# Drilling the Undrillable; a Review of Indonesia Onshore Managed Pressure Drilling (MPD) Operation Experiences

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## ABSTRACT

MPD (Managed Pressure Drilling) has been used worldwide to overcome drilling challenges in onshore and offshore operations. MPD has proven to save significant cost efficiency in every applications, by reducing NPT (Non Productive Time) caused by drilling problems such as, severe loss circulations, loss-kick cycle, and well control events. Indonesia is one of major country in Asia Pacific that has several needs to developing or exploring new opportunities with drilling challenges, especially in vuggy carbonate reservoirs, narrow drilling windows, and wellbore in-stability. This paper will present the basic theory on MPD, MPD equipment’s, types of MPD, and elaborate more on successful MPD operation in onshore Indonesia, and clustering the solutions of drilling challenges.

Kata kunci: MPD; onshore drilling; drilling challenges

## INTRODUCTION

Gala & Toralde (2011) and Hannegan (2015) mentioned that conventional drilling has shifted from Spindletop operations to overbalanced drilling which introduces the use of mud to the formations. Conventional overbalanced drilling uses the hydrostatic pressure of the annulus returns column becomes the primary well control barrier, and with circulation from the mud pump to help the cutting lifting to the surface in open atmospheric pressure. Overbalance drilling has brought the oil and gas industry maturity in over a century, and the challenges that were able to be overcome with mud weight hydrostatic to get the prospect. Eventually those drillable or should be call “easy to drill” formations have been drill and leaving challenging formations or should be call “undrillable” formations.

Those “undrillable” formations because of conventional drilling has some limitations in drilling with narrow drilling window, wellbore stability issues, severe losses, loss-kick cycles, which might create well problems and well control incidents. Hannegan (2015). Managed Pressure Drilling (MPD) could be beneficial to control more precise management of wellbore pressure both in static and dynamic conditions to reduce the risks of conventional drilling limitations.

Zein et al., (2016); Darmawan et al., (2011); Nas et al., (2009) discussed MPD equipment including Rotating Control Device (RCD), Automated Choke Manifold (ACM) with Coriolis, and in some cases combined with DIV (Downhole Isolation Valve) to reduce the skin of the drilled formations.

Indonesia is one of major country in Asia Pacific that has several needs to developing or exploring new opportunities with drilling challenges, especially in vuggy carbonate reservoirs, narrow drilling windows, and wellbore in-stability. Zein et al., (2016); Darmawan et al., (2011); Darmawan et al., (2011); Nas et al., (2009) described the most common MPD practice in onshore Indonesia, to overcome issues during drilling fractured carbonates. . But over the time many other areas in Indonesia feels the needs to be drill with MPD, such as drilling abnormal pressure shale, and many more.

This paper will present the basic theory on MPD, MPD equipment’s, types of MPD, and elaborate more on successful MPD operation in onshore Indonesia, and clustering the solutions of drilling challenges.

What is MPD?

Darmawan et al., (2011) quoted MPD definition from International Association of Drilling Contractors (IADC) as “an adaptive
drilling process used to more precisely control the annular pressure profile throughout the well bore. The objectives of MPD are “to ascertain the downhole pressure environment limits and to manage the annular hydraulic pressure profile accordingly”. The IADC differentiates MPD from Underbalanced Drilling (UBD) by stating that, “MPD is intended to avoid the continuous influx of formation fluids to the surface. Any influxes incidental to the operation will be safely contained using an appropriate process”.

The main difference between UBD (Underbalanced Drilling) and MPD is, UBD is mostly designed to prevent damage to the reservoirs, while MPD is mostly designed to solve or overcome drilling problems (Martin, 2006).

**MPD Theory**

In drilling design, the basic data requirements are the PPFG (Pore Pressure and Fracture Gradient) to ensure proper casing seat selections, mud weight selection to be used to avoid kick if mud weight below the pore pressure or losses if mud weight higher than the fracture pressure. The area between pore pressure and fracture pressure is called the drilling window, and assurance that the mud weight as well as the ECD (Equivalent Circulating Density) should be always within the drilling window to avoid any drilling problems.

The main purpose of MPD is to be able to drill in narrow drilling windows, which could lay between wellbore instability and mud losses pressure gradients. Having Bottom Hole Pressure (BHP) lower than the wellbore instability pressure could risk the collapse of the wellbore resulting in a stuck pipe that may lead to non-productive time in drilling operations as stated by Zein et al., (2016).

By having MPD in closed systems, where circulation can still be achieved with some considerations to minimize the drilling impact cost in drilling the undrillable formations with conventional drilling. Zein et al., (2016); Darmawan et al., (2011) mentioned mostly the design of MPD not limited to maintaining ECD and ESD (Equivalent Static Density) to maintain wellbore stability, flow rate high enough for hole cleaning without inducing losses to the formation, mud weight low enough for hole cleaning, and minimizing the amount of additive used should losses occurred. MPD could allow flexible equivalent density control from the surface with the utilization of RCD and ACM by manipulating surface back pressure, which directly affects the BHP throughout the drilling operation without increasing the mud weight or the flow rate.

During connection, where there is no circulation (pumps off), a back pressure pump (could be mud pump, or nitrogen pump) is used to generate circulation thus MPD ACM will keep adjusting surface back pressure to ensure BHP. One challenge during any MPD operation is how to maintain the hydrostatic in the wellbore when there is no strings in the hole where back pressure cannot be applied (open loop condition), this situation could be overcome by pumping predefined slug with a certain weight and to occupy specific heights. This should be calculated carefully to ensure no influxes or losses during open-loop conditions.

When drilling conventionally, the formation pressure was supported with the hydraulic pressure exerted by the mud weight. It will be difficult to maintain mud weight in such a narrow drilling window to avoid any drilling operation issues. In MPD, Surface Back Pressure (SBP) is the main control to be able to maintain the desired BHP if the well is in a closed-loop circulation where choke playing the role to apply accurately SBP as mentioned by Zein et al., (2016). SBP will be applied as additional pressure to the hydrostatic at all depths and will increase ECD, hence need to be ensured below the fracture gradient.

Zein et al., (2016); Krisboa et al., (2013) stated the generic equation for BHP due to additional factor of SBP:

\[
\text{BHP static} = P_{\text{hydrostatic}} + \text{SBP} \\
\text{(1)}
\]

\[
\text{BHP dynamic} = P_{\text{hydrostatic}} + \text{AFP} + \text{SBP} \\
\text{(2)}
\]

Where BHP static is the BHP while there is no circulation (referred to as ESD), BHP dynamic
is there is circulation (referred to as ECD). AFP is annular friction pressure due to circulation process, SBP is the back pressure applied.

**Figure 2.** ECD changes illustration due to formation pressure change, by adding SBP the ECD could be increased without changing the mud density, hence drilling could be continued without any issues; after Krisboa et al., (2013)

**MPD Equipment**

**Rotating Control Device (RCD)**

To be able to drill in a closed-loop system, RCD has the capability to contain pressure by sealing the annulus and divert fluids for BHP management. RCD installed on top of annular preventer on the Blowout Preventer (BOP) stack. RCD is not considered as a barrier in well control operations.

Zein et al., (2016) mentioned that the bowl of RCD is the main body where the bearing assembly is seated. The bowl has outlets to divert flows if the annulus is closed. Bearing assembly gives the static and rotational bearing against drillpipe while rotating in the bowl. The frictions on the assembly reduce the sealing capability and have to be monitored and replaced periodically.

**Figure 3.** RCD bowl and bearing assembly; after Zein et al., (2016)

**ACM (Automated Choke Manifold)**

ACM is ran on control systems with programmable logic controller which could be set to control the opening/closing percentage of the automated control valve on the ACM. Also the ability to connect to auxiliary mud or nitrogen pump to provide the back pressure (SBP), as well as monitoring the flow in/out. This ACM usually comes with Coriolis mass flow meter and pressure sensors to have an accurate flow reading to detect ballooning or flow (influx) identification.

**Figure 4.** Automated Choke Manifold for MPD; after Zein et al., (2016)

**METHODOLOGY**

This paper is literature research by assessing and reviewing several journals and papers related to MPD operation in the onshore areas. The results of those various works are compiled, analyzed, and used to retrieve conclusions on MPD in the onshore areas in Indonesia.

**RESULT AND DISCUSSION**

The term MPD was first introduced in 2003 in an offshore operation which was tailored from onshore-proven-techniques which include CBHP (Constant Bottomhole Pressure), PMCD (Pressurized Mud Cap Drilling), Dual-gradient Drilling, and RFC (Return Flow Control) as outlined by Hannegan (2015); Darmawan et al., (2011). CBHP is drilling in a narrow drilling window, relatively unknown safe drilling margin. PMCD is drilling in severe losses condition, dual-gradient for reducing hydrostatic head pressure in depleted formations, and RFC for drilling with a closed-loop system exclusively for safety and environmental reasons (Nas et al., (2009); Darmawan et al., (2011); Hannegan 2015). Every variant has its equipment and set-up for specific purposes, for example, PMCD operations could be perform simply with RCD, etc.

MPD preparation for onshore operations (Nas et al., (2009); Darmawan et al., (2011)):
RCD installation, the correct data of free space requirement below rotary table is mandatory to be able to draw the BOP sketch for the MPD section.

Connection from and to the RCD with the RCD power unit and control unit.

Return line for MPD and conventional drilling.

Annular injection line for PMCD

Enough location space for MPD equipment spread, with ACM, separator (if needed), etc.

In onshore Indonesia, there are many drilling issues related to formations that was not addressed properly during the drilling engineering design which leads to increasing drilling cost. In this paper, a recap of MPD in onshore Indonesia operations will be presented to summarize the trouble formations and benefits of MPD to overcome the drilling issues.

**MPD in Fractured Granite Formation**

| Table 1. MPD in Fractured Granite Formation (Cen et al., (2016)) |
| --- |
| **Formation** |
| Basement granite with 8.7 ppg with 170 ºC in Jabung Block. One of the best basement characteristic are their low pressure and well develop fractures. |
| **Drilling Challenges** |
| Severe to total losses in conventional drilling, leads to formation damage, kick (well control risks) and narrow drilling windows. Sour gas. Abrasive formation, proper TCB (tri cone bit) selection |
| **MPD Type and Section** |
| CBHP then to underbalanced operation in 8-1/2” section |
| **MPD Equipment** |
| RCD, ACM, and underbalanced package |
| **Results** |
| No losses or incident occurred during MPD operations in low pressure fractured granite with CHBP to underbalanced MPD. |

**MPD in Suban Field Sumatra**

| Table 2. MPD in Suban Field Sumatra (Dharma et al., (2008)) |
| --- |
| **Formation** |
| Batu Raja Limestone, Durian Mabok Sandstone and Pre-Tertiary Granite (fractured basement rocks). |
| **Drilling Challenges** |
| Crossing faults where severe losses occurred. Minimizing the use of loss circulation materials, as well as cement plugs. Sour gas. Big bore completion, need to ensure low reservoir damage. |
| **MPD Type and Section** |
| PMCD with one weakness, where killing the well has to be done prior pulling out the string, hence increasing the skin. The use of DIV (Downhole Isolation Valve) made it possible to pull out of the hole without killing the well. Used in 8-1/2” section. |
| **MPD Equipment** |
| RCD with DIV. Please refer to figure 5 for DIV explanation. |

*Figure 5. Schematic of Downhole Isolation Valve (DIV), in the open position (left), closed*
MPD in Baong Shale South Sumatra

Table 3. MPD in Baong Shale Sumatra

| Formation          | Lower Baong Shale |
|--------------------|-------------------|
| Drilling Challenges| Abnormal pressure in Lower Baong shale with narrow drilling window that might create total losses and causing wellbore instability. |

| MPD Type and Section | CBHP in 12-1/4” section. |
|----------------------|---------------------------|
| MPD Equipment        | RCD and ACM               |
| Results              | MPD was able to ensuring drilling in narrow windows to avoid any wellbore instability by applying back pressure to ensure CBHP. |

MPD in LFN Field Seram Island

Table 4. MPD in LFN Field Seram Island (Fajar et al., (2017))

| Formation                  | Overpressure Kola Shale and Manusela Limestone formation |
|----------------------------|--------------------------------------------------------|
| Drilling Challenges        | Narrow drilling window to avoid severe losses and well control issues in the limestone as they will be drilled in one section. |

| MPD Type and Section       | CBHP in 8-1/2” section |
|----------------------------|------------------------|
| MPD Equipment              | RCD and ACM            |
| Results                    | PMD and DIV combination could be used in drilling and completion thru the severe losses section without any efforts to kill the well. The use of DIV made it possible to lower the formation damage during drilling and completion operations. |

MPD in Lematang Field South Sumatra

Table 5. MPD in Lematang Field South Sumatra (Gustioro et al., (2011))

| Formation          | Carbonate formation |
|--------------------|---------------------|
| Drilling Challenges| Narrow drilling window to avoid severe losses. Sour gas. |
| MPD Type and Section| CBHP in 5-3/4” openhole section. |
| MPD Equipment      | RCD and ACM         |
| Results            | MPD could safely drilling the section with no losses and less reservoir damage. |

MPD in East Java

Table 6. MPD in East Java (Darmawan et al., (2011); Darmawan et al., (2011); Sasongko et al., (2011))

| Formation          | Kujung Carbonates |
|--------------------|-------------------|
| Drilling Challenges| Severe losses with vugular carbonates. High reservoir damage. Sour gas. |
| MPD Type and Section| PMCD in 8-1/2” openhole section. |
| MPD Equipment      | RCD and DIV.       |
| Results            | PMD and DIV combination could be used in drilling and completion thru the severe losses section without any efforts to kill the well. The use of DIV made it possible to lower the formation damage during drilling and completion operations. |

CONCLUSIONS

MPD was originally developed in onshore operation to overcome drilling issues mostly because of depleted formations. The use of MPD in onshore Indonesia has been proven to
avoid any drilling issues, both in the objective zones (carbonates and fractured basement) and in abnormal pressure shale with narrow drilling windows.

PMCD operation combined with DIV in onshore could minimize the skin by not killing the well for subsequent operations after it was drilled.

REFERENCES
[1] Gala, D. M., & Toralde, J. S. Managed Pressure Drilling 101: Moving Beyond “It’s Always Been Done That Way.” Society of Petroleum Engineers. (2011, February 1). doi:10.2118/0111-012-TWA
[2] Nas, S. W., Toralde, J. S., & Wuest, C. Offshore Managed Pressure Drilling Experiences in Asia Pacific. Society of Petroleum Engineers. (2009, January 1). doi:10.2118/119875-MS
[3] Zein, J., Irawan, F., Hidayat, A. M., Amin, R. A. M., Ardhiansyah, F., Redzuan, M., … Prasetyo, D. Case Study - Constant Bottom Hole Pressure of Managed-Pressure Drilling Utilization to Maintain Wellbore Instability in East Java Drilling Operation, Indonesia. Society of Petroleum Engineers. (2016, October 25). doi:10.2118/140269-MS
[4] Darmawan, G. R., Buntu Sangka, N., Djoko Susilo, S., Shaun, J. T., Nas, S. W., Eka Prasetia, A., & Sisworo, S. Integrated Downhole Isolation Valve And Managed Pressure Drilling To Facilitate Development Of Sour Fractured-Limestone Gas Reservoir In East Java, Indonesia. Society of Petroleum Engineers. (2011, January 1). doi:10.2118/140267-MS
[5] Jacobs, S., & Donnelly, J. Crossing the Technology Chasm: Managed Pressure Drilling. Society of Petroleum Engineers. (2011, February 1). doi:10.2118/0211-0030-JPT
[6] Fajar, R. A., Irawan, C., & Hasudungan, B. Drilling Operation Improvement in Overpressure Zone with Managed Pressure Drilling Technology in LFN Field. Society of Petroleum Engineers. (2017, April 4). doi:10.2118/185336-MS
[7] Krisboa, A., Iskandar, Y. P., Irawan, F., Karnugroho, A., & Toralde, J. S. Drilling Statically Underbalanced Gas Well with Managed-Pressure Drilling to Target Depth Safely and Efficiently. Society of Petroleum Engineers. (2013, October 22). doi:10.2118/165884-MS
[8] Dharma, N., & Toralde, J. S. S. Managed Pressure Drilling and Downhole Isolation Technologies Deliver High Rate Gas Wells. Society of Petroleum Engineers. (2008, January 1). doi:10.2118/114703-MS
[9] Chen, P., Wang, X., Chen, L., Wu, M., Xin, J., Cheng, C., & Chen, Z. Application of Under-Balanced MPD in Fractured Granite Formation of Indonesia. Society of Petroleum Engineers. (2016, August 22). doi:10.2118/180511-MS
[10] Toralde, J. S. S., & Hillis, K. Running Liners and Well Completion in Pressurized Mud Cap Drilling Mode in Indonesia. Society of Petroleum Engineers. (2010, January 1). doi:10.2118/132117-MS
[11] Lage, A. C. V. M., Arduino, E. G. do A., Loureiro, S. de A., Vanni, G. S., & Filho, H. P. da S. Well Safety and Performance Gains from MPD in Unconventional High Overpressure Reservoirs in Argentina. Society of Petroleum Engineers. (2019, March 4). doi:10.2118/194157-MS
[12] Purwagautama, G., Afandi, I. Y., Rachman, S. G., Purwanto, A., & Radley, D. MPD Application With CBHP Technique in Horizontal Well Drilling for the Development of an HPHT and Sour-Environment Gas Field: A Case History. Society of Petroleum Engineers. (2011, January 1). doi:10.2118/143100-MS
[13] Darmawan, G. R., Susilo, S. D., & Toralde, J. S. Successful Installation and Operation of Downhole Isolation Valve Combined with Pressurized Mud Cap Drilling to Safely Develop Sour Gas, Fractured-limestone Reservoir in Gundih Field, Indonesia. Society of Petroleum Engineers. (2011, January 1). doi:10.2118/140269-MS
[14] Sasongko, D., Darmawan, G. R., Susilo, S. D., Shaun, J. T., Sisworo, S., & Prasetia, A. E. Downhole Isolation Valve
Performance in Drilling and Subsequent Completion Operations. International Petroleum Technology Conference. (2011, January 1). doi:10.2523/IPTC-15445-MS

[15] Haris, A., Purwanto, B., Sasongko, D., Darmawan, G. R., Yulianto, I., Soekmono, O., ... Mailangkay, L. Workover and Completion Operations in East Java Sour Gas Field, Indonesia. Society of Petroleum Engineers. (2012, January 1). doi:10.2118/153090-MS

[16] Hannegan, D. Technology Update: Managed-Pressure Drilling Advances Expand Options of Onshore Drillers. Society of Petroleum Engineers. (2015, January 1). doi:10.2118/0115-0030-JPT

[17] Matthew Daniel Martin Managed Pressure Drilling Techniques and Tools. Thesis for Master of Science, Texas A&M University. (May, 2006).