A Simulation Study of Downhole Water Sink Guidelines Plot Application using Real Field Data

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Abstract: One solution for water coning problem is Downhole Water Sink (DWS) system. A dual completion system is used to produce the oil perforated zone and the water separated zone separately. Pressure drawdown in the water zone is used to oppose pressure drawdown in the oil zone so the water-oil contact is remained stable and prevents the water coning. A DWS guideline plot proposed by Marhaendrajana and Alliyah is used as a basis in application of DWS by using real field data. This research aimed to apply the DWS guideline plot to get the benefit of DWS which is controlling the water coning problem. A geological reservoir model has been upscaled and history-matched into a representative dynamic reservoir model used in this study. The simulation is conducted by applying 5 scenarios in DWS application considering the number of active wells and the variation of flow rate in this reservoir. DWS guideline plot and its application using real field data gave good results in increasing oil recovery with some concern related with the amount of water produced in water perforated zone. The best scenario which is using DWS in high and medium rate wells group gave 16.24% recovery factor.

1 INTRODUCTION

Water almost always co-exist with our desired fluids in a reservoir, therefore, it is expected to produce a certain amount of water during production. The amount of water produced is usually referred to as the water cut. The highwater cut will lower the oil production rate and increase the water treatment cost. This problem arises in a water drive reservoir and water injection in waterflooding operations. Water which has higher mobility than oil tends to bypass the oil flow and cause water coning. A lot of research has been conducted on studying critical production rates and water breakthrough time to control water coning (Chaperon et al., 1986; Abass et al., 1988; Høyland et al., 1989). On the other hand, economical production rates also need to be considered when production rates are limited. Downhole water sink (DWS) was introduced for controlling water coning without limiting the oil production rate below its critical rate (Wojtanowicz et al., 1991).

This paper presents a simulation study of DWS guideline application using real field data. The basic concept of DWS and its guideline will be covered briefly. Then, the field data and some assumptions used are presented before the result is summarized.

2 DOWNHOLE WATER SINK TECHNOLOGY

One technology to overcome water coning problem is Downhole Water Sink technology (DWS). DWS is a dual completion application technology where the oil zone and water zone are produced separately. This concept was proposed by Wojnatowicz in 1991 (Wojtanowicz et al., 1991) and then called as Downhole Water Sink for the first time in 1997 (Shirman and Wojtanowicz, 1997). An equal pressure drawdown is created in water perforated zone to prevent water coning and to create a stable oil-water contact, so oil can be produced from the top perforation while water is produced from the bottom completion. Astutik (2006) has listed several studies that showed the DWS application successfully worked to preventwater coning and increase oil production without water breakthrough. Those studies included numerical studies and field application. However, most of those studies were focused on comparing DWS with conventional completion technique.

Marhaendrajana and Alliyah proposed a guideline for DWS design (Marhaendrajana, Sukarno, and Alliyah, 2008) which incorporates parameter

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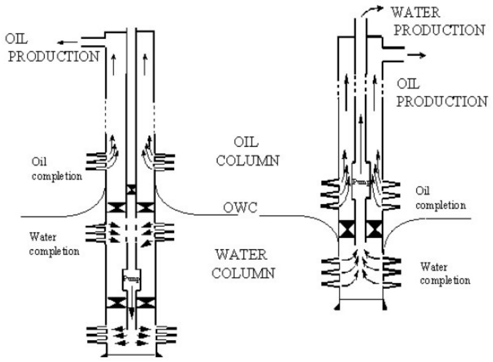

Figure 1: Schematic of Downhole water sink (taken from (Wojtanowicz, 2006)). A. DWS water drainage-injection. B. DWS water drainage-production.

affecting water coning such as permeability anisotrophy (k_v/k_h)and perforation interval (h_p/h_o). Where Qtop* and Qbottom* are respectively :

$$Q^*_{top} = Q_{top} + \left(10^{\alpha 1}\right) \left[\left(\frac{k_v}{k_h}\right)\right]^{\alpha 2} \left[\left(\frac{h_p}{h_o}\right)\right]^{\alpha 3} \qquad (1)$$

$$Q^*_{bottom} = Q_{bottom} + \left(10^{\beta 1}\right) \left[\left(\frac{k_v}{k_h}\right)\right]^{\beta 2} \left[\left(\frac{h_p}{h_o}\right)\right]^{\beta 3} \qquad (2)$$

Where : α1=2.401433, α2=0.518346, α3=1.283428; and β1=3.227316, β2=0.842945, β3=1.567493.

The preferable condition is where instead of water coning, the oil coning happened or called as reverse coning. The segregated and reverse coning phase in the DWS guideline plot become the guideline to determine the production rate in the oil zone (Qtop) and the water zone (Qbottom).

3 SIMULATION AND FIELD DATA

The simulation and field data used are from a Jurassic reservoir in China (Huawei et al., 2013). A reservoir dynamic model has been upscaled from geological model and well history-matched with its production history data. The model was built using PETREL and run using ECLIPSE. Production history data showed that water production rose rapidly and become a major problem. This reservoir has 4 major layers (Y71, Y81, Y82, and Y91) with an average permeability of 100 mD and average porosity 14.5%.

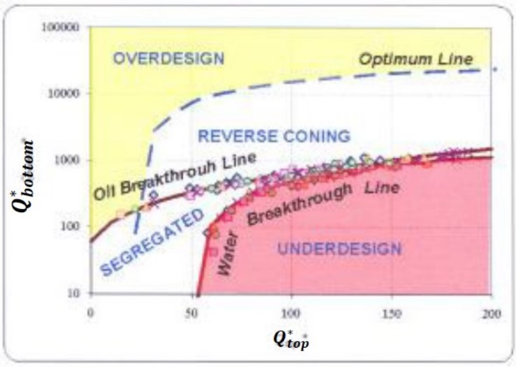

Figure 2: DWS Guideline Plot (taken from (Marhaendrajana et al., 2008).

Table 1 and Table 2 summarized the reservoir and oil properties.

In this reservoir there are 81 vertical wells and 1 horizontal well. At the end of history matching 12 wells are converted to be water injector wells. 15 years of production years is used as the basis for the development strategy.

The oil recovery factor at the end of history matching is 7.26%. From Figure 3, the remaining oil saturation for each layer is still quite high which is 0.6 inthe green color region.

Table 1: Rock Properties (taken from Huawei et.al., 2013).

Rock Characteristics	
Porosity, %	14.5
Horizontal permeability, millidarcy (mD)	100
Kv/Kh	0.1
Compressibility, 1/bar	0.00055

Table 2: Fluid Properties (taken from Huawei et.al., 2013).

	Oil	Water
Density, kg/m3	14.5 (32.15°API)	1000
Viscosity, cp	8.88	0.5494
FVF	1.13	1.014
Compressibility, 1/bar		4.16 x 10-5

At first, it was needed to optimize the water injection scheme to maintain reservoir pressure above the bubble point pressure while increasing the recovery factor (RF). The optimization resulted in recovery factor of 14.94%. The optimized water injection case will be used as our base case in implementing DWS.

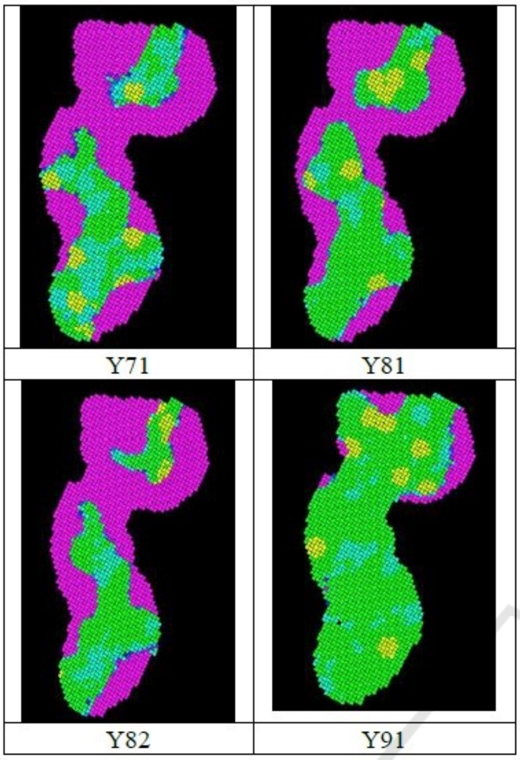

Figure 3: Remaining oil saturation at the end of history matching (So initial for development).

4 DWS GUIDELINE PLOT APPLICATION

For employing DWS concept in the reservoir simulation, a well with DWS is two wells in the same location with different perforation intervals. One perforation will perforate the oil zone while the other one will perforate the water zone in the same well. The production rate for the water zone is higher than in the oil zone to keep a good Oil-Water Contact (OWC) in straight line or to make the oil and water in segregated phase.

In applying the DWS technology, the wells are sorted into three groups. High rate wells (production rate > 15 m^3/day), medium rate wells (production rate between 10-15 m^3/day), low rate wells (production rate < 10 m^3/day). There are 5 cases conducted in this simulation study to evaluate which case gives the highest recovery factor. The operation condition for DWS (Qtop and Qbottom) are determined by 3 chosen operation conditions for each sorted group of different production rate (high, medium, and low).

High – Qtop* = 200bopd, Qbottom* = 1000bopd
Medium – Qtop* = 100bopd, Qbottom* = 800bopd

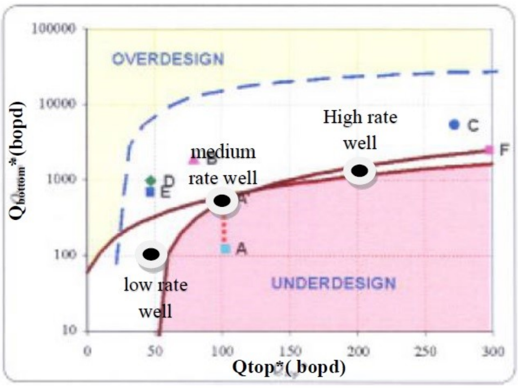

Figure 4: DWS Operation condition for each group well.(modified from Marhaendrajana, Sukarno, and Alliyah, 2008).

Low – Qtop* = 50bopd, Qbottom* = 100bopd

For Case 1, 8 wells from high rate wells group were using DWS with Qtop = 30 m3/day and Qbottom = 160 m3/day.

For Case 2, 5 wells from medium rate wells group were using DWS with Qtop = 15 m3/day and Qbottom = 80 m3/day.

For Case 3, 10 wells from low rate wells group were using DWS with Qtop = 8 m3/day and Qbottom = 30 m3/day.

For Case 4, DWS was implemented in high rate wells and medium rate wells and did nothing for the low rate wells.

For Case 5, DWS was implemented in each group of well, high rate, medium rate and low rate.

Qtop and Qbottom used in each group wells were calculated from the DWS guideline plot. The values also have been converted from SIunit (International System of unit) in reservoir data unit (China using SI unit) into field unit in DWS guideline plot. After the simulation, the results are presented in Table 3.

Table 3: Simulation Study Results.

Case	Scenario	RF (%)
Base case	Optimized Water Injection	14.94
Case 1	Base case + DWS high rate	15.37
Case 2	Base case + DWS medium rate	15.23
Case 3	Base case + DWS low rate	14.66
Case 4	Base case + DWS high and medium rate	16.24
Case 5	Base case + DWS high, medium and low rate	16.15

From the results, case 4 gave the highest recovery factor with only DWS application in high and medium rate. This shows that DWS application in low rate wells did not give significant water drainage in reducing water coning. These results correlate with DWS operation condition for the low group rate which is located at segregated zone (Figure 4). Segregated inflow production can only be achieved for a relatively low flow rate. In the field operations, reverse coning has been used mostly in the reversed coning mode of DWS production (Shirman and Wojtanowicz, 1997). While on other hand, the preferred oil coning provides additional constrain in terms of water treatment capacity as the more water will produce in conjunction with higher water production rate in water zone. DWS water drainage-injection mode can be used to overcome this excess water problem (Figure 1A.) The water drainage was pumped into water zone below the water drainage perforated zone. This approach has already been applied in real fields such as Greater Burgan Field (Al-Fadhli et al., 2019) and North Kuwait (Anthony and Al-Mosaileekh, 2016). But in general, the DWS guideline plot provide a good approximate operating condition in DWS application.In its application, the Qtop* and Qbottom* can be optimizedfor each well with different production rates. The grouped production rates are used to simplify the simulation considering the number of wells in this field. Production rate should be a screening criterion in DWS application. An adequate flow rate is needed to operate DWS in reverse coning region to optimize the benefit of DWS.

5 CONCLUSIONS

From this study, we observe that DWS guideline plot gave good approximate operation condition in terms of production rate in oil zone (Qtop) and water zone (Qbottom). Grouped production rate wells can be used to simplify the implementation of DWS application as different production rate need different DWS operation condition. Reverse coning region is the preferred operation condition for DWS application. Screening of production rate is needed to make sure DWS application in reverse coning operation region. In DWS application,economic evaluation is needed to make sure the incremental oil production can cover the investment of additional water treatment capacity as more water will be produced. DWS water drainage-injection mode can be used as alternative to overcome excessive water production.

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