Maximizing the Hydrocarbon Recovery By Overcoming the Challenges in ASP Flooding: A Case study of Viraj Field

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Abstract

Approximately 60-70% of the oil in place cannot be produced by conventional methods. Enhanced oil recovery phase of oil reservoirs production usually comes after the primary and secondary recovery through artificial lift and water or gas injection. Chemical EOR process are implemented to reduce the residual oil saturation by lowering the interfacial tension between oil and water and develop a favorable mobility ratio between displacing fluid and displaced fluid. The lowering of interfacial tension can be achieved by using alkali & surfactants that improves the oil displacement efficiency. Further the viscosity of the displacing fluid can be improved by using polymers which finally improves the volumetric sweep efficiency by developing a favorable mobility ratio between displacing fluid and displaced fluid. Viraj field which was discovered in year 1977 by ONGC ltd was found suitable for chemical EOR due to its viscous crude of viscosity of around 50 cp at reservoir condition (81ºc) and medium API of 18.9º. After completion of a successful ASP pilot, the field-wide implementation of ASP was commissioned on July 19, 2019. This technical paper examines a case study covering the widespread application of ASP flooding and the challenges encountered in Viraj Field.

Introduction

Brown fields are where the majority of the world's oil is currently produced. Currently oil firms are highly concerned for increasing oil recovery from the mature fields. After primary and secondary recovery, it becomes crucial to use some oil recovery techniques in order to recover any leftover oil in the reservoir. Earlier in the 1990s, the national oil firm, ONGC Ltd., recognized the value of the EOR mechanism and investigated the viability of chemical EOR in the L1&L2 reservoir of Viraj field of the Ahmedabad Asset. Viraj field is situated in the Ahmedabad-Mehsana tectonic block of Cambay basin. Viraj structure is a double plunging anticlinal closure with a North-South trend. It takes up about 4 km^2 of aerial space. L1 & L2 pays are the main reservoirs of Viraj field having high permeability in the range of 1 to 10 darcies. The reservoir is supported by a strong active aquifer. Because of the sand's poor consolidation and the resulting sand-cut issue, all of the wells have been completed on gravel packs. After doing a primary recovery of ~26%, studies for using chemical EOR seeing the medium heavy crude was carried out by Institute of reservoir studies of ONGC ltd. Following the laboratory studies an ASP pilot was designed and implemented in field by year 2002. After completion of pilot, the field wide implementation of ASP flooding was also conducted incorporating the lesson learned from the pilot period. The field-wide ASP scheme consists of 35 oil producers and 14 ASP injectors was implemented in July'2019 (shown in figure 1). The highlighted portion shows the pilot area.

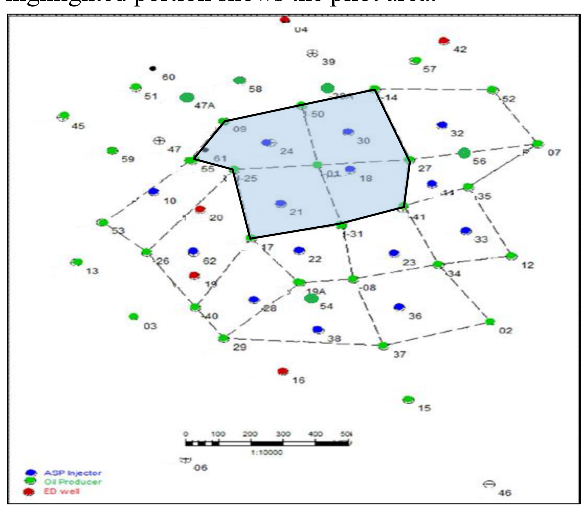

Figure 1: Map showing the pilot area.

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Reservoir description

The major producing horizons in Viraj field is K-IX+X which is subdivided into two layers viz. L1 and L2. These layers are separated by coal shale band of 4 to 5 meters. The structure of the field is a doubly plunging anticline. The Average reservoir depth and the average pay thickness are 1300 meters and 15 meters respectively. Area weighted average porosity is 30% and initial average oil saturation is in range 66-70%.

Crude is acidic in nature, having acidic component 1.825 mg KOH/gm of crude oil. Following are oil and formation water properties;

Crude properties	
API gravity	18.9
Viscosity at Res Temp.	50 cp
Asphaltene (%w/w)	4.48
Resin (%w/w)	18
Wax (%w/w)	5.67

Formation water properties, ppm	
Carbonate	Nil
Bicarbonate	1159
Chloride	4935
Sulphate	0
Calcium	112
Magnesium	44
Sodium	3422
Salinity as NaCL	8132

ASP Pilot Implementation

In year 1992, preliminary studies were conducted at IRS, Ahmedabad, to build the ASP pilot. On August 10, 2002, the ASP pilot was launched in L1 & L2 reservoir on four inverted 5-spot patterns with the goal of evaluating the process's effectiveness in real-world settings and optimizing the laboratory parameters for widespread field use. Multiple sulphonate surfactant samples were examined for solubility, CMC, thermal stability, and IFT reduction. Best screening results were found for petroleum Sulphonate. The alkali used was sodium carbonate because of its ease of propagation in porous media. Partially hydrolyzed poly acryl amide (PHPA) polymer was used as it was found thermally stable at reservoir temperature of 81°C. ASP pilot was started in July'2002 and concluded in Jan'2010. Following are the silent features of the pilot:-

a. ASP pilot had 4 inverted 5 spot patterns comprising of four injectors and nine oil producers.
b. 0.2 PV of ASP slug having alkali concentration of 1.5%, surfactant concentration of 0.2% and polymer concentration of 800 ppm was recommended for injection.
c. ASP slug of recommended concentration was injected for a period of 311 days at a rate of 800 m^3/day through 4 ASP injectors.
d. ASP slug was followed by 0.1 PV of graded polymer buffer of concentration 600, 400 and 200 ppm each for a period of 155 days at a rate of 800 m^3/day.
e. After polymer buffer, 0.6 PV of chase water injection was also carried out for a period of 622 days at a rate of 1200 m3/day.

Pilot results and learning

a. A total of 0.058 MMm3 of incremental oil was recovered during pilot phase.
b. Reduction of around 4.3% in water cut observed during pilot from pre pilot average water cut of 78.7%.
c. Early breakthrough of chemicals in some nearby oil producers was observed.
d. Laboratory studies were re-visited and a re-optimized chemical formulation and slug size was designed for commercial scheme.

Field wide Implementation

Following the successful conclusion of the ASP pilot, studies for the expansion of the field size were conducted. To re-optimize the chemical slug size and commercialize the ASP at a field scale, numerous laboratory experiments were carried out. Three Berea cores and one native core were used in the trials to test the effectiveness of core flood displacement efficiency experiments. The oil recovery for various alkali, surfactant, and polymer concentrations was found in the range of 10.2% to 18.9%. The study ultimately recommended to use an ASP slug of 0.3 PV with a higher chemical concentration compared to

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the pilot phase. Summary of displacement experiments are shown in table 1 and figure 2:-

Parameters	Expt No -1	Expt No -2	Expt No -3	Expt No -4
Type of core	Berea	Berea	Berea	Native
Core length (cm)	19.80	19.90	19.80	7.80
Cross sectional area, cm2	11.4	11.1	11.1	10.1
Pore Volume (ml)	48.0	49.0	49.0	21.5
Air Permeability(At Room Temp), md	1744	1794	1583	8693
OIIP, cc	41.4	44.7	42.8	17.5
Soi (Initial), %PV	86.25	91.22	87.35	81.40
WaterFlood Oil Produced, cc	15.50	19.20	18.80	5.80
Tertiary Oil In Place (TOIP), cc	25.9	25.5	24.0	11.7
Sorw (after WaterFlood), %PV	53.96	52.04	48.98	54.42
Slug details				
Slug size (PV)	0.3PV	0.3PV	0.3PV	0.3PV
i) Surfactant: Name	Sulfodet	Sulfodet	Sulfodet	Sulfodet
Conc. (%, A.M.)	0.25	0.25	0.25	0.25
ii) Alkali: Name	Na_2CO_3	Na_2CO_3	Na_2CO_3	Na_2CO_3
Conc., % by wt.	2.5	2.5	2.5	2.5
iii) Polymer: Name	P-1000	P-1000	P-1000	P-1000
Parameters				
Conc, ppm	1500	2000	1500	1500
Polymer Buffer-3: Size (PV)	0.1 each	0.1 each	0.1 each	0.1 each
Concentrations (ppm)	1200, 800, 400	1500, 1000, 500	1200, 800, 400	1200, 800, 400
Chase Water, ml	25	25.1	24.4	9.5
Chase Water, PV	0.52	0.51	0.50	0.44
ChemFlood Oil Produced, cc	14.50	11.25	13.6	5.5
DispEfficiency: Water flood (% OIIP)	37.44	42.95	43.93	33.14
Chemflood (% OIIP)	35.02	25.17	31.78	31.43
Stage of application of ChemFlood	tertiary	tertiary	tertiary	tertiary
Breakthrough Recovery (%) at PV	12.08% at 0.12PV	17.90% at 0.2 PV	18.93% at 0.2 PV	10.29% at 0.11PV

Table 1: LCDE Experiment data

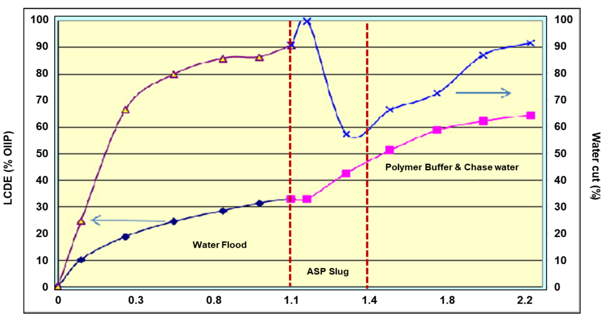

Figure 2: LCDE experiment results.

The dynamic adsorption of chemicals for different experiments are shown below in Table 2

Experiment	Core	Alkali mg/gm rock	Surfactant mg/gm rock
1	Berea	0.31	0.06
2	Berea	0.15	0.05
3	Berea	0.16	0.05
4	Native	0.50	0.08

Table 2: Dynamic adsorption of chemicals

The displacement experiments confirms the reduction of Sorw (residual oil saturation after water flood) by up to 38% by the end of ASP flooding. Hence after detailed laboratory studies and optimizations the Field wide ASP injection started on 19th of July 2019 at a rate of 1120 m3/day through 14 injectors. Following are the silent features of ASP scheme.

a. Phase-I comprises of injection of 0.3 PV of ASP slug having alkali concentration of 2.5%, surfactant concentration of 0.25% and polymer concentration of 1500 ppm for 56 months.
b. Phase-II comprises of polymer buffer of concentration 1200 ppm for 19 months.
c. Phase-III comprises of polymer buffer of concentration 800 ppm for 18 months.
d. Phase-IV comprises of polymer buffer of concentration 400 ppm for a period of 24 months.

Initial Challenges

Following were the challenges during implementation of scheme:-

a. The proposed profile recommended a desired liquid withdrawal rate of ~1250 m3/d from 35 oil producers. However, the initial rate of liquid withdrawal was constrained by the wells' gravel pack finish and lesser withdrawal pump capacity.
b. Initially, the scheme could not perform as optimally as envisaged due to COVID pandemic, since maintaining the desired ASP formulation was hampered.
c. High capability pumps were installed for optimizing the liquid withdrawal. Liquid withdrawal rate was enhanced from around 400 m3/d to upto 1300 m3/d.
d. Few Surface issues were seen to be observed like increase in the frequency of SRPS chocking, calcite deposition in heating treatment equipment, formation of difficult emulsions and increased SRP unit amperage.

Revisiting the full field simulation study

ASP slug samples were routinely collected to determine the potential cause of the ASP scheme's subpar performance. In order to identify the causes of variance and further implement the necessary midcourse corrections, the simulation research for whole-field ASP flooding was reviewed. The model included historical output rates till 2020 and initiation of ASP injection in year 2019 having alkali concentration of 2.5%, surfactant concentration of 0.25% and polymer concentration of 1500 ppm. The ASP slug's viscosity was also measured at reservoir temperature and determined to be roughly 4 cp. After performing an ASP injection at the suggested concentrations, a drop in IFT of around 1000 times was seen in the model shown in Figure 3. The Capillary number in reservoir which normally remains in the range of 10^{-6} increased up to 10^{-3} shown in Figure 4

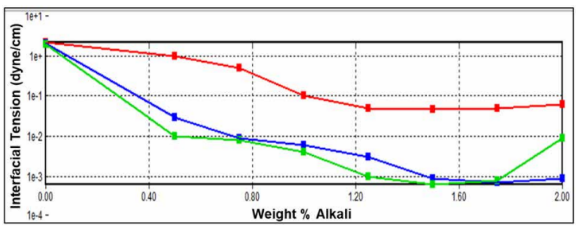

Figure3: IFT Curve.

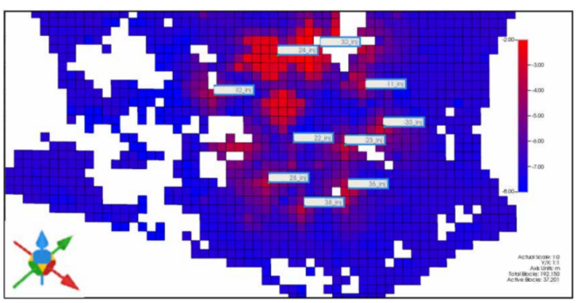

Figure 4: Capillary number distribution.

The field performance study and revisiting of the laboratory tests supported the conclusion that the main cause of the ASP scheme's sub-optimal performance is the lower slug viscosity compared to expected viscosity (~7cp). Low ASP slug viscosity made it difficult to attain the appropriate mobility ratio (<1) which leads to develop a poor sweep efficiency. Based on this, it was also proven that lowering the alkali level would increase the viscosity of the ASP slug. As a result, the formulation of 1.2% alkali, 0.25% surfactant, and 1500 ppm polymer has been finalized as a mid-course correction which was quickly implemented. Since December 2021, ASP injection has been performed with lower alkali concentrations (1.2% w/w) and suggested concentrations of surfactant and polymer.

Current Performance and results

As a results of quickly implementation of mid-course correction, the oil production increased from 138 m3/d in February 2022 to 304 m3/d in May 2022. Additionally, the water cut in the field decreased from 91 to 78.8%. As of April 2023, the scheme is producing 294 m3/d of oil with 80.7% water cut. The oil production performance of the field since implementation of ASP scheme is given in figure 3.

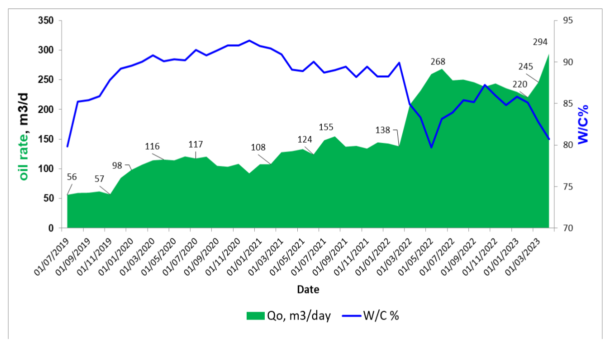

Figure 5: Production performance.

After implementing the midcourse adjustment, surface handling difficulties including the frequency of SRP chocking up and scale deposition on heater treater fire tubes were also minimized. The ASP project's monitoring tactics and methodologies provided the required insights for modifications to the plan midway through. The result is an increase in oil production of almost 200% (Figure 5). Because of the decrease in alkali use, OPEX was also decreased, which boosts the scheme's economics.

Monitoring and surveillance

The scheme was closely monitored from the very beginning. Based on field performance and the examination of crude samples, necessary steps such as pattern balancing and artificial lift optimization were carried out. The conformance of oil producers

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and ASP injectors were continuously monitored using streamlines as shown below in figure 4 (generated as on 01.04.2023). Based on the stream lines the upswept areas were identified for necessary actions. Water cut maps (Figure 6) aided in the examination of the field's high water-producing regions. Continuous analysis of samples from oil producers and ASP injectors helped in taking decision for implementation of mid-course correction.

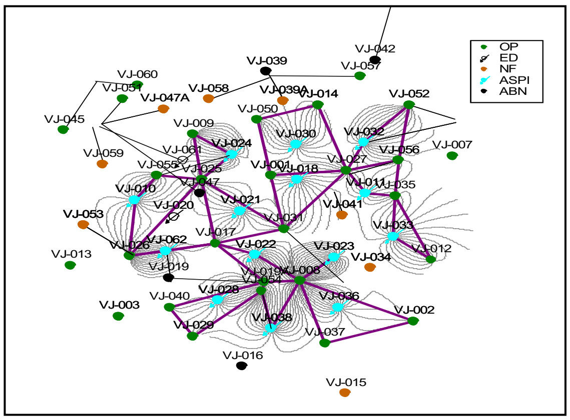

Figure 6: Streamline analysis.

Monitoring challenges

ASP flooding being one of the most critical EOR process comes with numerous challenges while implementing as well as during monitoring. Following are few challenges encountered during ASP flooding in Viraj field

a. Alkali reacts with divalent ions of formation water (ca^{++}, Mg^{++}) produces precipitations in the reservoir like calcium carbonates and magnesium carbonates. Further it becomes difficult to inject Slug in the injectors due to well bore chocking. For this purpose suitable scale inhibitors are used.
b. ASP injection arises processing challenges due to tough emulsion production. Suitable de-emulsifiers are being tested in the field for this.
c. Deposition of scale on fire tubes of heater treater becomes a challenge to give sufficient heat duty to emulsion. The XRD results of one of the deposited sample are shown in Figure 7.

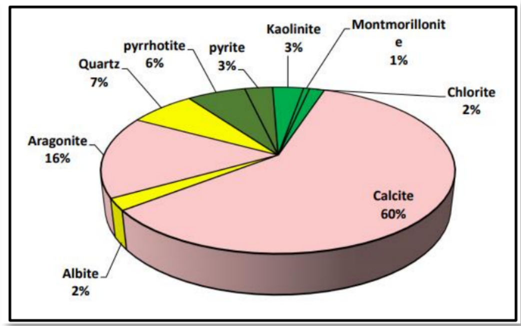

Figure 7: XRD results.

d. Maintaining uniform ASP front in the reservoir is a challenge for which pattern balancing was done on regular basis.
e. Fluctuation in water production is being observed in the field due to chemical injection.

Conclusions

The Viraj Alkali-Surfactant-Polymer Project was India's first commercial chemical EOR implanted by ONGC ltd. While the pilot was really being implemented, ASP flooding demonstrated positive outcomes. Any chemical EOR project's success depends on careful planning, implementation, and monitoring, as well as any necessary midcourse adjustments. Corrective action is dependent on a critical evaluation of the data generated during implementation, such as the injection fluid's quality and the output fluid's analysis for chemical breakthrough or concentration, among other factors. A 200% increase in production is the result of persistent work that included thoughtful mid-course correction to optimize the quality and quantity of the ASP solution, pattern balancing through producer withdrawal rate adjustments to create a uniform flood movement and improvement in sweep efficiency. Over a 15-year period, the scheme will continue to generate 7% more oil. The knowledge gained from this project would be essential and valuable for the

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accomplishment of subsequent ASP projects in oil and gas sector.

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