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Challenges and Opportunities in Oil Rim Reservoir Development

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ABSTRACT

Low oil recovery is one of the common problems in the field development of thin oil rims associated with gas-condensate. The fast gas and water conning of the reservoirs are the main causes of sharp oil rate decline and low cumulative oil production per well. Low recovery efficiency is related to the oil saturated thickness and if oil saturation is less than 10 m, most of oil volumes in place are moved to transition zones. 3D numerical and streamline simulations are performed for the development of thin oil rims of one of the pay zones in Bokabil Formation of Haripur gas field. The development option with four vertical oil production wells and nine water injection wells has been proposed to cover the entire reservoir with the efficient sweeping. The simulation study of the dynamic model has revealed that vertical wells through the reservoir are able to make a short drainage path and produce insignificant quantity of oil and the production period is terminated shortly. As an alternative development option a rim shaped production well and a rim shaped water injection well is designed. The development option with a rim shaped production and an injection wells covers large drainage length and produce significant amount of oil. This option is technically and economically feasible.

Introduction

The gas field development studies of the last decades showed the frequent presence of gas-condensate fields with thin oil rims. The major problem of the development of oil rims is low oil recovery from the thin oil rims to high initial water cut and fast gas and water conning that minimizes low cumulative oil production per well. It is observed that if oil saturated thickness is less than 10 m, most of oil volumes in place belong to transition zones causing low recovery efficiency. The challenges faced by the reservoir engineers are related to the selection of well completion type is better to use, impact on oil recovery of early gas production and whether it is better not to produce gas from the gas cap.

Gas or water breakthroughs are common during the development of gas condensate fields within oil rims causing low oil recovery and to increase oil recovery from a reservoir with a thin oil rim and large gas cap after a long depletion of the gas cap becomes challenging. When fluid injections are needed to control depletion and maintain reservoir pressure, the problem becomes more difficult (Al Khoury, et al., 2016). One common problem of developing of thin oil rims associated with gas-condensate fields is low oil recovery, caused by fast moving gas and water conning of the producers. As a result oil production rate declines sharply and cumulative oil production per well reduces. Low recovery efficiency is also related to oil saturated thickness and if it is less than 10 m, most of oil volumes in place are move to transition zones (Sergey, 2012).

Past drilling experiences are applied in the next phase of gas field development leading to more cost efficient drillings and higher production rates. It is observed that the recovery factor of thin oil rim can be enhanced from 18% to 34% through proper reservoir management of this delicately balanced system and mechanism for continued oil (Kamal, et al., 2005). One of the measures to maximize the distance to the gas-oil and oil-water contacts in the vertical wells can be maximize by the successful use of sand consolidation granting for limited completion heights instead of using gravel-packs with a normal completion height of some 10-20m in the (initially) 46m oil column. The low recovery of vertical wells (which have an average ultimate recovery of some $4.5X10^6$bbl per well), drainage of the remaining reserves would require some 180 additional (vertical and deviated) wells (Pelgrom et al., 1994).

The selection of the optimal timing of oil rim and associated gas cap production is important for the development of oil rim or associated gas caps in order to

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maximize the economic value of the asset. Oil rim reservoirs suffer from low oil recovery due to water and gas coning, and to the fact that oil may be pushed into the gas cap where a strong aquifer exists (Onyeukwu et al., 2012).

3D Static Model of Oil Rim Reservoir

Based on a 2-D seismic survey and a well log analysis, a 3D reservoir model has been constructed for the lower Bokabil Formation of the Haripur gas field. The geo-cellular model has 94 cells in X direction, 83 cells in Y direction and 15 simulation layers in Z direction extending from 9659345.47 ft to 9690169.78 ft in east direction and from 2625312.50 ft to 2652983.10 ft in north direction. The sand body is 30824.31 ft long in east direction and 27670.60 ft wide in north direction (figure 1).

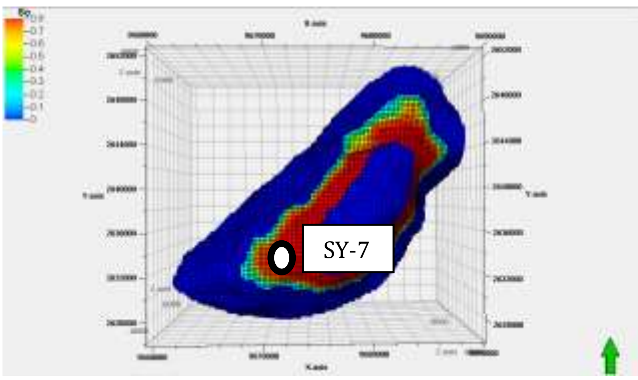

Figure 1: 3 D Static reservoir model of Haripur gas field

At the depth of 6660 ft, oil water contact (OWC) has been detected by the production well # SY-7 and the oil sample has API gravity 28.5. Performing the composition variation with the depth simulation has revealed the gas oil contact (GOC) at depth of6237 ft making a 423 ft thick oil rim in the reservoir (figure 2).

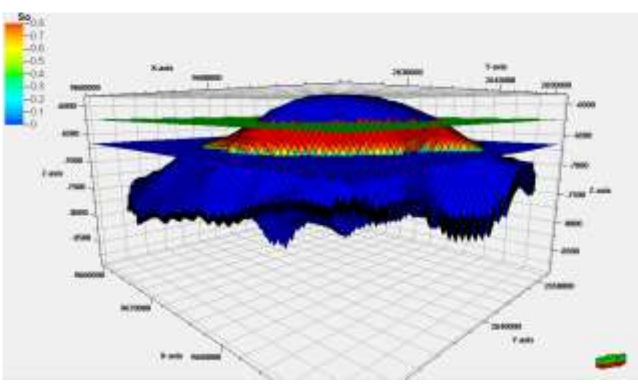

Figure 2: Position of GOC, OWC and oil rim of Haripur gas field

From the well log data, the porosity model shown in figure 3 has been simulated for the reservoir model using the sequential Gaussian simulation technique by scaling up the well log data as per the grid cell with an arithmetic mean and then make transformation by the Input Truncation method following construct variogram.

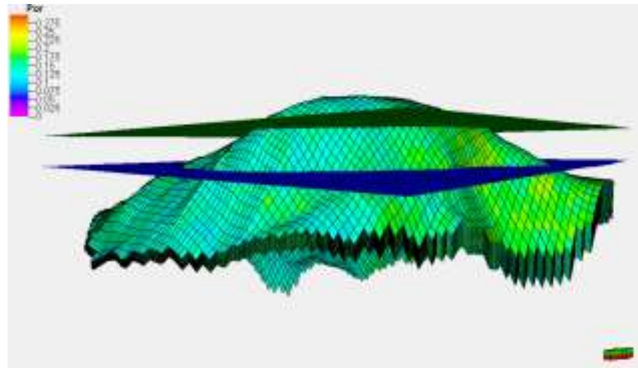

Figure 3: Porosity model of Haripur gas field

The Absolute Permeability model shown in figure 4 has been modeled from the well log data. Scaling up the well log data as per the grid cell with an arithmetic mean then make transformation by the Input Truncation method following construct variogram. The variogram sequential Gaussian simulation technique is used to simulate the Absolute Permeability model.

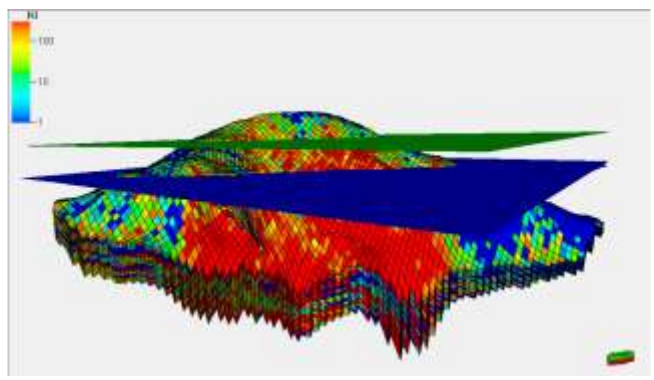

Figure 4: Absolute permeability model of Haripur gas field

Development Scenarios

Nine vertical injection wells and four vertical production wells have been proposed to bring the entire reservoir under sweeping shown in figure 5 for the oil rim development of the Haripur gas field.

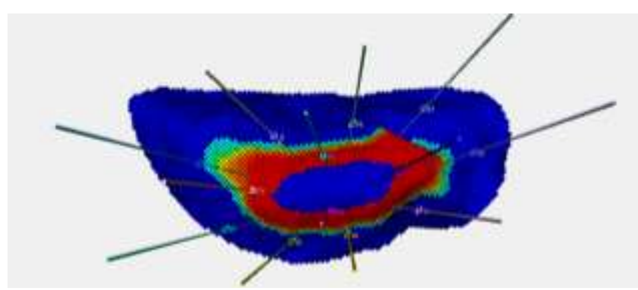

Figure 5: Position of nine injection wells at oil-water contact and four production wells at the middle of oil rim of Haripur gas field

Oil production rate has been predicted by the performance of the simulation model shown in figure 6. The oil production rate is 0.5 STB/D and terminates after one month from the production. The oil production rate and period is very negligible. This development option is not economically feasible.

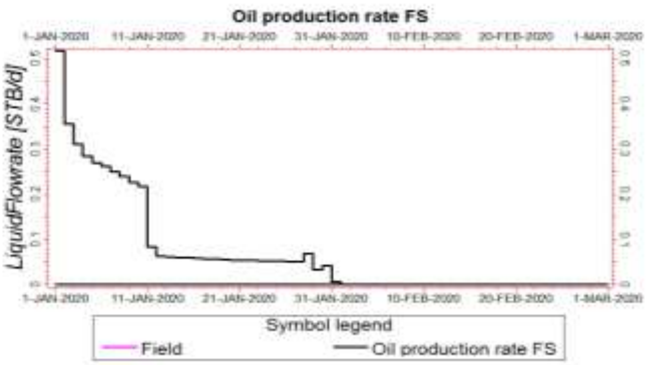

Figure 6: Oil production rate by vertical wells of Haripur gas field

To find out the alternate development option, the first development option has been analyzed which revealed that the vertical well provides only approximately 200 ft pay zone for drainage shown in figure 7. 200 ft pay zone length is insufficient for injecting water into the reservoir and to produce oil from the reservoir. To overcome this limitation alternative development option is proposed where wells are designed in such a way that the maximum well drainage lengths are achieved.

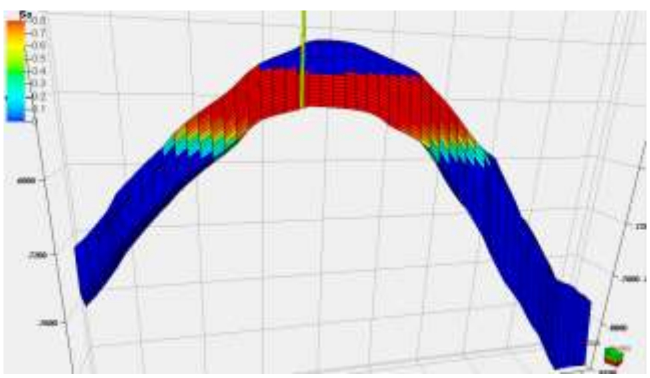

Figure 7: Vertical drainage length of vertical well of Haripur gas field

In the light of the previous study, one rim shaped oil production well P1 and one rim shaped water injection well I1 has been proposed to recover the oil from the thin oil rim shown in figure 8. To increase the oil drainage path a rim shaped production well has been designed at the middle of the oil zone to drain oil from the entire oil rim. On the other hand, for providing the water pressure to the entire oil rim a rim shaped water injection well at the oil water contact point has been designed.

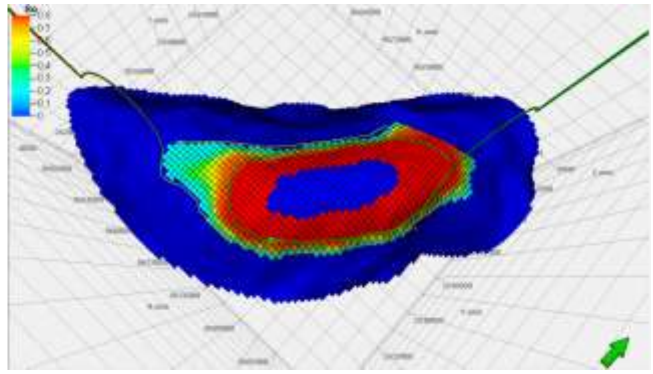

Figure 8: Well path of production and injection wells of Haripur gas field

The total length of the production well is 40,000 ft of which 7000 ft is vertical to reach the oil zone and remaining 33000 ft is rim shape passing through the middle of the oil zone shown in figure 9 providing 33000 ft oil pay zone. The total length of the injection well is 55,000 ft of which 8000 ft is vertical to reach the oil water contact and remaining 47000 ft is rim shape passing through the middle oil water contact zone shown in figure 9 providing 47000 ft for water injection.

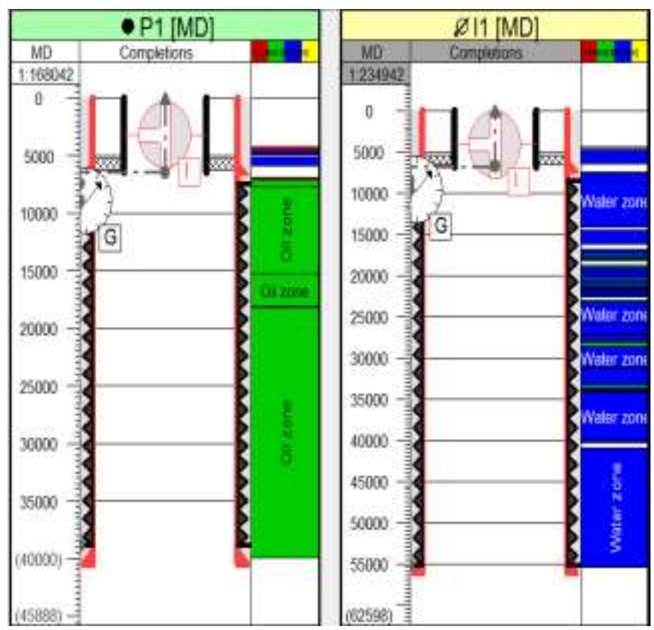

Figure 9: Pay zones of production and injection wells of Haripur gas field

A simulation has been performed on the rim shaped model to predict the oil production rate. The simulation outcome shown in figure 10, the oil production rate remains constant at 500 STB/D for the whole simulation period suggesting that this development option will be economically feasible.

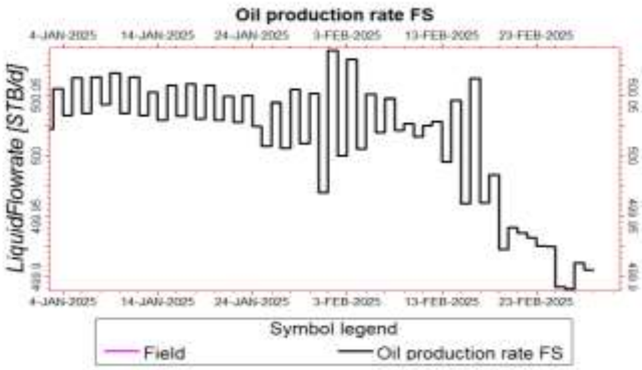

Figure 10: Oil production rate by rim shaped wells of Haripur gas field

Results

The oil rim development design is very critical as the oil zone is thin lying between gas cap and water zone. In this study two options have been designed for the development of a thin oil rim of Haripur: one by four vertical production wells and nine vertical water injection wells and in another one by a single rim shaped production well and a single rim shaped water injection well. The simulation study reveals that vertical production and injection wells are able to produce insignificant quantities of oil as the wells cover less drainage length through the reservoir that makes this option economically not viable. As an alternative development option, a rim shaped production well and a rim shaped water injection wells are designed. The development option with a rim shaped production and an injection wells covers large drainage length and produce a significant amount of oil. This option is both technically and economically feasible.

Conclusion

Large amounts of oil rim exist in the earth. Nowadays the oil rim development is extremely instrumental as the energy demand is exponentially growing and the easy oil has already exhausted. There are smart well technologies available to meet the challenges. An oil rim exists in the Haripur field. Different development scenarios have been designed to recover the oil economically. Water injection with a vertical well and a rim shaped well has been compared by performing simulation study. The rim shaped production and water injection wells increase the drainage path through the reservoir. The oil production rate of the rim shaped well has been predicted by performing a dynamic simulation. The oil production remains significant over the entire simulation period. The oil rim development of the Haripur field by the available smart technologies of rim shaped wells is technically and economically feasible at the same time.

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