Dual-Gradient Drilling: The future of offshore drilling

Gubkin University
Maria Alexandra Rojas Mikheeva
Introduction

• For successful oil and gas exploration, increased accessibility to reserves, improved wellbore integrity, reduced overhead costs and most importantly, providing a safe working environment to take place in this area, new drilling methods must be developed to carry out drilling operations in deep water.

• Dual-gradient drilling (DGD) is a method that eliminates the impact of water depth on offshore drilling.

• DGD represents the future of offshore drilling and improves safety.

• 3 wells drilled in 1800 – 2200m water depth.
Problem Statement

DGD is a new concept that allows reaching ultra deep water targets more economically and safely by eliminating the problems that occur due to the narrow operating window between pore pressure and fracture pressure.

This system minimizes the effect of hydrostatic pressure of the drilling fluid inside the riser and thus on the bottom hole pressure.

Using traditional techniques can mean the difference between success or failure: too much pressure and the formation will fracture; not enough will lead to hole instability and increase the chances of influx.

The success of DGD technology depends on the reliability of the subsea components i.e., equipment failures.
The primary objective of DGD is to explore the deep water environment and to drill deeper wells.

DGD is being contemplated by the industry to drill such narrow margins between pore pressure and fracture pressure profiles.

The DGD method uses two different pressure gradients to maintain adequate BHP.

A fluid with a density equivalent to seawater is used in the riser (seawater gradient from surface to seafloor) and a heavier drilling mud is used below the mud line (inside the wellbore).

DGD technology is used in water depths greater than 1500m.
DGD vs. Conventional drilling

[Diagram showing the comparison between DGD and conventional drilling, including labels for seawater hydrostatic pressure, drilling mud hydrostatic pressure, formation fracture pressure, and formation pore pressure.]
The aim of the conventional drilling is to optimize BHP between pore pressure and fracture gradient to make a controlled drilling where pore pressure is defined as the pressure of fluids inside the pore of the formation, usually hydrostatic pressure and fracture pressure are defined as the pressure at which a formation break down, or fracture.

In conventional drilling, the element used to balance pressure in interested depth of formation is hydrostatic pressure of drilling fluid. The pore pressure, where normal pressure gradient is in place, defined as:

\[ P_f \text{ (psi)} = \text{Formation Pressure Gradient (psi/ft)} \times \text{Depth (ft)} \]

Based on Eaton model, the fracture pressure can be defined as:

\[ P_{\text{fracture}} = \sigma_{\text{min}} + P_f \]

Where,

\[ \sigma_{\text{min}} = \frac{\mu}{1 - \mu} \sigma_z \]
DGD vs. Conventional drilling

And,

$$\sigma_z = \sigma_{\text{overburden}} - P_f$$

Therefore, to perform a balanced drilling, drilling fluid hydrostatic pressure value stays between pore pressure and fracture pressure.

$$P_{\text{formation}} < P_{\text{fluid}} < P_{\text{fracture}}$$

where,

$$P_{\text{fluid}} = 0.052 \times \rho_{\text{fluid}} \times D$$

Considering the deep water environment, pore pressure and fracture pressure are directly affected by the water column; the hydrostatic pressure of the water is also added to the pore pressure to calculate the total formation pressure of the interested depth, from sea level.
Therefore, the formation pressure is calculated like:

\[ P_f = \text{WaterPress.Gradient} \times WD + \text{FormationPress.Gradient} \times (TD - WD) \]

**How to Select Casing Setting Depths**
Operational window

- Presión [lb/psf]$^2$
- Tirante de agua
- Formación

Gubkin University
Maria Alexandra Rojas Mikheeva
RIPS 2017
Conventional drilling
Conventional drilling

DGD

[Diagram showing dimensions for conventional drilling and DGD]
Fluid return sections should be studied carefully. Different from the conventional drilling, return fluid is diverted to pumps and lifted to surface by using return line which is small diameter line from sea floor to drilling unit. The hydrostatic head below the mud line is made equivalent as drilling unit placed on the sea floor and the hydrostatic pressure problem of the sea water is eliminated.
DGD technology

In a well drilled with the DGD technology, the well pressure is the sum of two different fluid gradients, a riser fluid gradient, gas or liquid, and a drilling fluid gradient.

- Enables deep-water drilling to continue uninterrupted for longer periods
- Maintains a near-constant BHP
- Early kick and loss detection
Benefits and advantages

- Flexibility: option to switch to conventional drilling at any time.

- This drilling is cost effective for operators and helps in the control of trouble zones through proper mud properties.

- The technology manipulates bottom-hole pressure without swapping out the mud in the riser – you can change the mud level in minutes, not the mud weight in hours.

Limitations

- In conventional drilling, after detecting a kick (influx or flow of formation fluid into the well-bore), the well is immediately shut in. But, in DGD due to the pressure imbalance the well cannot be shut-in until equilibrium is reached. Otherwise it may lead to formation fracture and lost circulation.
Conclusions

- DGD is one of the very few methods available in the drilling industry to drill in deep water, where drilling window between the pore pressure and the fracture gradient is very narrow.

- The technology overcomes a significant deep water challenge: eliminating some of the casing strings necessitated by the relatively high pore pressures and low formation found in deep areas.

- To avoid any damage to the formation due to fracture, DGD technique has been successfully applied in many wells.

- Simpler wellhead configurations can be selected in deep water environment.

- DGD decreases the operation cost considering the limitations also decreases the operation duration and material cost.
Bibliography


Thank you!

Questions?

Gubkin University
Maria Alexandra Rojas Mikheeva