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Integrated Ultra Low Invasion–Nanoparticles Drilling Fluid (ULIN): Drilling Additives with Low Environmental Impact as Innovation to Solve Common Drilling Issues District)

Sasa Aulia
Gadjah Mada University | Bulaksumur, Caturtunggal, Sleman Regency, Special Region of Yogyakarta 55281
✉ sasaaulia@mail.ugm.ac.id

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Abstract: Drilling issues is extremely costly and a smart additives selection could be one of the ways to cope with these issues. Integrated Ultra Low Invasion–Nanoparticles Drilling Fluid (ULIN) purpose to overcome common drilling problems such as formation instability, differential sticking, lost circulation, and clay swelling by minimizing the invasion through environmentally safe drilling fluid additives. Ultra Low-Invasion produces a thin, deformable, yet robust shield that serves as the foundation for a low-permeability barrier at the formation's face, temporarily sealing pore throats. This seal forms after only a few seconds of invasion and has been demonstrated in laboratory experiments to be exceedingly effective at essentially inhibiting future fluid invasion or pressure transmission. On the other hand, nanoparticles drilling fluid inhibiting shales by either plugging pore in shales, viscosifying water in drilling fluids, and or osmotically dehydrating shales. It has a very high surface area to volume ratio resulting in improved physical and chemical sensitivity, boosting their performance efficiency. ULIN has exceeded the original oil production with an additional 1,800 BOPD produced by 11 wells. It also reduces the formation damage up to 93% from 64.3% to 4.5% in Naricual Formation. ULIN is safe for the environment while it can inhibit the reactive montmorillonite shales, declining rheology dropping back, controlling fluid loss amount and lubricity enhancement. Parameter of the feasibility of establishing a factory using economic analysis with an annual sales of 37,449,000 USD, and ULIN get a profit before tax of 23,108,266.89 USD and a profit after tax of 14,340,733.11 USD with a parameter calculation is a positive NPV, IRR of 40.01% including the cash flow and present value start to be positive in the 3rd year when the system starts operating. ULIN has a payback period of 4.3 years. From the result of the analysis, it can be concluded that ULIN has good prospects and deserves to be implemented.

Keywords: Economic Analysis, Environmentally Safe Drilling, Nanoparticles Drilling Fluid, Oil Recovery, Ultra Low-Invasion

1. Preliminary

In the last few decades, the oil and gas business has seen a revolutionary transformation. From exploration to drilling, production treatment, and refining, petroleum engineers have used technology to improve the oil and gas business in every way possible to assure efficient, safe, and cost-effective operations. Drilling operations are a vital stage because they are hampered by numerous problems that demand precision, expertise, and intelligence to overcome. Common drilling issues such as formation instability, differential sticking, lost circulation, and clay swelling are extremely costly (Arnold et al., 2016). While there are a variety of reasons for drilling issues, the majority of them are related to the drilling fluid, whose characteristics and optimization can aid in preventing/mitigating a variety of problems that may arise during drilling and saving a significant amount of money (Hassan, 2018).

Many of the most serious difficulties in well construction are caused by fluid invasion during drilling and finishing operations (Reid et al., 2003). Invasion in the payzone can result in formation damage as well as a reduction in the quality of log data and fluid samples. It can also cause differential sticking and encourage mud and cement circulation loss. Besides, when water absorbs into shale, it causes the clay swelling, increasing its tension and volume. The formation tension is reduced as tension is increased. Finally, it causes issues such as drill trapping, laminated drilling pipe entrapment, and drilling pipe trapping (Steve, 2011). In consequence, drilling fluid additives that require low invasion and prevent clay swelling are desired.

Therefore, as an innovative we propose the technology namely Integrated Ultra Low Invasion–Nanoparticles Drilling Fluid (ULIN), as a result, ULIN ability to reduce drilling invasion, the lowest possible finishing and rework fluid levels bring many benefits, including fewer formations breakdown, less differential attachment and prevention some kind of mechanical instability.

In this paper, we briefly discuss Integrated Ultra Low Invasion–Nanoparticles Drilling Fluid (ULIN) technology as a form of innovation in this energy and environmentally friendly on energy transition period. We then explain some examples of fields where sludge has been successfully reduced wellbore instability and reduce or eliminate induced losses. We will also give an example of a much reduced fluid invasion to permeable sand: in reservoirs, this can help limit formation damage and hence increase well productivity. We then explain an economic analysis of ULIN technology based on the parameters of NPV, IRR and payback period.

A. Description of the Integrated Ultra Low Invasion–Nanoparticles Drilling Fluid (ULIN) Technology

Ultra low invasion fluid is developed with patented chemistry that generates flexible “shields” in the drilling fluid system. It is a mix of non-ionic polymers with a variety of hydrophilic-lipophilic balancing values and solubilities in water and oil (Reid et al., 2003). The additive works equally well in oil and synthetic-based muds as it does in water-based muds because of the range of oil and water solubilities in the blend. Another added values of using ultra low invasion are the fact that it accommodates deformable particles with an adequately broad size distribution to seal a variety of microfracture openings, forms a very low permeability seal as rapidly as possible to avoid damaging numbers of fluid entering the microfractures, have low formation damaging characteristics, and meet expected health, safety, and environmental requirements. Then ULIN system also incorporates the use of nanoparticles, the additive is a type of drilling fluid additive that consists of nanoparticles where the size is between 1 – 100 nm. The nano size of this additive which is not higher than one-third of the pore throat makes it easier to penetrate to low permeability formation such as shale in unconventional resources (Suri & Sharma, 2004). It can inhibit shales by either plugging pore in shales, viscosifying water in drilling fluids, and/ or osmotically dehydrating shales. Because of their nano-sized particles, it has a very high surface area to volume ratio (Ikram et al,. 2021). As a result, nanoparticles may have improved physical and chemical sensitivity, boosting their performance efficiency.

B. Limit Fluid and Pressure Invasion

Invasion of the mud balance pressure into the rock matrix will increase the pore pressure. If pore pressure increase, it will unable to bleed fast enough (e.g. if stones very low permeability as in dense shale or siltstone), effective stress is reduced, bringing the stress state of the rock towards collapse. This can cause the rock to collapse and cause wellbore instability (Herdes et al., 2017).

If the pressure and fluid invasion can be stopped completely when drilling in the overbalance, it is clear that a lot of drilling trouble will never happen and most of the formation the damage associated with mud and supplementary fluids is removed. However, currently nothing is established technology that can completely prevent both forms of invasion and therefore, the industry is focusing on reducing it to the lowest possible level possible. By substantially reducing the invasion it is possible to remove, or at least reduce, the above problem: this will reduce unproductive time, make it more efficient operations and increase well productivity.

C. Wellbore Reinforcement

Ultra low invansion fluid additives have been used by one operator in more than 45 wells were drilled offshore in the Gulf of Mexico with data well can be seen in Table 1. Here, the big one most application have been in the reverse oil slurry where ultra low invansion fluid is used in the intermediate bore section to raise fracture gradient and reduce induced mud losses. Typical problems faced by operators in this region are that the fracture gradient is lower than the

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mud weight required to provide effective well and borehole control stability. In many wells, inflows are drawn or cavings are observed but when the weight of the mud is raised to combat this problems, large losses are induced: in some wells more than 25,000 barrels of oil sludge have been lost. This uncontrolled loss can result in subsurface kicks/losses a situation that can take days to resolve. Wells often need switch or set the case earlier.

2. Research Methods

Technical Description

ULIN system design consists of two main additive components which are Ultra low invansion with nanoparticles drilling fluid. These two additives will be added to Oil Based Mud (OBM) as it is illustrated in Figure 1.

The first additive, ultra low invansion fluid is added to provide ultra-low invasion in drilling. When a ultra low invansion fluid product is added to an oil-based liquid, same mechanism operates but now more hydrophilic components that make up the aggregate. These aggregates are the key to formation of a very low permeability barrier at rock surface with matrix permeability. This seal forms after only a few seconds of invasion and has been demonstrated in laboratory experiments to be exceedingly effective at essentially inhibiting future fluid invasion or pressure transmission (Herdes et al., 2017). Ultra low invansion fluid produces a thin, deformable, yet robust shield that serves as the foundation for a low-permeability barrier at the formation's face, temporarily sealing pore throats. With very wide particle size distribution, easy to see how the same ultra low invansion fluid additive can seal different matrix pore size and small fractures. The mechanism of action of ULIF is shown pictorially in Figure 2.

The second additive, nanoparticles, is added so it can penetrate into shale formation which usually makes up to 75% of the formation to avoid clay swelling and maintain wellbore stability. It will form a more even thin filter cake which blocks the entry of fluids. When these two additives are combined, it will provide a wide range of particle size from nano size to aggregates. Furthermore, these two additives offer a strong sealing capacity that protects the formation by limiting pressure transmission, enhancing pressure bearing capability, and decreasing fluid interaction between the borehole and the formation, so it protects the reservoir and improves the hole stability. The drilling fluid industry faces a new challenge in developing creative, high-performance, and cost-effective drilling fluids, and ULIN provides a solution to this problem.

3. Results and Discussion

Extra Oil Recovered

The sealing capacity that supplied by ULIN is success to prevent invasion and losses of oil. Invasion is prevalent in drilling resulting a reduction in the economic life of gas wells, that is why the prevention of invasion could lead to enhanced production. In Field, it is proven that 11 wells there yielded an extra 1,800 barrels of oil produced per day (Herdes et al., 2017). The extra oil recovered are shown in Figure 3.

Reduction of Formation Damage

The substantially decreased formation damage with ULIF is remarkable and it illustrates the technology's exceptional performance under tremendous pressure. Table 2 depicts the retained permeability test. It shows that ULIF has decreased formation damage up to 93% from 64.3% to 4.5% when differential pressure is increased until 2500 psi. Further evidence of the ability of ultra low invasion products to protect and strengthen the weak formation provided by them success in the difficult Nahr Umr Shale in the Middle East, and in using the ultra low invansion approach to drill 500 feet horizontal section of coal seams in North America.

Economic Result

Economic analysis is performed to assess the economic feasibility of the system. This study considered net present value (NPV), internal rate of return (IRR), fixed capital (FC), and payback period (tpayback) as the economic performance indicators. These indicators are calculated by developing cost functions of each component in the system along with the assumptions as mentioned in Table 3 based on literature studies of the research by Bachtiar et al. (2021), Mwagomba (2016), and Kesieme et al. (2013).

A project or system is feasible if the NPV is positive. NPV is formulated below (Bachtiar et al., 2021), where i is the discount rate, t is the project life in years, and CFt is the cash flow in the T-th year:

$$NPV = \sum_{T=0}^{T} CF_T/(1+i)^T \quad (1)$$

IRR is the discount rate that makes total present value equal to fixed capital (Achinas & Euverink, 2019). A project is feasible if the IRR is equal to or higher than the expected return. Fixed capital consists of equipment costs and additional costs, such as

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construction and project management costs, which are assumed to be 65% of total equipment cost. The payback period calculation includes construction duration, FC, additional net power output after implementing the proposed system (Wadd), OPEX, tax, and the sales income which are formulated as follows (modified from Noroozian et al., 2017):

$$t_{payback} = t_{construction} + \frac{FC}{(Sales - OPEX) \times (100\% - TAX\%)} \quad (2)$$

$$Sales = m_{oil} \times c_{oil} \quad (3)$$

This study performed an economic analysis for the proposed system to assess its feasibility from the economic point of view. From the economic analysis, the fixed capital, NPV, IRR, and payback period of the proposed system are obtained as can be seen in Table 4. These economic parameters are used to decide whether the system is economically feasible. In addition, the cumulative cash flow profile of the proposed system can be seen in Figure 4, which is used as the basis of calculation of NPV and IRR.

The amount of fixed capital needed to develop the proposed ULIN system is USD 10,755,549.83. The project yields a positive NPV of USD 56,160,800 with the IRR of 40.01%. Furthermore, the payback period is 4.3 years calculated since the beginning of the project or 2 years after finishing the construction phase. The positive NPV, high IRR, and short payback period show that the proposed system is economically feasible to implement.

4. Conclusion

The ability to reduce fluid invasion and pressure into formation to a very low level will bring benefits in terms of reduce mud loss, reduce formation damage, lower risk better differential attachment and wellbore stability in many types of formations are potentially unstable. Use of the ULIN approach is a simple and effective method of providing wellbore reinforcementin the transition energy era.

We present some results to demonstrate the benefits of using ULIN technology:

- ULIN has exceeded the original oil production with an additional 1,800 BOPD produced by 11 wells.
- ULIN also reduces the formation damage up to 93% from 64.3% to 4.5%.
- Economic analysis showed that the NPV and IRR of the proposed system are USD 10,755,549.83 and 40.01%, respectively, with a payback period of 4.3 years. The positive NPV, high IRR, and short payback period indicates that the proposed system is economically feasible to implement.

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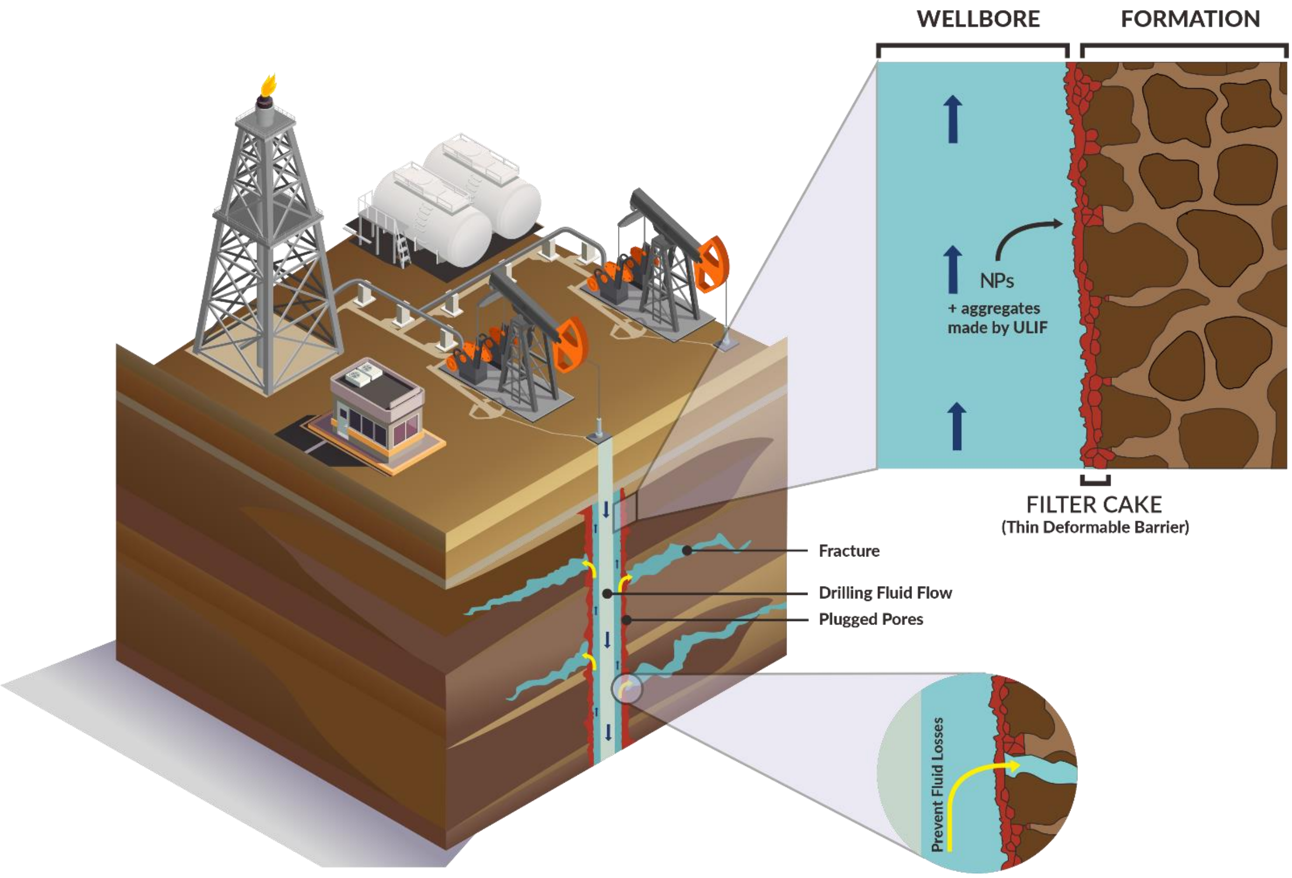

Tables and Figures

Figure 1. ULIN Design System

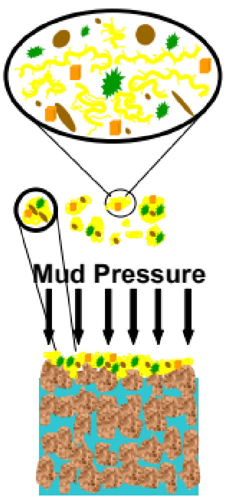

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Figure 2. A schematic representation of the ultra low invansion fluid polymers and solids forming aggregates in solution.

Table 1. Summary data of offshore Gulf of Mexico

Well	Offset Well	Unit
Interval	6630-16142	feet
Feet drilled	9512	feet
Mud Volume Lost to Formation	3164	barrels
Days on Location	154	days
Rig Day Rate	39,500	USD
Interval Rig Cost	6,083,000	USD
Cost of Sidetrack	180,000	USD
Cost of Fluids	1,137,000	USD
Interval Cost	7,400,000	USD

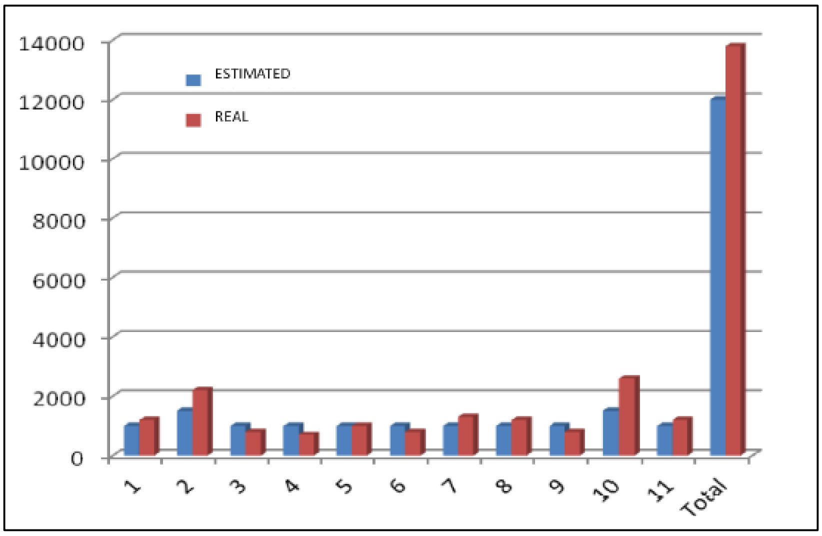

Figure 3. Well production in Fields drilled with Ultra low invasion exceeded expectations.

Table 2. Retained permeability test with and without Ultra low invasion

Parameters	Base OBM	OBM with ULIFT	Base OBM	OBM with ULIFT
ULIFT (lb/bbl)	0	4.5	0	7
Differential Pressure (psi)	**1000**	**1000**	**2500**	**2500**
Injection Rate (mL/min)	0.5	0.5	4.0	4.0
Filtrate (mL)	12	10	0.2	0
Lift-up Pressure (psi)	150	100	NR	NR
Retained Permeability (%)	82.87	83.33	35.7	95.5
Formation Damage (%)	17.13	16.67	64.3	4.5

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Table 3. Basic financial assumptions used for economic analysis.

Parameter	Value	Unit
Project duration	20	Year
Discount	10	%
Tax	25	%
Construction duration	3	Year
Fixed capital distribution for construction phase first, second, and third year	20/30/50	%
Operating expenditure (OPEX)	50	% modal
Rig Day Rate	39,500	USD
Interval Rig Cost	6,083,000	USD
Cost of Sidetrack	180,000	USD
Cost of Fluids	1,137,000	USD
Interval Cost	7,400,000	USD
Cost of Oil (C_{Oil})	60	USD/bbl

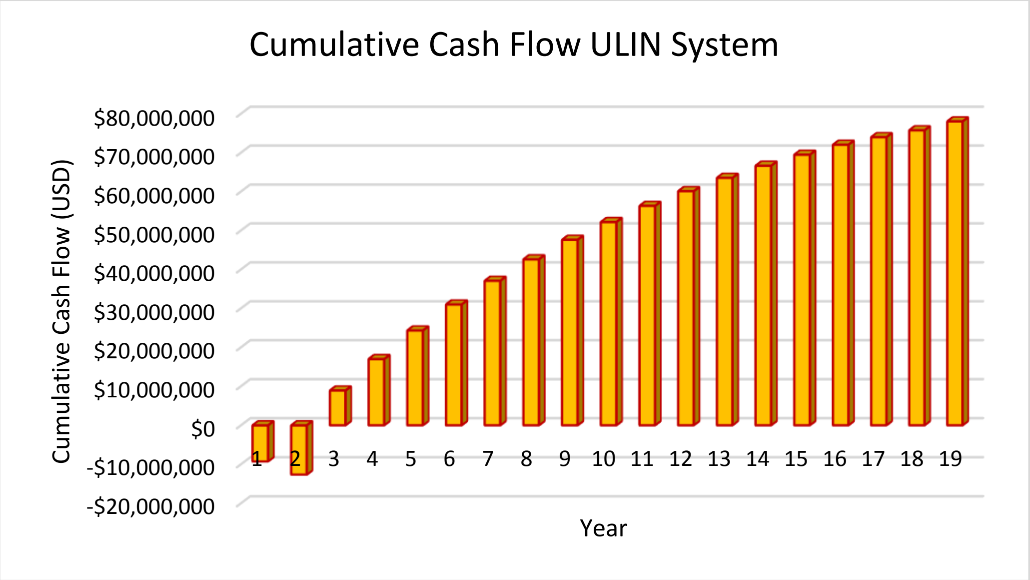

Figure 4. Cumulative cash flow of the proposed system.

Table 4. Results of economic analysis.

Economic parameter	Unit	Value
Fixed capital	USD	10,755,549.83
NPV	USD	56,160,800
IRR	%	40.01
Payback period	Year	4.3

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