8th Biennial International Conference
& Exposition on Petroleum Geophysics

"HYDERABAD 2010"

P-260

Capturing Bypassed Oil from a Giant Mature Carbonate Field under Water Flood - A Case Study of Mumbai High South.

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Summary

Mumbai High is a giant offshore field producing from a complex carbonate reservoir covering an areal extent of about 1500 sq. km. Presently the field is producing about 12 MMT of oil and 4 BCM of gas per annum. The field has undergone various stages of development and water injection is the main strategy for pushing the oil to the producers. The field has already produced 25% of the oil in place. Thus the real challenge is to maintain / enhance the production from this mature field.

Given thirty years of oil production history with simultaneous water injection, the development strategy focuses on better reservoir management to maximize the recovery from the existing wells. The recent exploitation strategy adopted in Mumbai High South has been to relocate the wells and targeting the bypassed oil through high-angle well bored in oil bearing zone. The exercise of relocation of sub-optimal producers and infill drilling of the bypassed oil targets has given expected dividends and has contributed significantly to the oil production. Many of these wells have reservoir zones with significant oil saturation behind pipe. Sidetracking of poor producers thus is a specialized exercise which helps in maintaining and improving the oil production. Improving productivity of these wells is expected to help in stabilizing the field production rates in a cost-effective manner.

The present paper outlines the case study of a well (A) from a platform (AA)of MHS field which was later drilled as AzH with long-drift side-track technology for tapping the bypassed oil. The well AzH was initially planned for production through a horizontal drainhole in deeper layer 'C' and also the perforated high angle portion of the casing against the shallower 'B' layer. However, during online monitoring of the progress of the drilling, it was observed that the oil saturation level in 'C' layer was poor and rather good in 'B' layer. Thus, it was decided to drill a drainhole in 'B' layer instead of 'C' layer. Well AzH produced oil @580 bpd with water cut of 73% against earlier well A oil production @ 124 bpd with 90% water cut. This has helped in exploiting the bypassed oil and controlling undesirable water production through skilful analysis of geoscientific data and bold initiatives.

Introduction

Mumbai High is the giant offshore oil field discovered in 1974 and located about 160 km west-north-west of Mumbai city in India. On the basis of an E-W trending shale channel in L-III reservoir the field is divided into two blocks: Mumbai High North (MHN) and Mumbai High South (MHS). Oil and gas has been discovered in a number of reservoirs, viz., L-I, L-II, L-III, L-IV, L-V, basal classics and fractured basement. Out of these, LII and LIII are the two main limestone oil reservoirs of Miocene age. The L-III reservoir is multilayered with shale & limestone and holds about 94% of the total initial oil in place of the field. Main pay zone L-III is a multi-layered limestone reservoir with a gas cap and partial water drive. Mumbai High is one of the most complex fields in terms of reservoir heterogeneity. The major reservoir (L-III) is multi-layered with 10 limestone sub layers designated as A1, A2-I to A2-VII, B & C of 2-5m thick each, separated by 1-5m shale layers. The multilayered heterogeneous carbonate reservoir has a complex mixed drive mechanism of depletion with expansion of gas cap. The field MHS under discussion is developed with about 600 wells (650 strings), both producers and injectors.

Production History

The MHS was put on production in October 1980 and by July 2009 has produced 257 MMt of oil from the reservoir, which amounts to about 26% of inplace oil. The average

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daily rate of production during 1980-81 was about 33,000 bopd. The field production increased continuously on account of drilling and completion of development wells. The field has produced between 2, 43,000 bopd and 3, 00,000 bopd for 7 years from 1984-85 to 1989-90 and thereafter production started declining. Oil production peaked @ 3, 08,097 bopd during 1989-90 with GOR of 360 v/v and water cut of 7.4 %. Present production rate from the field is @ 1, 41,367 bopd during July'09 with GOR of 352 v/v and water cut of 69.6 %. The field has passed the mature stage of its producing life and has entered into the decline phase. The decline in oil production is attributed to decline in reservoir pressure as a consequence of less voidage compensation, due to high GOR, drop in productivity of oil with increase in water cut and conversion of producers into injectors.

Development strategy

The large size and complex reservoir characteristics of the field have led to adopt the policy to acquire information, initially to have begun with a design to drill widely spaced wells determining geological and reservoir heterogeneities, areal extent, fluid properties, the initial oil and gas volumes and drive mechanism. In the present circumstances knowledge of these parameters is utilized in the placement of infill wells. Drilling of infill and sidetrack wells is a proven incremental recovery option and to recover more of bypassed mobile oil in complex carbonate reservoirs after water flooding. This has increased the amount of recoverable reserves and the effort is continued.

Under the redevelopment plan for this field, infill drilling through available spare platform slots/new platforms through which about 90 side-tracking/re-drilling of the existing wells and drilling of about 160 horizontal wells, drainholes and Extended Reach wells have been taken up to maximize oil production with minimum water cut. A number of sub-optimal producers were also converted as horizontal sidetracks under brown field development.

The side-tracking technology has been effectively used in the process of rehabilitation of existing producers and injectors and has led to improved slot utilization. This process has been found to be useful in planning a major brown field development programme. Short-radius (SRDH), medium-radius (MRDH) and long drift sidetrack (LDST) drainhole drilling tools have provided the opportunity to work the existing wells over and convert them from conventional wells to horizontal drainholes in the same/adjoining drainage area but with higher oil productivity.

Hunting for By-passed oil (Infill Drilling and Side-tracking)

Sidetracking of existing sub-optimal producers is decided in the following situations (1) Potential in the drainage area around the well does not exist. (2) If the well cannot be suitably worked-over to drain the oil though the potential exist. (3) The means to exploit the remaining hydrocarbons under the drainage area of the well have been exhausted. (4) Revival of producer or injector wells which are sick due to some mechanical problems. In MHS, some wells have been long-drift sidetracked (LDST) where either successive workover jobs have failed or wells have encountered some mechanical problems. These wells have been completed away from their original position. Some wells have been short-drift sidetracked (SDST) about 150-200 meters away from the original position. SDST has been done mainly in wells with bad well bore condition. Some wells have been sidetracked with medium radius drainhole (MRDH) drilling to access reservoir about 200-500 meters away from the original position. MRDH wells are mainly resorted to move away from areas flooded with injected water. Total number of sidetrack wells in MHS is 90.

Latest technologies like MRDH and SRDH have made sidetracking jobs less time consuming wherein drainholes can be drilled directly in the sidetracked locations thereby increasing the drainage area with enhanced production rates, to maximize hydrocarbon recovery and to minimize overall development costs.

The improved understanding of reservoir complexity through integration of geo-scientific data, refined geological and reservoir simulation models have provided a higher degree of confidence to assess the potential reserves of by-passed oil. Recovery of difficult oil under the large gas cap has been possible through horizontal wells with advanced technology of LWD-Geosteering. The inter-and intra-platform locales of the unswept /undrained oil in the various sub-layers of the reservoir have been targeted with sidetracking the trajectories of poor producers.

Bypassed-oil Exploitation Strategy

The main strategy for the exploitation of by-passed oil has been locating undrained oil and targeting it with suitably placed wells. Identify wells which are performing poorly and determine if they can be potentially exploited for further increase in oil production. Also try to spot out the presence of major / minor faults in the vicinity of the producing area which may act as conduits for injection water affecting the oil production. As already explained, the main productive reservoir of Mumbai High Field is a highly heterogeneous carbonate reservoir with number of limestone layers intervening with thin shale sections. The accurate placement of horizontal wells in such thin reservoir layers is sensitive to technology and hence needs real-time monitoring of the drainhole drilling which can be achieved by the further introduction of appropriate advanced technology. The highly heterogeneous character of the carbonate sub-layers has led to differential flooding leading to early water-breakthrough as well as by-passed oil locales. Faults have also affected the flow of injection water in terms of injector-producer connectivity/ communication.

In a mature field, the oil productivity of the well declines due to depletion of the oil saturation and/ watering out of the sub-layers. Workover jobs for water/gas shut-off and zone transfers were common in conventional wells. Water/gas shut-off with cement squeeze is not much successful but with introduction of sidetracking technology, poor producers have been relocated for better well productivity and improved reservoir drainage.

Side-tracking of Wells for Exploitation of by-passed oil

In one of the platforms in Mumbai High South, one allied technology, viz., LDST, has been implemented in the year 2008 to exploit the by-passed oil with control of excessive injected water production. The technology is implemented (location map shown in Fig-4) of the platform for the enhancement of oil production. After the sidetracking of wells as drainholes in comparatively better areas as found from the geo-scientific data, the rate of production of oil has increased from a total of 124 bopd to 580 bopd and water cut decreased from 90**%** to 73**%***(shown in Fig-1)*.

Case Study

Well "A" in 'AA' platform**,** a low producer in Mumbai High South Field, drilled in Mar-94, was producing oil @ 124 bpd with water cut of 90 % in June-2008. To enhance the production, the well was selected as a potential candidate for sidetracking and drainhole drilling. Therefore, the well was planned for sidetracking through LDST, as a high- angle section in 'B' layer and horizontal drainhole in 'C' layer with a horizontal drift of 1200 m at 'B' top in North 325 degrees. The detailed analysis of available geoscientific data of the platform and adjoining areas suggests that 'B' & 'C' layers have better development, so the sidetracking of the well IN-6 was planned with a high-angle profile in 'B' layer and drainhole in 'C' layer. However, during online monitoring of the progress of the drilling, it was observed that the oil saturation level in 'C' layer was poor and rather good in 'B' layer. Thus, it was decided to drill a drainhole in 'B' layer instead of 'C' layer. In Sep-2008 the drainhole was drilled from 1976m to 2450 m with 6" bit using LWD assembly. The length of the drainhole was 474 meters. During drilling, the drainhole was continuously monitored and efforts were made to keep the trajectory within the sweet zone of 'B' layer. Well trajectory and well log are shown in figure-5 & 6 respectively. Production performance of AA platform before and after sidetracking of well A has shown in Figure-7. A combination of blind and perforated 3 1/2" lower completion string was lowered in the drainhole and the well was completed with 3 1/2" upper completion string and gas lift valves. The sidetracking job was completed in 30 days.

Testing

Well "A", after getting activated with use of a surge plug, produced 588 bopd with a water cut of 75% and GOR of 263 v/v. Before sidetracking, the well was producing 124 bopd with water cut of 90%. Figure-1 shows the performance graph before and after the sidetrack. Figure-2 shows the performance graph of well AzH after sidetracking.

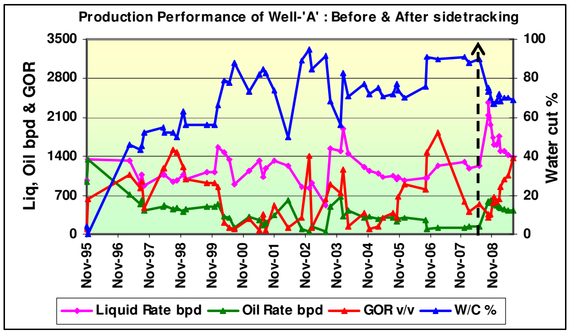

Fig 1 – Production Performance of Well 'A' before and after sidetracking

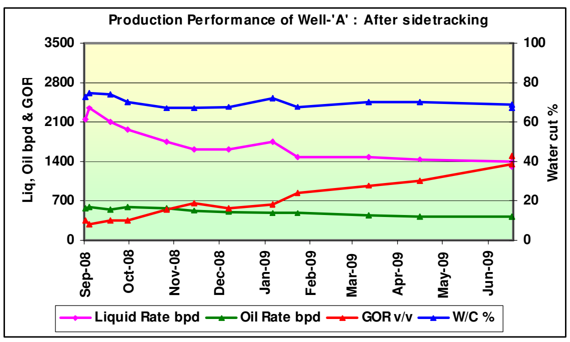

Fig 2 – Production Performance of Well 'A' after sidetracking

From the above case study, it is evident in Figure-1 that after sidetracking of well 'A' using LDST technology oil rate has improved from 124 bpd to 580 bpd with water cut of 73% against earlier with 90% water cut. Well was sidetracked in Sep-08 and within this one year period performance of the well has been consistent. Therefore it can be concluded that sidetracking of wells with LDST and MRDH-LWD coupled with whipstock technology is a cost effective means of salvaging a well by side-tracking and drilling a drainhole, resulting in saving of rig time while exploiting the by-passed oil and maximizing the profitability. The inter-and intra-platform locales of unswept/undrained oil in the various sub-layers of the reservoir have been targeted with well trajectories guided by real-time monitoring. The objective of side-tracking was to control production decline in the short term and to enhance recovery factor in the long-term.

Challenges

1. Identification of areas of by-passed oil/undrained oil in the multi-layered carbonate reservoir.
2. Placement of drainhole in the sweet zone of targeted layer.
3. Drilling of drainhole and well completion.
4. Differential flooding leading to early water-breakthrough due to heterogeneous character of the carbonate sub-layer.

Conclusions

About fifteen percent of the production wells of Mumbai High South field are producing sub-optimally mainly due to high water cut, high GOR or low liquid rate. Some of the wells are closed/recommended for closure. With the need for more inputs of water flooding, some more wells are expected to get into this category in the coming years. Rehabilitation of many of these wells is planned through sidetracking and in some cases, along with improved voidage replacement ratio in the specific layer/area. Improving productivity of these wells will help in stabilizing the field production rates in a cost effective manner. Long and short drift sidetracking of wells have been done to augment the water injection and to increase the incremental oil production and has helped in reducing the inventory of sick wells. This technology (sidetracking) has been continued in the field and encouraging results have been obtained. It is planned to continue sidetracking program at the current phase of about 32 wells per year in Mumbai High field.

Acknowledgement

The authors wish to express their gratefulness to the ONGC management, for providing the opportunity to prepare and publish this paper. The authors are deeply indebted to Shri. Apurba Saha, ED, Asset Manager, Mumbai High, for his constant support, guidance and encouragement to present this paper. The authors gratefully acknowledge the continuous guidance and support of Shri S.K.Verma Sub-Surface Manager, Mumbai High Asset in preparation of this paper. The authors also wish to acknowledge the tremendous roles of Surveillance and Reservoir Management and Development planning teams whose individual and collective efforts have contributed to improve field performance.

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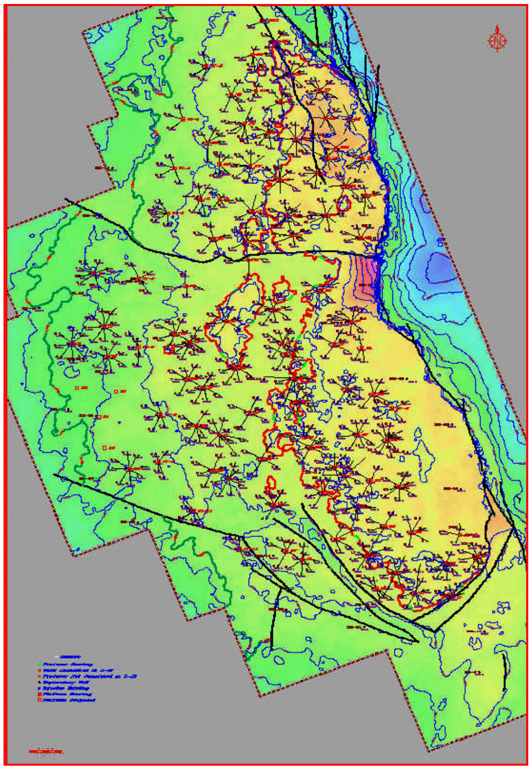

Fig 3: Sructure map of Mumbai High

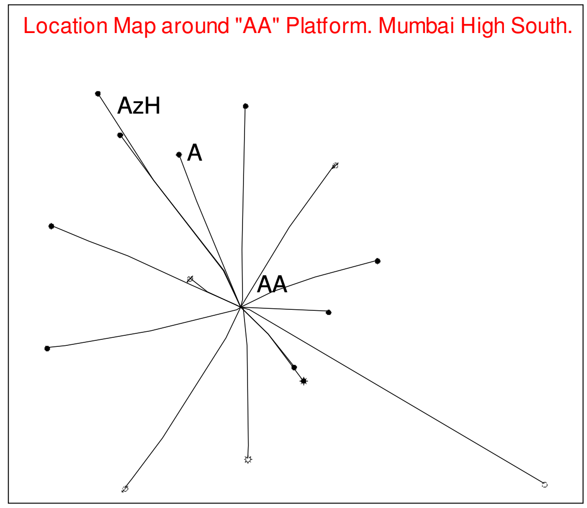

Fig 4: Original well and sidetracked well

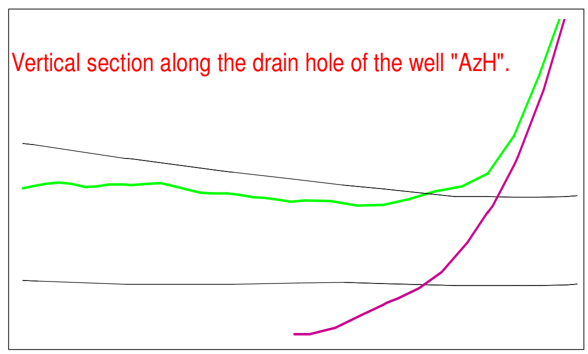

Fig 5: Trajectory of well AzH in 'B' layer

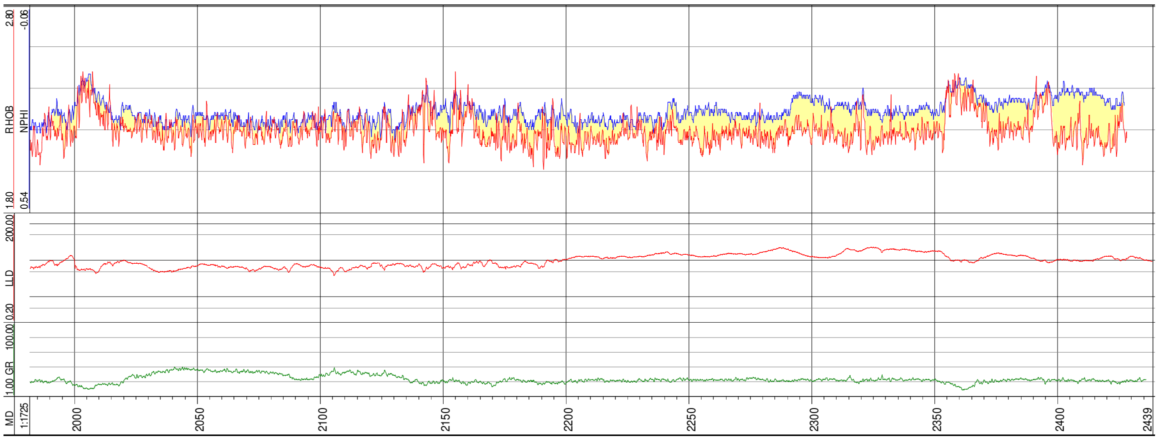

Fig 6: Log of sidetracked well AzH (Drainhole portion)

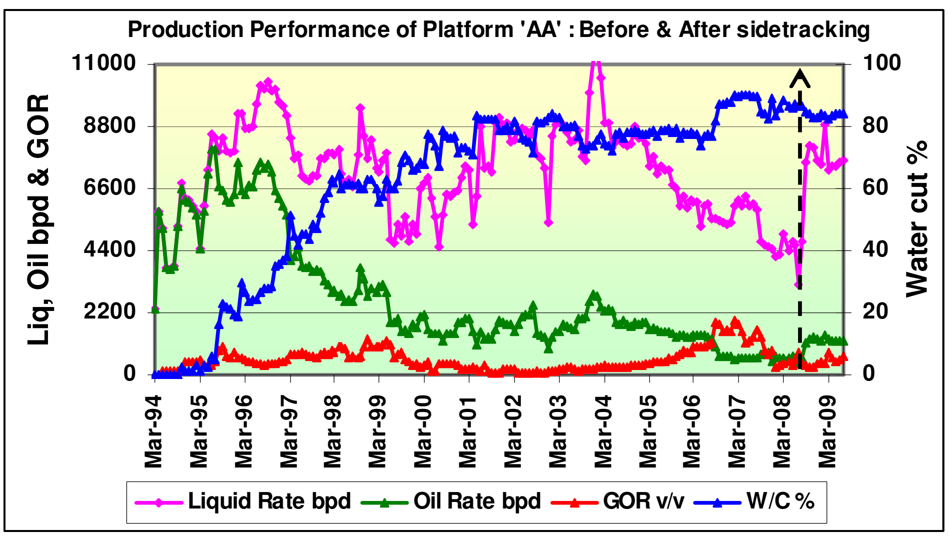

Figure-7: Production performance of AA Platform before and after sidetracking