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# Sand Consolidation Operation Strategy for Boosting Production while Performing Cost Optimization

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**Abstract.** Sand consolidation operation was demanded for more challenge for increasing number of operation. On contrary, cost optimization was also demanded due to more marginal reserves available. Innovation and strategy were developed to cope with both challenging objectives.

Boosting production achieved by increasing number of unit and product diversification. Increasing unit was applied on most utilized chemical. Product diversification involved careful consideration due to different chemical properties in order to ensure successful result. Cost optimization was achieved by reduction in operation duration and reduction in chemical usage. Operation duration was reduced by eliminating of coiled tubing usage. Treatment was deployed by bullheading method instead of conveyed by coiled tubing. Chemical reduction purpose was to reduce margin of penetration in order to have good enough treatment quality.

Additional units to perform sand consolidation were deployed on August 2019. It increased job capacity from 3 to 11 jobs per month. Chemical product was diversified for other 3 different products. Aqueous based resin was applied on 14 wells. 9 wells produced successfully without sand, 2 wells produced with sand, 1 well with sand burst during clean-up and 2 wells are not producing due to productivity issue. During production time, average gas rate of 1.1 MMscfd is achieved. Alternative sovent based resin product was deployed on 1 well with gas production result of 1.6 MMscfd and without sand produced during initial clean up. Furan resin was applied also in 1 well with gas production result of 2.7 MMscfd and without sand produced during initial clean up. Meanwhile, cost optimization could only be achieved by optimizing well-recognized product A. Bullheading method was successfully applied on 14 wells. 3 wells were already flowing with average rate 1.4 MMscfd without sand issue or tubing access issue. Daily operation effieciency was achieved up to 1.7 days. Penetration margin was reduced from 3.5 ft to 3 ft in order to achieve good-enough treatment quality. Sand consolidation performance was reviewed, resulting no sand consolidation quality reduction for 3 ft penetration treatment. 25% cost reduction from chemical was successfully achieved.

This paper shown a benchmarking of several sand consolidation chemical performance due to chemical diversification initiative. Cost optimization initiave has shown prove of controlled chemical usage reduction did not reduce sand consolidation quality. It also proves that correct parameter of bullhead treatment did not reduce treatment conveyance quality.

**Keyword:** Operation Optimization; Sand Consolidation; Bullheading Treatment; Optimized Penetration; Chemical Benchmarking

# 1 Introduction

Mahakam fields are initially developed by producing main zone. Reservoir targets located approximately below 2000 meters below sea level or 4000 meter measured depth (Duval, 1992).

In initial development, shallow zone is identified as gas pocket hazard due to narrow fracture margin during drilling phase. Therefore, shallow gas pocket is initially avoided (Setiawan, 2017). In the past decade, new method is developed targeting shallow reservoir located above 2000 meter below sea level. This method examines anomalies in seismic data on shallow depth in order to quantify the gas reserves, therefore economically can be justified for development. On the other hand, drilling method also developed in order to put completion barrier in shallow zone. Well control method is signifactly change from initial method using blow out preventor to contain gas influx into using diverter to divert gas to surface in order to avoid underground blow out in shallow zone (Oumer, 2010).

Shallow zone reservoir had been initially developed by gravel pack and standalone screen completion (Laidlaw, 2014), (Muryanto, 2018). Due to mature field natural declining, lower cost sand control is required. One of the developed method is sand consolidation (Chaloupka, 2010&2012). After certain level of confidence, sand consolidation is implemented as initial sand control completion. The well architecture is converted from gravel pack to tubingless shallow light architecture (Handoko, 2017). Sand consolidation method is successfully implemented in various field in Mahakam area (Mukmin, 2018), (Hadi, 2019), (Widarena, 2017), (Marisa, 2016).

Alternative sand consolidation products are also developed in parallel with current sand consolidation development. Hybrid Inorganic-Organic chemical as resin alternative, chemical remediation for failed gravel pack, and sand conglomeration technology had been field tested in Mahakam (Andrieu, 2018), (Mahardhini, 2015), (Styward, 2018). These technologies had shown promising result for further development. Therefore, diversification of chemical portfolio is interesting to be implemented for field development.

# 2 Methodology

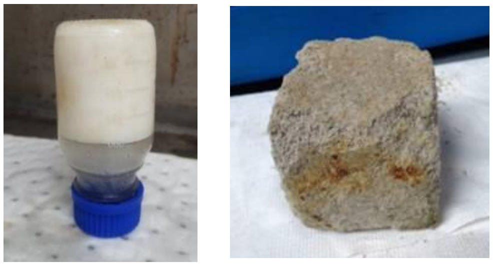
## 2.1 Increasing unit

The most straight forward effort to increase the number of operation in order to boost production is by increasing number of unit. Initially sand consolidation operation is performed by campaign mode. Therefore, the period of operation is limited due to low demand of particular operation. Since 2018, sand consolidation operation was continuously performed by 1 dedicated unit. Due to increasing number of demand, sand consolidation then assisted by 2 other coil tubing unit and 1 campaign based dedicated unit. 2 other coil tubing unit was initially designed for unloading and cementing operation.

### 2.2 Product Diversification

Other type of chemicals that has been tested in nearby area also has promising result (Riyanto, 2016), (Keith, 2013), while alternative solvent based chemical utilization was referred to initial development earlier in Mahakam (Fuller, 2011).

#### 2.2.1 Aqueous Based Resin



(a) (b)

Figure 1. (a) Aqueous Based Resin cured solution; (b) Sample prior compressive strength test

Aqueous Based Resin was promoted from success story from East Malaysia (Riyanto, 2016). Aqueous based resin is a water based emulsified resin system which used KCl brine as base fluid. This type of chemical is suitable for low permeability reservoir with optimized compressive strength value. The chemical visualization is as per seen on figure 1. The typical operation sequences for this type of chemical are:

- Preflush: KCl Brine + Solvent
- Main Fluid: Brine + Resin + Hardener + Coupling Agent + Retarder
- Overflush: Brine

#### 2.2.2 Alternative Solvent Based Resin


(a) (b)

Figure 2. (a) Alternative Solvent Based Resin cured solution; (b) Sample prior compressive strength test

The alternative solvent based resin was initially introduced in Mahakam at 2011 (Fuller, 2011). The alternative solvent based resin is suitable for reservoir with characteristic of reservoir temperature ranging from 100-170 F and permeability value above 500 mD. The chemical visualization is as per seen on figure 2. The typical operation sequences for this type of chemical are:

- Preflush: Diesel
- Main Fluid: Resin + Solvent + Curing Agent + Catalyst
- Overflush: Diesel

2.2.3 Furan Resin

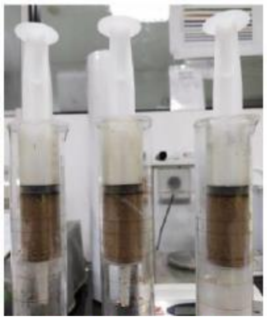


Figure 1. Furan Resin sample prior compressive strength test

Utilization of Furan Resin was successfully proven in Peninsular Malaysia (Keith, 2013). Furan resin is a water based resin type that used acid as an activator for hardening. Furan resin was catalyzed externally which eliminating the issue of hardened resin at surface. The typical operation sequences for this type of chemical are:

- Preflush: Brine
- Main Fluid: Resin + Fixer + Non Emulsifier
- Acid
- Overflush: Brine

Quality of sand consolidation is maintained by optimizing between parameter regain permeability and compressive strength. Regain permeability after sand consolidation treatment need to be maintained around 80% in order to achieve acceptable rate to production facility. Meanwhile, compressive strength relates to maximum drawdown that can be applied in order to produce the hydrocarbon without breaking sand consolidation treatment. Aqueous based resin has lower compressive strength due to lower concentration in the system, meanwhile typical resin based has compressive strength around 1000 psi. Sample preparation for compressive strength test could be seen on figure 1b, figure 2b, and figure 3. Regain permeability and compressive strength benchmark was summarized on table 1.

Table 1. Regain Permeability and Compressive Strength Benchmark

| Method | Initial Product | Aqueous | Alternative Solvent | Furan |
|---|---|---|---|---|
| **Regain Permeability** | 80% | 80% | 80% | 80% |
| **Compressive Strength** | 1000 psi | 300 psi | 1000 psi | 1000 psi |

### 2.3 Bullheading

Bullheading treatment will optimize operation for rig up simpler equipment instead of using coil tubing with isolation packer. It will save service charge for not utilizing coil tubing and also daily operating cost for quicker rig up and rig down process.

Bullheading method for sand consolidation was implemented on peninsular Malaysia (Othman, 2017). Lesson learned from those experience was to not pumping in bottle neck profile and low rate. Bottle neck profile from 3.5” tubing to 7” casing while pumping sand consolidation in 1 bpm causing treatment resin settle on the low side of perforation. Treatment was not uniformly distributed, causing early sand production after treatment and resin residue conglomeration inside tubing. Therefore, bullheading is only suitable for smooth completion profile, low inclination, and high permeability reservoir, in addition also allowing pumping treatment in high rate to minimize contact with tubing.

### 2.4 Chemical Reduction

Early development reference showed that the optimum range of sand consolidation treatment volume was between 30 to 50 gal per foot perforation (Hower, 1961). Initial best practice in Mahakam was by implementing 3.5 ft penetration of treatment, equivalent with 70 – 100 gal per foot perforation. Proposed chemical reduction during this campaign is at 3 ft penetration or equivalent with 50 – 80 gal per foot perforation, step by step approach is taken for intention not to jeopardize current sand consolidation quality.

## 3 Result and Discussion

### 3.1 Increasing Number of Operation

Evolution of sand consolidation operation in Mahakam as per following figure 4. Average of 1 unit from January to August was 3 jobs per month. Unit 2 and 3 were deployed in September, while unit 4 was deployed in November. The average of operation was increase to 11 jobs per month with 4 units. Until end of the year, 68 jobs of sand consolidation are successfully performed.

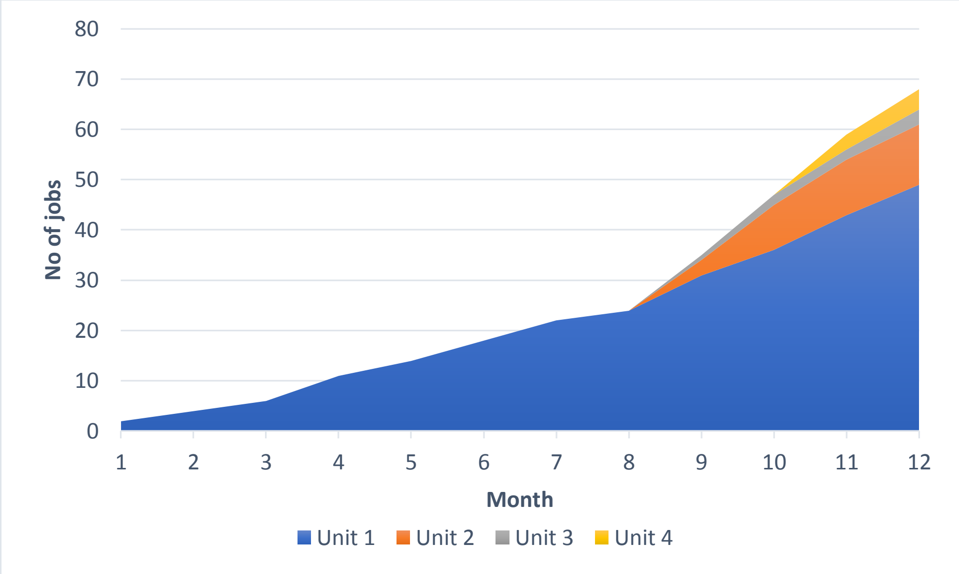



Figure 2. Cummulative Sand Consolidation Jobs Realization by 4 units

Equivalent of instantaneous gain contribution and its production increase was described as per following figure 5. Production increase was inline with unit increment trend. Additional unit increased instantaneous gain from 3.7 to 11.4 MMscfd/month started from September. Total instantaneous gain could be achieved at end of the year was at 83.5 MMscfd.

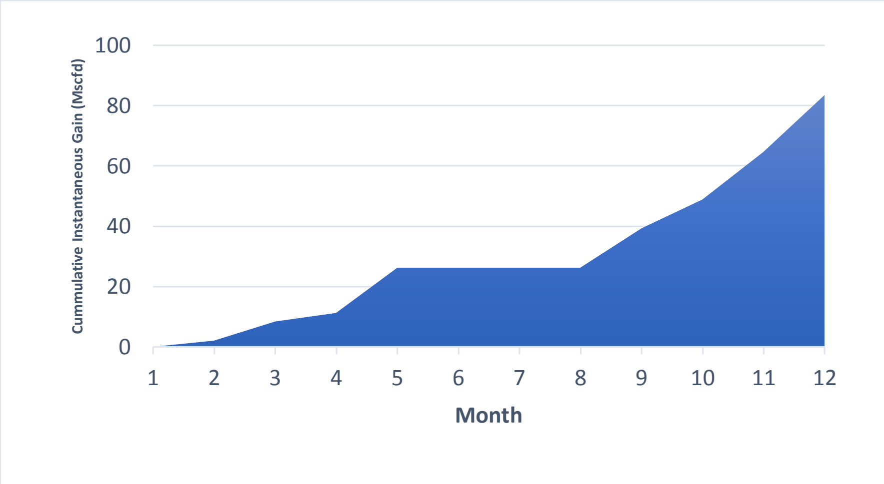



Figure 3. Gas Cummulative Production after Sand Consolidation Jobs.

3.2 Product Diversification

As mentioned before, different type of chemicals has different type of operation sequences. The result for each type of chemical on Mahakam will be explained below. The production performance was summarized on table 2.

**Aqueous Based Resin**

Total wells used for trial of aqueous based resin are 14 wells. During clean up, there are total 9 wells produced successfully without sand, 2 wells produced with sand, 1 well with sand burst during clean-up and 2 wells are not producing due to productivity issue. During production time, average gas rate of 1.1 MMscfd is achieved for wells with current condition of 6 wells still flowing, 3 wells died due to water, 3 wells died due to sand, and 2 wells not producing from the start due to productivity issue. Average production lifetime was 148 days. Total reserve unlocked with this treatment was 1.7 bcf.

**Alternative Solvent Based Resin**

TN-1 is the first well trial for alternative solvent based chemical. The targeted reservoir for well TN-1 is Res. 1a on 1224-1226 mBRT. Sand consolidation was performed by coiled tubing with isolation packer. Treatment sequence was cosnsist of pumping 16 bbls diesel as pre flush at 1 barrel per minute (bpm), continued with 24 bbls of alternative solvent based resin chemical at 0.6 bpm, and 36 bbls of diesel as post flush at 0.5 bpm

After the treatment is done and curing time process is finished. Clean up was performed for well TN-1. It appeared with a good result with gas production of 1.6 MMscfd and without sand produced. The well died after 98 days of production with sandy indication at the end of production. Total reserve unlocked was 0.16 bcf.

**Furan resin:**

TN-2 is used as trial for Furan Resin. The targeted reservoir for well TN-2 is Res. 2a on 1146-1147.5 mBRT. Same like others, injectivity test through coil tubing using KCL brine as fluid was performed. Based on the result, injection rate of 0.8 bpm can be performed for pumping 25 bbls KCl brine as pre flush fluid and injection rate of 0.5 bpm can be performed to pumped 10.3 bbls of Furan Resin Chemical, 20.6 bbls of 7.5% HCL as spacer, and 25 bbls of 1.03 KCL brine as post flush.

After the treatment is done and curing time process is finished. Clean up was performed for well TN-2. It appeared with a good result with gas production of 2.7 MMscfd and without sand produced. Average production rate until the well died is at 1.2 MMscfd. The well died after 52 days of production with sandy indication at the end of production. Total reserve unlocked was 0.07 bcf.

Table 2. Performance of Alternative Chemical

| Method | Aqueous | Alternative Solvent | Furan |
|---|---|---|---|
| **Number of treatment** | 14 | 1 | 1 |
| **Result** | 9 wells flowing without sand, 3 sandy on initial production, 2 productivity issue | Flowing without sand | Flowing without sand |
| **Production rate** | 1.1 MMscfd | 1.6 MMscfd | 1.2 MMscfd |
| **End of Production** | 6 still flowing, 3 died due to water, 3 sandy, 2 productivity issue | Sandy | Sandy |
| **Lifetime** | 148 days | 98 days | 52 days |
| **Reserve Unlocked** | 1.7 Bcf | 0.16 Bcf | 0.07 Bcf |

3.3 Success Implementation of Bullheading

Bullheading treatment method is started to performed on 2020. With total of 14 wells done by bullheading treatment, there are no issue of resin residue found at surface and for overall process during production. As per explanation before, bullheading treatment can optimize operation for rig up and rig down equipment with simpler configuration. Total days saved from bullheading operations instead of using coil tubing with CT packer is equal to 1.7 operation days as per figure 6. 3 wells already flowing up to 120 days, average production rate at 1.4 MMscfd as per figure 7.

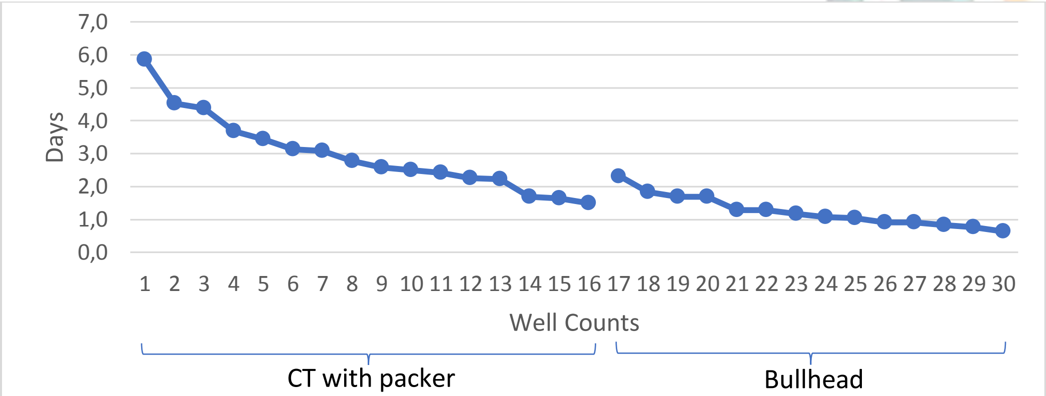



Figure 6. Daily Operation Comparison between Conventional Method with CT vs Bullheading Method

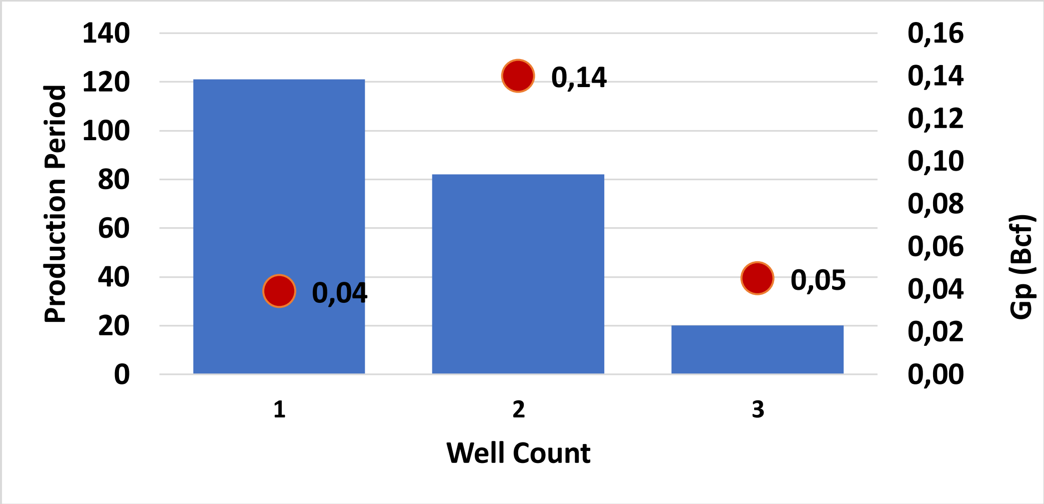



Figure 7. Bullheading Method Production Result

3.4 Maintained Quality After Chemical Reduction

Analysis of reduced chemical were performed by comparing reduced chemical result with initial performance of 3.5 ft penetration treatment. Total of 76 sand consolidation jobs were retrieved within 2019 and 2019 period as per seen on figure 8. 25 jobs among others are sand consolidation jobs with penetration length equal to 3ft. analysis was focused on died well since it gave final result of clean or sandy production.

Statistical parameter on figure 8 was summarized on table 3.

During initial clean up, 3.5 ft penetration has 2% sandy rate, meanwhile for 3 ft penetration has no sandy case. Sandy rate was furtherly observed until end of production. 3.5 ft penetration has 23% sandy issue while 3 ft penetration has 8% sandy issue. This result shown that chemical reduction from 3.5 to 3 ft penetration did not increase the sand failure. Sand consolidation quality was not jeopardized by reduction of chemical volume.

Chemical volume optimization was successfully achieved. By reducing penetration from 3.5 to 3 ft, it saved 25% chemical volume which equal to 25% of cost saving.

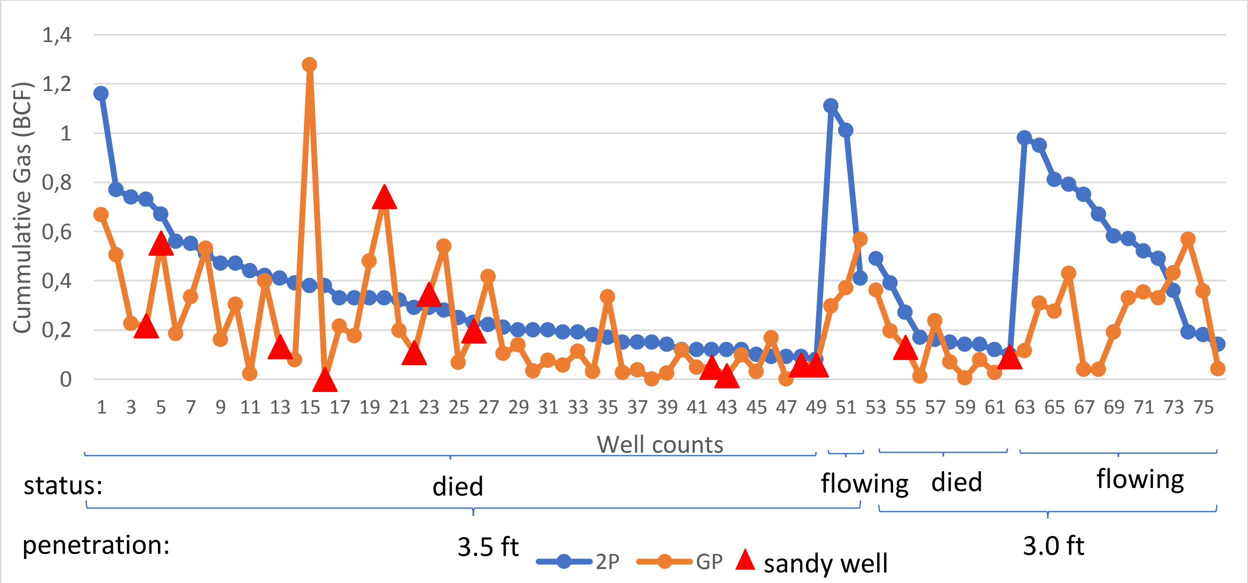



Figure 8. Production performance of current sand consolidation application vs reduced chemical treatment

Table 3. Production performance summary of current sand consolidation application vs reduced chemical treatment

| Penetration | 3.5 ft | 3 ft |
|---|---|---|
| Jobs | 52 | 24 |
| Clean up sand | 2% | 0% |
| Died with sand | 23% | 8% |
| Average GP/2P | 69% | 57% |

## 4 Conclusion

1. Increasing number of unit was well managed and able to contribute in production increase.
2. Product diversification on 3 different products was successfully implemented.
3. Bullheading method was successfully implemented with no issue with resin residue inside tubing. Optimum pumping rate was necessary to be maintained in order to prevent resin settlement on low side.
4. Chemical reduction to 3 ft penetration was proven not jeopardizing sand consolidation quality.

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