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Potensial of Lost Circulation Zones in RJ Well, CP Field by Calculating Hydrostatic, Formation and Fracture Pressure

Reynaldy Julio[1], M. Nur Mukmin[2] Firdaus[3], Afrida[4], Aprilino Alfa Kurmasela[5] , Iin Darmiyati[6] Annisa Efidiawati[7]
[123456] Sekolah Tinggi Teknologi Migas; Indonesia
correspondence e-mail*, wawanandipadang22@gmail.com

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Abstract

This study aims to analyze the potential of lost circulation zones in the RJ well at the CP field by calculating hydrostatic pressure, formation pressure, and formation fracture pressure. Lost circulation occurs when drilling fluid is lost into the formation, which can disrupt the drilling process. In this study, calculations were made for hydrostatic pressure, formation pressure, and formation fracture pressure at various depths of the well. The results show that at a depth of 741 ft, the hydrostatic pressure is 330.22 psi, formation pressure is 318.66 psi, and formation fracture pressure is 982.88 psi. Meanwhile, at a depth of 9517 ft, the hydrostatic pressure reaches 5438.78 psi, formation pressure is 5290.31 psi, and formation fracture pressure is 7237.24 psi. The significant difference between hydrostatic pressure and formation pressure leads to the occurrence of lost circulation. In conclusion, the potential for lost circulation in the RJ well is caused by hydrostatic pressure being higher than formation pressure. This study provides important insights into the factors influencing lost circulation and is expected to serve as a reference for future drilling operations.

Keywords Lost circulation, hydrostatic pressure, formation pressure, formation fracture pressure, RJ well

Introduction

Drilling is an integral part of the exploration and production of oil and natural gas operations, playing a vital role in the success of a project.[1] Without efficient drilling operations, the process of extracting hydrocarbons from reservoirs will be disrupted. Therefore, achieving the correct well depth quickly, safely, and economically is a key requirement in the drilling process. The success of drilling not only depends on the drilling technology itself but also on the selection

[1] Cícero Andrade Sigilião Celles et al., "Osseointegration in Relation to Drilling Speed in the Preparation of Dental Implants Sites: A Systematic Review," *The Journal of Prosthetic Dentistry* 133, no. 2 (2025): 394–401; Gensheng Li et al., "Intelligent Drilling and Completion: A Review," *Engineering* 18 (2022): 33–48.

of the right drilling fluid.[2] Drilling fluids play an important role, one of which is to reduce the risk of drilling problems such as fluid loss, also known as lost circulation(Equinor,2016). During drilling operations, unexpected issues often arise, one of which is the loss of mud(Ginting,2020). This loss occurs when drilling fluid enters a porous formation, resulting in a reduction of the fluid required to maintain pressure balance in the wellbore(Kulkarni,2015). Although mud loss is a well-known issue in the drilling industry, it continues to occur at various depths and oil and gas fields worldwide(Kurniawan,2015). Therefore, a thorough analysis is needed to identify the causes and appropriate solutions to address this problem(Akbar Pratikno et al., n.d.).

Furthermore, the condition of the wellbore and the presence of formation disturbances around the wellbore can affect the smoothness of the drilling process(Morita,1990). One of the main factors causing this problem is the imbalance between the hydrostatic pressure of the drilling fluid and the formation pressure around the well(Satiyawira,2018). When the pressure of the drilling fluid exceeds the formation pressure, the fluid will lose circulation and flow into the formation, a phenomenon known as lost circulation(Urselmann,1999). Therefore, accurate calculations of hydrostatic pressure, formation pressure, and formation fracture pressure are essential in analyzing the potential for this issue(Yanti et al., n.d.).

This study aims to evaluate the potential lost circulation zones in the RJ well at the CP field by calculating and analyzing hydrostatic pressure, formation pressure, and formation fracture pressure at different depths. Through this research, it is expected that a better understanding of the factors affecting lost circulation will be obtained, as well as the steps that can be taken to prevent such issues [3]. The selection of appropriate drilling fluids and proper pressure management during drilling operations can be key to reducing risks and enhancing operational efficiency [4]. The purpose of this research is to provide a clearer picture of how hydrostatic pressure, formation pressure, and formation fracture pressure can affect the occurrence of mud loss during drilling [5]. This study also aims to explore the main causes of lost circulation and provide recommendations for preventive measures that can be applied in drilling management(Ira Kumalasari et al., n.d.).

[2] Arturo Magana-Mora et al., "Well Control Space out: A Deep-Learning Approach for the Optimization of Drilling Safety Operations," *Ieee Access* 9 (2021): 76479–92; M Rafiqul Islam and M Enamul Hossain, *Drilling Engineering: Towards Achieving Total Sustainability* (Gulf Professional Publishing, 2020).
[3] Ikhwannur Adha, "RESERVOIR DI LAPANGAN CIPLUK KENDAL" 3, no. September (2021): 39–50.
[4] (Jamaluddin, 2021)
[5] (Sima, 2022)

Methods

Lost circulation refers to the loss of drilling fluid as it flows into formations with high porosity, cavities, fractures, or faults . This occurs due to various factors, including hydrostatic pressure in the wellbore causing formation fractures (Ph>Pf), which can be triggered by high mud density, annular friction pressure, low formation pressure, and surge pressure. Another factor contributing to lost circulation is the presence of natural fractures or high permeability in the formation, where overbalanced mud pressure causes the fluid to escape. Unconsolidated formations, fractures, faults, and cavities are often involved in these scenarios.

Lost circulation can be classified based on the volume of mud lost, as described by Morre, P.L. The classifications include Seepage Loss, Partial Loss, and Total Loss. Seepage Loss refers to the small loss of mud (less than 10 bbl per hour) typically found in porous formations like sand, gravel, and limestone with natural fractures. Partial Loss involves a more significant loss (10 to 50 bbl per hour) and occurs in formations with gravel, porous material, or rocks containing fractures. Total Loss refers to the complete loss of circulation, where no mud returns to the surface, usually occurring in formations with large cavities or fractures.

To address lost circulation effectively, the depth of the loss zone must be identified. Several surface detection methods can be used for this purpose. The Drill Monitor places sensors on the drilling equipment to monitor mud circulation and can provide real-time data to identify when circulation is lost. The accuracy of this method improves when combined with a pit level monitor, which tracks changes in fluid volume. Spinner surveys, where small spinners are lowered into the well, can detect the amount of fluid entering the formation through the wellbore. Temperature surveys measure the temperature difference between mud and formation temperatures to identify loss zones. Pressure transducers detect changes in pressure when mud circulation is lost. Hot Wire Surveys use sensitive wire to detect temperature changes in the wellbore, indicating lost circulation when the wire’s resistance changes.

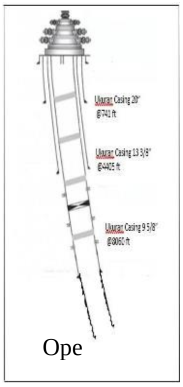
Preventing lost circulation is crucial in maintaining an effective drilling operation. The first step is managing mud density to balance formation pressure and prevent excessive pressure that may lead to formation fracturing. The use of additives can increase the mud density, but this must be monitored to ensure it doesn't exceed the formation’s pressure limits. Additionally, controlling viscosity and gel strength is essential to avoid excessive friction and formation failure. High gel strength can require more energy to overcome, potentially causing formation damage. Proper bit entry techniques should also be employed to prevent surge pressure that could fracture the formation.

When lost circulation occurs, several methods can be applied to mitigate the issue and minimize damage to the wellbore and formation. One approach is reducing the weight of the mud, which decreases the pressure differential between the mud column and the formation. This reduction helps lower the chances of mud loss. Another method is the use of Loss Circulation Material (LCM), which can block fractures and other porous zones in the formation. LCM comes in different forms, including fibrous materials, flakes, granular materials, and acid-soluble compounds, each suitable for different types of formations. Fibrous materials, such as cotton or fibers, help block large fractures, while granular materials like nut shells can seal larger openings. Acid-soluble LCMs are often used in production zones where conventional LCMs may damage the formation.

The techniques like cementing can be used to seal off loss zones, particularly in formations with many cavities. Cementing is effective in plugging the holes and preventing further mud loss. In extreme cases, blind drilling, where drilling is conducted without circulating mud, may be employed. However, this method carries risks, such as stuck pipe or failure to bring drill cuttings to the surface, which can lead to further complications. The key to successful mitigation is to carefully assess the formation conditions and apply the appropriate solution based on the severity of the lost circulation.

Result and Discussion

The RJ well at the CP field is a directional drilling well. This well has a 26" open hole and 20" casing up to a depth of 741 ft, followed by a 17 ½" open hole and 13 3/8" casing to a depth of 4405 ft. The well then continues with a 12 ¼" open hole and 9 5/8" casing to a depth of 8060 ft, followed by an 8 ½" open hole to a depth of 8113 ft. The well is then completed with an 8 ½" open hole down to a depth of 9617 ft. The RJ well profile is shown in the figure. The Productivity Index (PI) for liquid and oil was determined as 1.03 bfpd/psia and 0.1299 bopd/psia, respectively. Permeability was calculated at 22 md, indicating moderate reservoir quality. The skin factor analysis revealed a value of 29.53, confirming significant formation damage (Table 6)



At the CP field, data processing will be conducted with the aim of planning solutions to address lost circulation issues by recalculating hydrostatic pressure as follows:

Depth (ft)	Mud Weight (ppg)	Surface Pressure (Psi)	Open Hole (Inch)	Mud Flow Rate (Gpm)	ROP (Ft/hr)	WOB (Lb)	Rotary Speed (Rpm)
741	8,57	652,66	26	362,708	81,69	10	29
4405	11,66	2175,66	17,50	792,516	60,69	11	60
8060	11,16	1522,89	12,25	647,221	65,6	12.5	90
8113	10,8	1334,34	8,5	576,159	76,77	8	110
9517	10,99	1798,46	8,5	493,209	75,78	6	70

The table provided presents the well data for RJ well at different depths. It includes key drilling parameters such as mud weight (MW), surface pressure, open hole diameter, mud flow rate, rate of penetration (ROP), weight on bit (WOB), and rotary speed (rpm). At a depth of 741 ft, the mud weight is 8.57 ppg, with a surface pressure of 652.66 psi and an open hole diameter of 26 inches. The mud flow rate is 362.708 GPM, the ROP is 81.69 ft/hr, WOB is 10 lb, and the rotary speed is 29 rpm.

As the depth increases, there are noticeable variations in these parameters. For instance, at a depth of 9517 ft, the mud weight increases to 10.99 ppg, surface pressure rises to 1798.46 psi, and the open hole diameter decreases to 8.5 inches. The mud flow rate also decreases to 493.209 GPM, with a slightly lower ROP of 75.78 ft/hr. The weight on bit decreases to 6 lb, and the rotary speed is

70 rpm. These changes reflect the adjustments made during drilling to manage the challenging conditions encountered at greater depths.

RJ Well		
Data	Value	Unit
MW	8,57	Ppg
ROP	81,69	Ft/hour
WOB	10	Lb
Rotary Speed	29	Rpm
Bit Diameter	26	Inch

Formation pressure is calculated to determine the ability of the formation to withstand the density of the mud, so that the mud density can be properly planned. Formation pressure can be calculated using the d-exponent equation. Lost Circulation is the loss of drilling fluid, where part of the fluid enters the formation during the drilling process. The cause of lost circulation in well RJ is due to the difference between hydrostatic pressure and formation pressure, leading to the conclusion that lost circulation has occurred.

Hydrostatic pressure increases because of the high mud density, causing the hydrostatic pressure to exceed the bottom hole pressure, known as overbalance conditions. By comparing formation pressure and hydrostatic pressure, we can determine if lost circulation occurs.

Based on the data in the table, where formation pressure at depths of 4405 ft, 8060 ft, 8113 ft, and 9517 ft is compared with hydrostatic pressure at the same depths, it is found that hydrostatic pressure is greater than formation pressure. From this condition, it can be concluded that lost circulation has occurred, while at a depth of 741 ft, no lost circulation occurs because hydrostatic pressure is almost the same as formation pressure. Lost circulation refers to the loss of part or all of the drilling mud that enters the formation, leading to incomplete circulation of drilling fluid. Lost circulation can cause issues that hinder the drilling operation, and it happens when hydrostatic pressure exceeds the formation pressure.

Well RJ in the "CP" field has a mud density of 8.57 ppg, surface pressure of 652.66 psi, an open hole size of 26 inches, a mud flow rate of 362.708 gpm, a rate of penetration of 81.69 ft/hour, a weight on bit of 10 lb, and a rotary speed of 29 rpm.

To analyze the cause of lost circulation in well RJ, the first step is to calculate the formation pressure. To calculate the formation pressure, the values of the d-exponent, d-correction, and Equivalent Mud Weight must be known. The d-exponent value calculated is 0.57, the d-correction value is 0.60, and the equivalent mud weight is 8.27 lb/gl. Once the d-exponent, d-correction, and EMW values are known, formation pressure can be determined through calculations. The formation pressure calculated is 318.65 psi at a depth of 741 ft, 2602.12 psi at 4405 ft, 4551.64 psi at 8060 ft, 4429.69 psi at 8113 ft, and 5290.31 psi at 9517 ft.

The next step is to calculate the hydrostatic pressure in well RJ. The hydrostatic pressure calculated is 330.21 psi at a depth of 741 ft, 2670.83 psi at 4405 ft, 4677.37 psi at 8060 ft, 4556.26 psi at 8113 ft, and 5438.77 psi at 9517 ft.

Next, the fracture formation pressure at well RJ is calculated. The fracture formation pressure at a depth of 741 ft is 982.88 psi, at 4405 ft is 4846.40 psi, at 8060 ft is 6200.27 psi, at 8113 ft is 5890.60 psi, and at 9517 ft is 7237.24 psi.

Lost circulation occurs when hydrostatic pressure exceeds formation pressure (partial loss). In well RJ, lost circulation occurs at depths of 4405 ft, 8060 ft, and 9517 ft because the hydrostatic pressure is much higher than the formation pressure. However, at a depth of 741 ft, no lost circulation occurs because the hydrostatic pressure is almost the same as the formation pressure.

CONCLUSIONS

This study systematically evaluated scale formation mechanisms and the effectiveness of acidizing treatments in restoring well productivity through a comprehensive analytical approach. The investigation commenced with detailed formation water analysis utilizing the Stiff & Davis and Skillman-McDonald-Stiff methods, which revealed critical scaling tendencies under specific downhole conditions. Computational results demonstrated a positive scaling index (SI = 1.7) and significant gypsum solubility differentials (S = 46.17 vs S' = 12.492), conclusively identifying calcium carbonate ($CaCO_3$) as the predominant scale type in Well "YDK-01". These findings were substantiated through rigorous examination of key parameters including pH (8.3), temperature profiles (25°C/77°F), and ionic strength measurements (0.329). The acidizing treatment design incorporated advanced hydraulic calculations to optimize operational parameters while maintaining formation integrity. Critical design elements included fracture pressure determination

(1,568.18 psi), bottom-hole temperature estimation (131.97°F), and precise fluid volume calculations (20.5 bbl total acid volume with 22.3 bbl displacement volume). The engineered injection pressure (154.59 psi) was carefully maintained below the fracture threshold to prevent formation damage, demonstrating the importance of geomechanical considerations in stimulation design.

Post-treatment evaluation revealed substantial production improvements across all measured parameters. The three-phase IPR analysis showed remarkable production increases, with oil output rising 51.6% (91.33 to 138.49 bopd) and total fluid production improving by 118.7% (753.46 to 1,648.32 bfpd). These gains were further corroborated by productivity index enhancements, where liquid PI increased 121.4% and oil PI improved 53.5%. Permeability measurements confirmed significant formation conductivity restoration, increasing from 22 md to 34 md (54.5% improvement). The dramatic reduction in skin factor from 29.53 to 0.99 (96.6% decrease) provided conclusive evidence of successful near-wellbore damage remediation. The collective results demonstrate that the implemented acidizing protocol effectively addressed scale-induced formation damage while optimizing production potential. The methodology's success is particularly evident in the sustained production uplifts, improved reservoir connectivity, and complete mitigation of near-wellbore damage. This case study establishes a validated technical framework for scale management and production enhancement in similar well conditions, highlighting the critical importance of integrated formation evaluation, precise treatment design, and comprehensive performance monitoring in well intervention operations. The significant improvements across all measured parameters confirm the treatment's technical and economic viability, providing a replicable model for analogous scaling scenarios in carbonate reservoirs.

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