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How Casing Drilling Improves Wellbore Stability

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Abstract

Casing Drilling is a process in which a well is drilled and cased simultaneously. The original purpose of developing Casing Drilling technology was to eliminate Non Productive Time (NPT) associated with running casing. During early implementation of the technology, other benefits were seen while drilling with large diameter casing. Wellbore stability improvement is perhaps the most important of these advantages and is a primary driver for selecting intervals where applying Casing Drilling can be most beneficial.

The Plastering Effect is responsible for improvements seen in wellbore stability while using Casing Drilling. It is an inherent benefit of Casing Drilling that strengthens the wellbore, prevents lost circulation, and mitigates formation damage. The Plastering Effect strengthens the wellbore by smearing the generated cuttings and available PSD (Particle Size Distribution) into the formation face and sealing the pore spaces. This continuous process creates low porosity and low permeability filter cake on the wellbore wall that reduces or prevents losses to the formation and effectively widens the operating mud weight window.

Introduction

Years of drilling and exploiting petroleum reservoirs has left the drilling industry with a much more complex environment. Current drilling applications are frequently located in troublesome zones, depleted reservoirs, and wells with severe wellbore instability.

Casing Drilling has been used in numerous difficult wells and to drill through troublesome well sections that would not have been possible with conventional drilling techniques. The big question is what happens when we drill with casing instead of conventional drill pipe. In other words, how can we explain the Casing Drilling benefits in regards to wellbore stability?

In this study, the authors try to answer this question in two sections. The first section relates the benefits of Casing Drilling methodology and inherent differences with conventional drilling. In the second section, the Plastering Effect is introduced and analyzed as a dominant contributor to the unexplained advantages of Casing Drilling.

Casing Drilling and Wellbore Stability

Casing Drilling technology offers several distinct benefits that help mitigate wellbore stability problems. These benefits are the reason Casing Drilling is frequently selected as the superior method for drilling challenging wells that conventional drilling methods could not easily handle. The aforementioned advantages are listed below:

No Tripping

There is no tripping in Casing Drilling; the casing is always at, or near, bottom in every stage of the drilling process. Most of the wellbore stability issues happen during, or due to, tripping. The most common issue is swab and surge pressure which can lead to well control incidents or lost circulation. The inability to circulate the well from bottom is another problem, and can result in cuttings settlement or stuck pipe while tripping in the BHA. Elimination of tripping leaves no chance to instigate these problems. Moreover, by definition, there would be no need for wash and ream procedures after reaching TD and before running casing.

Gauged Well

The large casing/wellbore diameter ratios create gauged wells, which are more stable. The smooth continuous movement of the casing along with the dual cutting action of the bit and under-reamer (Level III Casing Drilling) generates a more circular profile. This has been proved by matching the annulus area with the amount of cement pumped to see returns on surface. The Plastering Effect of Casing Drilling prevents wash-out and break-out, further supporting the argument that gauged wells are beneficial. A geometric comparison between Casing Drilling and conventional drilling can be seen in Fig. 1.

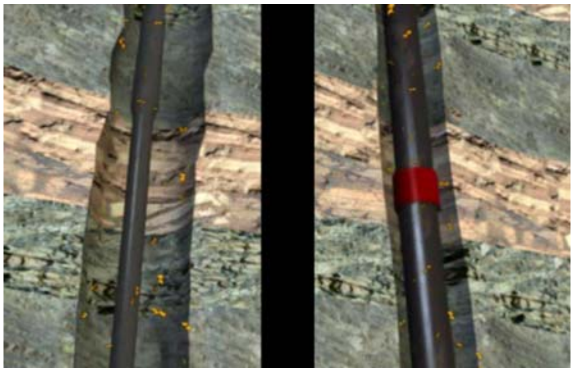

Fig. 1. Casing Drilling creates gauged wells.

Less Drilling Time

It is agreed that the more drilling time, the greater the probability of wellbore instability. Casing Drilling reduces the total amount of time that the well is being drilled by eliminating tripping, casing running, and mitigating NPT due to drilling problems.

Efficient Borehole Cleaning

Several wellbore stability concerns, such as hole pack off, barite sag, and stuck pipe, are related to inefficient borehole cleaning. There are more significant concerns in horizontal and directional drilling; more specifically, at the critical angles of 40˚ to 65˚ where cutting transfer proves very challenging. The small annulus of Casing Drilling (Fig. 2) produces a higher annular velocity which facilitates cutting transport.

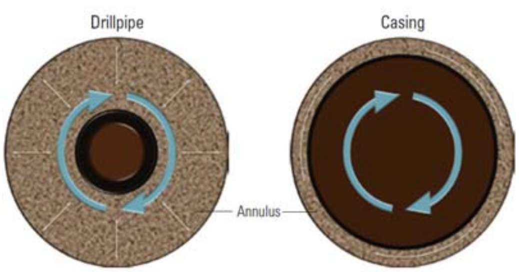

Fig. 2. The annulus is smaller in Casing Drilling in comparison to conventional drilling

The mono-bore annulus is another advantage regarding wellbore cleaning. Conventional drilling geometry results in different annular velocities around each drill string component. The velocity variation can lead to wellbore erosion around drill collars and inefficient cutting transport around the smaller diameter drill pipe. With casing as the drill string, the annular space along the entire wellbore is virtually equal allowing the hydraulic optimization based on the fluid properties, cutting concentration, and flow rate. (Galloway, 2003)

Superior Hydraulics

The large diameter of the casing allows for a smaller annular path for fluid to travel up the annulus. This causes an increased pressure loss and a higher ECD (Equivalent Circulating Density) at an equivalent flow rate. Casing Drilling hydraulics are designed to use a reduced flow rate to produce an ECD that is only slightly higher than seen in a conventionally drilled interval. Historically, this higher ECD is considered as a negative aspect of hydraulic design due to higher susceptibility of fracturing the formation and lost circulation. However, the process of Casing Drilling utilizes the higher ECD to act against borehole collapse and improves wellbore stability. The higher ECD is also an essential element in Plastering Effect design which will be explained in the next section.

Plastering Effect

An added benefit of the Casing Drilling process is the Plastering Effect, or smearing. This effect is caused by continuous trowelling of the wellbore wall by the casing. Filter cake is smeared into the wall and is not scraped off by bit passage or tool joint impacts. Cuttings are finely ground, and in most instances, fewer cuttings are returned to the surface; instead they are smeared into the wall to further strengthen the wellbore. This process offers the additional benefit of improved well control and stability. The Plastering Effect coupled with industry best practices leads to curing lost circulation, as well, wellbore instability and enables continuous drilling.

The authors propose that the combined forces of high annular velocity and pipe rotation coupled with the proximity of the casing wall to the borehole, results in cuttings being smeared against the formation; these elements create an impermeable wall cake. The Plastering Effect enables stress caging to occur when the cuttings seal the fractures in the near wellbore formation wall. This process mechanically strengthens the wellbore wall.

With the mechanical wellbore strengthening of Casing Drilling, the fracture gradient is augmented so there is a wider window of operation that allows for a better casing design by deepening casing setting depth or omitting one or more casing strings or liners. The proposed mechanism for Plastering Effect is shown in Figs. 3-1 to 3-3.

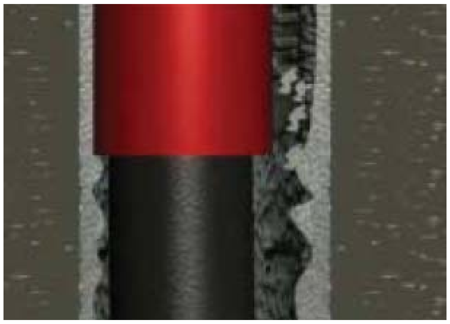

Fig. 3-1. Casing is forced against the bore wall as it advances into the borehole.

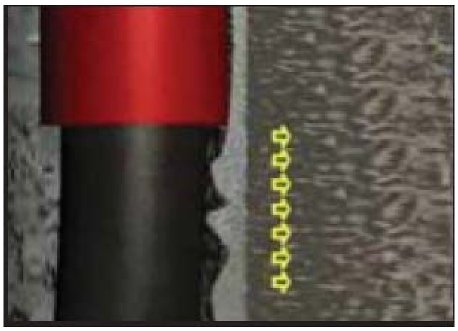

Fig. 3-2. Mud and cuttings are smeared into the formation, while filter cake builds up on the borehole wall.

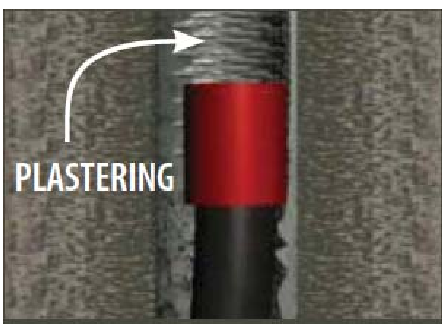

Fig. 3-3. Filter cake and cuttings are plastered against the borehole wall by the casing, sealing porous formations.

Several events can account for the occurrence of Plastering Effect and are listed below:

1. Smooth rotation of the casing grinds and pulverizes the cuttings as they travel up in the annulus, explaining the finer-sized cuttings of Casing Drilling. These small-sized cuttings are smeared into the formation face, and immediately create an impermeable filter cake. In conventional drilling, the contact between the drill pipe and the wellbore (by banging the pipe to the wall) is not smooth one: it doesn't have any order, scrapes the mud cake off the wall, and damages the drill pipe. Figure 4 compares pipe movement and mud cake formation between Casing Drilling and conventional drilling.

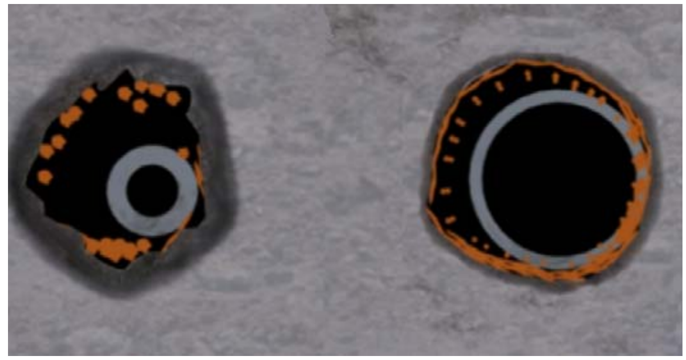

Fig. 4. Wellbore stability improvement by Casing Drilling as compared to conventional drilling.

2. The higher ECD of Casing Drilling works effectively by initiating small fractures that are readily plugged by the Plastering Effect.

3. When drilling through a porous and permeable zone like depleted sands, a very common Casing Drilling application, the drilled sand grains are consistent in size. A layer of sand becomes deposited on the wall as some of the drilling fluid flows into the formation, but a single layer of uniform grains of sand is extremely permeable. Because the grains are the same diameter as the grains in the formation, the wellbore will behave as though there is no filter cake. Fluid continues to flow into the formation and additional layers of sand grains are deposited. If all the sand grains were the same size, essentially, the filter cake is as permeable as the single layer, regardless of depth. Additional layers will be deposited until the rate of deposition equals the rate of erosion, (Mitchell, 2001).

To make this filter cake less permeable, a variety of grain sizes are required. The smaller grains nest in the spaces between the larger grains. Even smaller grains can nest into the pores between the small grains. The pulverized cuttings generated by Casing Drilling can play the role of the mentioned grains to plug the free spaces of the filter cake. The mixture of different grain sizes at the cuttings produces a filter cake that is much less permeable.

Side wall cores taken from Casing Drilling wells confirm that cuttings and filter cake have been pushed into formation. Moreover, experimental data has shown that mud cake is thinner in Casing Drilling than conventional drilling, thus assuring the effectiveness of Plastering Effect.

4. The eccentric motion of the drill string during Casing Drilling operations provides smooth contact with the wellbore wall and applies consistent mechanical force.

Success Stories

Casing Drilling literature is filled with operations successfully completed in zones with wellbore stability problems that could not have been accomplished with conventional techniques. A brief review of the most recent case studies where Casing Drilling has been proved in challenging applications is below:

Sanchez et al. (2010) reported the success of Casing Drilling in FIQA shale in Oman. According to them two surface sections were drilled successfully with large OD casing strings through formation notorious for hole instability, lost zones, and reactive shale problems. Their observations with regards to Casing Drilling benefits are quoted as "Casing Drilling reduced the drilling phase 40-45% in comparison with the field average. The exposure time of FIQA to aqueous environment was reduced considerably eliminating conditioning trips and NPT associated with wellbore instability. The total volume of pumped cement recovered at surface reached up to 98% of pumped excess (versus 25% in the Field), which is an indication of the good quality of the borehole. Casing Drilling will allow future wells to utilize "slim" top holes allowing drilling/casing much deeper sections in less time preventing the FIQA from collapsing and avoiding the use of more expensive oil-based mud", (Sanchez et al. 2010).

Lopez et al. (2010) present a case study of successful Casing Drilling application in the Cira Infantas field in Colombia. This field is crossed by faults and is characterized by depleted and shallow gas bearing formations that resulted in challenging drilling operations with both loss circulation and well control issues. They believe utilizing Casing Drilling reduced NPT associated with wellbore instability due to the plastering effect formed around the wellbore, (Lopez et al. 2010).

Dawson et al. (2010) report the recent success of Casing Drilling in Angsi field in Malaysia. Formations in this area are soft, unconsolidated, and have a history of wellbore instability issues and severe losses. Their conclusions are "Casing Drilling brought the additional advantage that if mud losses did occur; the mud system could be switched to seawater while continuing to drill ahead. No time was expended to mitigate incurred losses. The fine drilled solids and continuous drilling of the Casing Drilling process has been effective in combating the wellbore instability issues and essential to the successful application of the Casing Drilling technology", (Dawson et al. 2010).

Another study was done by Gallardo et al. (2010) on fluid loss mitigation in the Cashiriari field in Peruvian jungle. Total or partial fluid losses in shallow sections turn conventional drilling into a non-cost-effective way to drill this area. "The main purpose in using Casing Drilling in these shallow hole sections was to drill the upper intervals quickly and minimize hole problems resulting from wellbore instability issues. Casing Drilling improves the mechanical seal in the borehole due to the Plastering Effect. The Casing Drilling application was able to meet the planned objectives of drilling the shallow hole sections in a total loss scenario uneventfully", (Gallardo et al. 2010).

Beaumont et al. (2010) reported another successful Casing Drilling application in Peruvian fields. "The main problem in this area was time-consuming gumbo events in the intermediate hole. Severe drag and tight spots led to high risk trips out-of-hole requiring extensive back-reaming and near-lost hole events in offset wells (severe pack-offs while tripping out). Potential problems associated with hole instability, clay swelling, stuck pipe, hole cleaning, gumbo, surface equipment downtime and seepage losses were entirely mitigated with Casing Drilling application", (Beaumont et al. 2010).

Torsvoll et al. (2010) have done a case study on the successful application of Liner Drilling technology in Norwegian Continental Shelf (NCS) where many fields have formation instability and/or depletion history. The planned interval was directionally drilled and the borehole was sealed off by liner and cemented after being drilled, (Torsvoll et al. 2010).

According to Rosenberg et al. (2010) Liner Drilling has been successfully practiced in the Gulf of Mexico to mitigate hole instability problems. Previous attempts to drill the problem formation were unable to reach the objective depth because of wellbore instability and lost circulation issues. According to the results, the liner successfully drilled through the unstable formation and was set at the planned depth, minimizing the open hole exposure time, (Rosenberg et al. 2010).

Kotow et al. (2010) propose riserless Casing Drilling as an enabling technology to set up a new paradigm for deepwater well design. The unique ability to overcome the wellbore instability issues allows deeper casing seats. The authors believe this will improve the ability to manage such risks as: drilling hazards, shallow gas, shallow water flows, hole instability, and loss of circulation. Nunzi et al. (2010) reached the same conclusion and believe that adopting the Casing Drilling/Liner Drilling technology has the potential of eliminating contingency strings in deepwater.

Watts et al. (2010) demonstrated that the plastering effect of Casing Drilling allows successful drilling through unstable loss zones. "If wellbore strengthening can be systematically achieved, then wells can be drilled in known loss areas without contingency strings of casing. In addition, wells drilled in mature fields, where producing horizons have altered pressures, either from depletion or pressure maintenance, can be drilled with fewer casing strings". Their study shows that a significant improvement in fracture gradient can be achieved with the right clearance between the hole and the casing and the proper sized particles added to the mud system. With confidence that strengthening can be achieved to the levels of improvement demonstrated, wells can be evaluated with significant cost savings by eliminating casing strings and preserving hole size for completions or further drilling, (Watts et al. 2010).

Jianhua et al. (2009) studied the application of Liner Drilling technology as a solution to hole instability and loss circulation in offshore Indonesia. According to them Liner Drilling was used to drill successfully through the known lost circulation zone with the 7-in. liner cemented in place. This allowed the operator to reach their completion objectives while realizing a savings of more than $1 million (USD), (Jianhua et al. 2009).

Avery et al. (2009) completed a study on high angle directional drilling with 9 5/8-in. casing in offshore Qatar. “The problem was that the interface between the shale and pay zone formation is often a point where highly conductive faults are encountered. Severe losses of drilling mud often occur at this interface, thus resulting in a dramatic reduction of hydrostatic pressure as the wellbore annulus fluid level falls. This pressure loss causes the unstable formation to collapse in on the drill string and BHA, packing it off and making it practically impossible to retrieve. A potential solution to this problem was to drill the section with casing and a retrievable BHA”. The operation was successful and effective, (Avrey et al. 2009).

According to Kunning et al. (2009), a non-retrievable rotating Liner Drilling system has been successfully deployed to overcome a challenging highly stressed rubble zone in a GOM ultra deepwater sub-salt application. “Using the Liner Drilling technology enabled operators to drill through and isolate a challenging highly stressed rubble zone found adjacent to a problematic tar/bitumen layer. The plan was flawlessly executed, and Liner Drilling technology proved highly effective,” (Kunning et al. 2009).

Conclusions

1. Wells with borehole stability problems can be very good candidates for Casing Drilling application.
2. Continuous drilling is a key factor in successful deployment of Casing Drilling technology.
3. Plastering Effect seems to be the main mechanism creating high quality wellbores.
4. Liner Drilling has successfully taken the Casing Drilling benefits from onshore to offshore environments.

Acknowledgments

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Nomenclature

Define symbols used in the text here unless they are explained in the body of the text. Use units where appropriate.

BHA	=	*Bottom Hole Assembly*
ECD	=	*Equivalent Circulating Density*
OD	=	*Outside Diameter*
NPT	=	*Non Productive Time*
PSD	=	*Particle Size Distribution*
TD	=	*Total Depth*

References

1. Moellendick. E.: “Casing Drilling Improves Mature Field Production, Eliminates Fluid Losses, Directionally Drills Wells” Drilling Contractor, page 76-79, July/August 2008.
2. Mawford. N.: “Avoid Wellbore Stability Problems with Casing Drilling” E&P Journal, April 2009.
3. Mitchell. J.: “Trouble-Free Drilling” by Drilbert Engineering Inc. Volume 1, 2001.
4. Galloway. G.: “Rotary Drilling with Casing – A field proven method of reducing wellbore construction cost” Paper WOCD-0306-02 presented at the World Oil Casing Drilling Conference, Houston, Texas. March 6-7, 2003.
5. Karimi. M.: “Wellbore Strengthening and Lost Circulation Prevention due to the Plastering Effect of Casing Drilling in Depleted Reservoirs” Master’s Thesis, University of Louisiana at Lafayette, Fall 2010.
6. Watts. R.D., Greener. M.R., McKeever. S., Scott. P.D., Beardmore. D., : “Particle Size Distribution Improves Casing-While-Drilling Wellbore Strengthening Results” Paper IADC/SPE 128913 presented at the IADC/SPE Drilling Conference & Exhibition, New Orleans, Louisiana, 2-4 February 2010.
7. Tessari. B.: “Casing Drilling Reduces Formation Damage, Enhances Production” presented at SPE Luncheon, Houston, Texas, February 2009.
8. Kunning J., Wu. Y., Thomson I., Marshall L., Daigle D. Mata H., Pena R., Hensgens M., Eppley B., “Non-Retrievable Rotating Liner Drilling System Successfully Deployed to Overcome Challenging Highly Stressed Rubble Zone in GOM Ultra-Deepwater Sub-Salt Application” Paper SPE 124854 presented at the SPE Annual Technical Conference & Exhibition, New Orleans, Louisiana, 4-7 October 2009.
9. Nunzi P., Molaschi C., Beattie S., Feasey G., Odell A., Twardowski E. “Drive Down Costs at Surface: Eliminate Contingency Strings in Deepwater” Paper SPE 132279 presented at the SPE deepwater Drilling and Completions Conference, Galveston, Texas, 5-6 October, 2010.
10. Rosenberg S., Gala D., Xu W., “Liner Drilling Technology as a Mitigation to Hole Instability and Loss Intervals: A Case Study in the Gulf of Mexico” Paper SPE/IADC 128311 presented at the SPE/IADC Drilling Conference, New Orleans, Louisiana, 2-4 February, 2010.
11. Torsvoll A., Abdollahi J., Eidem M., Weltzin T., Rasmussen S.A., Krueger S., Schwartze S., Freyer C., Huynh T., Sorheim T., “Successful Development and Field Qualification of a 9 5/8 in and 7 in Rotary Steerable Drilling Liner System that Enables Simultaneous Directional Drilling and Lining of the Wellbore” Paper IADC/SPE 128685 presented at the IADC/SPE Drilling Conference and Exhibition, New Orleans, Louisiana, 2-4 February, 2010.
12. Beaumont E., Crevoisier L., Baquero F., Sanguino J., Herrera D., Cordero E., “First Retrievable Directional Casing While

Drilling (DCwD) Application in Peruvian Fields Generates Time Reduction and Improves Drilling Performance Preventing Potential Non-Planned Downtime" Paper SPE 139339 presented at the SPE Latin American & Caribbean Petroleum Engineering Conference, Lima, Peru, 1-3 December, 2010.

13. Gallardo H., Cassanelli J.P., Barret S., Romero P., Mufarech A., "Casing-Drilling Technology (CwD) Mitigates Fluid Losses in Peruvian Jungle" Paper SPE 139065 presented at the SPE Latin American & Caribbean Petroleum Engineering Conference, Lima, Peru, 1-3 December, 2010.
14. Dawson G., Buchan A., Kardani I., Harris A., Werchoulk L., Khazali K., Shariff A., Sission K., Hermawan H., "Directional Casing While Drilling (DCwD) Heralds a Step Change in Drilling Efficiency from a Production Platform" Paper OTC 20880 presented at the Offshore Technology Conference, Houston, Texas, 3-6 May, 2010.
15. Lopez E., Bonilla P., Castilla A., Rincon J., "Casing Drilling Application with Rotary Steerable and Triple Combo in New Deviated Wells in Cira Infantas Field" Paper SPE 134586 presented at the SPE Annual Technical Conference and Exhibition, Florence, Italy, 19-22 September, 2010.
16. Sanchez F., Turki M., Nabhani Y., Cruz M., Houqani S., "Casing while Drilling (CwD); a new approach drilling FIQA Formation in the Sultanate of Oman. A Success story" Paper SPE 136107 presented at the Abu Dhabi International Petroleum Exhibition and Conference, Abu Dhabi, UAE, 1-4 November, 2010.
17. Kotow K., Pitchard D., "Riserless Drilling With Casing: A New Paradigm for Deepwater Well Design" Paper OTC 19914 presented at the Offshore Technology Conference, Houston, Texas, 4-7 May, 2009.
18. Jianhua L., Andrias D., Zhao C., Rosenberg S., Hillis K., Budi O., "Use of Liner Drilling Technology as a Solution to Hole Instability and Loss Intervals: A Case Study Offshore Indonesia" Paper SPE /IADC 118806 presented at the SPE/IADC Drilling Conference and Exhibition, Amsterdam, Netherlands, 17-19 March, 2009.
19. Avery M., Stephens T., Ali. K. A., Turki M., Abed M., "High Angle Directional Drilling with 9 5/8 Casing in Offshore Qatar" Paper IADC/SPE 119446 presented at the SPE/IADC Conference and Exhibition, Amsterdam, Netherlands, 17-19 March 2009.