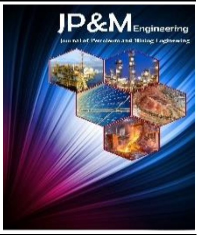
JP&M Engineering
Journal of Petroleum and Mining Engineering



Reducing Well Deliverability Time and Drilling Costs using Casing While Drilling Operations, West Kuwait

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Article Info

Received 18 Apr. 2024
Revised 27 Jun. 2024
Accepted 3 Jul. 2024

Keywords

Well Deliverability; Casing While Drilling; Wellbore Strengthening; Mechanical Specific Energy.

Abstract

Casing while Drilling (CWD) is a method of drilling which has been proven to mitigate many of the drilling problems. In this technique, drilling, and casing of a well bore is carried out concurrently, which enhances the drilling efficiency by decreasing the non-productive time (NPT). It has shown to be advantageous in controlling loss circulation and improving wellbore stability by 'Plastering' effect, high quality cement job and increased rig floor safety. Casing while drilling techniques use a drillable drill bit. This bit is specially designed and manufactured with a material that can be drilled out with either conventional roller core or fixed cutter bits. A plastering process was used, which smears the cuttings generated by drilling against the borehole wall, seals the pores or fractures in the formation, and helps reduce fluid losses while maintaining well integrity. Several challenges have been monitored during casing while drilling such as severe mud loss, destabilized shale, and hole instability. These conditions can result in hole collapse, or the drill string lost in hole that requires sidetracking. The main aims of this paper are to present an engineering solution to drill through the difficult zones, reducing nonproductive time, and reduce the total well cost. Umm Gudair field in western Kuwait faces a lot of challenges while drilling, specially while drilling 16-in casing section. The successful implementation of 16 x 13.375-in. casing-while-drilling job in Umm Gudair field reduced well delivery time for the operator and saved 17 rig days with cost savings of 450,000 US Dollars considering rig rate only. The maximum drilling torque is 16,260 ft-lb at 6,962 ft, which represents 24% of the maximum torque for the 13.375-in 68 ppf, K-55. A 7 bladed and 16 mm cutter size was selected for drilling operation. The section was drilled successfully while encountering total mud losses through fractured dolomitic limestone and sandstone formations. Preventing the risk of losing the bottomhole assembly in the hole and alleviating the use of multiple cement plugs saved additional cost for loss-cure plugs to heal the loss-prone formations. After reaching the target depth, cementing, pressure testing of the casing was carried out successfully. Lesson learnt from the first job were applied in the subsequent job completing the section with faster ROP with substantial savings to operator. For both the jobs, drillout of the drillable casing-while-drilling bit using a fixed cutter bit and Rotary Steerable bottom-hole assembly were performed successfully, the drillout bit continued drilling to section TD in one run. With the successful implementation and the savings obtained by using this casing-while-drilling technology in the West Kuwait field, there is the potential for substantial annual cost savings, aiding the operator deliver wells in less time, and eventually increase production by increasing the number of wells drilled per year.

Introduction

Casing drilling has been developed for more than years, and thanks to technological advancements, it has been successfully used recently. Using the active casing, or typical oil field casing, as the drill string, casing drilling entails simultaneously drilling and casing the well [Error! Reference source not found.]. Instead of using a typical drill string, the casing in

DOI : 10.21608/jpme.2024.283667.1194

casing drilling transfers mechanical and hydraulic energy to the drill bit via the Drill Lock Assembly (DLA). The expense of buying, checking, carrying, and transporting the drill string is just one of the difficulties associated with the traditional well-drilling procedure [**Error! Reference source not found.**]. When the Bottom Hole Assembly (BHA) needs to be updated or the complete depth is achieved, a common issue is the drill string tripping in and out [**Error! Reference source not found.**]. Drill string tripping results in well-control issues like these in addition to contributing to Non-Productive Time (NPT).

The concept of casing during drilling was eventually recognized by the oil and gas sector by the end of the 1990s. The traditional approach to drilling a well has been beset with difficulties, including the expense of buying, inspecting, handling, and shipping the drill string. When the entire depth is achieved or the Bottom Hole Assembly (BHA) needs to be replaced, a frequent issue is the drill string tripping in and out. Drill string tripping causes well control issues such wellbore instability and lost circulation in addition to increasing non-productive time (NPT). Casing while drilling (CWD) was a novel technique that was required to overcome these problems since they had to be solved [**Error! Reference source not found.**]. It is mandatory to note that the casing is the same grade and weight as in conventional drilling operation. With that in mind, there is no additional cost for casing string [**Error! Reference source not found.**].

Mitigation of Lost Circulation by Plastering:

Mud loss to the formation is decreased by casing while drilling since the casing is plastering the cutting in the bore wall forming a strong mud cake. This superior mud cake that is produced by the plastering effect, sealing the wellbore, and obstructing the flow of fluid between the borehole and the formation. Drilling will continue with minimized losses until the casing reaches the total depth in the worst-case scenario, this scenario is much more effective in the cases that are not easy to repair. To prevent hole collapse and stuck pipe, it is necessary to eliminate the issues and risks related to swab, pit volume monitoring, hole volumes, and fill up related to steel removed from the wellbore in a lost circulation scenario [**Error! Reference source not found.**].

Karimi et al. [**Error! Reference source not found.**] described the plastering effect in detail. Drill cuttings are crushed and smeared against the formation by the combined effects of high annulus velocity, pipe rotation, and the casing wall's close proximity to the borehole, making the wall cake much less permeable. The suggested method is displayed in Figures 1-a through 1-c.

Particle size distribution examination reveals that casing drilling operations produce reduced particle sizes when comparing cuttings from casing drilling with conventional drilling. This is because of the plastering effect, which smears the cuttings into the wellbore wall, and the casing string grinding action, which pulverizes the cuttings as they move up the annulus. Put differently, cuttings serve as a replacement for lost circulation material.

The cuttings and thick filter cake are plastered into the formation interface with the well by the casing rotating smoothly. No extra room is left for the drilling fluid to leak into the formation during this process. This differs greatly from traditional drilling in that, depending on mud overbalance and permeability, filter cake accumulates when particles build up on the borehole wall. In the worst scenario, drilling can proceed with reduced losses until the casing reaches the designed depth if the losses (large fractures, vugs, caverns, etc.) cannot be repaired. It's feasible to keep drilling with casing in some situations. These are the capacity to pump from the backside, improved wellbore cleaning, and a reduced necessary flow rate [**Error! Reference source not found.**].

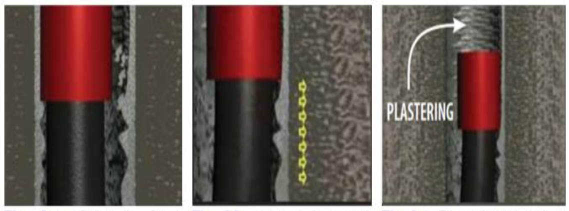


Fig. 1-a: Casing is forced against the bore wall as it advances into the borehole [5]. **Fig. 1-b:** As mud is smeared into the formation, filter cake builds up on the borehole wall [5]. **Fig. 1-c:** Filter cake and cuttings are plastered against the borehole wall, sealing porous formations [5].

Figure 1 Casing while drilling procedures Plastering [**Error! Reference source not found.**]

In contrast to traditional drilling, a reduced flow rate is necessary due to the narrow annulus in order to properly circulate the mud. Reduced flow rate aids in mud loss, particularly in the event that losses occur near the bit. In order to avoid adding to the formation's pressure and exacerbating the losses, a lower flow rate also regulates the ECD. Higher annulus contributes to more effective wellbore cleaning, particularly when partially lost mud column causes cavings and breakouts into the wellbore. Because of the narrow annulus, filling the back side of the casing is made easy with casing drilling. This feature aids in better well management and cooling of the connections in a drilling scenario when losses occur.

When significant losses occur in traditional drilling, the operation is typically stopped until the losses are repaired through the use of cement plugs, among other procedures. There will be several hours of NPT as a result. Casing Drilling allows the operator to keep drilling, ensuring that the well is cased secured and prepared for cementation once the casing reaches the full depth and that the trouble is left behind after the casing passes the loss zone. Furthermore, the duration of the casing's contact with the wellbore is a significant factor affecting the plastering effect. Drilling further will cause the Plastering Effect to begin healing the loss zone, which increases the likelihood that returns will eventually occur. This is especially crucial if the loss zone is in a section above the bit.

Wellbore Stability Improvement by CWD

Casing while drilling technology helps reduce wellbore stability issues by providing a number of unique advantages. Casing while drilling is commonly chosen as the best technique for drilling difficult wells that traditional drilling methods could not readily manage because of these advantages. These are a few of the previously mentioned benefits **[**Error! Reference source not found.**,** Error! Reference source not found.**]**:

1. No tripping
2. Gauged well
3. Reduced drilling time
4. Effective wellbore cleaning
5. Plastering effect
6. Wellbore integrity
7. Wellbore Strengthening
8. Reduced formation damage
9. Superior hydraulics
10. HSE benefits

In addition to what is mentioned in the literatures [**Error! Reference source not found.**, **Error! Reference source not found.**], there are some points need to clear regarding to the other benefits of casing while drilling. After examining the data from the offset well, it was strongly believed that CWD would generate significant value addition to the wells drilled in this field. These are some of the value contributions that were anticipated [**Error! Reference source not found.**]:

Elimination of Casing Running Flat Time

Through the CWD process, casing running flat time is reduced since casing is already on bottom when TD is reached (considering most of the interval will be drilled conventionally).

Better Hole Cleaning

CWD provides better hole cleaning with less flow rate. This results from increased annular velocity (due to smaller annulus between the casing and hole wall) compared to conventional drilling. Improved hole cleaning when drilling with casing eliminates the need for extra reaming and circulation. Lower pump rate reduces impact on the wellbore and, more significantly, reduces load on the rig. In summary, improved hydraulics and better hole cleaning will allow the section to be drilled with better drilling performance by using less rig power demand.

Reduction of Mud Losses

Through the CWD process, it is expected to see some improvement in the ability to control losses, as the casing is always at the bottom of the wellbore. This also allows every foot drilled to be kept cased bringing value through the elimination of non-productive time in response to excessive reaming back into the open hole.

Wellbore Strengthening

One of the benefits of CWD technology is a stronger wellbore. Even in highly sensitive formations, the ability to smear drilled cuttings into the pores of the formation results in a stronger wellbore that might make multiple stage cementing unnecessary. Additionally, due to the wellbore strengthening enhancement provided by CWD technology, the wellbore retains a smoother, more uniform surface thereby providing stability as well as decreased permeability of the drilling fluid into the surrounding near wellbore area. This aspect alone can improve cementing quality and reduce the likelihood of differential sticking.

Figure 2 depicts the comparison between drill pipe and casing in the bottom hole. Rotating casing smears cuttings into the borehole wall, sealing pores in the

formation to reduce fluid losses and producing a stronger borehole for improved cementing.

Figure 2 Drilling with conventional drill pipe (left) allows a larger annulus, while drilling with casing (right) minimizes annulus.

Table 1 presents a general comparison between conventional drilling and casing while drilling operations. The table shows the common non-productive time (NPT) related to troubled formations in the wellbore, some of these issues were also encountered in the offset well.

Table 1 Common wellbore issues leading to non-productive time.

Conventional NPT	Conventional Drilling Response	Casing Drilling Experience
Losses	Stop, pump loss circulating response	Lower viscosity muds are used
	Case off section early	No contingency strings required
	Pump cement – redrill section	
Reactive Shales / Borehole Instability	Well bore trajectory changes	No tripping just drilling
	Time based – tripping NPT	Continual circulation
	Case off section early	It's cased it's drilled
	Redrill section	No contingency strings required
Swabbing	NPT – Well control operations	No open hole tubular tripping
		Continual circulation
		No contingency strings required

Reduced Formation Damage

Drilling fluids and cuttings from traditional drilling techniques can contaminate the formation by penetrating its pores and fissures. By casing the well as soon as it is drilled, CWD eliminates this problem. This preserves reservoir production and minimizes formation damage by preventing the uncontrolled entrance of drilling fluids and cuttings into the formation [**Error! Reference source not found.**]. This action is similar to the effect of nanomaterial applications for reducing formation damage operation as depicted by many investigators [**Error! Reference source not found.**] [**Error! Reference source not found.**] [**Error! Reference source not found.**].

The Plastering Impact

The plastering effect is the main advantage of CWD. The big diameter casing's constant contact with the wellbore wall is what causes this phenomenon. The well bore is strengthened as a result of the cuttings becoming finely ground and plastered on the wellbore wall due to the reduced annular space between the casing and the wellbore wall. By wedging the formed fractures, this process-known as the plastering effect - restores the hoop stress in the wellbore. Additional advantages of enhanced well control and stability are provided by this approach.

When drilling in depleted formations or loose formations, this action strengthens cementing to preserve wellbore integrity and closes pore gaps in the formation to lower fluid losses. Because of this consequence, fewer cuttings are returned to the surface whereby there is a great reduction in solid handling problems [**Error! Reference source not found.**, **Error! Reference source not found.**].

The plastering effect reduces NPT resulting from borehole-related problems [**Error! Reference source not found.**], such as

- Sloughing shales
- Tight holes
- Borehole bridges
- Lost circulation
- Large-diameter surface hole resulting in hard-to-remove cuttings from the annulus
- Damaged producing zones
- Stuck pipe

Casing While Drilling Types

Technology has come a long way, from drilling the first well to drilling the longest lateral with the CWD. The market is filled with various iterations of CWD technology. But those can be broadly divided into two categories.

Non-Retrievable BHA CWD System:

This is the most fundamental kind of CWD. A drillable bit, a casing string, and a casing drive mechanism comprise this system. The BHA lacks direction and is non-retrievable. This is primarily utilized in the well's tangent or vertical portions.

Retrievable BHA CWD System:

A sophisticated variation of CWD in which BHA is specifically made to be extracted from the hole without requiring the removal of the casing. This system's primary benefit is its ability to be employed and directed in different directions.

Figure 3 shows the different types of casing while drilling (CWD) in comparison to the conventional drilling operations.

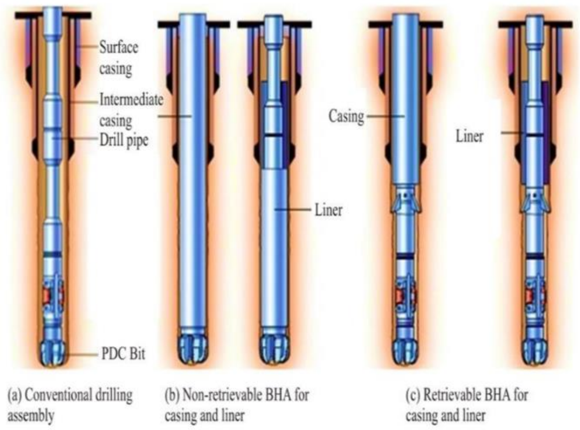


Figure 3 Different types of CWD Systems [**Error! Reference source not found.**]

The industry has recently created liner while drilling technology, which can take the place of traditional drilling in the liner portion. The most recent developments allow the BHA to be set up to support various directional tools and logging while drilling configurations. Because of this, the technology's application envelope has grown **[**Error! Reference source not found.**].**

Equipment of Casing While Drilling

Drill Lock Assembly

A crucial component of the retrievable CWD system is the Drill Lock Assembly (DLA). Which is shown in Figure 4 [**Error! Reference source not found.**,**Error! Reference source not found.**]. Drilling BHA components, including MWD/LWD and DD tools, can be removed from the hole with the use of DLA, leaving the casing in place for subsequent operations like cementing [**Error! Reference source not found.**].

Casing Drive System

The hydraulic system powers the Casing Drive System (CDS), often referred to as the Casing Running Tool (CRT), a piece of machinery used in the oil and gas sector to run the casing into the well. The rig top drive is attached to this tool. This provides torque for drilling and creating and breaking connections while supporting the entire weight of the casing string. Through CDS, the drilling rig's top drive system is linked to the casing string. Depending on the casing-catching mechanism, there are two types of CDS: internal catching and exterior catching [**Error! Reference source not found.**].

Drilling Rig

Since the drilling rig supplies the hydraulic power needed to drill, it is a crucial component of CWD. The rig must also have a top drive system in order to use CDS. Since the Kelly drive rigs aren't compatible with CDS, they can't be utilized for CWD [**Error! Reference source not found.**].

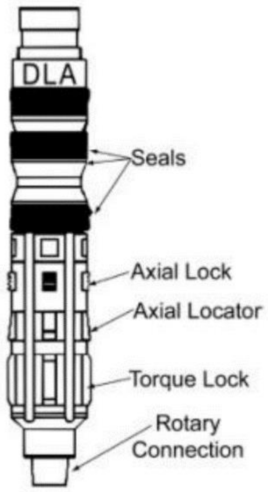


Figure 4 Drill Lock Assembly [**Error! Reference source not found.**].

Casing String

In conventional drilling, casings are utilized similarly to those used in CWD. All that differs between CWD and normal drilling is the quantity of loads casing encounters. To handle various drilling loads, such as buckling, fatigue, and wear, among others, an appropriate casing string can be selected based on the load analysis [**Error! Reference source not found.**].

The 16-in hole section in Umm Gudair field is typically drilled vertically with a rotary BHA upto the top of Shuaiba (60 ft above), followed by wireline logging run, and then drilled with another rotary BHA run to the section target depth (TD). The 13.375-in casing is then run to TD and cemented.

The 16-in non-retrievable CWD BHA was planned to be run instead of the rotary BHA. The main objective in terms of wellbore construction process optimization is to avoid the second run of rotary BHA and running the casing in total losses.

The solution proposed for 13.375-in casing string is to use non-retrievable CWD system equipped with a 16-in drillable bit. The bit type was selected based on offset well records, to maximize its durability and performance.

CWD would significantly increase the chances of achieving the target depths efficiently without any non-productive time, and that the historical hole problems seen in the offset wells such as wellbore instability, are minimized [**Error! Reference source not found.**].

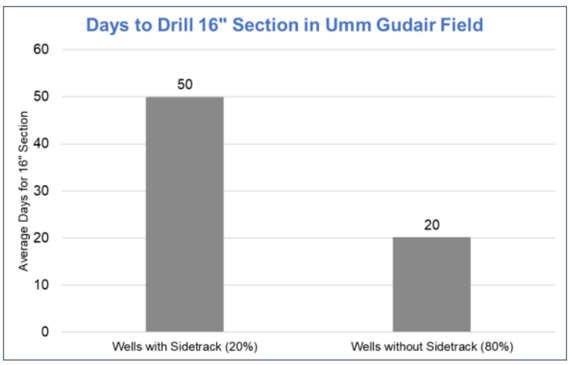
In order to further improve CWD operational efficiency, Soi et al. [**Error! Reference source not found.**] demonstrated the important lessons discovered during the non-directional Casing While Drilling (CWD) project in ONGC's Bombay High field and how the operational workflow was adjusted in light of those lessons. The emphasis is on discussing the difficulties that arose throughout the procedure and disseminating the related fixes.

The lessons learned from addressing extremely unique challenges such as high torque, casing sinking, DAB drill-out issue, and CRT stuck issues during the operation are shared in the paper. The insights gained from this study will benefit drilling engineers, well planners, and operators seeking to implement CWD technology more efficiently, reduce NPT, optimize well delivery, and maintain safety standards [**Error! Reference source not found.**].

Offset Well Analysis

The test well was considered as a candidate well based on the analysis done in the offset wells and wells drilled across the field in the last one year.

The 16-in hole section in Umm Gudair field possess challenges while drilling through the loss zone formation. With the well complications arising, the number of days taken to drill the 16-in section can range from 15 to 60 days of drilling. In some wells the hole complications were such that it was required to plug back and sidetrack the original hole. In the last one year, of the total wells drilled in Umm Gudair field, 20% of those wells ended up with side-track of



original hole section. Figure 5 below shows the average number of days taken to drill the 16-in section in Umm Gudair field in two scenarios, wells with no sidetrack and well that have required sidetrack.

Figure 5 Comparison of days taken to drill 16-in section in Umm Gudair field.

Due to the challenges and well complications encountered in this field, it was decided to use the CWD technology in the test well with an objective to achieve the below

- Avoid multiple cement plugs
- Mitigate the risk of losing BHA in hole
- Minimize time exposure of the reactive shales
- Avoid multiple trips before running casing

Tested Wells

Test well was a deviated production well. Surface casing 24-in was set in Damman at the depth of 553 ft. 18.625-in casing was set in Tayarat at 3,091 ft. 16-in section was planned to drill vertically from Tayarat to top of Zubair with 13.375-in casing point at 6,962 ft (TD). The 16-in section was planned to be drilled vertically with performance motor bottom hole assembly (BHA) up to base of Burgan formation at 6,684 ft, 30 ft above loss prone Shuaiba formations.

After drilling to 30 ft above Shuaiba top, it was planned to pick-up and run in hole 13.375-in casing with 16-in casing drilling bit and to drill the remaining 278 ft through Shuaiba and land the casing 100 ft inside Zubair as section TD. Figure 6 below shows the proposed scope of work.

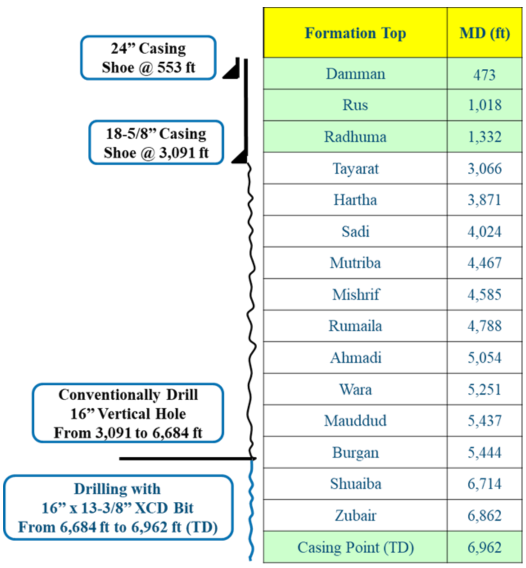


Figure 6 Proposed Scope of Work for the 16-in x 13.375-in CWD job

Results and Discussion

Design Parameters

The 16-in casing used for engineering analysis is 68 pounds per foot (ppf), K-55 grade, with Butress Connection (BTC) and torque rings. The 13.375-in casing planned TD is at 6,962 ft measured depth (MD) and the CWD BHA will start drilling approximately ~30ft above the top of Shuaiba formation.

Torque and Drag Analysis

The maximum anticipated drilling torque is 16,260 ft-lb at 6,962 ft (planned casing point), which represents 24% of the maximum torque for the 13.375-in 68 ppf, K-55, BTC connection with torque rings installed, as shown in Table 2.

All the drilling parameters for the fatigue calculations were assumed considering conservative values for the area.

Hydraulic Analysis

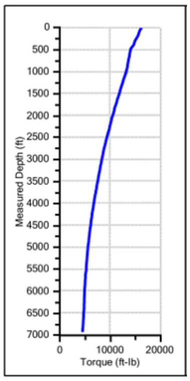
The bit hydraulics will be optimized to get both a good rate of penetration (ROP) and proper cooling on the cutting structure. As rule of the thumb, any annular velocity that exceeds 150 ft/min, will provide adequate good hole cleaning.

Drillable Casing Drilling Bit Selection

The casing drilling bit was designed based on the successful design of polycrystalline diamond compact (PDC) bit that was proven and run in Umm Gudair field. The cutting structure design of the PDC bit was matched to the cutting structure design for the casing drilling bit to ensure higher success of drilling the section to target depth without any complications arising from the bit damage. Figure 7 shows the cutting structure comparison between the baseline PDC bit and the casing drilling bit

Table 2 Maximum torque calculation.

INPUT PARAMETERS (Assumptions)	
Block Wt.+ top drive + CDS (Klb)	51
Open hole friction (factor)	0.4
Cased hole friction (factor)	0.3
Weight on Bit (Klb)	20
Surface RPM	60
Bit Torque (ft-lb)	4,500
Anticipated minimum ROP (ft/hr)	15
OUTPUT	
TD of Interval (ft MD)	6,962
Maximum String torque at TD (ft-lb) *	16,260
Accumulated Fatigue at TD**	0%
Pick Up Weight, (x1000 lb)	475
Slack Off Weight, (x1000 lb)	431
Rotating Weight, On Bottom (x1000 lb)	432



A 7 bladed and 16 mm cutter size was selected for drilling the application in the test well. The casing drilling bit is made of unique copper-based alloy and can be easily drilled out with a standard PDC bit which eliminates the use of special drillout bits. Bit was equipped with cutter technology which has high wear resistance for improved footage and increased impact resistance for durability and extended bit life.

 DOI : 10.21608/jpme.2024.283667.1194

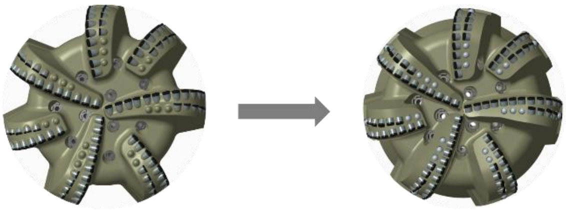


Figure 7 Proven performance PDC bit on the left. Casing drilling bit on the right.

Hazard Analysis and Risk Control Matrix

A detailed Hazard Analysis and Risk Control Matrix was prepared for each step of the CWD run starting from pre-job planning to drill out of the drillable casing drilling bit. Some of the examples of the hazard analysis done are as shown below in Table 3, Table 4 and Table 5.

Table 3 Hazard analysis for Pre-Job Planning

Challenges	Prevention	Mitigation
Bit damage during preparation and make-up to casing	Ensure Make-up procedures as per best practices are observed during Bit to casing M/U.	If possible, the make-up of the drillable casing drilling bit to the casing joint to be carried out in the workshop
Torque required to drill to TD exceeds maximum torque of the Top Drive (TDS) or Casing Drive System (CDS)	Re-assess current rig planned to drill interval. Any opportunity to choose larger one? Optimize well path for torque as much as possible.	Use highest torque Premium Connections or torque rings to meet torque requirements. Torque reduction agents may be added to mud system. Use 6.625 reg connections between the CDS and the TDS
Torque required to drill to TD exceeds 80% of makeup torque of planned connection.		

Table 4 Hazard Analysis for Casing Connection

Challenges	Prevention	Mitigation
Casing Connections damaged during make up or break out may result in damaged or galled threads unable to be reused.	Torque required to rotate casing String at TD must be modelled using accurate (or conservative) estimates of Friction Factors and well trajectory. CWD Operations Reference Manual Basis of Design specifies connection must be made up to 20% more torque than required at TD as safety factor. If possible, use casing drive system (CDS) to make up (10 feet or more above rotary table) Drill as far down above/into rotary as possible with CDS to create maximum rat hole.	Ensure connections are selected in accordance with the criteria as specified in the CWD Operations Reference Manual (ORM) Replace damage casing with new casing as required.

Table 5 Hazard Analysis for Casing While Drilling

Challenges	Prevention	Mitigation
High solids content due to cuttings regrinding may cause increase in Plastic Viscosity (PV), raise equivalent cuttings density (ECD) and excessive equipment erosion	Confirm solids control capability of rig (centrifuge) Monitor total solids and low gravity solids (LGS) to make sure values are consistent with planned mud properties. LGS to be below 5%. Involve mud company for mud monitoring to ensure proper rheology.	Screen down. Dump and dilute as needed.
Plugged Nozzles	Monitor Standpipe Pressure while drilling Ensure pump inlet screens are installed and in good condition. Consider running suction pump screen smaller size than bit nozzles. Shale shaker screens to be in a good condition to ensure proper solids control. Isolate surface equipment and check to make certain increase in pressure is down hole. Monitor to establish if trend indicates additional pressure with time.	Avoid running jets smaller than 12/32" as risk of plugging increases as jet size decreases. Use of high-pressure high-temperature (HP-HT) valves or double valve on the float collars which are typically more resistant for erosion (prolonged circulating hours) Pressure test the pop-off valve setting pressure so that it is well below the opening pressure for dual stage collar. This is to mitigate activating dual stage collar in case of plugged nozzles

Um Ghudair oil field's wells

Offset Wells encountered total losses with well complications leading to BHA lost in hole, sidetrack and multiple cement plugs. In the Test Well, even while encountering losses casing-while-drilling (CWD) managed to drill through Shuaiba to TD in one run reducing flat times and preventing the hole complications.

In the Test Well, CWD was implemented successfully, drilled to section TD without complication and resulted in saving 17 rigs compared to average days taken to drill the 16-in section in Umm Gudair field. Considering the daily cost of the rig, a total cost savings of 430,000 united states dollars (USD) were saved for the operator.

With the successful implementation of CWD in the test well, the operator decides to further use CWD technology in their upcoming wells in Umm Gudair field. A total of 3 wells were drilled with CWD in Umm Gudair field and subsequently and consistently reducing the total number of days taken to drill 16-in section well after well where CWD was implemented. Figure 7 below shows the comparison of drilling days with well using CWD and wells with conventional drilling. It depicts that the days used for completing 16-in CWD for well#1 is 9 days, and that for well # 2 is 8 days, while for well # 3 is 7 days. On average, the CWD of 16-in casing section is about 8 days, which is quite excellent for drilling such section. Comparing such time with that of the conventional drilling operations, which took 50 days for a well with sidetrack and 20 days for a well without sidetrack as illustrated in Figure 8.

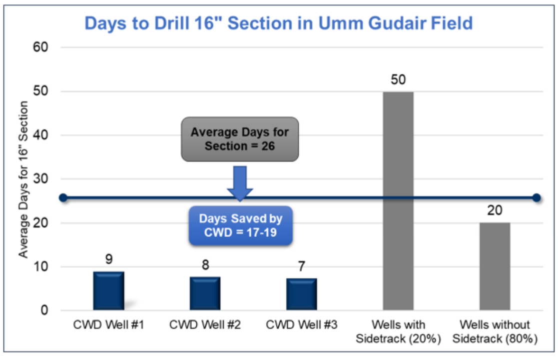


Figure 8 Drilling days comparison between Test Well and Offset Well

Conclusion

The main conclusion is listed as follows:

- The casing-while-drilling (CWD) technology implementation showed consistent performance and days saving enabling the operator to complete the wells faster and drill a greater number of wells in this field and over achieve the target for the year.
- "The casing while drilling applications reduced well time deliverability and saved 17 rigging days which approximated by about 450000 USD based of the rig daily rate." In umm-Gudair wells, 16-in casing drilling with CWD techniques took 8 days on average which represents 1/3 time period of drilling 16-in by normal drilling operation.
- Conventional "best practices" may need to be modified to account for the particular circumstances of casing drilling.
- Casing drilling gives drilling hydraulics design additional freedom. Rethinking the drilling parameters for casing drilling is necessary to get the best possible performance.
- According to field parametrical data, casing drilling produces more energy that is used efficiently.
- According to quantitative Mechanical Specific Energy research, when using casing drilling as opposed to traditional drilling, there is a larger input energy transfer from the bit to the rock.
- Although the Plastering Effect hasn't been scientifically demonstrated yet, casing drilling has been shown to lessen mud loss.

Acknowledgement

The authors would like to thank management at Kuwait Oil Company (KOC) and Schlumberger, for permission to publish the well data. Thanks also to KOC's operations team and rig team along with Schlumberger design and engineering for their support and expertise.

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