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Evaluation of Chemical Application as Pilot to Improve Oil Production from High Viscous Oil in Sandstone Reservoir

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Abstract

Chemical injection stimulation is one of worldwide proven technologies for viscosity reduction and mobility enhancement. The principle mechanism is to reduce heavy oil viscosity by injecting of active chemical agent solution into reservoir as huff and buff practice, the agent solution is act at near wellbore area by remove plugging of heavy organic material, Energy support due to large quantity of stimulation liquid being injected into the formation, viscosity reduction by emulsification and micro-emulsion which will greatly enhance oil mobility; therefore, accelerate oil recovery and reduce interfacial tension (IFT); therefore, increase oil recovery. as global oil industry many technologies introduced to Sudanese oil fields such as chemical which had been implemented in 2018 to increase oil production by developing high viscous oil reservoirs. The pilot was done in two wells in Moga and Fula fields; they are located at southern part of western escarpment trend of Fula sub-basin, Main oil-bearing distributes in Aradeiba, Bentiu and Abu Gabra formations. Bentiu formation was selected for pilot, it is consolidated medium productive sand stone reservoir as per well test interpretation productivity index is 0.05 to 0.2 bbl/day/psia, PVT features: low bubble point pressure, low gas oil ratio (GOR), viscosity at initial pressure between 396–5902 mPa.s and 8986–13880 mPa.s at surface pressure and 29°C, permeability lab test results show strong heterogeneity formation. This paper discusses the chemical injection as enhanced oil recovery (EOR) application in block-6, investigate and evaluate pilot results, then discuss lesson learned from this pilot. Basic reservoir engineering principles and lab test result had been used to calculate production and reservoir parameters before and after implementation. The results of first well shows instantaneous downhole fluid level (DFL) raising about 129 m and remain stable while same pump speed was maintained after the chemical injection, the water cut dropped from 64% to 42% and Oil rate jumped from 95 BOPD to 204 BOPD. second well shows bad performance post the chemical injection and the oil rate decreased from 60 to 40 BOPD and WC increased from 70% to 93% due to well located in the down dip close to OWC and strong reservoir pressure support.

Keywords: Downhole fluid level, enhanced oil recovery, chemical flooding, sustainable energy production, mobility enhancement

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INTRODUCTION

Because primary and secondary recovery methods fail to recover more than 20%–40% of the original oil-in-place out of these reserves, any use of enhanced oil recovery (EOR) techniques for incremental oil recovery has become absolutely essential [1].

Chemical injection stimulation is one of worldwide proven technologies for viscosity reduction and mobility enhancement. The chemical flooding methods hold particular attraction for recovering the “residual oil” left in the reservoir after water flooding [2].

Gbadamosi (2019) highlighted the challenges encountered in the application of the various conventional chemical EOR methods, demonstrating that a large amount of oil deposits remains unrecovered after the application of traditional oil recovery methods. Chemical EOR has been recognized as an effective oil recovery technique for recovering bypassed oil and residual oil trapped in reservoirs. This study provides detailed information on chemical EOR applications for sustainable energy production [3].

The conventional viscosity reducer is sulfonate surfactant and phosphate surfactant, the main mechanism for viscosity reduction is by emulsification.

To achieve high viscosity reduction by conventional surfactant, strong stirring intensity is needed, therefore, the actual viscosity reduction rate is not good as lab test result.

Chemical cold production technique of heavy oil targeted the following conditions:
1. The low productivity wells at late stage are not economical for steam injection.
2. The wells that unable to produce by steam flooding due to thin oil layers and large well spacing.
3. The low productivity wells due to low reservoir temperature and high viscous crude oil.

PRODUCTION TECHNIQUE

The principal mechanism is to reduce the viscosity of heavy oil by active chemical agent solution injected into the reservoir. Agent solution act at near well bore area by remove plugging heavy organic materials, emulsion plugging etc.; therefore, improving the mobility of heavy oil, force the deep heavy oil flowing and eventually increase the recovery of oil wells.

Principle of Chemical Cold Production for Heavy Oil

1. *The energy support mechanism for oil displacement:* The large quantity of stimulation liquid injected it will act to support formation energy to drive the oil.
2. *The mechanism of viscosity reduction:* by emulsification and micro-emulsion, it will enhance the crude oil mobility for rapid recovery, also increase the drainage radius around the wellbore.
3. *The mechanism of reducing the interfacial tension (IFT) stimulation*: liquid will make the oil/water interfacial tension at a lower level, that is, significantly reduce the capillary force, viscous force of fluid.
4. *The mechanism of blocking removal Stimulation* liquid can dissolve the deposit heavy organic substance near wellbore zone, therefore restore its reservoir permeability, in addition the chemicals sticking in the wellbore has the function of preventing the asphalt remaining in the wellbore.

Lefebvre (2012) studied building a roadmap for enhanced oil recovery prefeasibility study. The outcome of this roadmap is at field scale, for a given EOR method, an expected additional recovery factor and the corresponding discounted NPV with an uncertainty analysis on the main technical and economical parameters [4].

In 2016, Husham et al. illustrates that the previous studies in screening of EOR methods for the Sudanese oil fields show that Heglig Main Oil field is suitable candidate for CEOR operation, and from simulation the results show that a combination of 0.4wt% of Alkaline, 0.1wt% of Surfactant, and 0.1 wt.% of polymer in an ASP flooding process can increase the recovery factor of Heglig Main up to 43.54% [5].

Farog (2016) discussed the scope of the laboratory study, which includes the core sample, fluid sample, phase behavior test, spontaneous imbibition test, compatibility test, viscosity mixture and core flood, well selection analysis, and the implementation of SEMAR as a pilot project in the Bamboo Oil Field. The results of the pilot as Huff and Puff in three wells show that approximately 18,000 STB of oil gained from adjacent wells, indicating that SEMAR is very interesting to be evaluated for further steps in chemical EOR implementation for continuous injection [6].

The core flood results show a reduction in residual oil saturation of more than 30% of oil-in-place for an onshore oil field in East Africa. This is due to the presence of viscous oil, which has a viscosity of 20 cP and an API gravity of 28°. The majority of the produced wells were observed to have early water breakthrough and high water cut at the time of this study. The greatest technical challenge in this study was to identify an effective surfactant that could significantly reduce the water-oil interfacial tension (IFT) under the operating range. Despite the difficulties, an optimized ASP formulation containing 0.5 wt. percent alkali, 0.2 wt. percent surfactant, and 0.2 wt. percent polymer met all the requirements of the KPI [7].

Lu, 2017 discuss the optimization of chemical flooding methods to enhance oil recovery of strong heterogeneity, high temperature and high salinity reservoirs—case study of Shengli Oilfield, and the results shows that in recent five years, SPPG flooding applied in GDCR1 block enhanced current oil recovery 5.6% (total oil recovery over 60%) and decreased maximum water cut over 19.7%. Compared with other nearby same blocks, this performance is very good. This indicates that the screening method presented in this paper is effective and accurate [8].

Ali 2020 discussed that more oil can recovered from mature reservoirs after the primary and secondary oil production stages and the polymer flooding will be most effective if applied in the early stages of a water flood [9].

A comparison of water flooding and conventional surfactant flooding was performed using the numerical simulation CMG STARS to perform the sensitivity analysis on the core scale and the result obtained in CSF, which indicates that the optimum porosity and permeability range of 0.26 to 0.29 in porosity and 390 to 2220 mD in permeability is suitable to be implemented in continuous surfactant application [10].

Table 1. Lab test report FC-19 1 Well A.

<table>
<tr><td>Product name</td><td colspan="3">Multifunctional heavy oil chemical agent/viscosity reducer</td><td colspan="3">Model: trademark</td><td colspan="2">YR-ZY</td></tr>
<tr><td>Company</td><td colspan="3">Shanghai Yarun Energy and Technology Co., Ltd.</td><td colspan="3">Lab Location</td><td colspan="2">Dongying Lab.</td></tr>
<tr><td>Sample code</td><td colspan="3">FC-19 Well A</td><td colspan="3">Report Date</td><td colspan="2">1/10/2017</td></tr>
<tr><td>Evaluation standard</td><td colspan="8">Q/SH 1020 1519–2013 General Technical specification for Heavy Oil Viscosity Reducer</td></tr>
<tr><td rowspan="2">Well no.</td><td rowspan="2">Dosage (ppm)</td><td colspan="2">Sample oil Viscosity (mPa.s)</td><td colspan="2" rowspan="2">Viscosity Reduction Rate</td><td rowspan="2">Natural dehydration rate</td><td>Organic chlorine</td><td rowspan="2">Remark</td></tr>
<tr><td>Original Viscosity</td><td>Viscosity after treatment</td><td>content</td></tr>
<tr><td>FC-19</td><td>3000</td><td>2890 (50)</td><td>18(50℃)</td><td>99.38%</td><td>91%</td><td>None</td><td colspan="2">Test temperature: 50℃ Emulsion is stable; Creaming is slow</td></tr>
<tr><td>Evaluation conclusion</td><td colspan="8">As the test result of Sample FC-19 shown, we reckon well No.:FC-19 can be choosing as one target well for chemical stimulation pilot projection. But the final collection of the well shall consider the actual well condition.</td></tr>
<tr><td>Reported by</td><td colspan="2">Zhao Kuifeng</td><td>Verified by</td><td colspan="3">Li Qilian</td><td>Approved by</td><td>Ju Yi</td></tr>
</table>

Sudan Block-6 Case: Five (5) oil samples were collected from 5 producing wells (FC-19, Fula-2, Fula-10, Moga20-2 and Moga26-7) and sent for laboratory study, the study shows a very positive result with minimum 99.2% reduction on the oil viscosity (Tables 1–3).

Table 2. Lab test report Fula-2 Well B.

Product name	Multifunctional heavy oil chemical agent/viscosity reducer		**Model: Trademark**	YR-ZY			
Company	Shanghai Yarun Energy & Technology Co., Ltd		**Lab. Location**	Dongying Lab.			
Sample code	Moga-20–2 Well B		**Report Date**	1/10/2017			
Evaluation standard	Q/SH 1020 1519–2013 General Technical specification for Heavy Oil Viscosity Reducer						
Well no.	Dosage (ppm)	Sample oil Viscosity (mPa.s)		Viscosity Reduction Rate	Natural dehydration rate	Organic chlorine	Remark
		Original Viscosity	Viscosity after treatment			content	
Moga-20-2	3000	2740 (50)	16 (50℃)	99.42%	90%	None	Test temperature: 50℃ Emulsion is stable; Creaming is slow
Evaluation conclusion	As the test result of Sample Moga-20–2 shown, we reckon well No.: Moga-20–2 can be chosen as one target well for chemical stimulation pilot projection. But the final collection of the well shall consider the actual well condition.						
Reported by	Zhao Kuifeng	**Verified b***y*	Li Qilian	**Approved by**	Ju Yi		

Table 3. Lab test report Moga 20–2 Well C.

Product name	Multifunctional heavy oil chemical agent/viscosity reducer		**Model: Trademark**	YR-ZY			
Company	Shanghai Yarun Energy and Technology Co., Ltd		**Lab. Location**	Dongying Lab.			
Sample code	Moga-20-2 Well C		**Report Date**	1/10/2017			
Evaluation standard	Q/SH 1020 1519–2013 General Technical specification for Heavy Oil Viscosity Reducer						
Well no.	Dosage (ppm)	Sample oil viscosity (mPa.s)		Viscosity reduction rate	Natural dehydration rate	Organic chlorine	Remark
		Original viscosity	Viscosity after treatment			Content	
Moga-20-2	3000	2740 (50)	16 (50℃)	99.42%	90%	None	Test temperature: 50℃ Emulsion is stable; Creaming is slow
Evaluation conclusion	As the test result of Sample Moga-20–2 shown, we reckon well no. Moga-20–2 can be chosen as one target well for chemical stimulation pilot projection. But the final collection of the well shall consider the actual well condition.						
Reported by	Zhao Kuifeng	**Verified by**	Li Qilian	**Approved by**	Ju Yi		

RESULTS AND DISCUSSION

Technical proposal has been submitted for multifunctional chemical agent for heavy oil as a pilot test for two wells observing the following KPIs:

1. Reduce oil viscosity.
2. Evaluation period will be 3 months starting from day one after resuming the production.

Ensure the pump of the candidate wells will work smoothly during the evaluation period.

Well Selection Criteria

1. *Viscous crude oil:* 100~200,000 mPa.s (at 50°C).
2. *Water cut* between 30% to 70%.
3. *Low API:* < 20.
4. Low sand production.
5. Shallow to medium depth (max. 2000 m).

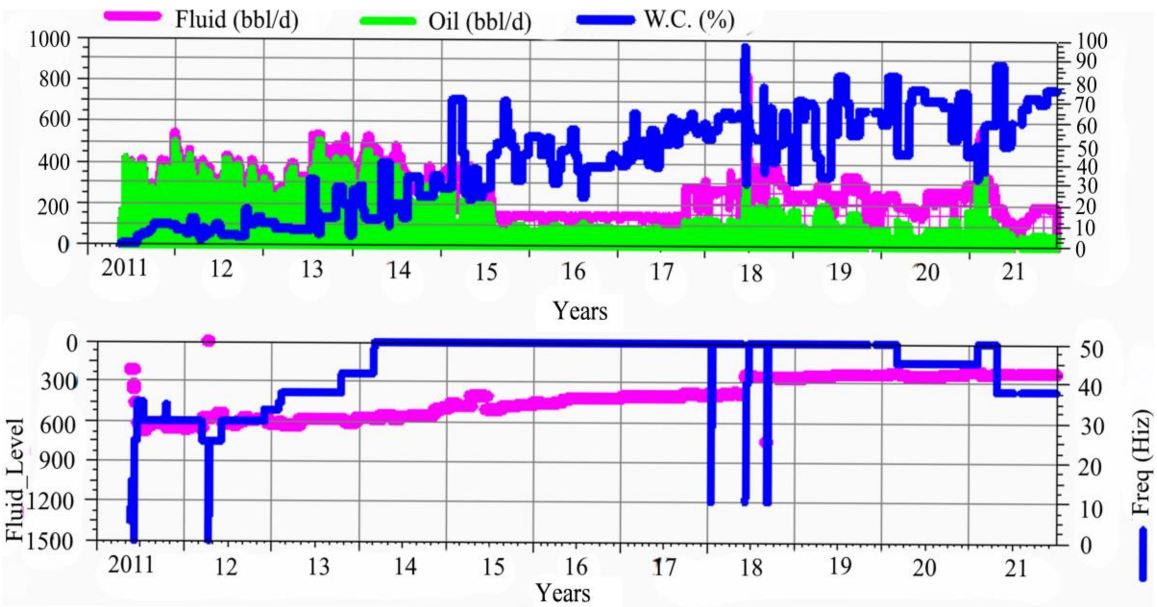
- Based on the screening criteria, two wells selected as candidate wells for the pilot test of multifunctional chemical agent: FC-16 and Moga 20–7.
- As per technical proposal, 5 ton of MFCA is to be diluted with 400 m^3 and injected into each well, concentration ratio is 1.25%.
- Lab analysis for oil sample from two chosen wells showed 98% reduction in oil viscosity under reservoir temperature.
- The field operation was run smoothly for both of well within the scheduled timetable as per designed injected volume.

Moga20–7 Well 1

Well 1 Moga20-7 is one of the development wells on the development well pattern of the Moga-20 Fault Block. Well had been drilled in 2009 and completed on July 2010 and put into production on March 2011 with 400 BOPD initial oil production and 300 BOPD average oil production rate within the first year (Figure 1).

Base on production performance:

- After 4 years of production (2014) water production start increase dramatically with obvious increase in DFL which reflecting aquifer interference to reservoir production.
- Since mid of 2015 pump fluid production had been decreased sharply reflecting low pump efficiency.



Well 1

Figure 1. Moga 20–7 production performance 1.

Well 1 Moga20–7 finished chemical injection operation on June 1, 2018, and kept under soaking for 7 days, the well resume production on June 7, 2018.

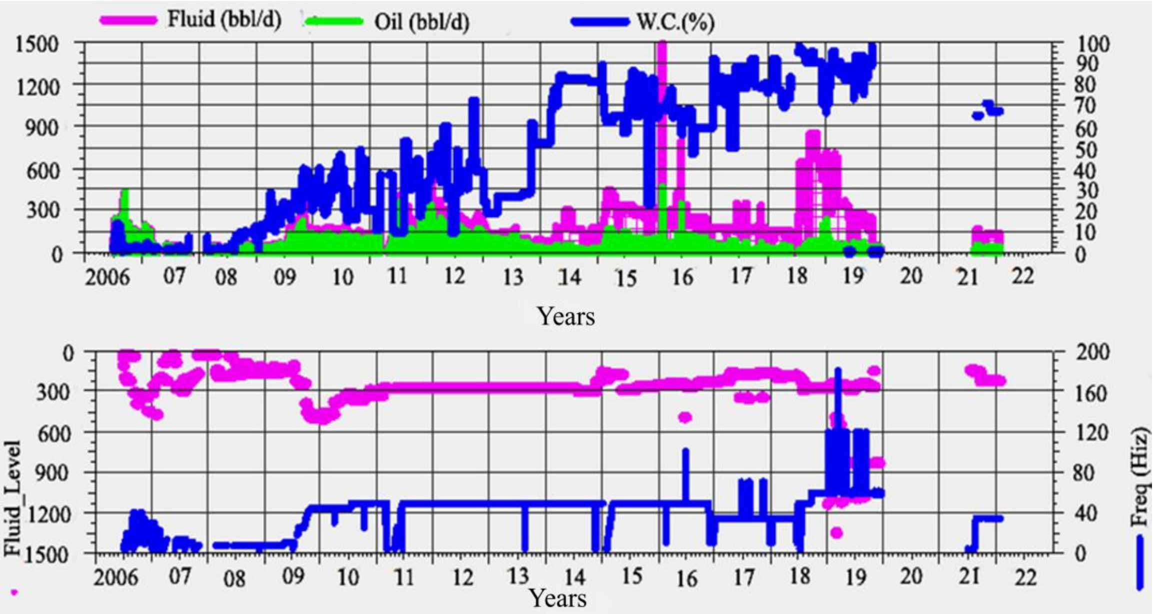
The well resume production after successful injection job with 515 BLPD liquid flow rate, 225 BOPD oil flow rate and 56% average WC the fluid level record show that 244 m was the dynamic fluid level below the surface. The well continue producing till October 2019 without any intervention then get pump failure.

Fula Central-16 Well 2

Well 2 FC-16 is one of the development wells on the development well pattern of the Fula Oilfield. The aim of drilling this well is to appraise the reservoir in the block and confirm the structure further. Well had been drilled on February 2, 2006, and completed and put into production on July 06, 2006, with 200 BOPD initial oil production and 200 BOPD average oil production rate within the first year (Figure 2).

Base on production performance:

- Well suffer from high viscosity leading to pump failure after 4 months of initial production.
- After 2 years of low water production WC start to increase sharply and reach above 80% since 2013.



Well 2

Figure 2. Fula C–16 production performance 2.

Well 2 FC-16 finished operation June10, 2018 and kept under soaking for 7 days, the well put under production on June 17, 2018, unfortunately the well fail to resume production due to pump failure. Then WO job was arranged to resume well production

The well resume production on July 6, 2018, and shut-in again on September 18, 2018, due to pump failure and resume production again on September 25, 2018.

The well resume production after successful injection job with 838 BLPD liquid flow rate, 61 BOPD oil flow rate and 93% average WC the fluid level record show that 200 m was the dynamic fluid level below the surface.

CONCLUSIONS AND RECOMMENDATIONS

Well 1 Moga20-7: The well shows instantaneous DFL increase about 129 m and remain stable while same frequency was maintained after the injection of MFCA. WC dropped from 64% to 42% and continue decreasing. Oil rate jumped from 95 BOPD to 204 BOPD and continue increasing.

The well shows excellent performance posts the MFCA injection and the oil rate increased 115%.

Well 2 FC-16: The well shows instantaneous DFL decrease about 100 m and continue decreasing with increasing of frequency. WC increased from 70% to 93% and Oil rate increased from 50 BOPD to 60 BOPD then decreased to 4. Possible reasons for bad performance of MFCA in this well are strong reservoir energy support, reflected in fluid level was close to surface, therefore; high pressure was needed to squeeze the MFCA solution into formation plus Well located down dip close to OWC.

The well shows bad performance posts the MFCA injection and the oil rate increased.

Nomenclature

%	percent
API	American Petroleum Institute
BBL/D	barrel per day
BOPD	barrel oil per day
°C	degree Celsius
CEOR	chemical enhanced oil recovery
DFL	dynamic fluid level
EOR	enhanced oil recovery
GOR	gas oil ratio
IFT	interfacial tension
IOR	improved oil recovery
m	meter
Max	maximum
MFCA	multifunctional chemical agent
mpa.s	milli pascal second
OWC	oil water contact
PVT	pressure volume temperature
OEPA	Oil Exploration and Production Authority
OGM	oil gathering manifold
STOIIP	stock tank oil initial in place
WC	water cut
WO	work over

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