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Designing Bullheading Simulations in PMCD Operations

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Abstract
Managed Pressurized Drilling (MPD) is a non-conventional drilling technique that has become an important tool to drill well in scenarios characterized by fluid losses. One of your variants is Pressured Mud Cap Drilling (PMCD) which is used to avoid massive circulation losses. These techniques are being used in pre-salt fields in Brazil specially in highly fractured wells. With the use of software, it is possible to model PMCD operations and simulate well control and intervention such as bullheading scenarios. The idea of this paper is to present how a PMCD operation is modeled in well control traditional simulator software and how to perform bullheading simulation in this environment.

Keywords
Bullheading simulations, drilling fluid management & disposal, operational safety, drilling fluid selection and formulation, drilling operation, fluid loss control, shut-in well, swarm, upstream oil & gas, downhole condition

Introduction
Drilling operation is one of the most important part in an E&P project. In the recent years, with the discovery of the pre-salt in Brazil, the necessity of identify new drilling techniques has become a challenge specially for offshore wells. More and more techniques were developed or improved to be able to drill wells in deep environment.
One of this improvement is related with the MPD system and their variants. Managed Pressurized Drilling (MPD) is a non-conventional drilling technique used to control the annular pressure following the security limits of the operation. With this technique, wells that were not feasible to drill because of their narrow drilling window, now has become possible.
PMCD (Pressurized Mud Cap Drilling) is one of the MPD variation and according to International Association of Drilling Contractors (IADC) during the drilling there is no return to surface. In addition, it is used to maintain the annular wellbore pressure to prevent massive circulation losses in fractures formations and well control (Romualdo *et al.* 2019).
During a PMCD operation, the normal procedure is to pump 2 types of fluids. The first one is called sacrificial fluid (SAC) which is normally the sea water. This fluid is pumped down the drill pipe at a specific flow rate to cool down the bit and inject the cutting into the thief zones.
The other fluid is called light annular mud (LAM) which is pumped down the annular. This fluid has a density lower than the pore pressure and it is used to control and provides surface pressure below the Rotation Circulation Device (RCD) which is an important equipment used in all MPD operation including PMCD. Besides, it is used to maintain the annular full of fluid and avoid the gas migration to surface if occurs (Amanbyev and Karmanov, 2018).
Over the years, computation simulation proved to be an important tool to mitigate future problems during the drilling operation. With the use of software, it is possible to design problematic scenarios and predict potential solutions to solve them.
Drillbench is a dynamic drilling simulation software from Schlumberger which is able to model typical drilling operations. It was built as a friendly user interface, adapted to drilling scenarios, with an OLGA motor inside. One of its modules called blowout control is used to reproduce hydraulic simulation related with various types of well control and intervention including relief well and bullheading operations.
Bullheading consists in an operation that use a mud with a high density to push the undesired influx generated inside the well back to the formation.
Usually, this type of operation is the last response applied because this solution can cause series damage to the formation. It is used in kick with high amount of H_2S or in situation that the kick circulation is not possible (Santos, 2014).
The objective of this paper is to explain the procedures to model a bullheading operation considering a PMCD environment using the Drillbench Blowout Control. It will be presented the minimum pump rate to avoid the migration of the influx to the surface and also, an estimative of the pump rate and fluid volume necessary for the bullheading in PMCD operation.

Drilling Problems

One of the many challenges faced in the oil industry is to drill in environments with several fluid losses. According to Tomita (2015), the problems associated with fluid losses include:

- Increase in field project price since the well cost is more expensive due to the use of special materials;
- Increase in the duration to build the well since the operation to control the fluid losses requires more time;
- Increase in operation risks due to the decrease in the hydrostatic pressure causing influx inside wellbore.

In Brazil, MPD is being used in operation that can not be drilled with conventional drilling techniques since it has a narrow drilling window and high tendence of fluid losses. The pre-salt area in Santos Basin is an example of that where some wells from this field were drilled using this technique.

MPD has lots of variants, but in all of them some tools are required such as the RCD to isolate the annular and the choke valve used to maintain the pressure constant (Muir, 2006).

PMCD is the MPD variant used in cases with high fluid losses. Two fluids are pumped simultaneously down the drill string so, the cuttings are carried into the loss zone. There are no return of fluids to the surface and the bottomhole pressure remains constant during the process.

Well Control Methods

Well control methods are performed when the kick happens and need to be controlled before it become a blowout. The methods can be divided in conventional and unconventional methods.

The conventional methods include the driller methods (most used in Brazil), wait-on-weight method and volumetric method. All of them are used to circulate the kick and eliminate the influx making the well clean. In the driller method, for instance, the kick is circulated out of the well and then the kill mud is injected. However, whatever the method used, the flow bottomhole pressure must be kept constant during the whole circulation.

On the other hand, the well know unconventional methods in the industry are bullheading, low choke pressure and stripping.

In bullheading, the influx is pushed back into the formation by a mud with high density. This type of operation is used when the volume of the influx is very large, and it is not safe to circulate or when the circulation using conventional method can cause excessive pressure at surface.

However, this operation is one of the last options adopted since it may result in some serious concerns like fracture or damage the formation.

Methodology

To model a bullhead scenario in Drillbench software, it is necessary some inputs such as:

- Well trajectory
- Wellbore geometry
- Drill string (optional, if it is part of the scenario)
- Surface equipment and their measurements
- Fracture pressure
- Fluid Properties
- Formation Temperature
- Reservoir properties

For the simulation purpose, a theorical well was modeled, trying to reproduce an ultra-deep water well. The inputs values for a single well are presented in Tab.1. The well is deviated and is located offshore.

Table 1. Well Data

Item	Length(m)	ID (in)	OD (in)
Riser	2020	19.5	21
Casing 1	2030	12.25	14
Casing 2	3250	8.5	10.75
Open Hole	500	8.5	8,5
Drill Pipe	5030	4.625	5.875
Other tools	236	2.8	6.75

In addition, the reservoir and fluid properties are shown in Tab.2. The fluid is considered volatile oil.

Table 2. Reservoir and fluid properties

Properties	Details
Top of Reservoir	5270 m
Bottom of Reservoir	5645 m
Top Pressure	8820 psi
Bottom Pressure	9450 psi
Top Temperature	85 C
Bottom Temperature	95 C
Productivity Index	5000 $(m^3/d)/(kgf/cm^2)$
Injective Index	500 $(m^3/d)/(kgf/cm^2)$
GOR	400 sm^3/sm^3
Water Cut	0

The fluid used to pump the influx back to the formation has a density of 9.5 ppg, a viscosity of 25 cP, and is considered a water base mud.

To represent a PMCD operation, some inputs should be placed in a different way as usual. This is the case of the riser that should be filled as a casing to indicate that the BOP is on the surface. Actually, in this simulation, the BOP will work as an RCD.

In the surface equipment, the kill line should have a length of 10-30 m which represents that this tool is placed below the rotary table.

Figure 1 represents the well schematic created by the software.

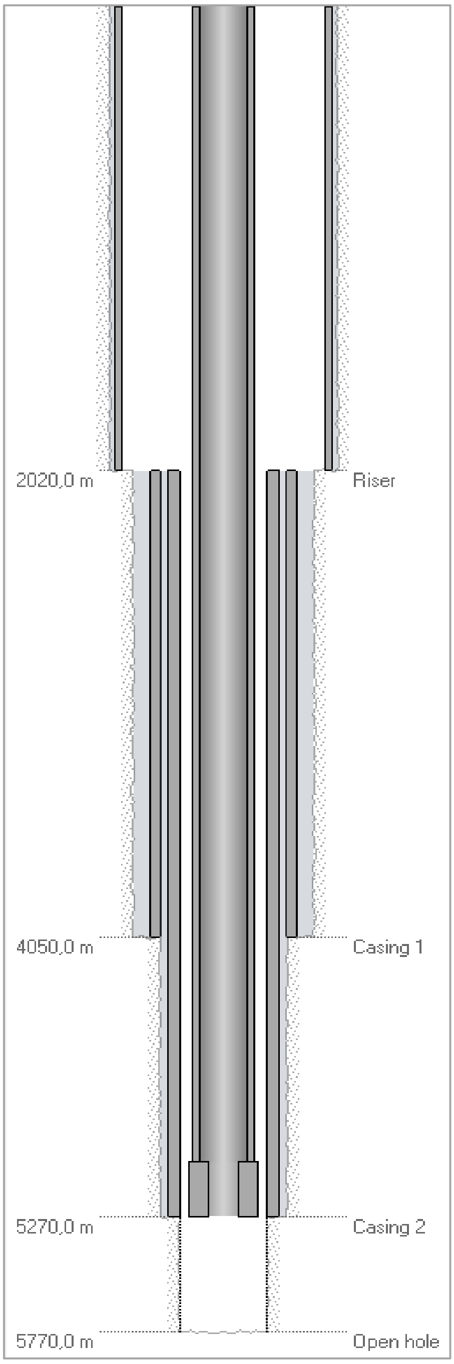

Figure 1- Well Schematic

After all the inputs were filled, the simulation could be run. First, it was necessary to create an influx inside the wellbore and in front of the reservoir. This influx is artificial and is only created to perform the required operation in the simulation.
Usually, in PMCD operation the influx is generated by applying a under pressure in the reservoir which means a multiplicator factor is used to reduce the reservoir pressure during a period. The reason for that is to obtain the exactly pre-determined volume of influx inside the well otherwise this volume can be bigger than expected.
For the scenario presented here, the influx volume expected was around 20 bbl.
With the influx generated, the fluid with 9.5 ppg could be pumped throughout the kill line with different rates. It was used pump rates from 1-9 bpm to decide the minimum value required to avoid the migration and do the bullheading.
To calculate the volume of the influx for each pump rate the equation used is indicated in the eq.1. This equation is according to the time step, so for each of them, the influx volume can change.

$$Vinflux = 0.0031871 \text{ x } (OD^2 - ID^2) \qquad (1)$$

Where:
Vinflux = influx volume, bbl
OD = external diameter of volume, in (in this case is the casing ID)
ID = internal diameter of volume, in (in this case is the string OD that limited the influx volume)

Results and Discussion

Influx Period

During 5 min, the influx period was generated. Figure 2 represents the oil fraction curve over the depth. It can be seen that the influx is in front of the reservoir. Also, the top of the influx is in 5340 m.

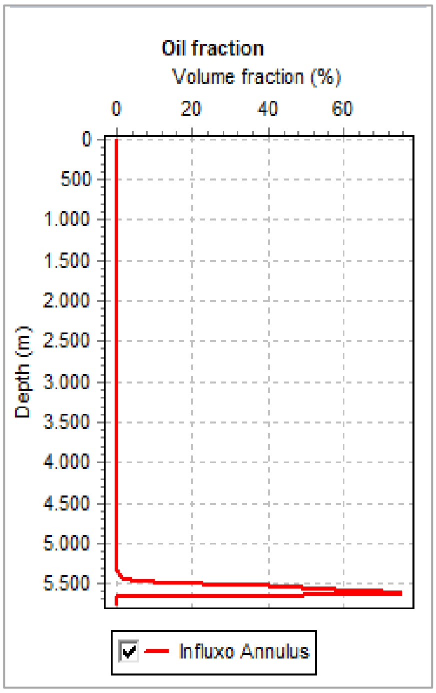

Figure 2- Location of Influx

This curve is also used to calculate the volume of the influx contained in the wellbore. The calculation was done by using the eq.1 and it was found an influx volume of 20.6 bbl which is perfectly acceptable since the volume defined was 20 bbl.
Figure 3 shows the volume influx rate in the pipe with relation to time.

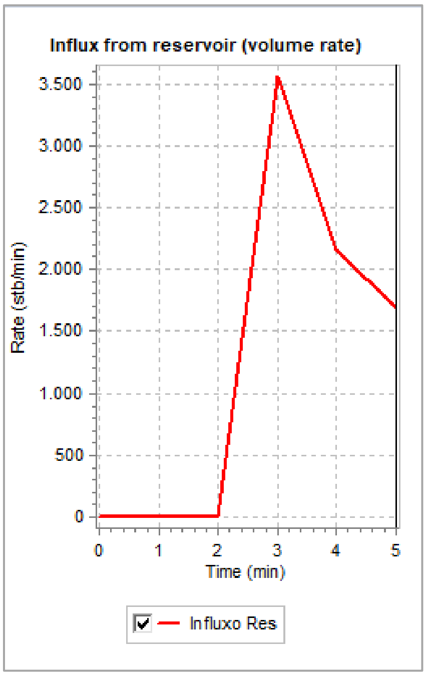

Figure 3-Influx Volume Rate

Control and Bullheading

After the influx period of 5 min, it was pumped a fluid mud of 9.5 ppg throughout a line that represent the injection in an RCD system.

To pump rates from 1-7 bpm, it was not possible to do bullheading. From figure 4 is possible to see that the influx remains in the wellbore for pump rates of 1, 4 and 7 bpm after 6 h of pumping since the oil fraction is 100% in pipe depth. However, the migration did not happen, and the influx remains in front of the reservoir.

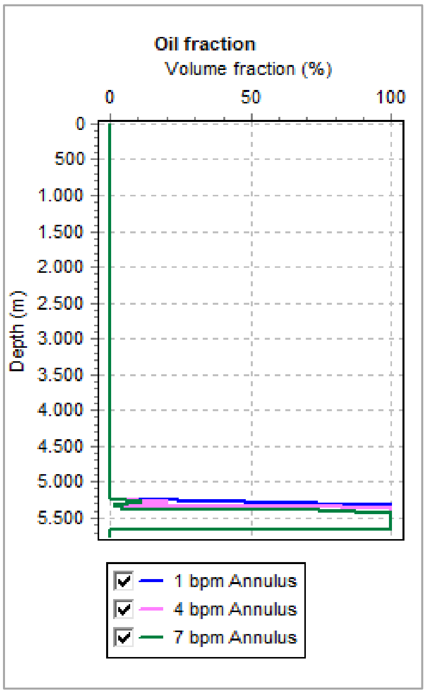

Figure 4-Oil Fraction after 6h

After 7 bpm, it is possible to do the bullheading operation since the volume that remains inside the wellbore is less than 0.5 bbl. The fig. 5 compares the rates of 1, 7 and 8 bpm. After 31 min is possible to do bullheading for the rate of 7 bpm. The oil fraction curve shows that the oil fraction is 0% in the whole depth for this rate.

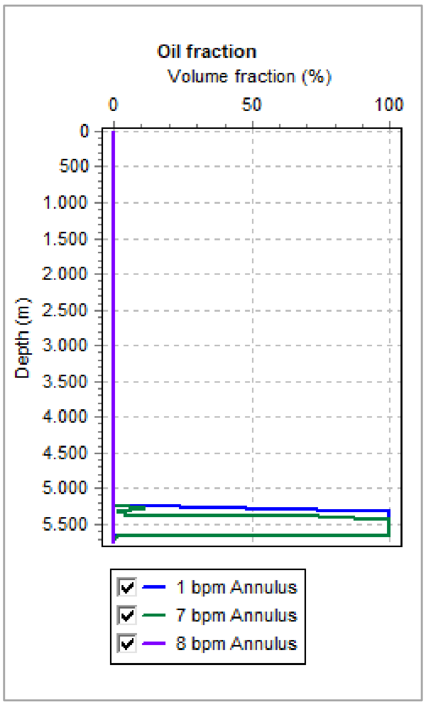

Figure 5- Oil Fraction after 31 min

Figure 6 shows the oil fraction curve considering pump rate of 1, 7 and 9 bpm after 27 min. For this scenario, the bullheading operation is possible since the curve remains in 0 % for this rate.

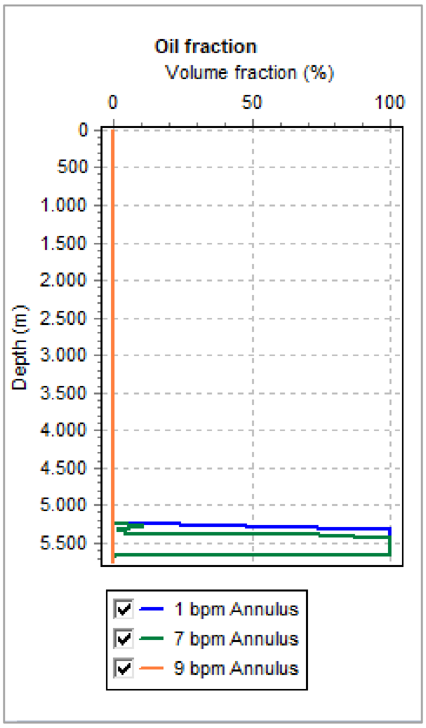

Figure 6- Oil Fraction after 27 min

Conclusion

Drilling in ultra-deep water has become one of the biggest challenges in the oil and gas industry. More

and more techniques are being developed to be able to drill environments like this in safe.
MPD and their variants like PMCD is an example of a technique created to drill wells that has a high tendency of lost circulation. With this method, now is possible to drill wells that were not feasible to drill before.
Computation Simulation has become an important ally specially in complex scenarios. With the use of software, it is possible to reproduce real scenarios to predict potential problem that can occurs and how to solve then in safe.
The idea of this paper is to present how a bullhead operation can be design in a traditional well simulator and show the results of different variables regarding this operation.
It was concluded that pump rates from 1-7 bpm, the bullheading operation is not possible. However, the migration did not happen, and the influx remained in front of the reservoir.
For pump rate high then 7 bpm like 8 and 9 bpm, the bullheading operation is possible.
The decision of what pump rate will be used comes from the responsible engineer that request the simulation.

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Responsibility Notice

The authors are the only responsible for the paper content.

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