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Optimization of Well Performance by Dual Gradient Drilling - A Literature Analysis

Priyadharshini Saptharishi*, *Pandit Deendayal Petroleum University*

Summary

Drilling for hydrocarbons offshore, in some instances hundreds of miles away from the nearest landmass, poses a number of challenges over drilling onshore. In order to meet the world's increasing demand for energy, deep water Exploration and Production has become a requisite in the past years. Hence need for newer technologies become essential for safe and successful operation into deep waters. The wellbore pressure (at any depth) should be maintained between the naturally occurring pressure of the formation fluids and the maximum wellbore pressure the formation can maintain without fracture. Well control is the management of the dangerous effects of unexpected high pressures on the surface equipment of drilling rigs searching for oil and/or gas. The well control procedure includes primary control (maintaining a hydrostatic pressure equal to or greater than formation pressure) and secondary control (usage of blow out prevention equipment in case of failure of primary control). A variety of new drilling technologies are being developed to address the phenomena of narrow pore-pressure/fracture-gradient windows as pore-pressure/fracture-gradient prospects are drilled in greater water depths. Amongst them, one of the more proficient types of drilling is the dual gradient drilling. This paper will discuss in detail the concept of dual gradient drilling, its significance in deep water offshore drilling- history of origin, the system description, types of DGD, Advantages and Limitations with an overall review of DGD process.

Introduction

Dual gradient Drilling refers to drilling where mud returns do not go through a conventional, large-diameter, drilling riser. Instead the returns move from the seafloor to the surface through one or more small - diameter pipe(s) separate from the drillpipe. A Mudlift system is used in the Return Line. A Dual Gradient mud system is achieved.

In the past, the oil and gas industry has typically used the single gradient system to drill wells offshore. With this system the bottom holepressure was controlled by a mud column extending from the drilling rig to the bottom of the wellbore. This mud column was used to achieve the required bottom hole pressure. Because of the narrow margin between the pore and fracture pressures it is somewhat difficult to reach total depth with the single gradient system. This led to the invention of the dual gradient system. In the dual gradient method, heavy density fluid runs from the bottom hole to the mudline and a low density fluid from the mudline to the rig floor so as to maintain the bottom holepressure. Dual gradient Drilling is an unconventional method of drilling in which a relatively small diameter return line is used to circulate drill fluids and cuttings from the sea floor to the rig's surface mud system. During DGD, the rig's marine riser is kept full of seawater. A rotating diverter, which is similar to a rotating control head, separates the wellbore and its contained fluids from the seawater in the marine riser. During wellkill operations, the return line is utilized as the choke line in conventional riser drilling.

Single vs. dual gradient drilling

In the past, the oil and gas industry has typically used the single gradient system to drill wells offshore. With this system the bottom hole pressure was controlled by a mud column extending from the drilling rig to the bottom of the wellbore. This mud column was used to achieve the required bottom hole pressure. But, as the demand for oil

B-108, PDPU girls hostel, Pandit Deendayal Petroleum University, Raisan Gandhinagar-382007
Email: priya.sbtech08@spt.pdpu.ac.in

and gas increased, the industry started exploring for oil and gas in deep waters. Because of the narrow margin between the pore and fracture pressures it is somewhat difficult to reach total depth with the single gradient system. This led to the invention of the dual gradient system. In the dual gradient method, heavy density fluid runs from the bottom hole to the mudline and a low density fluid from the mudline to the rig floor so as to maintain the bottom hole pressure.

In single gradient wells, the wellbore contains a single density fluid and single pressure gradient exists whereas in dual gradient wells, wellbore fills seawater gradient to the seafloor, and mud gradient to bottom.

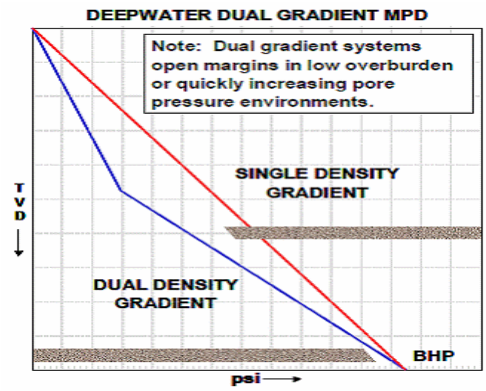


Fig. 1 shows the dual-gradient pressure profile. In this case, using a single density fluid for this wellbore will cause the wellbore pressure to exceed the formation pressure and result in lost circulation. With dual-gradient drilling, a lighter fluid is used in the upper portion of a wellbore and a heavier fluid at the lower portion. This enables the pressure to remain in the pressure window between the pore pressure and fracture pressure.

Preparations that must be made before using dual-gradient drilling on a rig are the two circulating systems, one mud and one sea water. The sheer weight of the mud pump also must be considered.

Rigs are not designed to accommodate the BOP and LMRP while using the mud pump, so you have to modify your rig for that."

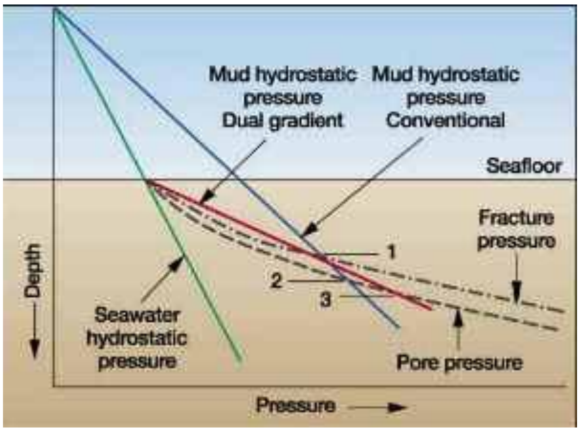


Fig 2: Pressure effects with conventional and dual gradient drilling.

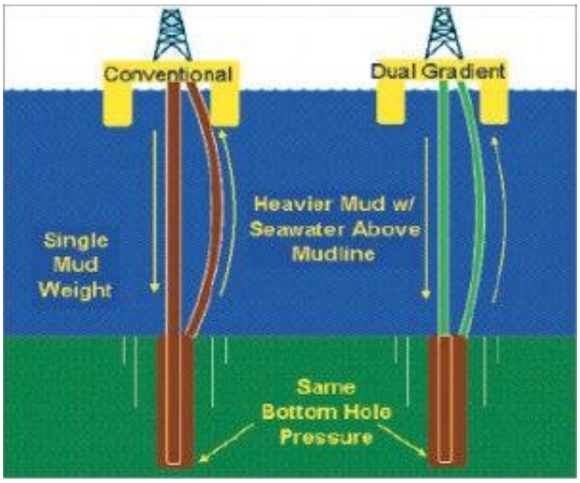


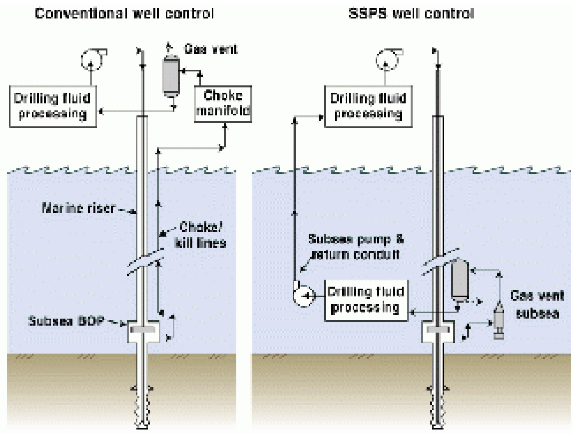
Fig 3: www.drillingcontractor.org (Reference)

Dual gradient drilling system

The sub-sea equipment of dual gradient drilling includes:

- Marine Riser
- SRD - SubSea Rotating Diverter
- DSV - Drillstring Valve
- MLP - MudLift Pump
- Return Lines
- Manifolding
- Dual Trip Tanks

Temporary riser modifications consist of two external lines attached to the riser. One line furnished seawater power fluid to the MLP while the other returned drilling fluid from the sea floor to the rig. Each line was supported at surface by a tensioner, backed- up by a top clamp assembly.



A conventional well control design (left) and the SSPS well control design (right).

Fig 4: Comparison of a conventional well control design and DGD well control design.

The diverter and pump are both part of the SubSea MudLift Module. The DSV was developed because when circulation stopped, the U-tube imbalance could equalize at high rates for several minutes, masking other potential problems such as well flows or lost returns. The DSV is a pressure-balanced drill pipe float with a large spring that is run at or near the bit. Its opening pressure is adjustable from the rig. When mud flowing up the annulus reaches the mudline where it normally would enter the riser, return flow is diverted from the annulus to the SubSea MudLift Module located at the mudline. The diverter in the subsea module diverts return mud from the riser base to the subsea pump suction.

The MudLift pump acts as a check valve, preventing the hydrostatic pressure of the mud in the return lines from being transmitted back to the wellbore.

The positive displacement pump unit is powered by seawater, which is pumped from the rig using conventional mud pumps down an auxiliary line attached to the marine riser. The cuttings-laden mud, as well as any other well fluids, will be returned to the rig via another line attached to the riser. The MudLift pump will normally be run in an automatic mode, responding to pressure conditions it senses in the well. So the driller can operate the surface mud pumps much as is done in conventional drilling.

Surface piping and manifolding are highly fabricated. The two temporary riser lines and all of the SMD surface skids had to be tied-in to existing rig systems. A valve control panel was provided to allow remote control of the additional valves incorporated within the mud return and seawater power lines.

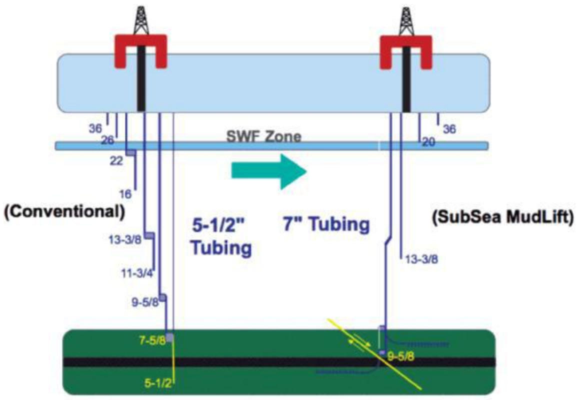


Fig 5: Schematic comparing casing design for a conventional deepwater well with one drilled with dual-gradient technology.

Dual gradient drilling: Types

Several methods have been developed to achieve the dual gradient drilling principle, the main methods being "pump based" dual density drilling and "Dilution based" dual density drilling.

PUMP BASED DGD is where the systems all rely on subsea pumps. The drilling systems were designed to provide a continuous loop circulating system for pumping mud down the drillstring and up the annulus to the wellhead, where the wellbore pressure at the seafloor is essentially the hydrostatic pressure of the seawater column above it. In PGDB, the hydrostatic pressure in the wellbore at the wellhead is at or near seawater hydrostatic. PGDB was first designed to be operated in the Gulf of Mexico by Chevron.

The usage of pumps was further classified as seabed centrifugal pumps, mud-riser centrifugal pumps, Electrical submersible pumps with seabed solids separation, etc depending on the gradient required to be achieved and the quantity of solids to be handled.

One advantage of the PBDG systems is absence of a riser margin. Since the wellhead pressure is already at or near seawater hydrostatic, there is no "riser margin" to be lost, thus providing an obvious advantage. But the disadvantage being the placement of complicated machinery (the subsea lift pumps, rotating head, solids processing unit – which grinds oversized cuttings down to pumpable dimensions) on the bottom of the marine riser, thus necessitating a riser trip for any required mechanical repairs. This would also add to increasing the installation cost and the requirements may vary from rig to rig.

DILUTION BASED DGD also employs two fluid gradients in the wellbore. In dilution- based DG drilling, the "riser" mud weight is determined by the "downhole" mud weight (the density of the mud pumped down the drillstring and up the annulus to the injection point, nominally just above the BOP stack), the density of the "dilution" mud (which is pumped down an auxiliary line such as the riser boost line, and the ratio of their respective flowrates (the "dilution ratio"). These different densities and dilution ratios are engineered to meet the particular requirements of the holesection being drilled. A bank of specialty centrifuges is installed to separate the returning "riser mud" back into the heavy "downhole" and light "dilution" mud weight components. Additional control equipment is also required to monitor and control fluid densities and flowrates.

The various dilution methods include gas dilution, solids dilution, etc depending on the hydrocarbon type encountered and also the target depth and other chemical problems.

The main advantage of the DBDG system is that the system's most complicated components (high volume centrifuges and fluid control system) are located on the drilling rig, obviously making maintenance and repair much more straightforward this reducing the cost relatively. But one of the disadvantages of DBDG is the necessity to account for the riser margin.

Both PBDG and DBDG systems require a flow stop valve (FSV) in the lower drillstring. The FSV permits pumping at normal drilling or reduced well control kill flowrates, but closes when pumping is stopped. The FSV must close to prevent the heavier mud inside the drillpipe from U-tubing out of the drillstring (e.g., on connections) and to prevent the heavier mud weight hydrostatic from acting upon the wellbore in the event that the BOP is closed.

Riser less Dual-gradient drilling: Dual-gradient drilling can also be achieved in deep water without a riser when first starting a subsea drilling location. A subsea RCD (**R**otating **C**ontrol **D**evice) and remote operating vehicle are used. The ROV is able to adjust backpressure at the mudline by adjusting the choke. When the ROV closes the subsea choke, the BHP increases. This results in drilling with a slight overbalance as if a marine riser filled with drilling fluid were present. The advantage of being able to drill with a slight overbalance is that it helps to prevent shallow gas or water flow. The seawater is used as the drilling fluid so the drilling fluid and cuttings can be left on the sea floor.

Advantages

There is a broad range of advantages offered by dual gradient drilling that include:

- Casing strings can be run deeper without the risk of exposing the formation to the high pressures of the mud column. This not only means fewer casing strings, but a larger wellbore at TD.
- Smaller deckloads for rigs and lower hook loads will result. This means smaller rigs might be called into service to drill deepwater wells.
- Reduced mud losses
- Adaptability: easy change from single gradient to dual gradient drilling
- Risk reduction & safety improvement due to less manual handling & improved kick detection
- Reduced non-productive time.
- Increased efficiency due to reduction of non productive time.
- Improved access to challenging drilling targets.
- Financial savings for the operators.
- Improved wellbore management.

Dual-gradient drilling promises to overcome the limitations imposed by sending drilling mud through thousands of feet of drill pipe and riser. This tremendous volume of fluid creates a huge hydrostatic head that can induce fracturing, particularly in shallow zones. Dual-gradient techniques dramatically change the physics of the drilling process, such that the rig effectively sits on the seafloor, rather than at its actual physical location thousands of feet above on the sea surface. In dual gradient, the mud column extends only from the bottom of the hole to the mudline. Subsea pumps are used to reduce the hydrostatic head from the mudline to the surface. Other benefits include reducing the number of casing strings, enabling the use of larger completion strings for increased flow capacity, improved drilling efficiency and decreased mechanical risk.

Limitations

Some of the limitations of Dual gradient drilling faced by Operating companies that employed DGD process in the past includes:

- Difficulty in primary subsea cuttings separation that necessities the use electrical submersible pumps (ESP).
- Subsea well control vents gas subsea, protecting rig personnel and eliminating the need for high-pressure containing equipment downstream of the subsea choke.
- Major drawbacks in gas dilution dual gradient drilling includes:
  - Corrosion and in flammability associated with air injection.
  - Deeper water depths require huge amount of gas for it to be effective.
  - Large gas expansion takes place when the gas traverses from shallow to deep.
  - Control of hydrostatic pressure for riser margin difficult.

Conclusions

Dual Gradient Drilling is one of the very few methods available to the drilling industry to drill in deepwater, where the drilling window between the pore pressure and frac gradient is so very narrow. With DGD, the margins between fracture gradient and pore pressure are significantly greater while drilling the well. This technology overcomes a significant deepwater drilling challenge: eliminating some of the casing strings necessitated by the relatively high pore pressures and low formation strengths found in deepwater areas.

The intent of dual gradient variation is to mimic the saltwater overburden with a lighter density fluid whereas the bottom hole pressure adjustment can be accomplished by injecting less dense media such as inert gas, glass beads, plastic pellets into the drilling fluid within the marine riser.

This paper will discuss in detail the concept of dual gradient drilling, its significance in deep water offshore drilling-history of origin, the system description, types of DGD, Advantages and Limitations with an overall review of DGD process.

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