Rudarsko-geološko-naftni zbornik	Vol. 17	str. 19-26	Zagreb, 2005.

UDC 622.273.5:622.245.1

Review
Pregledni rad

Language/Jezik:English/Engleski

CASING DRILLING TECHNOLOGY

NEDILJKA GAURINA-MEĐIMUREC

University of Zagreb, Faculty of Mining, Geology and Petroleum Engineering
Pierottijeva 6, 10000 Zagreb, Croatia
e-mail:ngaumed@rgn.hr

Key words: casing drilling, equipment, depleted reservoirs

Ključne riječi: bušenje uz primjenu kolone zaštitnih cijevi, oprema, djelomice iscrpljena ležišta

Abstract

Casing drilling is an alternative option to conventional drilling and uses standard oilfield casing instead of drillstring. This technology is one of the greatest developments in drilling operations. Casing drilling involves drilling and casing a well simultaneously.

In casing driling process, downhole tools can be retrieved, through the casing on wire-line, meaning tool recovery or replacement of tools can take minutes versus hours under conventional methods. This process employs wireline-retrievable tools and a drill-lock assembly, permitting bit and BHA changes, coring, electrical logging and even directional or horizontal drilling. Once the casing point is reached, the casing is cemented in place without tripping pipe.

Sažetak

Bušenje uz primjenu kolone zaštitnih cijevi je alternativna opcija za klasično bušenje koristi standardnu kolonu zaštitnih cijevi umjesto niza bušaćih šipki. Ova tehnologija predstavlja jedno od najvećih unapređenja u procesu bušenja, a obuhvaća istovremeno bušenje i zacjevljenje bušotine.

Tijekom bušenja uz primjenu kolone zaštitnih cijevi, sklop alatki na dnu se može izvući na žici kroz kolonu, što znači da izvlačenje ili zamjena alatki traje minutama a ne satima kao što je to slučaj kod klasičnog bušenja. U procesu bušenja koriste se alatke izvlačive na žici i sklop za zabravljivanje što omogućava zamjenu dlijeta i sklopa alatki na dnu (BHA), jezgrovanje, EK mjerenja i čak usmjereno ili horizontalno bušenje. Nakon izrade kanala do dubine planirane za ugradnju kolone zaštitnih cijevi, kolona se na toj dubini cementira bez izvlačenja cijevi.

Introduction

Casing drilling has been employed in many countries as an effective method of reducing the overall drilling costs by reducing drilling time and drillstring problems encountered during conventional drilling process. In addition to the productive drilling time lost to tripping, unscheduled events during tripping can make the drilling process even more inefficient and even lead to loosing the well. While the potential savings from reducing drill-string tripping and handling times are important, the savings from reducing hole problems may be more significant. There are many situations where problems such as lost circulation, well control incidents, and borehole stability problems are directly attributed to tripping the drill-string and other situations where these problems prevent the drill-string from being tripped. Since the CDS process provides a continuous ability to circulate the well, it is inherently safer than leaving the well static without a means of circulating it while a conventional drill-string is tripped.

Reduced pipe tripping with the CDS should also reduce surge and swab pressure uctuations.

There are two basic methods of drilling with casing (Fisher et al., 2004):

- a latched retrievable BHA inside the casing that incorporates a motor to drive a conventional bit and under-reamer or
- a rotate the casing at surface system incorporating an Internal Casing Drive System and a drillable "cement in place" drilling BHA.

The Weatherford Drilling with Casing (DwC™) system is a simple rotate casing at surface system incorporating the drillable DrillShoe™ allowing a one trip drilling system which is cemented in place at TD and drilled out conventionally with the next drilling assembly.

Casing drilling system has been designed primarily for multi-well offshore platforms, multi-well operations on land, deep-water operations, and for situations requiring operators to drill through and place casing across problem formations quickly.

This technology was applied successfully to drill through depleted reservoir (problems: wellbore instability, mud losses into the depleted zones) as an alternative to the underbalanced drilling, which requires special equipment.

Casing Drilling Equipment

The casing drilling process eliminates the conventional drillstring by using the casing itself as the hydraulic conduit and means of transmitting mechanical energy to the bit. A short wireline retrievable bottom hole assembly (BHA) consisting of at least a bit and expandable underreamer (**Fig. 1**) are used to drill a hole of adequate size to allow the casing to pass freely.

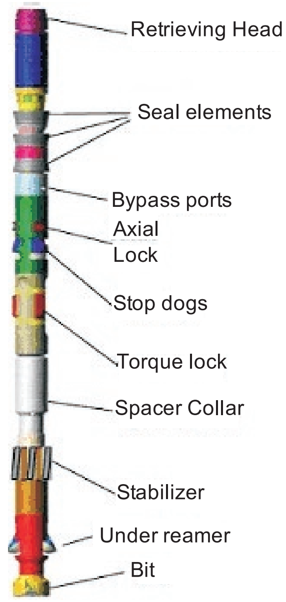

Figure 1 Wireline retrievable BHA

Slika 1. Sklop alatki na dnu (BHA) koji se izvlači na žici

The BHA is attached to a drill lock that fits into a full bore landing sub on the bottom of the casing in such a way that it can be retrieved with a wireline unit without needing to trip pipe out of the well. The wireline retrievable drill lock assembly is the heart of the casing drilling system. It lands in a lower section of casing consisting of a casing shoe, torque lock profile and axial no-go and lock profile located in a specially machined collar section (**Fig. 2**). The drill lock engages both a uted profile to transmit rotational torque from the casing to the drilling assembly and an internal ush no-go and axial lock profile to transfer compressive and tensional loads to the BHA. A stabilizer on the BHA positioned opposite the casing shoe reduces lateral motion of the assembly inside the casing. The casing shoe is normally dressed with hard material to ensure that a full gauge hole is drilled ahead of the casing, but it also provides a torque indication if the underreamer drills undergauge. Centralizers on the casing stabilize it within the borehole and prevent wear on the couplings.

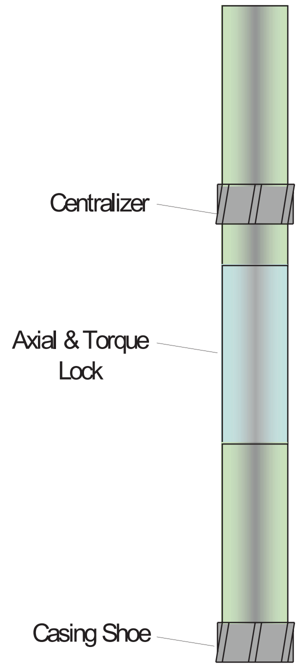

Figure 2 Exterior Casing components

Slika 2. Vanjske komponente kolone zaštitnih cijevi

The BHA generally consists of a pilot bit and underreamer, but may include other tools needed to perform almost any operation that can be conducted with a conventional drill string. The pilot bit and underreamer pass through the drill-casing and drill a hole that provides adequate clearance for the drill-casing and subsequent cementing. Conventional directional tools (bent housing positive displacement motors, MWD tool, and isolation monels) and LWD tools can be suspended below the drill casing shoe for directional drilling. A conventional core barrel can be run for coring.

In many ways designing a well for Casing Drilling is similar to designing a conventional well. One significant difference is that the casing is subjected to additional stresses while Casing Drilling, so buckling, fatigue, and hydraulics deserve special attention. Figure 3 shows some of interactions that affect the integrity of casing used for Casing Drilling (Warren et al., 2000).

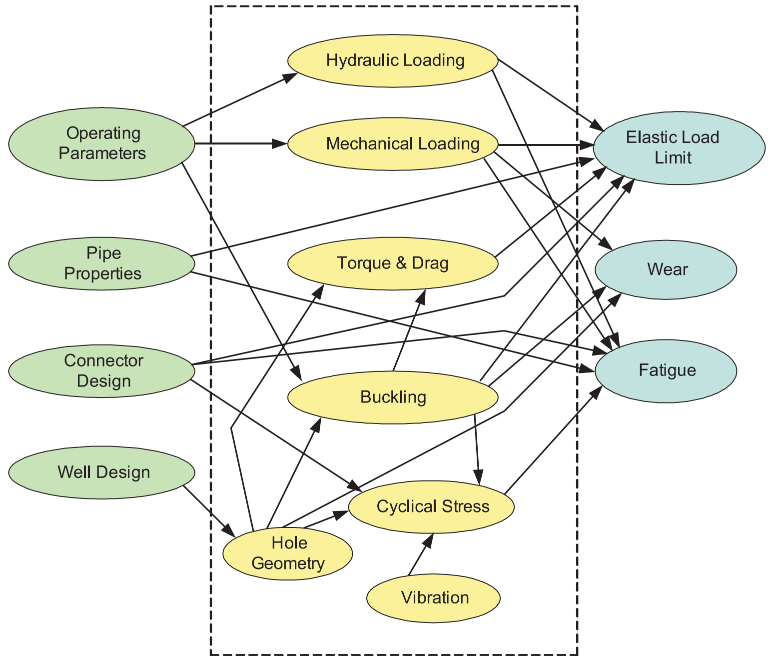

Figure 3 Interactions affecting casing integrity for Casing Drilling applications

Slika 3. Interakcije koje utječu na cjelovitost zaštitnih cijevi tijekom njihove primjene

Buckling

A significant difference between drilling with a conventional drill-string and casing drilling is that drill collars are not used to provide weight-on-bit. For years drillers have been taught that they need to run drill collars to make sure their drill-string is not damaged by buckling. An obvious question then is "How can the casing drilling process operate effectively without using drill collars?" The lower portion of the drill-casing will support only a limited compressive load before it buckles. Buckling occurs when the compressive load and casing/hole geometry create a sufficient bending moment so that the casing becomes unstable. After it buckles (becomes unstable), it is incapable of supporting the compressive load without lateral support, but this does not mean that there is a structural failure. The borehole wall surrounding the casing provides lateral support to limit the lateral de ection for any given set of parameters. There is nothing inherently destructive in the fact that the casing buckles, but the buckling causes two effects that may be detrimental. First, the lateral contact forces between the drill-casing and borehole wall can cause wear on the casing and will increase the torque that is required to rotate the casing.

Secondly, the buckling causes the casing to assume a curved geometry within the borehole that increases the stress in the pipe and may increase the tendency toward lateral vibrations. For casing drilling applications it is important to determine whether or not the casing is buckled and if so whether or not the buckling is sufficient to cause a problem (wear, high torque, or high stress). In straight holes, the compressive load that causes buckling is determined by the stiffness of the pipe (EI), the lateral force of gravity (pipe weight and hole inclination) and distance from the bore hole wall (radial clearance). In a perfectly vertical hole, the portion of the drill-casing that is in compression is always buckled if the bore hole does not provide lateral support through centralizers, just as drill collars are buckled in a vertical hole. If the well is straight, but not vertical, the normal wall contact force from the pipe laying on the low side of the hole provides a stabilizing in uence and increases the compressive load that can be supported before the drill-casing buckles.

Casing drilling rig

Drilling rigs used for casing drilling can be specially developed for this technology **(Fig. 4**), or modified conventional drilling rigs (Fontenot et al., 2003).

One of the most important things on rig is casing drive system (CDS) which provides safe, non-threaded connection between top-drive and casing string (**Fig. 5**) (Warren et al., 2003).

Casing drive system is run hidraulically, and it transmits torque and mud uid to the casing string.

There are two types of CDS: internal – for greater casing radius, and external – for smaller casing radius. It is controlled automatically from the drillers cabine with PLC (Programmable Logic Control).

Figure 4 Drilling rig used in South Texas

Slika 4. Bušaće postrojenje korišteno u Južnom Teksasu

Figure 5 Internal Casing Drive System

Slika 5. Unutarnji sklop za hvatanje zaštitnih cijevi

Casing Drilling in practice

The experience gained from drilling with casing in Wyoming, South Texas and Brunei will be presented through several case histories.

Wyoming

BP and Tesco undertook a project to drill five gas wells in the Wamsutter area of Wyoming using the casing drilling process to evaluate the technology for use at both this location and for broader application in BP's worldwide operations (Fontenot et al., 2003). The project was undertaken specifically as a joint technology evaluation project between an operating company and service company. A multi-well program was approved because it often takes several trials to successfully implement a new technology. Tesco provided the casing drilling services, as well as the rig for the project, under an incentive contract.

Table 1 shows the general lithology encountered in the area. The conventional drilling program is to set 12,19 m of 406,4 mm (16") conductor, drill 279,4 mm (11") hole and set 219,08 mm (8 5/8") casing at 350,5 m, and then drill 200,03 mm (7 7/8") hole to 122 m below the top of the Almond where 88,9 m (3 1/2") tubing is set as the production string (Shepard et al., 2001).

The surface hole in each well was drilled to approximately 365,8 m with the casing drilling system. A Tesco underreamer was used in each well. A roller cone bit was used in wells one and two while a PDC bit was used in the third well. In each case the BHA was installed at the surface and retrieved with the wireline when the casing point was reached. The cement service company was called out before casing point was reached and began rigging up for the cement job while the BHA was being retrieved.

Table 1. General lithology in the Wamsutter area

Tablica 1. Litološki opis Wamsutter područja

Formation	Typical Depth (m)	Potential Problems
Wasatch	Surface - 762	Hole cleaning in fast drilling
Fort Union	762-1463	Fresh water ows, bit balling
Lance	1463-2195	Fresh water ows, loss zones
Fox Hills	2195-2316	Fresh water ows, loss zones
Lewis	2316-2743	Bit balling tendency, loss zones, hard stringers
Almond	2743-2896	Increased pressure, hard abrasive formations, well control potential, loss in upper zones from weighted mud

Figure 6 shows the time from spud to completion of the cement job for the three casing drilled wells compared to the average offset well (Shepard et al., 2001). A typical offset takes about 8-12 hours to drill the surface hole and a total of about 18,9 hours (based on the average of the last 19 wells in the field drilled since June 2000.) from spud to completion of the primary cement job.

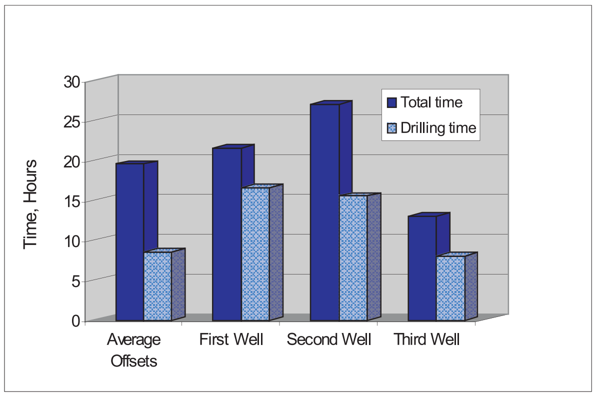

Figure 6 Drilling and cementing time for surface hole

Slika 6. Vrijeme izrade kanala i cementiranja uvodne kolone

The first casing drilled well required 16,5 hours drilling time and the total time from spud to completing the cement job was 21 hours. On the second well the WOB and rpm were increased to reduce the drilling time to 15 hours. Difficulties in retrieving the BHA, ow line plugging problems due to gumbo, and a failure of the seal in the casing clamp increased the overall time to 26 hours. For the third well the rotating time was reduced to 8 hours and the overall time was reduced to 12,5 hours (excluding time waiting on water for the cement).

Successfully drilling the production hole with the casing drilling process proved more challenging than drilling the surface hole. Again difficulties were encountered in achieving an acceptable ROP compared to the offsets. However, an even more challenging problem with lateral drillstring vibrations was encountered. These vibrations resulted in two casing connection fatigue failures. The matrix body shoe and the three bladed steel body bit were selected for the first run in the first well. Drilling proceeded reasonably well to a depth of 905 m where the ROP fell to zero. The BHA was retrieved assuming that the PDC pilot bit had failed, but the cutting structure was still undamaged except for severe erosion around the cutters. The bit was changed to the more erosion resistant five bladed matrix body PDC bit and the BHA pumped down. The BHA failed to reach the profile nipple and the casing was pulled to diagnose the problem. The drill lock assembly (DLA) had set prematurely in the slight internal upset of a connection eleven joints above the shoe due to an improper tool set-up.

Experience demonstrates that casing drilling can reduce the time required to drill and cement the surface casing. This observation is consistent with the results of an offshore project where the 311,15 mm (12 1/4”) surface holes were casing drilled. The larger surface casing rotates smoother and allows more robust underreamers that have dedicated jets for each arm. This is essential to matching the penetration rate of the conventional drilling process in soft, ballable formations. Once a comparable penetration rate is achieved, time savings result from eliminating the need to condition the hole, eliminating conventional drill-string tripping, and eliminating the time required to lay down the drill collars. The casing drilling process also reduces the risk of not getting casing to bottom after the surface hole is drilled.

South Texas

Drilling with casing was identified in early 2001 as a technology that could potentially solve the problems and provide a step change in drilling performances in the mature Lobo field in South Texas. Tesco’s casing drilling system was selected to evaluate the potential impact of drilling with casing on Lobo drilling economics.

A five well pilot program was undertaken as phase 1 of the effort to introduce casing drilling technology at Lobo. The objective of these first wells was to determine if casing drilling technology could deal effectively with the specific issues encountered at Lobo to reduce overall drilling cost. Performance on these five wells steadily improved and matched that of conventional drilling by the time the last well was completed. This occured even though there was obviously considerable room for further impovement in casing drilling system.

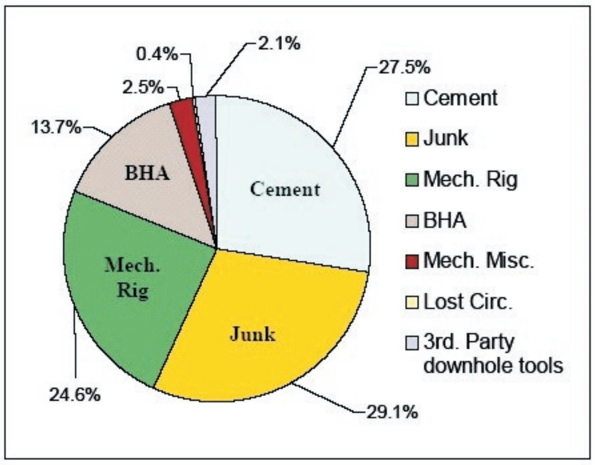

Figure 7 Trouble time for phase two casing drilled wells

Slika 7. Neproduktivno vrijeme tijekom bušenja uz primjenu kolone zaštitnih cijevi za drugu fazu projekta

The phase two program proved that casing drilling could eliminate the formation related trouble time experienced with conventional rigs. This allowed additional wells to be drilled that would otherwise be uneconomical. The wells were not drilled trouble-free, but the trouble was associated with the mechanical equipment limitations shown in Figure 7 (Fontenot et al., 2003). These mechanical problems can be fixed, as opposed to the formation related problems that are encountered when drilling with conventional rigs. In fact, solutions to most of the problems that caused lost time in phase two have already been implemented.

The third phase of the Lobo casing drilling program has been initiated by bringing in the first of three new rigs to begin full-scale implementation of casing drilling at Lobo.

Casing protection. It is important to know that the casing is in good condition after drilling is completed. This issue was evaluated in the phase one Lobo trials when the intermediate casing was tripped out several times. No wear or damage was seen on the pipe body, but some of the couplings in the lower portion of the casing were worn on one side. Wear protection was developed for the couplings that resolved this concern.

The couplings are protected against this wear by installing ''wear bands'' on the lower half of the 177,8 mm (7'') casing (Fig. 8) (Fontenot et al., 2003). These bands are installed in the field with a portable hydraulic crimping tool. The lower end of the wear bands includes about 25,4 mm (1'') of thungsten carbide hard facing material similar to that used for wear protection on drill pipe.

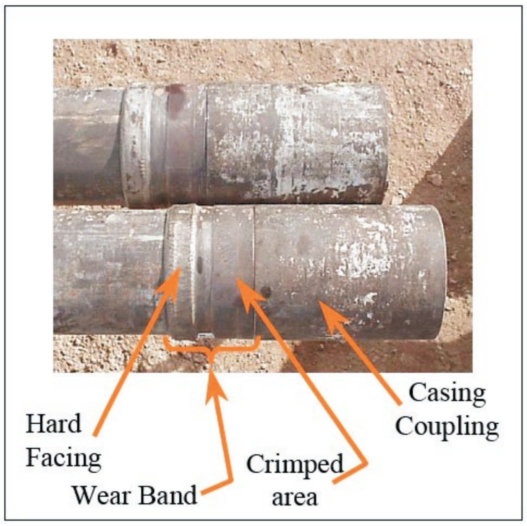

Figure 8 Wear bands installed below couplings

Slika 8. Zaštitni prstenovi postavljeni ispod spojnica

Stabilization. Stabilizers are used on the lower end of all three strings of casing to function as cementing centralizers and on the 177,8 mm (7'') casing as key-seat wipers spaced about every 229 m along the entire lenght of the casing. Several different custom designed and manufactured stabilizers have been used.

One type is shown on **Figure 9** (Fontenot et al., 2003). They provide a blade structure that does not have the sharp transition between stiff blade and exible tube material. The heat-affected zone created by the massive welding used on the previous stabilizer design is also minimized.

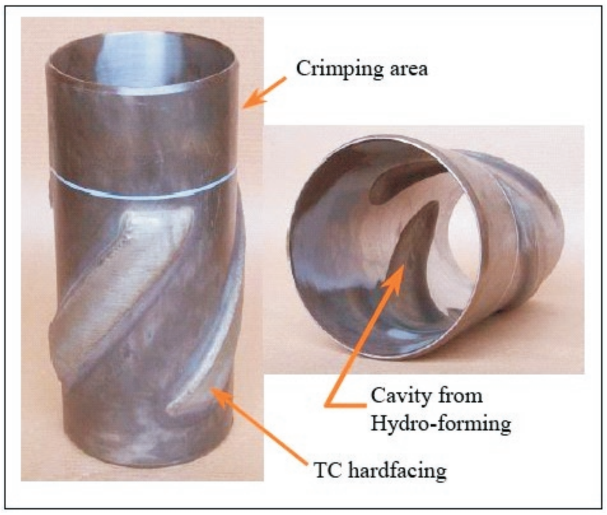

Figure 9 Hydro formed crimp-on stabilizer

Slika 9. Hidraulički oblikovana rebra na stabilizatoru

Logging. Open hole logging can be accomplished in a variety of ways that involve LWD or memory logs, but these are too expensive to be cost efective at Lobo.

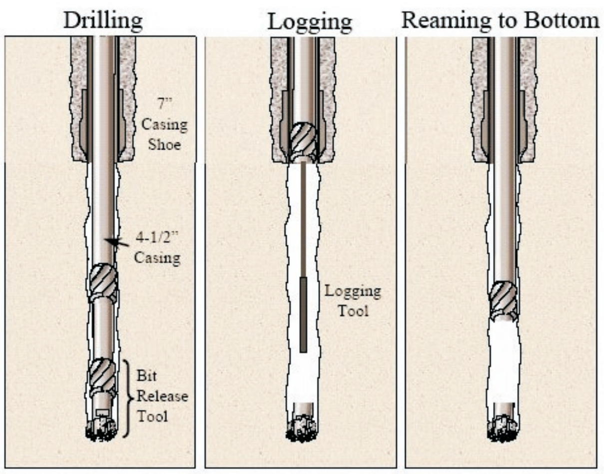

Figure 10 Procedure for logging below 114,3 mm (4 ½'') casing

Slika 10. Postupak izvođenja karotažnih mjerenja ispod zaštitnih cijevi promjera 114,3 mm (4 1/2")

After drilling twenty-two Lobo wells, the casing drilling process has proven to significantly reduce the in-hole trouble time to less than the low value that was already obtained at Lobo. Most significantly, time lost due to lost circulation and stuck pipe has been almost totally eliminated. Even when well locations were selected where the offsets required multiple cement jobs and unscheduled liners to reach TD because of lost circulation problems, the casing drilled wells experienced little lost circulation problem. This has lead to the ability to effectively drill wells in lost cicrulation areas that are uneconomical with conventional drilling techniques.

Brunei

Shell Brunei Petroleum (BSP) is an active member of a global Shell Common Interest Network (CIN) for mature technologies, one of which is casing drilling. It performed casing drilling job in September 2003 as a means of reducing well cost in the Seria field on Brunei´s western coast (Fisher et al., 2004). The 0,31111 m (12 1/4") surface hole on S-816, a vertical well, was selected as the most appropriate for trialing the CDS. The formations to be drilled were sand and soft shales with some harder silstone stringers. The last casing was the 0,406 m (16") conductor set at 59 m. It was determined that the clearance of the conductor flange to the 0,2445 m (9 5/8") casing would allow the casing to be rotated in the wellhead. The internal casing drive system could be used to land the casing hanger after drilling to TD. The surface casing was 0,2445 m (9 5/8"), 69,94 kg/m (47#), N-80 with New VAM connections.

The 0,2445 m (9 5/8") casing on S-816 was drilled to 721 m, taking 57 hours from spud to casing TD. No recordable incident or accident occurred. The Convertible PDC drilling shoe drilled 662 meters from 59 m to 721 m in 44 drilling hours and 52 circulating hours. Cementing was carried out without any problems, and a good LOT/FIT was achieved. After milling the shoe, the 215,9 (8 ½") drilling assembly passed through the drillshoe and drilled on with no indications of problems. The system maintained excellent bore hole quality with no wellbore related problems, Through fluid volumes it has been established that the well bore was 0,3084 m (12,7"). Good hole cleaning and hole size was maintained without inducing losses, despite higher ECDs. No hole/fluid related problems were noted during drilling with casing. Conventional drilling on the offset well had encountered bit balling, and back reaming was required on every stand with the same drilling fluid.

Drill shoe. The world´s first convertible casing drill shoe job is performed onshore Brunei in September 2003 during a 0,2445 m (9 5/8") surface casing job on S-816 well in the Seria field (Fisher et al., 2004). Convential drill bits are capable of drilling long intervals but are compose of non-drillable materials. The convertible drill shoe has a novel feature that allows the cutting structure and blades to be extruded outwards once section TD is reached. By this process, the drill shoe converts to a cementing shoe, allowing the casing to be cemented in place. The cementing shoe and next hole section can then be drilled without interference from the casing drill shoe cutting structure and blades. Application of the extrusion process allows a more aggresive and durable cutting structure on the casing drill shoe and hence allows deeper, more resistant formations to be drilled. The standard DrillShoe™I and DrillShoe™II are composed of drillable materials, but the distance and hardness of formation that can be drilled with this tool are limited. DrillShoe™III (DS III) has attributes of a conventional PDC bit (Fig. 11) (Fisher et al., 2004).

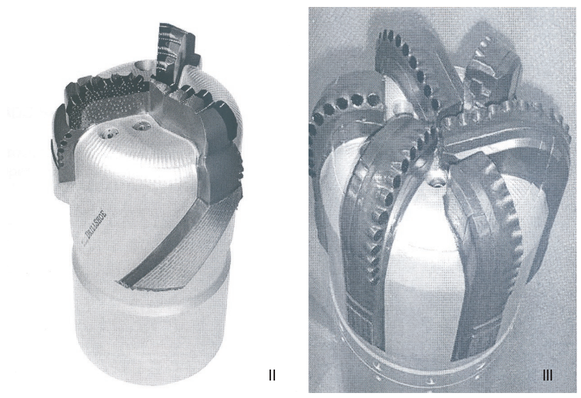

Figure 11 DrillShoe™II and DrillShoe™III

Slika 11. Peta za bušenje II i peta za bušenje III

It incorporates PDC cutters mounted on special alloy blades. While drilling, the blades are supported in a matching profile on the inner piston. Prior to cementing the casing string, a ball is dropped which seats in a ball seat at the top of the inner piston, sealing off the fluid ports. The convertible PDC drillshoe requires a 0,762 m (3") ball to be seated in the ball seat to close off the normal fluid passage and the use of a large bore float collar through which the drop ball can pass.

The resultant pressure build-up shears the locking mechanism, displaces the inner piston downward and converts the drill bit to a drillable casing shoe. The pressure of 14,5 MPa (2100) psi is required to convert the drillshoe. As the inner piston is pushed out the end of the bit, cement port are exposed. As the inner piston is displaced the cutter blades unfold from the drillshoe face like the fingers opening from a first to rest out of the way of the subsequent bit in the wells annulus. Once the cement ports are opened, circulation is reestablished and cementing can begin. The cement stinger receptacle incorporated a 0,0826 m (3 ¼") ID. When lead cement slurry returns is detected at surface the cement stinger is pulled from the receptacle and the cement reversed out of the inner string. The auto fill oat valves held back pressure as designed. The actual cementing operation is identical to conventional wells.

Casing Drilling and ERD wells

Casing drilling has proven benefits for certain classes of wells. To date, most of these wells have low deviations. Therefore, low torques and loads are generated during the casing drilling process. It is considered that this approach is unlikely to work for large ERD (Extended-Reach Drilling) wells. However, it is quite possible that provided good directional control is achievable, casing drilling would be beneficial for limited step-out, shallow ERD wells (Mason et al., 2003).

Conslusion

The Casing Driling system may eliminate costs related to purchasing, handling, inspecting, transporting, and tripping the drill-string, reduce hole problems that are associated with tripping, and save on rig equipment capital costs and operating costs. Casing Drilling system has been used in more than 500 well intervals to drill more than 460 000 meters with casing since it was introduced in 1999.

Based on the knowledge gained to date, the CDS in its current state of development is well suited for drilling softer formations with casing sizes of 7" or larger. In these situations, the penetration rate can easily match conventional rates, and the reduced tripping and drillstring handling can be used advantageously.

Prior to apply casing drilling in any particular well, the hole condition, such as unscheduled events and litological characteristics of the formations have to be examined in order to evaluate the design criteria of the casing and to improve drilling performance.

Received: 11.09.2005.
Accepted:15.10.2005.

References

Fisher, A., Reid, D., Zo Tan, M., Galloway, G.: Extending the Boundaris of Casing Drilling, paper IADC/SPE 87998, presented at the IADC/SPE Asia Pacific Drilling Technology Conference and Exhibition, Kuala Lumpur, Malaysia, 13-15 September 2004.

Fontenot, K., Highnote, J., Warren, T., Houtchens, B., (2003): Casing Drilling Expands in South Texas, paper SPE/IADC 79862, presented at the SPE/IADC Drilling Conference, Amsterdam, The Netherlands, 19-21 February 2003.

Lyle, D., Duey, R., Perdue, J.M., Rasheed, W., Bradbury, J., Lang, K., (2002): Casing Drilling : Saving time, saving money; A supplement to: Hart's E&P

Mason, C.J., Lopez, J., Meling, S., Munger, R., Fraser, B. (2003): Casing Running Challenges for Extended-Reach Wells, paper SPE 84447, presented at the SPE Annual Technical Conference and Exhibition held in Denver.

Shepard, S.F., Reiley, R.H., Warren, T.M., (2001): Casing Drilling: An Emerging Technology, paper IADC/SPE 67731, presented at the 2001 SPE/IADC Drilling Conference, Amsterdam, The Netherlands, 27 February – 1 March, 2001.

Tessari, R.M., Madell, G., (1999): Casing Drilling – A Revolutionary Approach to Reducing Well Costs, paper SPE/IADC 52789, presented at the 1999 SPE/IADC Drilling Conference, Amsterdam, Holland, 9-11 March 1999.

Warren, T., Houtchens, B., Madell, G., (2003): Directional Drilling with Casing, paper SPE/IADC 79914, presented at the SPE/IADC Drilling Conference, Amsterdam, The Netherlands, 19-21 February 2003.

Warren, T.M., Angman, P., Houtchens, B., (2000): Casing Drilling: Aplication Considerations, paper IADC/SPE 59179, presented at the 2000 IADC/SPE Drilling Conference, New Orleans, Louisiana, 23-25 February 2000.