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Enhancement of oil production from an offshore brown field platform by entering in an undrained area with integrated approach - A case study in Mumbai High Field.

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Summary

The carbonate formations of Mumbai High field are the most prolific oil reservoirs in India. These Miocene carbonates are very complex in nature in terms of reservoir heterogeneity. The Mumbai High South (MHS) field was put on production in October 1980 and by Sep 2011, has produced 273.17 MMt of oil, which is about 27.28% of the in-place oil. The main pay zone L-III is a multi-layered limestone reservoir with a large gas cap and partial water drive. The field is under water injection for the last 25 years for reservoir pressure maintenance.

Phase-wise development efforts are being made to improve recovery following a strategy incorporated entering in an undrained area, reduction of inter-well spacing through infill drilling and improvement in water injection to enhance areal sweep. Targeting the zones and patches of untapped oil for enhancement of oil production from offshore brown field by entering in an undrained/ new area with integrated approach were planned through existing platform in the southern part of Mumbai High South.

This paper focuses on performance of drifted inclined conventional and horizontal wells through one of the existing platform, named here as 'X'. The platform was installed with 9 slots but initially only six wells were drilled out of which three wells are oil producers, two wells are water injectors and one well was abandoned. The wells falling in the northern part of the platform are having oil bearing layers A2-VII, N, B and C. The platform 'X' is located in the low, bounded by two NNE-SSW trending faults. The L-III section in the wells drilled in this low is observed to be shaly/poorly developed. Well X-B of this platform was drilled down to 1685 m and 9 5/8" casing was lowered and was abandoned as the L-III was expected to encounter poor facies. Based on G & G data and reservoir properties of MH-A block, one development location X-AH was drilled as horizontal ERD well in May 2004 for exploitation of oil from new area with available slots located in the South of the platform 'X' where layers A2-II+III, IV are oil bearing. The well X-AH is presently producing oil 609 bopd with 73% of water cut. Encouraging results of this well gave the lead to drill another inclined conventional well X-Bz using the abandoned slot and has been completed in layer A2-III+IV in August 2010 for the further development of this block. The well is presently producing oil 629 bopd with 64% of water cut. The oil production from platform 'X' has improved from 428 bopd to 1700 bopd after completion of these two wells from the new block.

The present study has shown that placement of the wells based on detailed analysis of available geoscientific data of nearby area with integrated approach has yielded encouraging results, as confirmed by the performance of the conventional inclined and horizontal wells drilled. The data generated from these wells would help in further development of MH-A block by drilling the wells from remaining available slots on the southern part of platform and help in further enhancing the production of MHS field.

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Enhancement of oil production from an offshore brown field platform by entering in an undrained area with integrated approach- A case study in Mumbai High Field.

Introduction

Mumbai High is the giant offshore oil field of India 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 and each of 2-5m thickness, separated by 1-5m thick shale layers. The multilayered heterogeneous carbonate reservoir has a complex mixed drive mechanism of depletion with expansion of gas cap. Development of L-III layer was carried out in phases, since 1976. Water injection with rows of injectors was started from Apr-84 and gas lift facilities were created in March-92.

As many as 73 well platforms have been installed in Mumbai High South field. Platform X, Y and Block MH-A are shown in the southern part of map of Mumbai High South field (Figure-1). Geologically this is the crestal part of the multilayered LIII reservoir. The nine-slot platform 'X' was installed in 1992-93 and six wells have been drilled. Out of the six wells, three wells X- C, X-Dz and X-E are oil producers producing from different sub-layers of L-III reservoir, two wells are water injectors in L-III reservoir converted during 1993-94 period and one well was abandoned in L-III reservoir during the year 1994. Although the platform was a prolific producer with initial oil rate of around 8,000 bopd, the oil rate gradually declined due to water-cut and high GOR and by April 2004, the platform production was hardly 428 bopd. Integrated geoscientific studies were taken up to examine the possibility of production enhancement from the platform by venturing into an area of structurally unknown and uncertain development of reservoir facies in the block MH-A located towards south of the field. This area is outside the area of the current re-development programme of Mumbai High South. Positive results of drilled wells X-AH and X-Dz in this area have extended the area for exploitation of oil from MH-A block using the available facilities and also open up the avenue for further development.

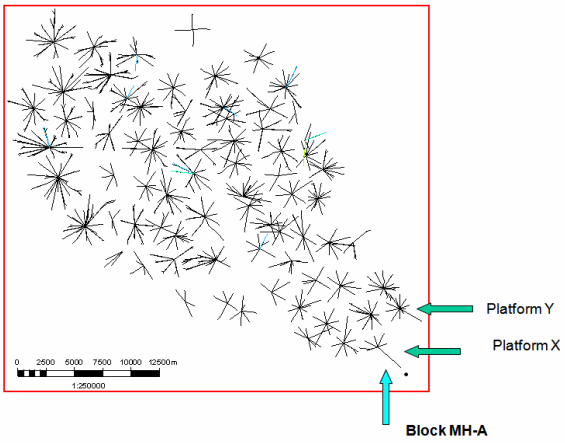


Fig: 1 Platform location map of Mumbai High South

Production History

The MHS was put on production in October 1980 and by Sept 2011 has produced 273.17 MMt of oil from the reservoir, which amounts to about 27.28% of inplace oil. The average 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, 38,352 bopd during Sept'10 with GOR of 337 v/v and water cut of 72 %. The field has passed the mature stage of its production life and has entered into the declining phase. Concern was felt in 1998-2000 because of continuous decline in oil rate and increase in water-cut in spite of drilling inputs. 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.

Geology of the Area

The structure contour map at L-III top indicating structural disposition and the location of the platform-X and Y wells are given in figure 2. The area of the study falls in the BH-A fault block in the southern part of the Mumbai High South field. It is separated by a NNE-SSW trending saddle near X-Y platforms from the main field. The BH-A block is oil bearing in A2-II+III to A2-IV layers of L-III reservoir in the western part of the block whereas A2-V +VI appear to be oil bearing in Eastern part. The pay thickness in MH-A block is depending on the structural configuration. In MH-A block four wells have been drilled; one exploratory well MH-A and four development wells X-AH, X-Bz , X-Dy & Y-A. In MH-A no GOC/GSC is seen and OWC is at 1341.5 m (TVD-SS) in A2-IV layer. In well X-AH A2-III top is at 1321.35 m (TVD-SS) no GOC/OWC is seen. In the well Y-A the GOC is at 1313.5 m (TVD-SS) in A2-IV and OSC is at 1322.7 m (TVD-SS) in A2-VI layer.

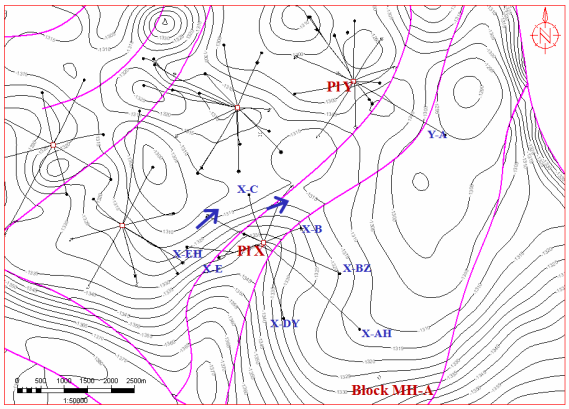


Fig: 2 Structure map on top of L-III in platform-X and Y area

Methodology and results

Drilling development wells through available platform slots and sidetrack wells is a proven incremental recovery option and to recover more of bypassed mobile oil/undrained oil in complex carbonate reservoirs after water flooding. This has increased the amount of recoverable reserves and the effort is continued. A number of sub-optimal producers were also converted as sidetracks under brown field development.

The drilling, completion and production history of all the wells in the area was critically reviewed. In 1981, exploratory well MH-A was completed in a separate culmination in the Southern part of Mumbai High structure, separated by a narrow graben from the main field. The well was drilled to Basement and produced oil @ 2117 bpd with 10% water cut through 0.5" bean from sub-layer of A2-III of L-III reservoir. It was seen that out of the six wells drilled on 9 slots platform X, well X-B was abandoned due to poor facies, well X-Dz was closed due to high water cut, two producer X-C & X-E was producing around 400 bopd and two injector X-F & X-G was injecting @5000 to 6000 bwpd each. Well X-E was sidetracked as X-EzH in a better area for exploitation of bypassed oil. For enhancing the oil production from the platform through available slots one well X-AH was drilled towards MH-A block in May 2004. Wells X-Bz and X-Dy were considered as good candidates for sidetrack in L-III reservoir. One well Y-A in another platform Y was drilled to know the hydrocarbon extension in the eastern part of BH-A block. The details of these four wells are as under.

Case Study: Well X-AH

Well "X-AH" is a horizontal ERD well drilled from X platform in south-easterly direction during March to May 2004 and completed as 6" drainhole from 2974-3393m (419m) in A2-III layer with bare foot completion and subsequently put on production in May 2004. In well X-AH upper part of L-III layer limestone, Viz., A1, A2-1 & A2-II are shaled out. Layer A2-III is having good reservoir facies and is oil bearing. A2-III top is at 1321.35 m (TVD-SS) no GOC/OWC is seen. A2-III top in this well is shallower to the regional GOC of main Mumbai High South field (1330m MSL). However location of the well is shallower in comparison to well MH-A by 12.5m.

The well on completion as a drainhole in A2-III layer started producing with an initial oil rate of 422 bpd with water cut of 83% and GOR of about 1476 v/v on gas lift. Since inception well consistently producing liquid 3000-3500 bpd, oil 400-450 bpd with high water cut ranging from 85-90% and GOR around 200 v/v. In October 2005,

it was decided for WOJ and complete the well with an intelligent completion in order to reduce the water production and enhance the oil productivity. Based on production history and petro-physical characteristics, well was completed with three sliding sleeves for dividing the drain hole in three segments. After testing of individual segment it was inferred that, there is hardly any gain in oil production and no reduction in water cut observed. This may be due to malfunctioning of the sliding sleeves. After the job, all the three segments were opened for production. The peak oil rate was 896 bpd with water cut of 72% and GOR of 317 v/v in June 2009. The cumulative oil production from the well is 0.192 MMt. At present well producing with oil rate of 561 bpd with water cut of 75% and GOR of about 607 v/v on gas lift. The reservoir pressure recorded in well in May 2007 was 1650 psi at datum.

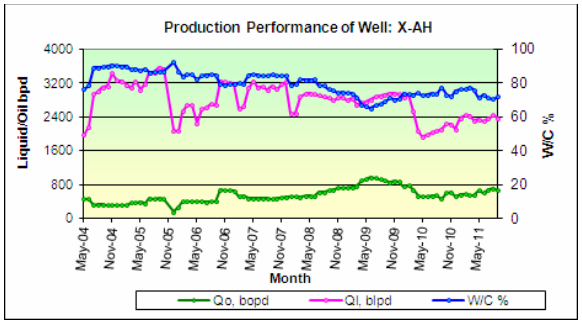


Fig: 3 Production Performance of Well 'X-AH'

LOG Motif of Drain Hole section along with Completion

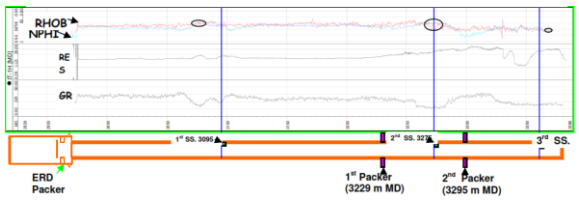


Fig: 4 Log motifs of Well 'X-AH'

Well X-Bz

Well X-B of X platform was drilled down to 1685 m in May 1993 and was abandoned as the L-III was expected to encounter poor facies. The abandoned well X-B was identified for revival by sidetracking in the area of MH-A block for exploitation of undrained oil. Accordingly X-B was sidetraked as X-Bz in South-east direction, a high angle well drilled during June-July 2010 and completed in layer A2-IV and subsequently put on production in August 2010. The well started producing with an initial rate of 82 bopd with 90% water cut and salinity of about 25740 ppm (formation water). The layer A2-IV are found to be good in this well with effective thickness of 4m, resistivity varying from 6 to 12ohm-m and porosity varying from 20 to 27%. To know the source of water, PLT was carried out in Sept'10. After analysis of data it is observed that water is flowing up through channels behind casing from the lower water bearing layers. Well is worked over during Sept-October 2010 for water shutoff through selective re-perforation of A2-IV layer. The well had achieved a peak oil rate of 650 bpd with water cut of 62% during September 2011. The planned rate of oil production was around 300 bpd with water cut of 67%. The characteristic of MH-A block is that initially wells started producing with high water cut and gradually water cut reduced from 90% to 62% and oil rate has enhanced from 80 to 650 bpd. This phenomena is observed in other completed well X-AH in this block due to cleaning of well and change of relative permeability's. The cumulative oil production from the well is 0.017 MT. At present well producing with oil rate of 629 bpd with water cut of 64% and GOR of about 594 v/v on gas lift. The reservoir pressure recorded using MDT is 1698 psi in July 2010.

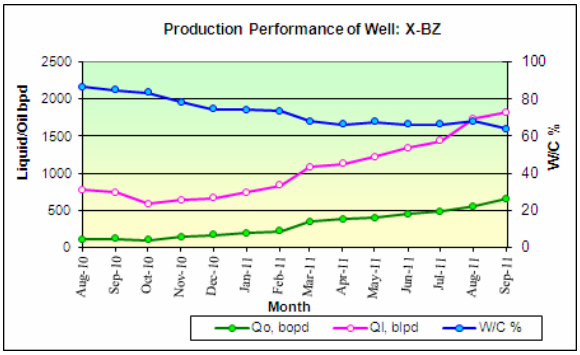


Fig: 5 Production Performance of well X-Bz

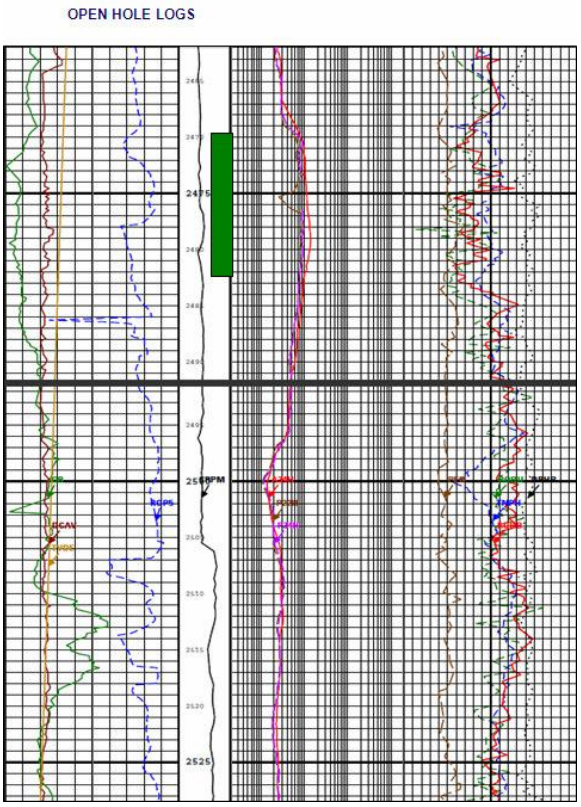
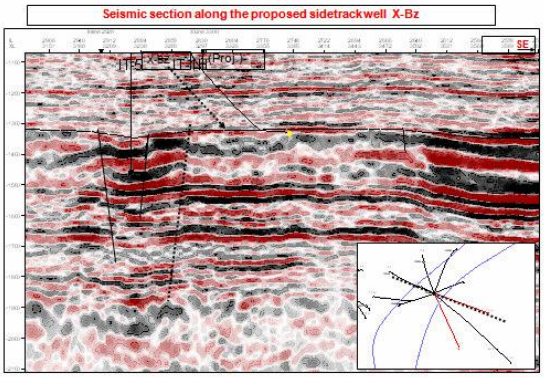


Fig: 6 Log motifs of Well X-Bz



Well X-Dy

Well X-DZ of X platform was sidetracked in north-westerly direction during Oct 1996 and completed in layers A2-V, VI, VII, N, B with gas lift. On the basis of PLT result gas shut off was carried out by squeezing the layers A2-V,VI,VII. From Mar'2001 well was producing with an average oil rate of 30-40 bpd with high water cut of more than 90%. The low producer well X-DZ was identified for revival by sidetracking in the area of BH-A block as a water injector for pressure maintenance. Accordingly X- Dz was drilled as X-Dy in South direction, a high angle well during August-September 2010 and completed in layer A2-IV, V and on testing produced traces of oil. It is observed that two wells are producing significant amount of oil in BH-A block, pressure maintenance is required for consistent production from the block. Subsequently well X-Dz is converted as water injector in August 2011 with the injection rate of 4658 bawd.

Well Y-A

The assessment cum development well Y-A drilled from clamp-on of Y platform with the objective to test the hydrocarbon potential towards the extreme east and structural position in the block of BH-A in MHS area. The upside potential of the L-III sub-layers below A2-IV was expected due to the structurally favourable position. Well Y-A was completed in south-east direction during Feb 2009 and completed in layer A2-V. GSC observed in layer A2-IV and OSC in layer A2-VI. During initial testing well produced gas 1.70000 m3/d. Poor cementation was seen as per CBL log and cement squeeze job done with marginal improvement. Well was closed for reservoir management.

The improved understanding of reservoir complexity through completion of all the four wells outside the area of the current re- development programmer on the basis of integration of log characteristics and seismic attributes, refined geological and reservoir simulation models have provided a higher degree of confidence to assess the potential reserves of undrained oil. Recovery of difficult oil has been possible through horizontal and conventional wells with advanced technology of LWD-Geosteering.

The main strategy for the exploitation of undrained oil has targeting it with suitably placed wells in better petrophysical properties, reservoir facies. Consistent production performance of the wells indicates that the block has higher potential and there is scope for drilling additional wells with the existing facility for exploitation.

Further on the basis of production performance and pressure data of all the wells will help for exploitation of untapped oil through mix of conventional and horizontal wells and increase in oil production. Also try to spot out the presence of major / minor faults and hydrocarbon limits in the vicinity of the producing area.

Based on log characteristics the wells have been completed in sub-layers of A2-III/IV of L-III. The oil production from platform 'X' has improved from 428 bopd to 1700 bopd after completion of two wells in MH-A block. In May'07 recorded pressure in well X-AH was 1582psi at 1330m and in well MH-A was 2210 psi at 1330 m Jan'1981. Pressure data indicated that with the consistent production from BH-A block reservoir energy is depleting therefore one well is completed for reservoir maintenance of the block. These wells have helped to ramp-up production from the platform.

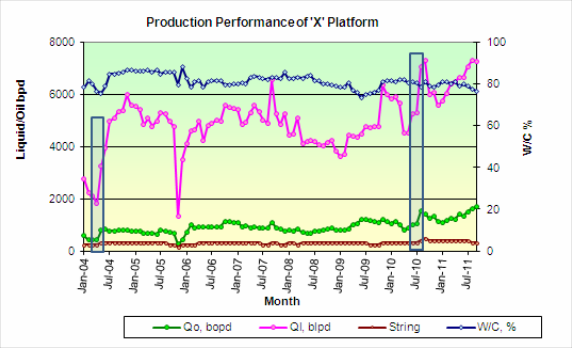


Fig: 7 Oil production improvements after completion of wells

Challenges

1. Variation in structural position in separate culmination in the southern part of Mumbai High structure, separated by a narrow graben from the main field.
2. Estimation of reserves and hydrocarbon limits.
3. Placement of well in the targeted sub layers.
4. Drilling, well completion and cement bond of high drift wells.

Conclusions

In mature offshore fields there is scope of enhancing production from the existing platform location areas by changing drainage area through drilling of new well/sidetracking of existing poor performers. The area of study block of BH-A is outside the area of the current re-development programme of Mumbai High South, therefore suitable placement of horizontal and conventional wells for enhancement of production is a big challenge. The geological model for study area was based on very scanty data, fluid contacts and hydrocarbon limits was also not certain. Therefore reprocessed logs of well BH-A helped in estimation of porosity, water saturations, oil and gas contacts in the area. Phase-wise drilling of wells helped updating the structure map and encouraging oil production results from the extended area using the available facilities opened the avenue for further development of the block.

The risk can be mitigated by integration of all available geoscientific data and using multi-disciplinary approach. Enhancement of oil production from offshore brown field poor performance platform entering in an undrained area with integrated approach can be identified and realized with careful analysis, judicious use of new technologies and readiness to accept the challenge with some risk.

The success of the MDT approach has been encouraging and will help in further development of the block and enhancement of production. Improving productivity of these wells will help in stabilizing the field production rates in a cost effective manner and reducing the inventory of sick wells.

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