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New Concept For Drilling Hydraulics O.M. Vestavik, ReelWell a.s.

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Abstract

The feasibility of a new concept for drilling and lining of a well has been investigated. The patented concept is based on the use of a dual channel drill string, where one of the channels is used for the return flow from the well. A sliding piston in the annular downhole section of the well, is used for force and pressure control. The concept is suited for drilling with a liner, which optionally can be expanded in place in the same run. The concept has special advantages for improved downhole pressure control, and for safe and efficient drilling of reservoirs with challenging pressure zones. The concept is also expected to provide solutions for cost efficient drilling, especially for sub-sea wells.

Introduction

Exploration and production drilling is often subjected to challenges for downhole pressure control to avoid kick and loss. Such situations can occur when drilling into zones with unexpected or difficult pressure variations, such as depleted or abnormally pressured reservoirs, or in deep waters. The handling of these challenges are often time consuming and expensive.

Here is outlined an alternative hydraulic arrangement for drilling that can meet these challenges, ref 1. The patented new concept is based on the following modifications from the standard arrangement:

- 1. The use of a dual drill string, where one channel is used for pumping drilling fluid into the well, and the other is used for the return flow from the well.
- 2. The use of a dowhole sliding piston, that isolates the annular fluid in the well, for downhole pressure and force control.

3. Optional use of a liner as a part of the Bottom Hole Assembly (BHA). The liner may be expanded in place in the same run after drilling a new section.

This new concept offers new oppertunities, compared to conventional drilling hydraulics:

- Improved downhole pressure and force control.
- Improved efficiency, due to parallel operations.
- New features, light solutions, monodiameter well etc.

A feasibility study on the new concept has been performed, supported by Statoil and the Research Council of Norway. Some results from this study are given in the following.

Concept description

Figure 1 presents the basic outline of the conceptual arrangement, which consist of the following items:

- A drill string with two flow channels, for example a concentric tubing.
- A lower BHA consisting of conventional BHA elements, i.e. drill bit and optional near bit reamer, downhole motor, logging and steering tools, flow check valaves etc. The lower BHA also contains a x-over tool or other means to bring the return fluid back into the return channel of the dual drill string.
- An optional liner length between the lower and upper BHA, which also may be expanded in place in the same run after a new section has been drilled.
- An upper BHA consisting of a sliding piston, which is used for downhole pressure and force control, and that also may be used for the liner expansion.

The system can be implemented on jointed dual drill string, and is well suited for the use of a reeled dual string, for wired downhole communication and control. The optional liner can be a conventional liner, a slotted liner or a sand screen. This optional liner can be an expandable type that is expanded in place after drilling the new section.

A cased upper section of the well is required in order to start drilling with the new concept. The upper section can be a new shallow well that is drilled and cased in conventional ways. It can also be an existing well that is to be deepened or side-tracked with this new metod. A Blow Out Preventer (BOP) with an annular "stripper" type of packing element should be positioned at the top of the well. The well annulus between the casing and the drill string may be closed and pressurized during drilling, for downhole pressure and force control.



Figure 1. Schematic of the new drilling concept

The procedure for drilling a new section of the well with the concept can be as follows:

- The liner enters the well and hung off at surface.
- The lower BHA and the dual drill string enter the well through the liner and the lower BHA is attached to the lower end of the liner.
- The upper BHA is attached to the top of the liner.
- The assembly consisting of the lower BHA, liner and upper BHA is lowered into the well.
- When the bit reaches the bottom of the well, the drilling can start.
- The annular fluid in the well above the upper BHA is not a part of the active circulation fluid, but can be weighted and pressurized from surface for downhole pressure and force control.
- When a new section corresponding to the liner length has been drilled, the liner can be released from the BHA and left in the well, and optionally expanded in place before pulling the drill string out of hole.
- The well is filled with new reconditioned drilling fluid as the drill string is pulled out of hole.

 The procedure is repeated with new liner sections, until the target depth is reached.

The concept opens for new means of downhole pressure and force control during drilling. It also opens for improved efficiency and solving of drilling problems, as discussed in the following.

Concept features

The concept has the following unique features for downhole pressure and force control:

- The active fluid volume is constant with depth, the volume can be monitored and controlled precisely.
- The sliding piston separates the annular well fluid from the circulation fluid.
- The sliding piston prevents loss of the annular fluid in a lost circulation situation.
- The sliding piston can be used to control the Weight On Bit by means of hydraulic pressure.
- A surface controlled valve in the return flow conduit and the sliding piston will act as a downhole BOP.
- The annular well fluid and the active circulation luid may have different fluid properties.
- The system allows for safe use of a low-density and low viscosity active circulation fluid.

The concept is expected to have unique possibilities for drilling in difficult pressure regimes, including depleted reservoirs and safe underbalanced drilling. In addition the system also provides other unique benefits:

- The hole is always clean from cuttings, since the cuttings are transported in the drill string.
- Extreme drilling reach is possible, due to hydraulic WOB and buoyancy in the drill string.
- The system is suited for extremely slender or monodiamater well solutions.
- Riserless drilling is possible, since the riser function is built into the drill string.
- The system is suited for compact reeled pipe, for cost efficient offshore exploration drilling.
- Operation time is saved, since drilling, lining and logging can be performed simultaneously.

Results from the feasibility study

The feasibility study has investigated several aspects of the conceptual arrangement. One important aspect is the hydraulic beaviour of the system. Table 1 presents a calculation example of tha hydraulic performance of a version of the system. The example system uses a dual 4 $\frac{1}{2}$ " x 2 3/8" concentric tubing for drilling of a 8 $\frac{1}{2}$ " hole. The center tubing is assumed as the return flow conduit. As can be observed from the table, there is significant hydraulic power available downhole, even with the limited flow rate that is used in the arrangement. The arrangement allows for very efficient cuttings transport, even with a low viscosity active fluid. The arrangement allows for a safe reduction of the density of the active circulation fluid. This gives the operator large flexibility to adjust and control the downhole pressure, i.e. by the fluid density, by the flow rate or by the surface choking of the return flow.

Item or parameter	Value
Outer tubing OD [in]	4.5"
- wall thickness [in]	0.27"
Inner tubing OD [in]	2 3/8"
- wall thickness [in]	0.15"
Length of reeled dual tubing [km]	3
Hole diameter [in]	8.5"
Pore pressure at TD [bar]	320
Mud density to balance pore pressure [kg/l]	1.3
Assumed circulation fluid density [kg/l]	1.1
True vertical depth for the bit [m]	2500
Max. shut in pressure in return conduit [bar]	50
Return choke pressure while drilling [bar]	1
Circulation fluid pump pressure [bar]	250
Circulation fluid flow rate [lpm]	330
Pressure loss in inner tubing [bar]	50
Pressure loss in tubing annulus [bar]	20
Pressure available for bit and motor [bar]	>180
Hydraulic power available for motor [kW]	90
Average ROP in typical formation [m/h]	21
Cuttings concentration in return [% vol.]	3.9 %

Table 1. Example calculation for a concentric tubing system.

Furthermore the study gave the following results:

- 1. The downhole hydraulic power is limited, but is expected to be satisfactory for efficient drilling.
- 2. The downhole pressure and force control is expected to be superior to conventional drilling.
- 3. Liner jamming may be a challenge, however, there are several options to handle such situations.
- 4. Plugging of the return flow may be a challenge.
- 5. The concept is applicable for light surface solutions, that can strongly reduce offshore drilling costs.
- 6. Improved efficiency due to parallel operations, i.e. lining, logging and drilling in the same run.

The implementation of the concept for reeled tubular solutions on offshore drilling vessels, have large potential to lower the cost for sub-sea exploration and production wells. The reason for this is the expectiations for reduced rates, lower manning and faster operations. The further development of the concept therefore seems to have significant potential for offshore drilling applications.

Discussion of the results

The concept feasibility is supported by a miniature model, which demonstrates the basic hydraulic operation principles. The concept hydraulics differs significantly form conventional drilling hydraulics, and the direct comparison is therefore not easy. The concept uses reduced flow compared to conventional drilling, however, the basic hydraulic functions still seems to be satisfied, i.e. cuttings transport, cleaning and cooiling of the bit, downhole power etc. The additional advantages of the concept are the possibilities for downhole pressure and force control. The utilization of the downhole forces are especially related to horizontal drilling. This is because the WOB can controlled by hydraulic means and not form string tension at surface, which is the normal procedure in conventional drilling. The advantages of using hydraulic downhole forces is also important for horizontal reach, handling of stuck pipe situations, WOB control etc.

Liner jamming and pluggig of the return flow conduit are two possible challenges with the concept. However, there are several options to tackle liner jamming, and the liner can optionally be omitted. Plugging of the return flow conduit is expected to be avoided by proper operational handling, ref 2.

Any need for further increased downhole power can be sloved either by the use of larger diameter tubing, or for example by a downhole electric motor, which is a feasible solution for reeled tubular applications. The use of alternative downhole power sources also will reduce the pressure loading and the fatigue, in the case of using reeled tubulars.

The calculations in the feasibility study needs to be verified by a physical demonstration. The planning and search for funding of the suggested demonstrations are ongoing at the moment of writing this article.

Conclusion and outlook

The feasibility study of the new drilling concept discussed above indicates the following potential for the new concept:

- 1. Improved safety and pressure control, i.e. avoid lost circulation and provide a downhole BOP.
- 2. Reduced cost due to fast operations and light surface equipment, especially for offshore applications.
- 3. New features to improve drilling performance, i.e. hydraulic WOB, increased horizontal reach, riserless drilling etc.

The study did not identify items or procedures that were not rated as feasible to solve. The upper BHA was rated as the most critical system component. The further work will concentrate on prototype verification and demonstration.

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