PROCEEDINGS
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Resin Sand Consolidation Technique Successful Implementation and Its Challenges in Handil Field

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Abstract

Handil Field is a mature oil and gas field located in Mahakam Delta, East Kalimantan, Indonesia, developed since 1975. Handil reservoirs were deposited in a fluvio-deltaic environment. Oil reservoirs mainly located in shallow zone, whereas gas bearing reservoirs are mainly located in lower main until deep zone. Handil shallow zone consist of multi layer reservoirs located at depth 200 to 1500 TVDSS. This zone is penetrated by different kinds of completion well techniques: gravel pack well for shallow zone and tubingless and dual string well for main and deep zone. The oil production from shallow zone is supported by gas lift. The characteristic of shallow reservoir is poorly consolidated to unconsolidated sand with strong aquifer support. Due to sand prone reservoir, sand control technique is mandatory to prevent sand production on surface.

Gravel pack is commonly used as completion technique. Yet it still has limitation in number of reservoir coverage. As an alternative solution to produce remaining uncovered oil reservoirs, resin sand consolidation (SCON) is chosen.

SCON technique in Handil shallow oil reservoir was put on pilot project in 2011. Until End of 2018, 19 jobs have been implemented in different type of well architectures. In term of production gain, SCON jobs have been delivering 1,100,000 bbls cumulative oil production with 100% success ratio on job execution and durability of the resin (no sand on surface). In 2018, 11 SCON jobs were performed with an average production gain 400 bopd and reserves 80,000 bbls. Due to its succesful result, SCON remain the main option to unlock oil potential of the unperforated shallow reservoir in Handil Field.

Introduction

Handil Field Generalities

Handil Field is located in east Kalimantan in the Mahakam delta. It comprises of more than 500 reservoirs which divided into three development zones, namely Shallow, Main and Deep Zone. These zones have different characteristics in term of fluid, rock consolidation, and drive mechanism. This paper is focusing on Shallow Zone, which expands from 200 m to 1500 m TVDSS. Its fluid is predominantly oil with few gas caps. Its rock properties are distinguished by unconsolidated sand and strong aquifer support as main driving mechanism. Gas lift is the most common method used in Handil field apart from other methods, namely PCP and ESP. The gas lift is provided by two gas lift compressors with gas source taken from Handil's produced gas. Until June 2019, Shallow Zone contributes around 45% to Handil oil production, whereas its gas production including associated gas contributes only 18% to Handil gas production. This significant oil production has become one of the backbones to maintain field's production.

Unconsolidated Reservoir

Core samplings were performed in this interval and the result of the core analysis shows that reservoirs are categorized as unconsolidated sand **(Figure 1)**. To deal with this high degree of unconsolidation, sand control technique is mandatory to be implemented. Sand control technique applied in this zone is mostly gravel pack completion that contributes ~60% of production and the rest are hanging screen, screen patch, and resin sand consolidation. Without sand control, massive sand production at surface can cause serious integrity problem such as errosion on the choke, flowline, and tubing. It can contribute to production lost due to well could not be produced for some period of time or even oftenly well become inaccessible due to massive leak and tubing parted.

Figure 1 Handil shallow field unconsolidated core sample

Poorly Sorted Reservoir

Besides unconsolidation issue, Handil shallow zone is also categorized as poorly sorted reservoir. Granulometry analyses were performed in all interval of the field and the result can be seen on **Figure 2**. It shows that grain size

distribution (d50) is widely sparsed. Another parameter that emphasizes poor sorted grain size distribution is by average Folk's sorting value ~2. Poor sorting of reservoir grain size could create serious issue of gravel pack or screen plugging which reduce the productivity of the reservoir.

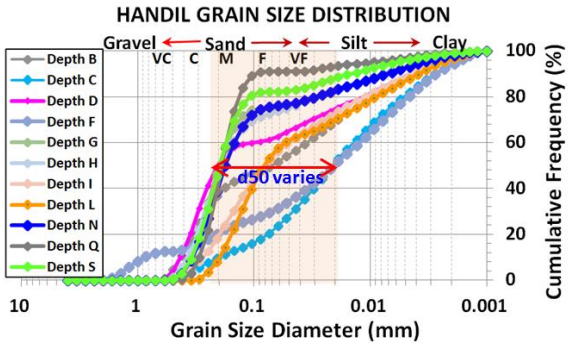

Figure 2 Granulometry analysis (d50) of several intervals of Handil shallow field

Well Completion Types of Handil shallow

Handil shallow oil reservoir development can be devided into two different types of wells: Shallow zone decicated well called HSO wells which are developed since 2005 until now and non-dedicated shallow wells which are initially produce from main and deep zone (older than HSO wells). HSO wells produce multilayer reservoirs using gravel pack (GP) completion. Due to number limitation of zones provided by gravel pack, several reservoirs which are found are not able to be produced. For Non-HSO wells, common completion types installed are dual string, tubingless, and tubingless+gaslift. Several heavy preparations need to be performed in these types of well since most of remaining unperforated reservoirs are coming from old wells. Typical well preparations are tubing investigation, annulus cementing, and additional perforation.

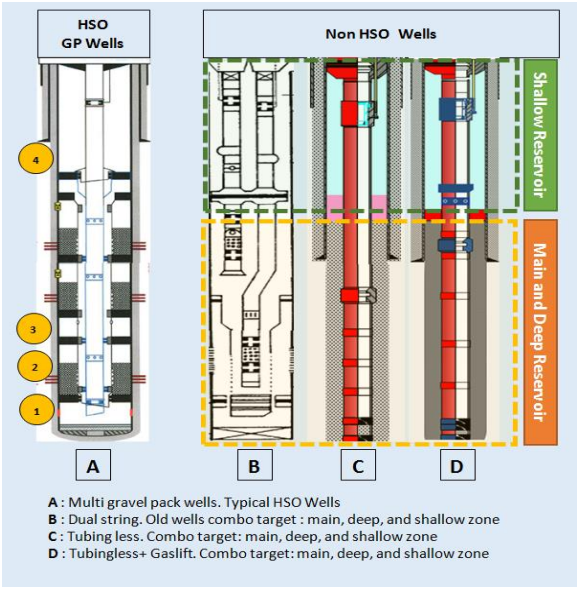

Figure 3 Handil oil field typical well architectures

Sand Control technique in Handil Shallow

Since 2005, where plan of development of Shallow oil zone was established, main options of sand control are gravel pack. Nowadays, maximum numbers of zone that can be covered by gravel pack are 7 zones due to current applied completion equipment limitation. Therefore, another sand control technique should be applied to unlock remaining potential of Handil shallow oil reservoirs.

As mentioned before, due to its poorly sorted sand stone reservoir, gravel pack completion is reluctant to experience plugging issue due to fine migration. Liquid production decline rapidly and reduce the production of the well. Other sand control techniques have been applied such as hanging screen and screen patch since 2011. None of them were delivering positive results. Screen was prematurely plugged during clean-up period of time and well was unable to flow. Several sceen sizes have been applied but still showing the same result.

All above sand control techniques are categorized as mechanical approached which have common plugging issue. Chemical approached then proposed by injecting epoxy resin in to the reservoir to consolidate near well bore sand. This technique then called Sand Consolidation (SCON) which was put on pilot project in 2011.

SCON Production Performance of 2018 Candidates

SCON is currently become the best solution to unlock remaining potential of Handil shallow oil field. Due to its succesful result in the past: No early sand break-thru, productions meet expectation, and jobs were safely performed, in 2018 SCON job for oil were performed 11

times, it is the most SCON job performed in a year with average 385 bopd of oil production gain. Can be seen in **Figure 4**, cumulative reserve is ~ 700,000 bbls, all targets exceed economic reserve cut-off at 15,000 bbls and average realized reserve is more than expected.

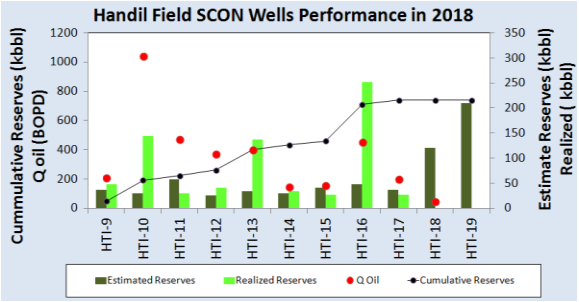

Figure 4 Handil field SCON well performances in 2018

Resin injection to reservoir is inevitably reducing productivity of the reservoir. Analyses are performed in determining regained permeability of injected reservoir by performing nodal analysis using production test data before and after treatment. 4 out of 11 have proper production test in term of duration and production stabilization rate period. As seen on **Figure 5**, Regained permeability obtained from 4 wells in average is 70%.

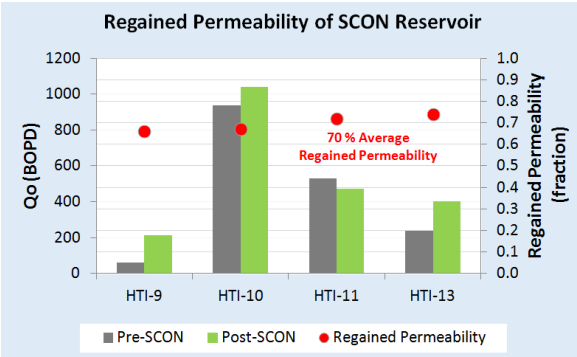

Figure 5 Regained Permeabaility of SCON Reservoir

As seen on **Figure 6**, SCON technique able to deliver production without having liquid production decrease compare to gravel pack wells. Qoil production decline of SCON well is only driven by evolution of water cut whereas in gravel pack there is plugging of fine particle in the vicinity of perforation tunnels.

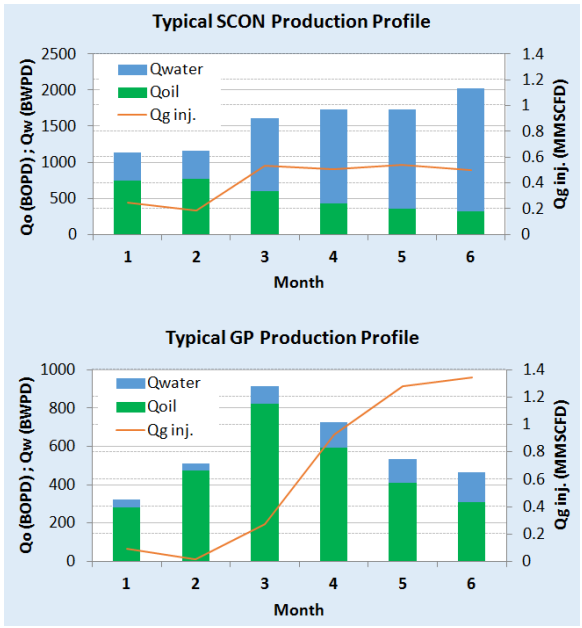

Figure 6 Typical Production Profile of SCON Vs GP Wells

Durability of SCON in Handil oil field are summarized in **Figure 7**. The longest SCON production is HTI-4 (>33 months) which are performed in 2015 until now well is still producing 186 bopd with cumulative production 161,000 bbls. The shortest duration is in HTI-8 (14 months) which was performed in 2017. The main reason of this short life time is due to this well was produced aggresively. It can be seen from cumulative production 134,000 bbls in only 14 months or equal to > 900 bopd/month, this value is considered very high for common SCON reservoir with have average ~400 bopd.

Year	Well	Start of Prod.	End of Prod.	Life time (Months)	Ultimate Production (kbbls)	Cum. Production (kbbls)	Current Qo (bopd)	Remarks
2015	HTI-4	Mar-15	-	33	302	161	186	Sand Free
2016	HTI-5	Nov-16	Sep-18	20	76	76	0	Water break-thru
2017	HTI-8	Sep-17	Dec-18	14	134	134	0	Sand break-thru
2018	HTI-10	May-18	-	16	144	123	165	Sand Free

Figure 7 Durability of SCON chemical since 2015 until 2018

SCON Challenges in Handil Field

Reservoir Accessibility and Well Deliverability

The simplest SCON operation, which not required many Pre-SCON works, is performed on tubingless well with only single reservoir open. However, in some cases reservoir may be inaccessible for direct SCON. Reservoir target may be buried by solid/sand which required sediment wash, or it need to be isolated from other reservoirs open

which currently produce water by annulus cement or MWSO, etc.

Most complex operation is performed on ex-GP well which reservoir target is located in the same zone with existing open reservoir. Theoretically, cement zone isolation could be done. However, in field application scale with current applicable technology, this job success ratio is still considered low. Limited data gained to evaluate cement strength quality and proper isolation on existing zone is the main stopper to continue with SCON operation on this typical reservoir target.

Some oil reservoir candidates are located on tubingless well innitialy designed for gas well without artificial lift means. By this condition, well shall be modified by some intervention job to install gas lift means.

Well Integrity: Tubing leak and Well envelopes
Handil wells are mostly completed with dual string with gas lift accessories as artificial lift systems, which already produced for more than 20 years, meaning tubing and its accessories integrity start to degrade. Well with integrity problem (i.e tubing leaks at some point) may eliminate the well from candidate due to additional cost for intervention remedial works after SCON.

In addition, some SCON potential reservoirs are not targeted in the past (i.e located above top production packer) require additional intervention works to create annulus cement packer to create sufficient barriers regulated by well integrity rules.

Surface readiness
In some cases, well candidate is addressed to long shut in well which already preserved with incomplete surface facilities (well control panel, flow line, etc). Close coordination shall be made with related entity (Field Production) to ensure any delay on well delivery and additional cost due to surface facilities works are well captured.

Non technical challenges
Handil field is located in Mahakam River which has fast sand sedimentation. Due to increase of river bed in the neighboring area of well/platform, barge access becomes restricted in some cases. Removing mass of sand by dredging barge becomes mandatory prior to preparing well intervention operation. It oftenly becomes the show stopper of SCON operation in Handil field. Besides fast sedimentation several wells are located in an artificial river channel which has limited access window. Comprehensive planning between entities is required to solve this non technical problems.

Optimization of SCON in Handil Field

Reducing cost
More marginal target is proposed for sand consolidation, meaning job cost have to be reduced without jeopardizing treatment results. Some optimization performed:
- **Penetration reduction**: initial penetration was 4 ft during beginning of SCON milestones. Then gradually reduced to 3.5 ft penetration with no degradation on treatment result. To be noted that this penetration value was based on empirical data taken from all fields in Mahakam. Then penetration is going to be reduced to 3 ft. with this reduction, chemical consumption is 25 % lowered. Some pilot well candidates were selected to validate the effect of chemical reduction with a satisfactory result.
- **Adjusted radial penetration**: Initial volume calculation is based on 360 deg tubular volume with height of perforation interval and diameter of SCON open hole penetration (3 – 3.5 ft). Recently, by empirical laboratory experiment it is found that 0 deg perforation, only required 50% volume to cover 180 deg of open hole areas (which already covers perforation interval). By this condition, especially in Handil field in which probability to perform SCON in dual string is higher (with applied 45 deg perforation), chemical consumption may be reduced up to 50 %.

Multiple SCON
Currently, sand consolidation using Epoxy resin is still limited for single reservoir treatment. Contrast injectivity become the main contributor why direct multiple SCON to be avoided. Contrast injectivity can be caused by some factor: porosity and ratio open perforation compared to reservoir thickness. Once one reservoir is tighter, SCON main treatment and diesel over-flush are unevenly distributed into both reservoirs, which lead to poor main treatment (early sand break) or poor overflush (plugged reservoir) in one of reservoir.
Another approach of multiple SCON is planned in Handil shallow oil field by performing single treatment with gap one or two days between treatments (by ensuring strength build up prior move to next treatment). This method has been successfully applied in other field in Mahakam.

Conclusions

Following conclusion can be drawn from this paper:
1. Since 2011, SCON treatments have been performed in Handil shallow oil field 19 times, 11 jobs were performed in 2018. SCON treatment can be implemented in all kinds of completion type in Handil under specific requirment
2. Reservoir properties such as porosity and heterogeneity are the main factor contributing to the success of the treatment due to limitation of SCON chemical
3. All SCON jobs performed succesfully solve sand production issue in Handil shallow oil field

4. Compared to gravel pack completion, production from SCON wells do not experience reservoir plugging issue that trigger liquid production decline
5. In term of production gain All SCON candidate performed in 2018 were performed succesfully: estimated reserves are achieved and no early sand break-thru. Average production gain ~400 bopd/well and average reserves ~80,000 bbls/wells
6. In term of productivity of SCON regained permeability in average is 70%. Means SCON does not severely damage the reservoir deliverability
7. Durability of injected SCON chemical can last more than 2 years depends on drawdown monitoring. Less drawdown means less production and more durability of chemical
8. Until now, SCON is still the best solution which technically and economically proven to unlock remaining potential of Handil shallow oil field..