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Solvent Stimulation as a Solution for Heavy Oil Production in B Structure Pertamina

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Abstract

Producing heavy oil requires more efforts than usual. Low degree of API, High viscosity, and high pour point make producing wells with this oil type quite challenging. B Structure oil in Pertamina has $17\text{-}23^0$ API, 10-222 cp viscosity, and 45^0 C pour point. Producing wells in this structure results in either low production rate or water coning. Altering oil characteristic by pumping suitable chemical would be an ideal solution for this problem. However, the efforts that have been made since 2011 could not meet expectation in terms of production gain and decline of water cut.

Laboratory test was performed to find proper chemical that can alter oil characteristics for this structure. Since oil in B structure contains asphaltene and paraffin, the logical thing to do to achieve this goal is to utilize aromatic solvent. Mixture of xylene and diesel as the main ingredients was chosen. Solubility test with oil from B structure showed that the mixture can dissolve its asphaltene and paraffin content. A dose of surfactant, mutual solvent, and potassium chloride are added into the mixture to condition formation. Compatibility test with brine from B Structure was observed, and neither emulsion nor sediment was formed. The mixture's laboratory tests showed promising result.

Stimulation jobs using solvent mixture mentioned above were performed for three wells in B Structure: well B-104, B-122, and B-121. The problem in well B-122 was the same, i.e. sudden increase in water cut after performing well service. In well B-121 case, it lost its production after water shut off activity. B-104 showed significant oil cut in swab job sample but could not be produced due to its heavy oil characteristics. Stimulation was performed using bullhead method with 6 ft penetration into the formation and minimum 120 minutes of soaking time. The best result out of these three treatments is from well B-121. The well's oil production before treatment was 25 bbls per day and is improved post treatment into 175 bbls/day, with decreasing trend for its water cut. Another improvement also happened in well B-122. Pretreatment oil production for this well was 21 bbls/day and is improved into 76 bbls/day. In B-104 well, which delivered zero production since intervention job, delivered peak oil production of 54 bbls/day. All wells were produced using artificial lift and still have more than 300 m of pump submergence, which means the door for production optimization is wide open.

The success from these stimulation jobs using aromatic solvent provide a solution for heavy oil production in B Structure in Pertamina. Several more wells are already scheduled to receive solvent stimulation treatments. Production monitoring is still on going with production optimization is on the plate. Wells' lifetime is also closely monitored as well as design optimization for stimulation treatment.

Introduction

Even though B Structure oil in Pertamina has been produced since 1959, remaining reserves in B Structure is still quite a lot: 6.43 MMSTB. Currently, wells in the B structure are produced using artificial lifts: ESP and SRP. Based on pump submergence data, these wells can still be optimized by increasing their gross production, which will ultimately result in more oil production. However, this optimization opportunity cannot be carried out because when the well gross production is increased, water coning tends to occur. In addition, there is also the problem of water handling in surface facilities.

Rock properties in B structure tend to be oil wet. Stimulation have been performed by using surfactants to change rock wettability from oil wet to water wet, however the results obtained are far from optimum. Wells' water cut after surfactant stimulation were relatively unchanged. Table 1 shows B Structure overview.

Reservoir Characteristics	
Reservoir formation	Talang Akar Formation (Sandstone)
Reservoir Wettability	Oil Wet
Driving Mechanism	Strong Water Drive
Avg Reservoir Pressure	1500 psi
Avg Reservoir Temperature	200^0 F
Initial Oil in Place	164,137 MMSTB
EUR	37.65 MMSTB
Remaining Reserve	6.43 MMSTB (23% URF)
Fluid Properties	
API	$17\text{-}23^0$ API
Oil Viscosity	10 – 222 cp (@res condition)
Pour Point	46^0 C
Production	
Number of Wells	107 wells (61 on production, 18 suspended wells, 22 water injection wells, 6 plug & abandoned wells)
Average production rate	55,300 bfpd 1800 bopd 7.91 mmscfd 95.69% WC
Average injection rate	53,309 bwipd
Decline rate per year	16.56 %

Table 1 B Structure overview

Oil in B Structure is heavy oil with API values ranging from $17\text{-}23^0$ API, and viscosity of 10 – 222 cp at reservoir condition. There were cases in wells with small water cuts, when a sample of oil is taken on the surface through a faucet in the flowline, the sample obtained was only gas. It happened because heavy oil is difficult to flow out of the small diameter of the faucet hole. Therefore, the oil sampling should be done in the separator. Oil from B structure required an assistance to be delivered to refinery unit. In this case, light oil from other structures is utilized as blended oil.

Fig. 1 to 3 show cases of abnormal drops in oil production in three B structure wells, in which water cuts of the three wells rises suddenly. This is thought to be due to the formation of plugging near wellbore due to changes in fluid pressure and temperature from the reservoir to the wellbore. Heavy oil which has a smaller relative permeability makes it difficult to produce. Well stimulation is needed to eliminate damage near wellbore and improve oil relative permeability.

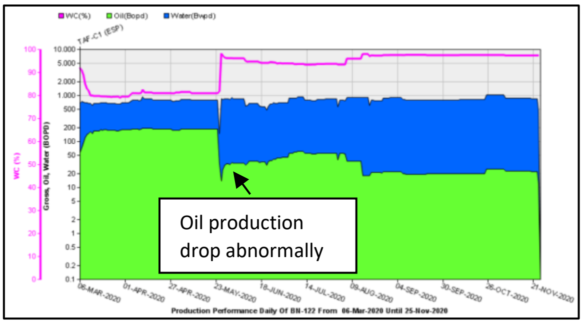

Fig. 1 B-122 Production Profile

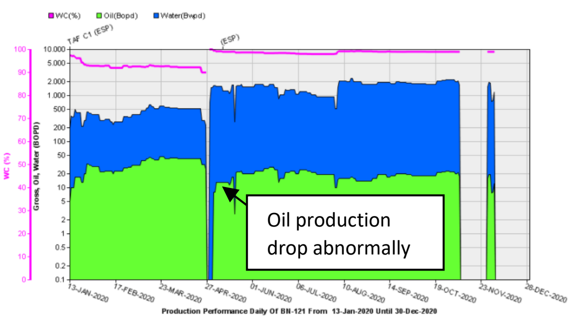

Fig. 2 B-121 Production Profile

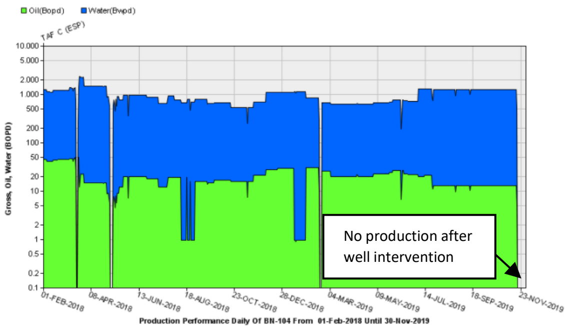

Fig. 3 B-104 Production Profile

Data and Method

Matrix Treatment Selection

Xiong and Holditch 1995 discussed about several fluid options that have been used successfully in matrix treatment (Table 2).

Fluid Type	Specific Fluid	Damage That Fluid Can Remove	Remarks
Acids	HCl	Scale, solid plugging, water block	Used in carbonate sand sandstones with 20% or more calcite, or preflush for HF acid treatment
	Acetic acid	Scale, solid plugging, water block	Same as HCI and in high temperature
	Formic acid	Scale, solid plugging, water block	Same as HCI and in high temperature
	HF	Clays, scales, solid plugging, water block	Sandstones (with HC1 or organic acids). Used to cleanup drilling mud damage
	In-situ generated HF acid	Clays, scales, solid plugging, water block	Possibly deep penetration. Sandstones only
Solvents	Mutual solvent	Water block, emulsion, wettability change	Used with other additives such as surfactant to improve hydrocarbon relative permeability
	Aromatic solvent	Asphaltene, paraffin wax, sludge, lubricant plugging	Used with a suspending agent or remove asphalt deposit with dispersant(s) for sludge
	Ethylene diamine tetra acetic acid (EDTA)	Sulfate scale	
Water	Hot water	Paraffin wax	Used with suspending agent(s)

Table 2 Fluid Used in Matrix Treatment Selection (Xiong and Holditch, 1995)

Laboratory test result for crude oil from B structure shows that asphaltene and paraffin content of oil from the B structure is quite high, as shown in Table 3. Matrix treatments suitable for oil containing paraffin wax based on Table 2 are hot water and solvents.

Specific Gravity 60/60 ºF	[ ]	0,9170
API Gravity at 60 ºF	[ ]	22,8
Kinematic Viscosity at 140 ºF	[cSt]	142,4
Kinematic Viscosity at 180 ºF	[cSt]	54,45
Kinematic Viscosity at 210 ºF	[cSt]	30,70
Pour Point	[ºC]	45
Flash Point "ABEL"	[ºC]	82
Reid Vapor Pressure at 100 ºF	[psi]	solid
Water Content	[%vol]	Nil
Water & Sediment (*)	[%vol]	0,40
Salt Content as NaCl	[%wt]	--
Salt Content as NaCl	[lb/1000 bbl]	> 151
Total Acid Number	[mg KOH/g]	0,053
Strong Acid Number	[mg KOH/g]	Nil
Total Base Number	[mg KOH/g]	0,514
Gross Heat of Combustion	MJ/kg	44,481
Sulfur Content	[%wt]	0,155
Asphaltene Content	[%wt]	0,428
Wax Content	[%wt]	11,51
Congealing Point of Petroleum Wax	[ºC]	67
Conradson Carbon Residue	[%wt]	8,360
Ash Content	[%wt]	0,3612
Hydrogen Sulfide	[mg/kg]	0,57
Mercaptane	[mg/kg]	1,97
Total Nitrogen	[%wt]	0,038
Characterization Factor, K_{UOP}	[ ]	12,3
Metal Content: - Vanadium	[mg/kg]	0,47
- Nickel	[mg/kg]	5,25

(*) The result is after free water treatment

The results are summarized as follow:

- API Gravity	[ ]	: 22,8
- Specific Gravity at 60/60ºF	[ ]	: 0,9170
- Pour Point	[ºC]	: 45
- Sulfur Content	[%wt]	: 0,155
- Asphaltene Content	[%wt]	: 0,428
- Wax Content	[%wt]	: 11,51

Table 3 Laboratory Evaluation of B Structure Crude Analysis

The use of hot water that has been applied in Indonesia to deal with heavy oil problem is by performing steam flood injection. Referring to steam flood study in Pertamina's S Structure, it is necessary to add 15 injector wells to support 26 producer wells at a cost of 1.1 million USD per well. It is equivalent of 16.5 million USD for 15 wells. The well in S Structure has a depth of 300 meters, while the well in B Structure has a depth of 1200 m. The cost of making injection wells in B structure will be higher, it is not including investment in production facilities such as steam generators. The steam flood in B structure still needs further economic studies, that it cannot be realized in the near future. Besides, prospect zones in B structure have around 200^0 F average reservoir temperature, which means reservoir temperature is still far from its oil pour point, hence no problem temperature wise.

Referring to Table 2, there are three types of solvents: mutual solvent, aromatic solvent, and EDTA. The type of solvent that is suitable for removing asphaltene and paraffin is an aromatic solvent. This fluid is preferred to deal with the heavy oil problem in the B structure.

Fluid Design

Straub et al. 1989 tested the effect of various solvents on paraffin solubility rate (Fig.4). This experiment was carried out at a temperature of 159 F. The results were that xylene was able to dissolve 100% of paraffin to 0% in +/- 4 minutes, followed by condensate +/- 7 minutes, kerosene +/- 8 minutes, light oil +/- 22 minutes, and diesel +/- 30 minutes.

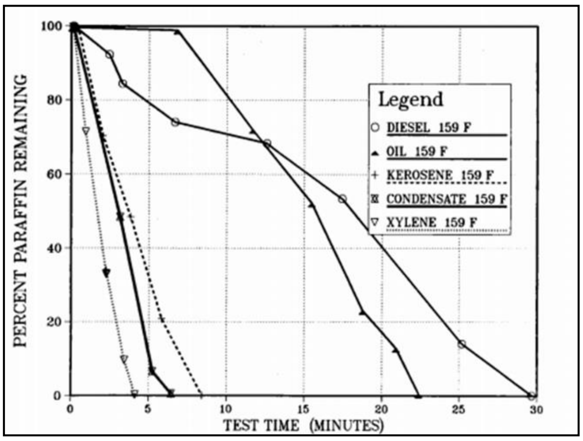

Fig. 4 Effect of Various Solvents on Paraffin Solubility Rate (Straub et al. 1989)

Although xylene is the type of solvent that dissolves paraffin the fastest, the flash point of xylene is low (Table 4).

Solvent Type	Flash Point
Xylene	27 ^{0}C
Condensate	-40 ^{0}C
Kerosene	37.8 ^{0}C
Oil	-20 ^{0}C
Diesel	65 ^{0}C

Table 4 Flash Point of Solvent Types

If the temperature rises to 5.5^0 C above the flash point, the vapor cannot be controlled and has the potential to cause fire. When the job is on site, the ambient temperature can reach 40^0 C. For safety mitigation, xylene is mixed with diesel to increase its flash point. Xylene and diesel are fluids that are compatible with each other. A 50:50 mixture of diesel and xylene makes the flash point 45^0 C (Table 5).

% Diesel	% Xylene	Flash Point ^{0}C
100	0	65
70	30	55
50	50	45
25	75	38
0	100	27

Table 5 Flash Point of Mixture Diesel + Xylene

Solubility test was performed at room temperature, and within two hours a 50:50 mixture of diesel and xylene was able to dissolve B-8 oil samples quite well, 85.42% solubility, as shown in Table 6. In order to maximize solvent stimulation job in B Structure, mutual solvent was added to improve hydrocarbon relative permeability, and a little surfactant was added as demulsifier. Table 7 shows the contents of final fluid mixture that will be used in well stimulation treatment.

Chemical	Temp (^{0}C)	Time (hours)	Solubility (%)
(40% Xylene + 60 % Diesel)	23	2	77.5%
(50% Xylene + 50 % Diesel)	23	2	85.42%
(60% Xylene + 40 % Diesel)	23	2	89.09%
(70% Xylene + 30 % Diesel)	23	2	90%
(80% Xylene + 20 % Diesel)	23	2	92.92%
(90% Xylene + 10 % Diesel)	23	2	93.13%

Table 6 Effect of Mixture Xylene and Diesel on B-008 oil sample

Chemical	Concentration	UoM
Xylene	500	gal/Mgal
Diesel	400	gal/Mgal
Musol	50	gal/Mgal
Surfactant	2	gal/Mgal

Table 7 Contents of Xylene Solvent System

Prior to the stimulation treatment, a solubility test was carried out on the xylene solvent system on samples of oil wells B-008 and B-122 at a formation temperature of 191^0 F. Within 2 hours, Xylene Solvent System was able to properly dissolve paraffin oil samples of 92.03% solubility for samples B-008 and 94.81% solubility for samples B-122. Table 8 shows this solubility test result. *(No sample can be collected from well B-104 & B-121 due to heavy oil damage near wellbore)*

Sample	Chemical	Temp ^{0}F	Time hours	Solubility %
B-008	Xylene Solvent System	191	2	92.03%
B-122	Xylene Solvent System	191	2	94.81%

Table 8 Solubility Test Result of B-008 and B-122 Oil with Xylene Solvent System

Result and Discussion

Solvent Stimulation Execution

Here is job procedure for xylene solvent system stimulation:

- Spotted Pumping and Mixing Equipment
- R/U pumping line
- Pressure tested pumping line
- Mix brine with 7% KCl
- Fill up well with 7% KCl water
- Performed pre-injectivity test using brine 7% KCl water.
- Mix Xylene Solvent System
- Pumped Xylene Solvent System
- Pumped displacement 7% KCl
- Soak Xylene Solvent System for 2 hours
- R/D Pumping Line
- R/D Pumping and Mixing Equipment

Xylene solvent system stimulation in B Structure required rig/hoist utilization. Equipments needed for this treatment were as shown in Fig. 5: chemical transport trailer, pump trailer, accessories trailer, acid tank 120 bbl, water tank 120 bbl, and compressor. Examples of injectivity rate test and main treatment job stimulation of solvent are as shown in Fig. 6 and Fig.7. Stimulation was performed using bullhead method with 6 ft penetration into the formation and minimum 120 minutes of soaking time.

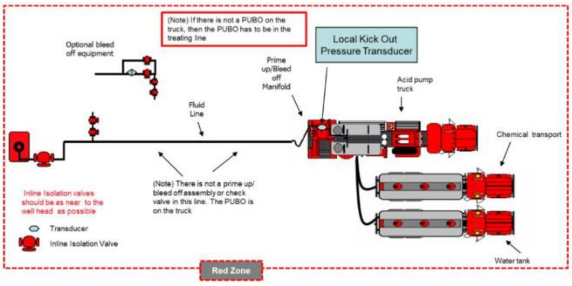

Fig. 5 Equipment Layout for Xylene Solvent System Stimulation Job

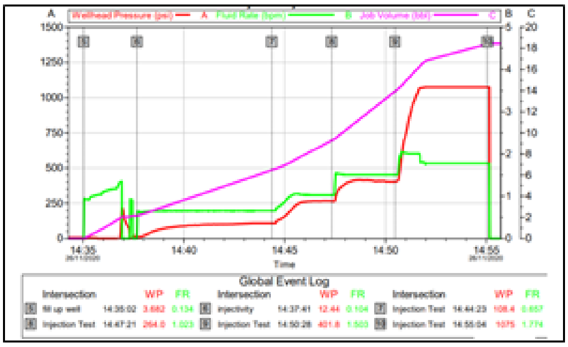

Fig. 6 Injectivity Rate Test Chart of Solvent Treatment B-122

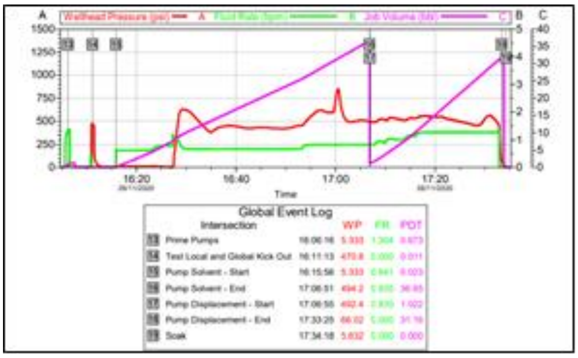

Fig. 7 Main Treatment Chart of Solvent Treatment B-122

Results

The best result out of these treatments was from well B-121. The well's oil production before treatment was 25 bbls per day and was improved post treatment into 175 bbls/day, with decreasing trend for its water cut. Another improvement also happened in well B-122. Pretreatment oil production for this well was 21 bbls/day and was improved into 76 bbls/day with the same pump setting after treatment. In B-104 well, which delivered zero production since well intervention job, delivered peak oil production of 54 bbls/day. All wells were produced using artificial lift and still have more than 300 m of pump submergence, which means the door for production optimization is wide open. Fig. 9 to 11 and Table 9 and 10 show summary of this stimulation project.

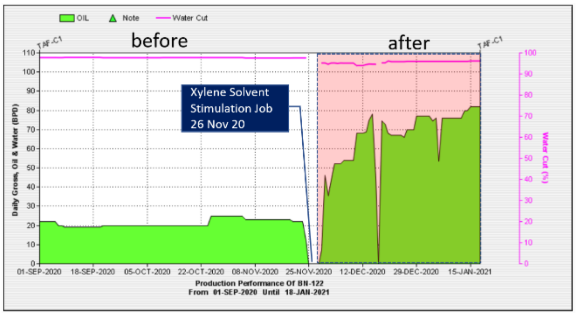

Fig. 9 B-122 Oil Production Comparison after Solvent Stimulation

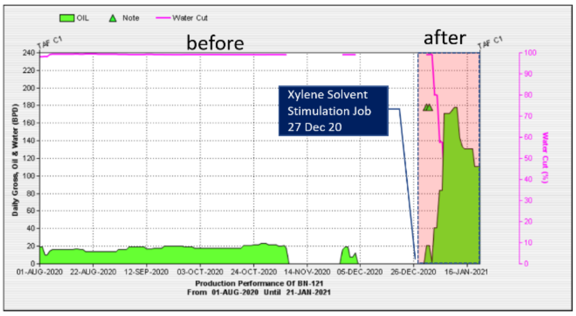

Fig. 10 B-121 Oil Production Comparison after Solvent Stimulation

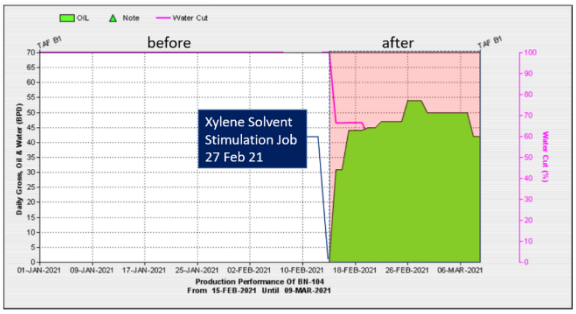

Fig. 11 B-104 Oil Production Comparison after Solvent Stimulation

Well	Average Production (bopd)		Gain (bopd)
	Before	After	
B-122	21	76	+55
B-121	25	175	+150
B-104	0	54	+54

Table 9 Recapitulation of Gain Production

Well	API Gravity	
	Before	After
B-122	17.12	22.19
B-121	19.39	25.01
B-104	19.26	22.15

Table 10 API Gravity Change

Conclusions

The success from these stimulation jobs using aromatic solvent provide a solution for heavy oil production in B Structure in Pertamina. Several more wells are already scheduled to receive solvent stimulation treatments. Production monitoring is still on going with production optimization is on the plate. Wells' lifetime is also closely monitored as well as design optimization for stimulation treatment.

References

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