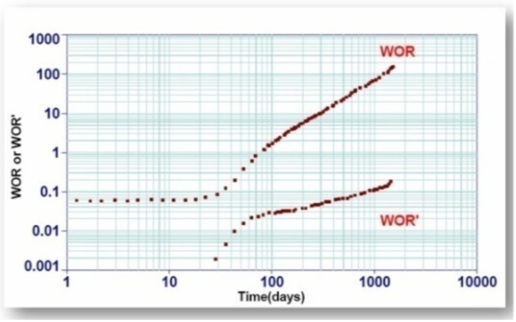

Fig. 1: Channeling

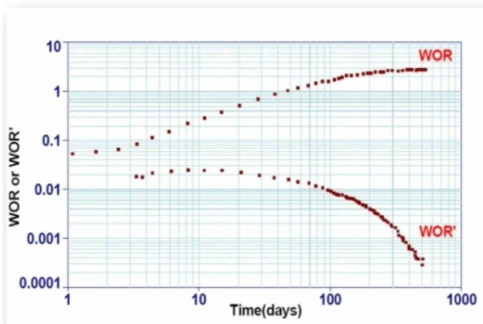

Fig. 2: Water coning

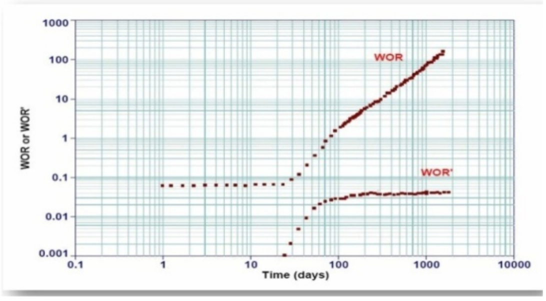

Fig. 3: Water/oil contact rising

Step three: Find the most appropriate solution for controlling the excess water production.

The success in this step has direct relation with the previous two steps, i.e. obtaining the necessary production information and diagnosing for the reason of water production.[2]

3. The Oilfield under Study

The field is located in the Persian Gulf and has four separated reservoirs. The oil production is just for Ghaar sandstone reservoir. Depth of the reservoir is between 820 to 880 m and is a shallow field. About 100 wells with different geometries, i.e., vertical, horizontal and deviated have been drilled in 10 production platforms, located in the western and eastern wings of the field.70 wells are productive and some, because of producing high amount of water, have been abandoned. The field has a strong aquifer. The drawback of the field is the lack of sufficient information about the reservoirs and especially the updated logging data which confines the reservoir study to some initial information. The other problem about the reservoir is producing too much of sand that leads to using the gravel-pack screen. The permeability of the reservoir is about 2000-3000 md, porosity of 30% and the saturation of water 35%. A number of wells were studied in this work, but only a typical well is analyzed and discussed in the of this paper for brevity.[3]

4. Well A

It has been completed in 1997 as a horizontal and open-hole. The ultimate depth is about 464ft and the length of the open-hole part is about 239. In order to prevent producing sand in this reservoir, sand liner has been used. Charts 4 to 9 show oil and water production, water cut, water/oil ratio and derivation of water/oil ratio before and after work-over operation. [3]

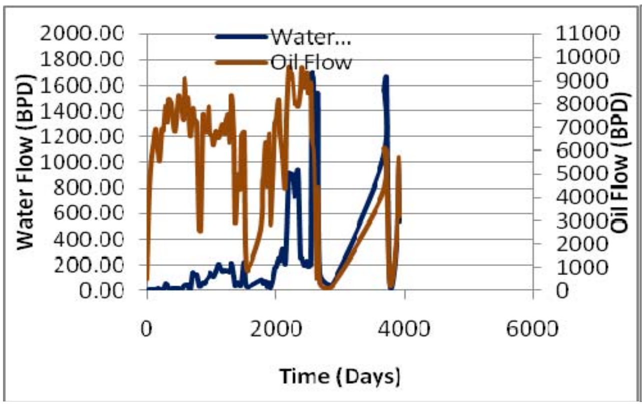

Fig. 4: Oil & water production before work-over

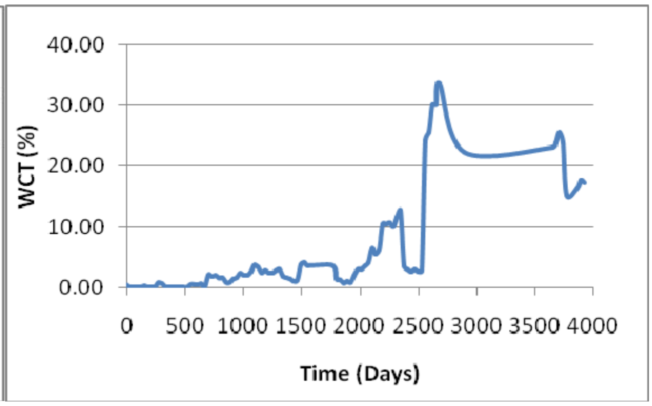

Fig. 5: Water cut before work-over

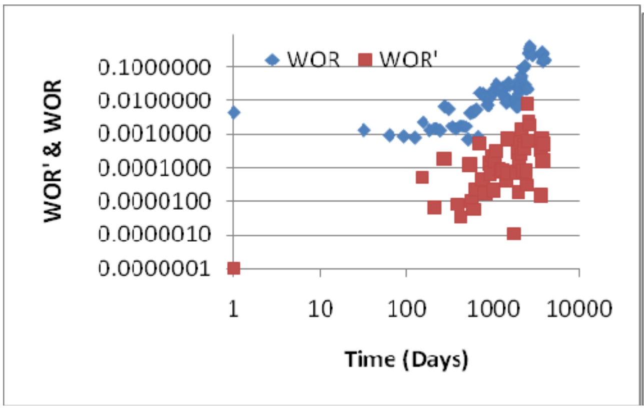

Fig. 6: WOR & WOR' before work-over

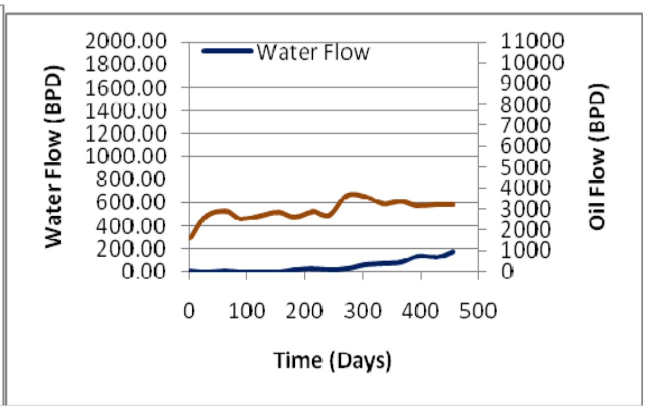

Fig. 7: Oil & water production after work-over

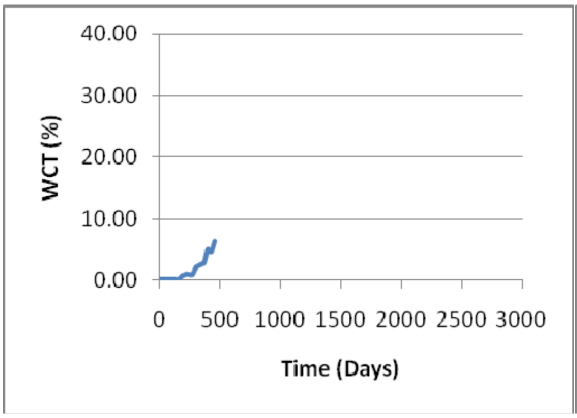

Fig. 8: Water cut after work-over

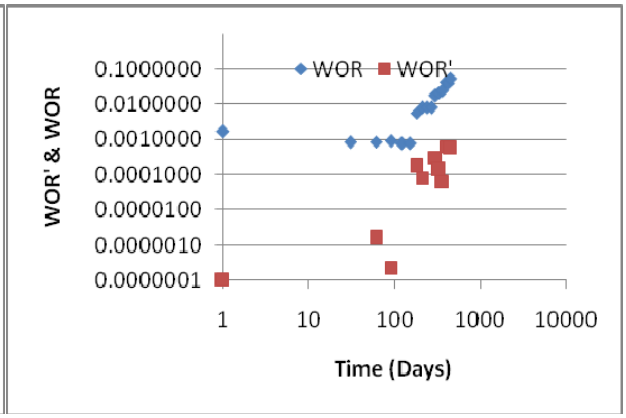

Fig. 9: WOR & WOR' after work-over

5. Discussion

Chart 4 shows the flow of water and oil in well A before repairing. As shown, the well after 2650 days with oil production of 4400 barrel daily (bbl/day) in the middle of 2004. Because of excess water production, water cut increases and reaches 33% (chart 5) and in order to get the oil production up to 328 barrel per day, the excess water rate must be decreased. To control the water cut, the well was closed for 6 months, which as a result, the percentage of water cut decreased to 22%, that is still a high percentage. After that, it was again closed because of high production of sand. Then it was proposed to wash the well, analyze the sand samples and survey the probable damage, and install the gravel pack & screen in the well. The diagnostic diagram shows that the reason for high water production is channeling because of high permeability of layers. Closing the well for two years and performing the listed operation caused the oil production to be increased by 2000 barrel and the total daily production reached to 6100 barrels. But increasing the water cut continued and finally after 3928 days it was closed for 518 days and sidetrack operation performed and the well is completed in a higher position in pay zone. Chart 7 shows the water and oil production after sidetrack operation. The operation decreased the water cut from 17% to 0.2% (chart 8). The diagnostic chart has been drawn for this well after operation in chart 9. In spite of high cost for digging operation, it is quite clear that the course of water production is increasing gradually, that is the problem of water channeling because of high permeability of layers. Surely this leads to decrease in the water production in well, although the water/oil ratio and derivation of water/oil ratio shows the continuity of channeling phenomenon.

6. Results

1 The surveyed reservoir is the kind of sandstone with high vertical and horizontal permeability, high water saturation, and completion of opened cavity of the reservoir well set the channeling phenomenon as the main reason of watery wells.

2 It can be concluded that in sandstone reservoirs like the surveyed reservoir, channeling phenomenon is the reason of watery wells.

3 Considering the kind of completion of these wells, mechanical blocking to ban water production in these reservoirs and similar kinds is not a good choice and the best one is using Relative Permeability Modifier (RPM). In addition, these materials have the compatibility with the other chemical agent, used for solving the other problems of reservoirs.[4],[5] and[6].

4 It is strongly recommended to use other way, but using sand laces in order to control sand in sandstone reservoirs that have not only the problem of water production but also sand production to avoid problems in the process of isolation of water layers, both in chemical or mechanical methods.

7. References

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