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Current Trends and Future Development in Casing Drilling

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ABSTRACT

Operators in the Oil and Gas (O&G) Industry are constantly seeking cost effective methods of drilling and producing oil and gas wells to optimize production and maximize profits. Conventional drilling methods have been plagued with huge operational and financial challenges, such as cost of purchasing, inspecting, handling, transporting the drill string and most importantly, tripping in-and-out of the drill string whenever the Bottom Hole Assembly (BHA) needs a replacement or when total depth is reached. The tripping in-and-out of the drill string not only contributes to Non Productive Time (NPT) but also leads to well control difficulties including wellbore instability and lost circulation. Casing Drilling, otherwise known as Casing while Drilling (CwD) or Drilling with Casing (DwC) has been under development for over a decade and has only been executed successfully in recent times as a result of advance in technology. Casing Drilling encompasses the process of simultaneously drilling and casing a well, using the active casing. This paper presents current applications of casing drilling, along with practical applications and limitations. A study is also undertaken in discussing the possibility of applying retrievable liner drilling to further improve on the casing drilling technique. The main advantages that are evident by this future development are the casing string cost savings, its application in wellheads requiring limited number of casings and in some subsea well control situations.

Keywords: *Casing Drilling, CwD, BHA, DLA, CDS.*

1. INTRODUCTION

Casing Drilling has been under development for over a decade and in recent times has been successfully executed as a result of advances in technology. Casing Drilling involves the process of simultaneously drilling and casing the well using the active casing (standard oil field casing) as the drill string [1]. The conventional method of drilling a well has been fraught with challenges such as cost of purchasing, inspecting, handling and transporting the drill string [2]. A common problem is the tripping in-and-out of the drill string whenever the Bottom Hole Assembly (BHA) needs to be replaced or when total depths is reached [3]. The tripping of the drill string not only contributes to Non Productive Time (NPT) but also leads to well control difficulties such as wellbore instability and lost circulation. These problems have however, been addressed by an alternative drilling technique known as Casing Drilling [4].

In Casing Drilling, the casing transmits hydraulic and mechanical energy to the drill bit through the Drill Lock Assembly (DLA) rather than the traditional drill string. A specific drilling shoe, connected to the end of a casing string, could be used in place of the normal rotary drill bit to drill vertical wells [5]. Directional casing drilling is however, employed in the drilling of wells with high build rates. This method uses conventional surface equipment and casing accessories applied in vertical wells and also uses a retrievable BHA to steer the well. This enables changes to be made to the BHA and/or the bit without tripping the casing [6]. Casing drilling, otherwise known as drilling with casing (DwC), is not limited to retrievable systems. It even has a simpler and less expensive application in non-retrievable systems [7]. The non-retrievable system involves a simple rotate casing system at the surface [8] and a fixed drilling bit down hole [9]. The bit is attached to the end of the casing and is usually drillable enabling it to be drilled out when the casing point is reached or left in the well at Total Depth (TD) [10].

The major importance of casing drilling is the ability to eliminate flat spots in the drilling curve, which improves the drilling efficiency. It excludes the application of drill pipes and thus decreases time spent on tripping in and out of the well. Casing drilling also saves operational time spent on activities such as fishing, reaming and taking kicks resulting from tripping [11]. It improves wellbore stability and well control and is also capable of solving problems associated with bridging troublesome zones. Rosenberg, 2008 [7] described casing drilling as a key part of a drilling hazard mitigation solution.

Recently, casing drilling has been merged with other technologies such as underbalanced drilling, stage tool cementing, expandable tubular, rotary steerable systems and managed pressure drilling. This development has enabled huge savings in terms of manufacturing, logistics, time and cost. A huge challenge faced by the Oil and Gas industry is the difficulty in reducing well cost and at the same time increasing production to maximize the return on investment in well reserves. This has been achieved to an extent by applying an alternative drilling technique known as casing drilling. Casing drilling eliminates use of drill pipes, thus reducing tripping times as well as time lost due to unscheduled events such as 'reaming' and 'fishing' [11]. This drilling method has been widely used successfully as an efficient means of decreasing Non Productive Time (NPT) associated with conventional drilling methods [12]. However, casing drilling may not be practicable in some *subsea well control* situations which require the ability to shear the pipe during drilling and also in situations where the wellhead can

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accommodate only a few casing strings. Thus, a need exists for a more practical way of improving the casing drilling technique to further boost drilling economics.

This paper presents a review of current techniques used in casing drilling technique and identifies the problems associated and proffers solutions to casing drilling. A comparison between the conventional drilling method and casing drilling is also presented. Effort has been made to identify the advantages, limitations and practicability of retrievable liner drilling.

2. CASING DRILLING

Organic matter (remains of animals and plants) decays and decompose as a result of very high temperatures and pressures within formations below the earth's surface. These extreme conditions transform the organic matter into hydrocarbon products. Oil and gas wells are then drilled to primarily produce these hydrocarbons from the hydrocarbon containing formations. Oil and gas wells can also be drilled to inject fluids into the formations to boost hydrocarbon production [13]. Obtaining hydrocarbons from reservoirs were found to be complicated, and thus, adequate drilling techniques needed to be developed to combat these difficulties. The rotary drilling process substituted percussion (cable) drilling in the 1930s and it involved attaching drill bit to the end of a length of hollow pipe and the bit needed to be replaced whenever it was worn out [14]. The need to cut down on the trip time and reduce operating cost led to the introduction of casing drilling technique. Casing drilling did not find a wide application due to the technological difficulties experienced in the late 19th century and a major part of the 20th century [15]. The first patent of casing drilling dates back to 1890, which involved a rotary drilling process for drilling the well with the casing and afterwards retrieving the hydraulically expandable bit [6]. Another patent was introduced in 1926, which included a retrievable and re- runnable casing bit. The advantages of this patent were the elimination of drill pipe, reductions in overall drilling time, stuck pipe, crew and drilling costs. Other benefits included application of few casing string, decrease in accident occurrence on the rig and the ability to drill every foot in the well [16]. However, the first extensive work on casing drilling was accomplished by Brown Oil Tools Company in the 1960s. This patent developed a casing drive system which comprised down hole and surface tools which were used to drill with the casing and retrievable bits [6]. These components included casing centralisers, wire line retrievable drilling assembly, under reamer, casing drive tool and top drive [16]. This patent, like the works that preceded it, was not successful due to the unavailability of the required technology [16]. Interestingly, the patent encouraged the development and commercialization of the top drive [4]. Tesco Corporation Ltd eventually developed a casing drive system in the late 1990s, which was approved by the drilling industry. This system has been successful in reducing well costs and eliminating NPT [6].

Casing drilling, otherwise known as drilling with casing (DwC) or casing while drilling (CwD) is an alternative drilling technique to the conventional drilling method. Casing drilling involves the simultaneous drilling and casing of well with a casing string [6]. The casing string replaces the drill pipe and other drill string components used in conventional well drilling. The casing is usually put into rotary motion and cemented in the well at the total depth (TD) [16]. It is imperative to note that the grade, size and weight of the casing string used in this process is not different from the casing set in place after drilling a well traditionally [6]. Casing drilling can be employed in a variety of ways but can be grouped into two main categories namely, retrievable and non-retrievable systems. Fig.1 shows the BHAs for these systems and the conventional drilling technique.

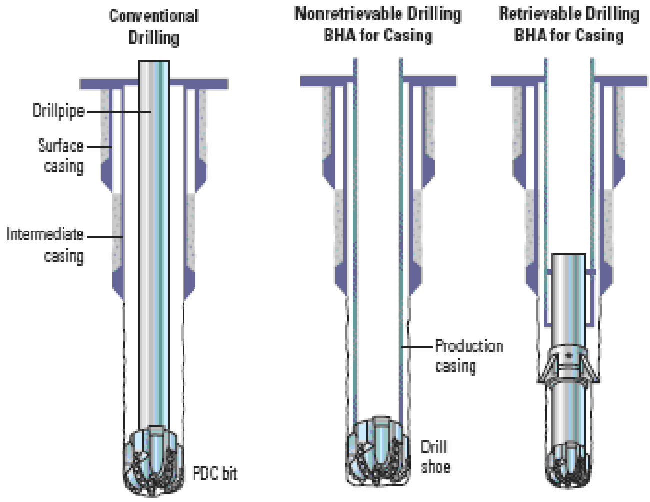


Fig.1: Conventional drilling and casing drilling BHAs [17]

2.1 Retrievable Casing Drilling

The retrievable casing drilling comprises a BHA fastened to the base of the casing string and stretching beneath with a pilot bit and an under reamer [6]. It also consists of a wire line winch, which is used to retrieve the drilling assembly. This enables the pilot bit to be replaced or kept outside the hole before cementing operation is done. This retrievable system, which could be used in vertical drilling, is the only practicable option for directional wells [9]. The size of casing used while drilling directionally determines the achievable build up rates. Table 1 shows the higher limits of the normal build rates attained with varying sizes of casing strings based on their fatigue limitations [6].

Table 1: Curvature for drilling with casing [6]

Casing Size (in.)	Casing Weight (ppf	Casing Grade	Max Curvature
5.5	17	P110	13

7	23	L80	8
9.625	36	J55	4.5
13.375	54.5	J55	3

Tesco Corporation Ltd is the major provider of retrievable casing drilling. Houtchens et al, 2007 [4] states that over 280 wells and more than 2 million feets of hole have been drilled with casing drilling method between 1999 and 2007. These wells have been drilled in formations with varying lithology for both offshore and onshore environments. Table 2 below presents a summary of statistics on the retrievable BHAs that have been applied on commercial wells, which were drilled from January 2001 to June 2006 by Tesco Corporation Ltd for vertical and directional applications. From the table, a total of 890 BHA retrievals were carried out, 822 retrievals in vertical wells and 68 retrievals in directional wells. From the results shown, 857 of the total number of retrievals were successful, showing an outstanding performance of 96%, leaving only 4% as the fraction of the unsuccessful retrievals [4].

Table 2: Statistics for Unsuccessful and Successful BHA Retrievals [4]

Retrievable BHAs	Vertical BHAs	Directional BHAs	Successful retrievals	Unsuccessful retrievals
890	822	68	857	33
100%	92%	8%	96%	4%

2.1.1 Equipment Used in Retrievable Casing Drilling

Casing drilling is carried out with the aid of surface and downhole tools in which the standard oilfield casing is simultaneously used in drilling and casing off the well [18]. These tools are briefly described as follows:

Casing Drive System

Tesco Corporation Ltd casing drive system (CDS), also known as casing quick-connect is a casing running and drilling system illustrated in Fig 2. It contains an internal spear assembly, which acts as a fluid seal to the casing, and a slip assembly to grasp either the external part of the small casing or the internal part of the large casing. The use of the casing drive system accelerates the casing handling process and also removes one make/break cycle, thus avoiding damage to the casing threads. This casing drive system (CDS) connects the casing string to a top drive without screwing into the top coupling [3].

Fig. 2: Casing Drive System [19]

Topdrive

The top drive, located at the surface, connects the casing to the casing drive system in retrievable casing drilling and to the overdrive system in non- retrievable casing drilling. The top drive puts the casing in rotary motion and also provides torque, which is required to make-up the connections of the casing [5]. This surface tool also uses its high horsepower to make-up the casing in a single smooth motion [19].

Casing Connections

The casing connections used in casing drilling differ from the connections used in conventional drilling. Casing drilling connections are subjected to severe well conditions [20]. These connections are required to have satisfactory torsional strength, good flow clearance, adequate sealability and strong ability to resist fatigue [6]. The providers of casing drilling connections are Hydril, Vam, Hunting Energy Services, GB Tubulars and Grant Prideco. A casing connection is shown in Fig 3.

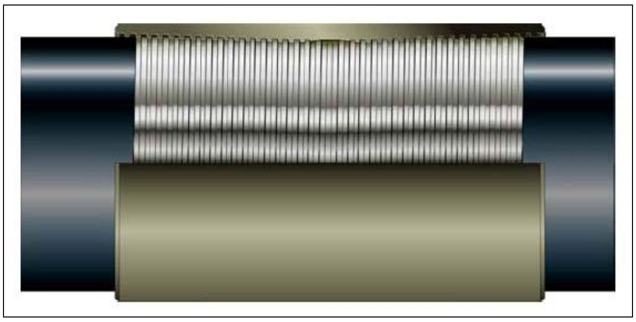
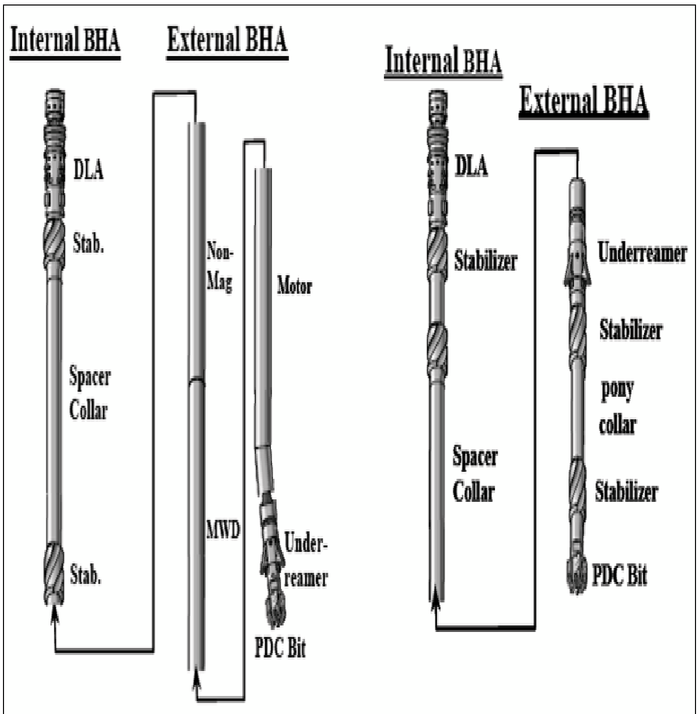


Fig. 3: Grant Prideco DwC connection [21].

Retrievable BHA

The retrievable BHA comprises an underreamer and a pilot bit. The size of the pilot bit is usually smaller than the internal diameter of the casing to enable it pass through. The underreamer has a larger diameter than the casing and it bores the hole to a size employed for normal running of casing. For instance, 6 ¼'' pilot bit is normally used with an 8½'' underreamer to drill with a 7'' casing weighing 23 lbm/ft [1]. Fig 4 shows the BHA used in drilling directional and vertical well. Besides the underreamer and the pilot bit, a few downhole tools are also used when required. In vertical drilling, stabilizers are added to the BHA to provide vertical control while directional drilling includes a nonm agnetic collar, steerable motor and a measurement while drilling (MWD) tool [9].



(a) (b)

Fig 4: Retrievable BHA for (a) directional drilling and (b)vertical drilling [5].

The Drill Lock Assembly (DLA)

The Drill Lock Assembly (DLA), shown in Fig. 5 below, is located at the top of the BHA and it connects the whole drilling assembly to the bottom of the casing. The DLA functions primarily by unlocking the BHA axially and torsionally [22]. The DLA also contains hydraulic seals, which enable the mud pass through the bit, and finally allows the downhole tools to be run in and out of the casing [2].

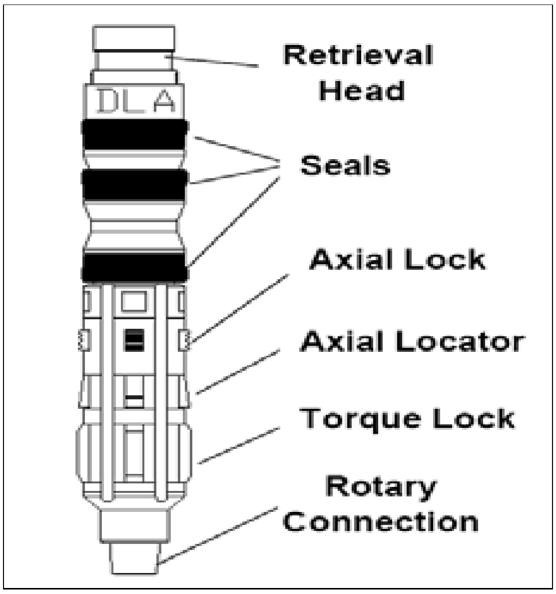


Fig. 5: Drill Lock Assembly [22]

2.2 Non-retrievable Casing Drilling

Approximately 80% of the casing drilling activity is done by non-retrievable systems [23]. The non-retrievable casing drilling is a non-steerable system with a simpler and less expensive system than the retrievable casing drilling system [7]. It involves drilling vertical wells with a drill shoe connected to the end of the casing string which could be left in the ground or drilled out once the depth for setting the casing is reached [10]. The particular application used is dependent on the type of formation to be drilled [24]. Weatherford is the main provider of the non-retrievable casing drilling system. Weatherford's patented DwC system has been applied in over 300 drilling with casing projects since January 2000. Weatherford also lately completed its first drilling with casing activity in the Java Sea, Indonesia from a floating drilling unit [25].

2.2.1 Equipment Used in Non-retrievable Casing Drilling

The non-retrievable casing drilling system uses the same casing connections and top drive with the retrievable casing drilling system. The other tools peculiar to the non-retrievable system are briefly described.

Overdrive System

The overdrive system is Weatherford's casing and running system as compared to the retrievable casing drive system. This tool is attached to the rig's topdrive system and it can be used with any topdrive system [26]. Fig 6 shows the overdrive system.

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Fig. 6: Overdrive system [25]

The heart of the overdrive system is the TorkDrive tool. With the aid of the rotational power provided by the top drive, the TorkDrive tool makes up or breaks out the casing thereby performing the duties, which would have required equipment, scaffolding and personnel on the rig floor. The TorkDrive tool is capable of circulating, reciprocating and rotating the casing, thereby decreasing any potential of differential sticking and other issues resulting to NPT [25].

Float Collar

The float collar (Fig. 7) and the drill shoe are usually made up to a casing joint before transporting to the drilling location. After drilling to the total depth (TD), the cementing operation can commence at once since the float collar is already installed within the drill string throughout the drilling operation [27]. This approach attains a single-trip procedure, which significantly reduces operational costs and time [28].

Casing Drill Shoe

The casing drill shoe, used in drilling formation, is a drillable casing drill bit attached to the end of the casing string [15]. Weatherford uses three drill shoe types- drill shoe I, drill shoe II (5 blade, 4 blade and 3 blade models) and drill shoe III. The drill shoe III was invented from the drill shoes I and II. The differences amongst these drill shoes shown in Fig. 8 are described in Table 3 below.

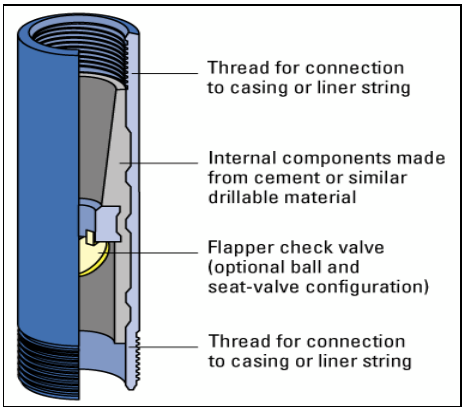

Fig. 7: Float collar [29].

Table 3: Features of the Different Types of Drill Shoe [25]

	Drill Shoe I	Drill Shoe II (3 Blade)	Drill shoe II (4 Blade)	Drill shoe II (5 Blade)	Drill Shoe III
Formation	Very soft and soft unconsolidated formations	Soft to medium soft formations	Soft to medium soft formations	Soft to medium formations	Medium to medium-hard formations
COMPRESSIVE STRENGHT (Psi)	2,000	7,000	7,000	7,000	15,000
Cutting Structure (On Casing Body)	Carbide	Thermally stable Polycrystalline (TSP) diamond	TSP diamond	TSP diamond	Carbide
Cutting Structure (Drillable Core)	Dense, thin layer of tungsten carbide	Polycrystalline Diamond Compact (PDC)	PDC	PDC	PDC on steel blades
Number Of Blades	3	3	4	5	5 through 9⅝x 2¼ could also have 6
SIZES (Inc)	9 ⅝ to 20	4 ½ to 30	4 ½ to 30	13⅜x17,	7 x 8½, 9⅝ x 12¼,

				18⅝x21	
Casing String Attached	Conductor and surface	Surface or intermediate	Surface or intermediate	Surface or intermediate	Surface or intermediate

Drill shoe I Drill shoe II(blade 4) Drill shoe III

Fig. 8: Drill shoes I, II and III. The size of each is 9⅝'' x 12¼'' [25].

A common feature with all the drill shoes is their ability to optimize hydraulic performance with the aid of their interchangeable nozzles [2 5] . The table above illustrates the various performances in different formations drilled by these drill shoes, their sizes, compressive strengths, cutting structures, number of blades and the casing strings attached to them.

2.3 Casing Drilling Rig

Casing drilling could be done on a retrofitted conventional rig or on a rig specifically developed for casing drilling [3]. Compatibility between the rig and the casing-driving tool is of great importance to ensure the casing is firmly held and can be picked up, rotated, slacked off and packed off to maintain circulation [30]. One of the vital modifications done to the conventional rig is the attachment of an additional mud pump and enhancement on the gas-handling and well- control equipment. These improvements make it possible for large influx of gas to be safely handled by the rig in situations where high-pressure gases are experienced in natural fractures. Furthermore, a casing clamp is included in the rig to boost its capability to effectively drill with casing. The design of the clamp is such that it is ideal for casing sizes ranging between 4 ½ '' and 9⅝'' and it does not require the application of threaded connection between the top of the casing and the top drive. On the conventional rig, the top drive is screwed to each casing joint with a casing thread crossover. It needs the making up and subsequent breaking out of the casing thread before the final make up. This exposes the thread to increased risk of damage [1]. The rig shown in Fig. 9 below is a specially designed rig by Tesco Corporation Ltd. The rig also contains drive system for rotating the casing, topdrive and wireline winch used to run and retrieve the downhole tools [31] .

Fig. 9 Casing drilling rig [31]

2.4 Considerations For Casing Drilling

Most of the engineering problems that could arise need to be addressed before carrying out the casing drilling process. A good number of factors affecting the integrity of the casing can be addressed by the conventional drilling method. Fatigue, buckling, hydraulics, torque and drag require a lot of attention and thus will be discussed below. Fig. 10 shows the different parameters, which affect integrity of the casing.

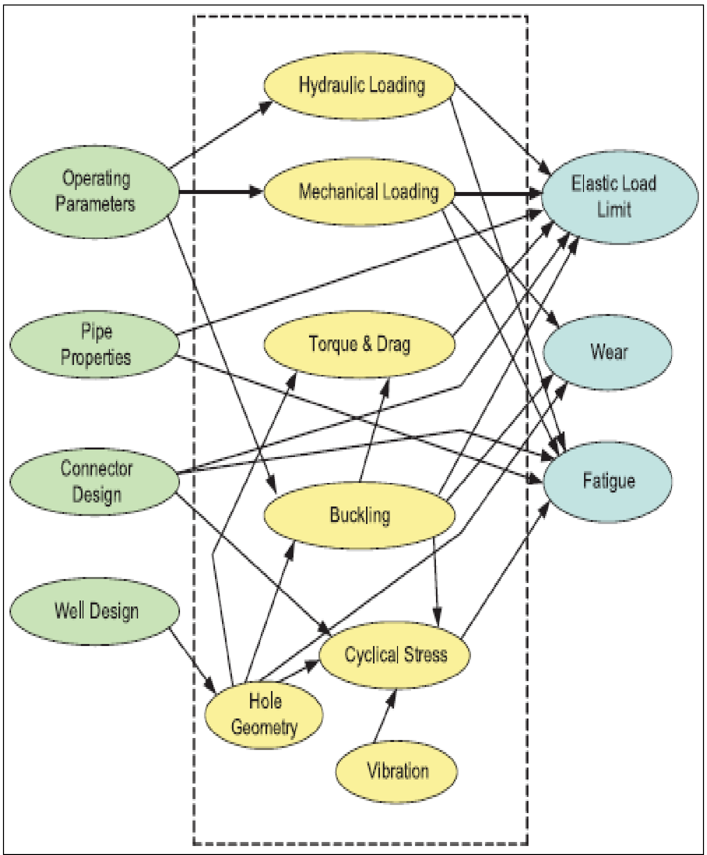

Fig. 10: Interactions affecting casing integrity for casing drilling applications [8]

2.4.1 Buckling

Conventional drill string, unlike the 'drill-casing' contains drill collars, primarily to provide weight on bit. The bottom of the casing is capable of accommodating restricted compressive load prior to buckling [2 6]. Buckling results from the creation of bending moments by the casing/hole geometry and compressive load on the casing making it unstable. This unstable condition makes the casing unable to support compressive loads except with lateral support which nay no result in structural failure of the casing [8]. For straight holes, buckling results form compressive load, which is established by the lateral force of gravity (hole inclination and weight of pipe), pipe stiffness (EI) and radial clearance (distance from the borehole). In deviated holes, the stability of the pipe increases with increasing inclination and may also loose stability with decreasing inclination at low curvature (normally lower than 1˚/100ft). This is the result of the axial compression which forces the pipe to the outside of the curve thereby helping gravity in keeping the pipe firm against the wall of the borehole [8]. The buckling curves in Fig. 11 below show the load for which 23 lb/ft 7'' casing in an 8 ½ '' hole and 9.5 lb/ft 4 ½ '' casing in a 6 ¼'' hole helically buckle.

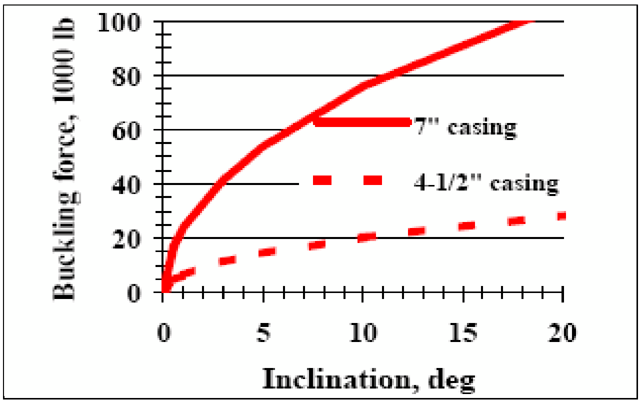

Fig. 11 Helical buckling force for 9.5 lb/ ft 4 ½ '' casing in a 6 ¼'' straight hole and 23 lb/ft 7''casing in 8 ½ '' straight hole [2 6]

2.4.2 Fatigue

Fatigue failures result from cyclical loading at stress levels, which are much lower than the elastic limit. With continuous loading, a little crack starts to manifest at the region of localized high stress and it spreads throughout the entire body until the left cross sectional area is inadequate to carry the static load. Fatigue failures are normally prone to local conditions and are usually statistical. Drill string failures stem from oscillatory bending loads. They are usually found at the bottom of the drill string and not at the upper part where the static tensile stresses are greatest. Occasionally, a fatigue crack precedes the final rapture. These failures are either located in the slip portion of the drill pipe or within the threaded area of the connection [2 6].

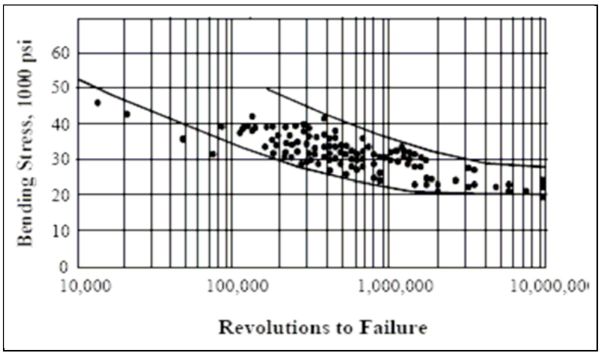

Fig. 12: S-N curve for grade D and E drill pipes [2 6]

The fatigue life of a particular portion is usually determined using the S-N curve which links the alternating stress level to the number of cycles that cause failure. Fig 12 above indicates a published S-N curve for grades D and E drill pipes. The data plots a band of failure rather than single line. This kind of fatigue is common to fatigue testing and the S-N curve is usually recorded as the average of the data. The data in Fig 12 shows the endurance limit (stress for which no failure occurs) for the drill pipe of approximately 20,000psi. [2 6].

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2.4.3 Hydraulics

Another noteworthy difference between the conventional drilling and casing drilling lies in the geometry provided by the fluid flow path. This path down the internal diameter of the casing is excessive and unrestricted resulting in a very small pressure loss within the internal diameter of the casing. The casing while drilling annulus usually provides a bigger restricted flow path causing increased pressure losses. With more restrictions to the flow path, it increases, making the annular velocities to be nearly uniform from the casing shoe to the surface. This enables the hole to be cleaned with small flow rates though a lot of considerations need be made to the drilling fluid properties and sufficient hydraulic energy is required to clean the under reamer and the bit [5].

2.4.4 Torque and Drag Analysis

The torque generated when running casing strings is as a result of the frictional forces acting between the wellbore and the casing. The torque and drag for casing drilling is usually higher than that of conventional drilling since the casing experiences certain wellbore issues such as sloughing shale, tight-hole conditions, differential sticking and sliding during drilling process [18]. The size and weight of the casing is also greater than the drill pipe. The torque and drag consideration is very essential in determining the suitability of a well (especially directional well) for casing drilling [5]. Torque and drag forces subjected to the casing can be analysed with the aid of a software such as Wellplan. It is pertinent to state that these parameters can be analyzed within the limits of the equivalent circulating density (ECD) caused by the strength of the formation and the pressure of the environment. The ECD for casing drilling are usually greater than that for conventional drilling even with the lower flow rates employed [2 6] .

2.5 Casing Protection Accessories

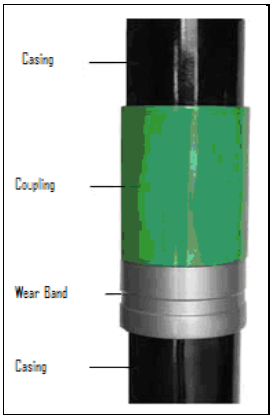
Wear protection accessories are provided to ensure that the casing is not damaged after the drilling process [3]. This is important because after drilling, the casing is used in completing the well. The common casing wears protection accessories are discussed below.

2.5.1 Wear Band

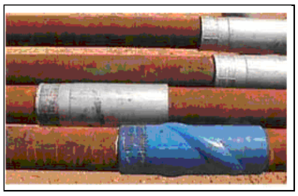
The wear band shown in Fig. 13(a) is a metallic ring coated with tungsten carbide hard facing. It is placed below the coupling to maintain the strength of the connection [31].

2.5.2 Wear Sleeve

The wear sleeve in Fig. 13 (b) is a cylinder made from steel with ample contact area, which is installed on any part of the joint as demanded. The sleeves are not coated with tungsten carbide hard facing [31].



Wear band


Wear sleeves

Figs. 13 Wear band and wear sleeves [31].

2.5.3 Centralisers

Centralizers are placed on the outside diameter of the casing to provide stabilization, directional performance, wear management, key-seat control and centralization for cementing. The centralizer, as shown in Fig. 14 has tough and strong-faced blades connected to the casing with a friction fit to enable rotation of the casing. Non-rotating centralizers made from zinc alloy have been used in directional casing drilling to reduce torque [22].

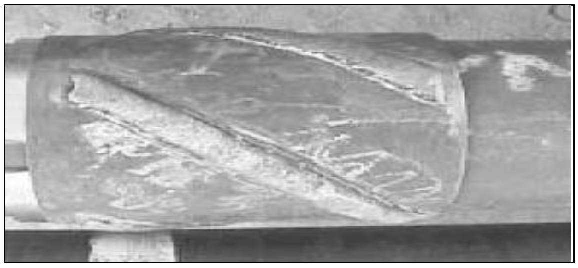


Fig. 14: Centralizer [1]

2.6 Flow Rates, Ecd and Lost Circulation

The flow rates for casing drilling are usually lower than those for conventional drill pipe due to the smaller annular volume. This decreased annular capacity results in higher annular velocities, which promote hole cleaning even with low flow rates. The transport of cutting and hole cleaning decreases the ECD. On the other hand, the frictional losses developed in the annulus alongside the high annular velocities elevate the ECD. It is important to ensure that during casing drilling, effective flow rate management to ensure cleaning the annulus of drilled cuttings is attained alongside proper ECD management [32].

Casing drilling reduces problems associated with lost circulation in areas exposed to fluid losses when drilled conventionally. This is possible because the lateral forces of the casing used in drilling smears the drilled cuttings into the formation of the wellbore, forming an impermeable cake,

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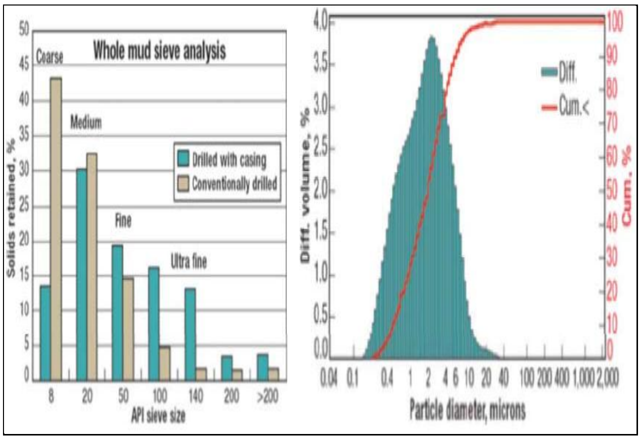
which decreases losses [24]. Fig 15(a) shows the result of particle size distribution carried out on the cuttings obtained from conventional drilling and casing drilling methods. The particle sizes for the DwC are smaller with an average particle size of 2.626 microns and approximately 90% of the particles having a diameter less than 6 microns Fig 15(b). The cuttings are pulverized because of the casing drilling side-load forces, as they are transported to the surface [32].



(a) (b)

Figs. 15 Conventional cuttings compared with DwC cuttings and Particle size distribution curve [32].

2.7 Casing Drilling Cementing

Cementing operation involves placing cement within the annulus to form a bond between the casing and the formation [33]. In the conventional cementing method, the cement plugs land on an equipment known as float collar, which is fixed close to the bottom of the casing [29]. In the retrievable system, where the bit has to be replaced before drilling to the next casing point, the DwC process requires full-bore access to enable the retrieving and running of the BHA through the ID of the casing. This makes it unsuitable to use floating equipment [34].

The initial solution to this challenge was to pump a wiper plug ahead of the cement and then a latch down cement plug behind the cement, which lands in the DLA locking profile. The problem with this procedure was the risk of the cement plug landing improperly [26]. With advance in technology, a pump down float valve was launched and landed in the same profile nipple used by the DLA. The valve serves as a conventional float collar to retain the back pressure from the cement job after bumping the cement plugs [35]. However with the non-retrievable system, the drill shoe is drillable and a float collar is already run on the casing string. This enables the cementing operation to commence immediately the total depth of the well is reached [28].

2.8 Benefits of Casing Drilling

The smear benefits of casing drilling and other advantages of casing drilling are discussed below.

2.8.1 Advantages of Casing Drilling

Casing drilling is a welcome development that has brought about significant improvement to the drilling process. Its advantages include:

- Less rig power is required
- Accidents on rig are drastically decreased–this has been achieved since the hazards connected with pipe handling are avoided.
- Fewer casing strings are needed–some sections of a formation do not require trip margin hence eliminating a few casing strings.
- Every foot of the well is drilled and It does not require the use of drill pipes
- The casing can be set deeper and water influx is controlled
- Overall drilling time is reduced–problematic formations can be drilled and sealed off in a single run, decreasing NPT relating to bore hole problems.
- Straighter holes are drilled and Few fishing jobs are needed
- Cases of stuck pipe or sidetrack are reduced–the decreased number of trips decreases the occurrence of hole collapse resulting from surging and swabbing.
- Reduced crew size–operations like positioning the casing string and latching the casing elevators to be done by rig member is eliminated with the use of the casing drive system / overdrive system
- Reduced trip time–the casing is already set in place when the TD is reached hence no need to pull out any drill pipe as in the conventional drilling method.
- Overall drilling cost is reduced–fewer casing strings are used resulting in huge cost savings [6].

2.8.2 Smear Effect Benefits

The wellbore annulus formed when drilling with casing is obviously smaller than that obtained with drill pipe as shown in Fig. 16. It was earlier thought that this limited annulus causes the casing to smear the drilled solids (cuttings) against the wall of the formation as it rotates, which subsequently creates an impermeable barrier. This 'smear effect' also known as plastering effect brings about the mixing of the drilling fluids with the cuttings such that it mechanically changes and seals the annular ring [24]. Fig. 16 below shows the difference in annulus formed during casing drilling and conventional drilling. Smear effect potentially solves wellbore problems such as wellbore stability, kicks, vibrations, high torque and lost circulation, and it also reduces the risk of the casing getting stuck during the casing drilling process. However, it is pertinent to note that the smear effect does not take place all the time and is also unpredictable [36]

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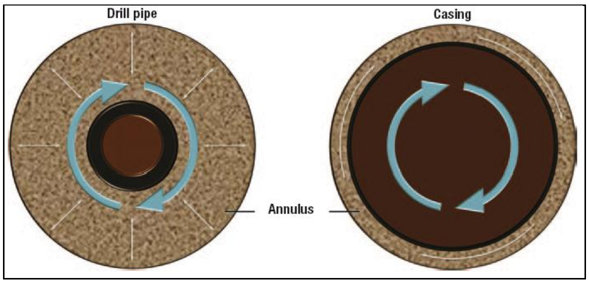

Fig. 16: Annulus formed by casing and drill pipe [37]

2.9 Challenges/Limitations with Casing Drilling

Fields where casing drilling has been applied has proved drilling with casing to be an effective and efficient technique of drilling. This technique is however charged with some challenges. These challenges will be discussed below and with possible solutions.

2.9.1 Formation Evaluation

Casing drilling involves the casing of the wellbore after a section is drilled [26]. This prevents the open hole to be logged with the traditional logging tools except if the casing string is hauled up above the interested zone for logging. A solution is this challenge is continuous logging while drilling takes place i.e. logging while drilling (LWD). Also the type of zone to be logged would determine if open logs are to be run outside the bottom of the casing or cased hole logs inside the casing to log the zones of interest. Testing equipment and core barrels can be suited to the wireline retrieving tools and employed after being secured on the casing [14].

2.9.2 Casing Connection

Another challenge with casing drilling is the inability of the casing connections to withstand high torque, fatigue and combined loads during bucking [20,38]. Tessari and Madell, 1999 [14] initially explained that a possible solution to this challenge is to drill the well with a reasonably low torque and low bit weight and also reduce the buckling to as low as practicable with decreased hole sizes. Finite Element Analysis (FEA) is now used to evaluate the connection performance before casing drilling [21]. The torque and drag analysis can also done with Wellplan torque and drag module from landmark software.

2.9.3 Changing the Bit and BHA

In the retrieval casing drilling system, it is difficult to retrieve the BHA if the tool experiences failure/damage. [26] stated that "*retrieval of the BHA has been somewhat problematic with an overall success rate of about 70%*". In some situations, the casing bore was confined, making it impossible for the tool to reach the top of the drill lock. A possible solution to this problem is to change the operating or to modify the tool.

2.10 Integrating Technologies with Casing Drilling

Casing drilling proffers advantages in drilling just as some other drilling technologies. The advantages of individual methods can be maximized by their combination [2]. This has resulted into a merger between casing drilling and other technologies such as underbalanced drilling, rotary steerable systems, stage cementing tool and expandable tubulars. These combinations have on the overall, resulted in optimal production and reduced well costs.

2.10.1 Underbalanced Drilling and Casing Drilling

Underbalanced drilling is a drilling technique that requires the hydrostatic pressure in the wellbore to be kept lower than the formation pressure, which normally would result in a kick (influx of the formation fluid into the wellbore). The controlled invasion of the formation fluid into the wellbore is carried out to reduce or completely prevent borehole problems such as formation damage [13]. Underbalanced drilling reduces lost circulation, eliminates differential sticking and increases the rate of penetration. This drilling technique is expensive and differs from the normal method where the formation pressure is always less than the hydrostatic pressure of the wellbore thus preventing flow of formation fluid into the wellbore [39]. Merging the casing drilling with underbalanced drilling method has improved both technologies significantly. The combined methods have effectively shown better effect and greater values attained compared to applying either technology individually. The main advantages of underbalanced drilling are increased penetration rates and decreased formation damage while those of casing drilling are reductions in well drilling costs and elimination of NPT. The combined application of these two technologies has resulted in greater productivity, as opposed to their single application. The high cost of underbalanced drilling coupled with the risk of tripping would be eliminated. Adequate well control will be achieved by the increased equivalent circulating density and friction resulting from casing drilling [39]. Underbalanced drilling and drilling with casing has successfully been applied in the mature South Texas fields leading to cost reductions of about 30% [40].

2.10.2 Casing Drilling With Rotary Steerable Systems

Initial casing directional drilling was done with steerable motors. The use of motor has however experienced major problems in the BHA designs [41]. There has been increased rate of wear and tear on the downhole tools, decreased rate of penetration and decreased efficiency in drilling smaller holes. Warren and Lesso, 2005 [5] explained that these findings show that the advantages tapped by the use of rotary steerable directional systems in conventional drilling,

would also be beneficial for casing drilling operations.
Rotary steerable system (RSS) can be used to drill smaller hole sizes of 9 ⅞'' – 8 ½'' which is less effective when using steerable motors. The BHA design for the 23lb/ft 7'' casing as shown in Fig. 17 below has huge innovatory characteristics.

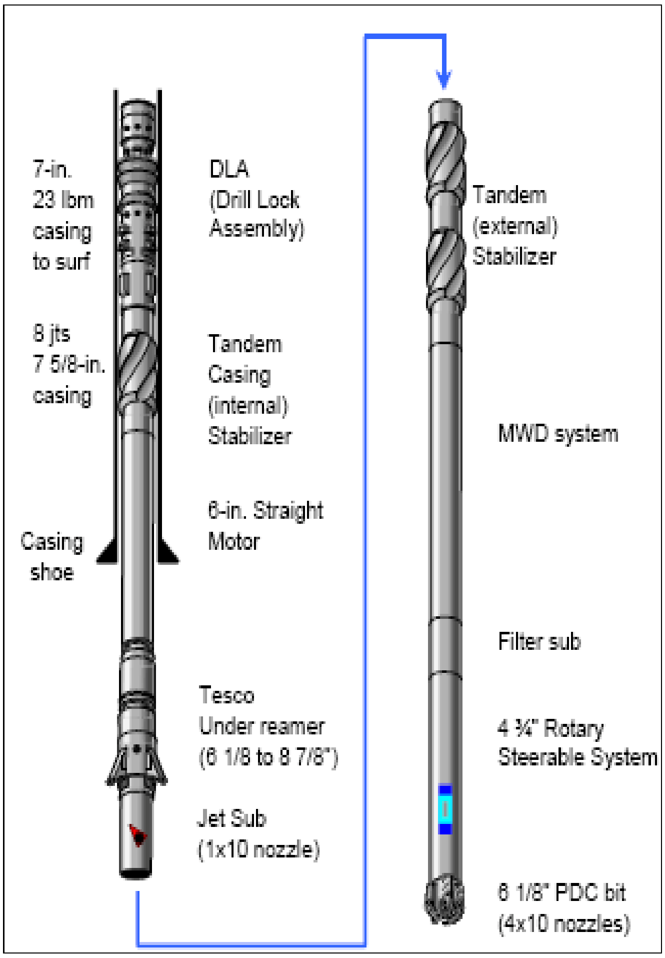

Fig. 17: BHA for casing directional drilling with an RSS [5].

ConocoPhillips Upstream Technology Group and Lower 48 Exploration and Production Group jointly came up with a project showing that the merging of casing drilling and rotary steerable directional systems secures the advantages of casing drilling and at same time preserves the directional efficiency of the RSS [41]. Tesco has also used the combination of casing drilling with Schlumberger's power drive rotary steerable systems to provide a feasible well construction alternative in drilling mature offshore fields.

2.10.3 Casing Drilling With Expandable Tubulars

Expandable tubular technology is a process of enlarging steel by fitting it downhole to the desired diameter in the oil well. This technology involves cold working of the steel without exceeding the plastic region as shown in the stress-strain curve below. The pipe is permanently deformed during the process and therefore, the material must be of high ductility [42].

Both technologies have similar operational practice, which enables their combination into a single procedure. The idea is to use the expandable casing string for the drilling operation and at the same time expand the casing when the TD is reached. Expansion of the casing will only be possible with casing drilling process where an underreamer initially drills into the formation to produce a larger hole and the BHA changed into an expandable BHA [43]. However the combination of both technologies is purely theoretical and it is poised to harness the advantages proffered by each of the technologies. The obvious benefits of merging both methods are monetary savings, reduction in rig time and better well control [2].

2.10.4 Casing Drilling With Stage Tool Cementing

In cementing the casing string to the surface or an intermediate string, challenges such as high pump pressures, long pumping times and excessive hydrostatic pressures from the cement column usually occur. These issues necessitate the need to carry out the cementing operation in two or more stages referred to as stage cementing. This cementing procedure is carried out with the aid of a stage-cementing collar, otherwise known as stage- cementing tool [44]. The use of the stage-cementing tool enhances the placement of cement slurry at selected sections between the well bore and the casing string [45]. Stage cementing and casing drilling have been combined to provide an effective drilling and casing operation, which in turn, decreases cost and NPT. This technology combination has also proved to be efficient in minimizing hole deviation, placing the casing to planned total depth, minimizing loss circulations and above all, improving cement job operation when applied in the fields, a typical example seen in the Western Piceance, Northwest Colorado [12].

3. FUTURE DEVELOPMENT

3.1 Background

The Oil and Gas (O&G) industry constantly gears its activities towards providing cost effective and efficient drilling practices. To that effect, casing drilling was introduced as a drilling alternative to the conventional drilling method. Casing drilling, as shown in the previous chapters has led to reduced well costs, decreased NPT and minimal wellbore problems. A future development prospect is closely examined to improve drilling performances and save cost in any drilling operation. This development is centred on retrievable casing drilling with focus on liner systems, which could be termed ''Retrievable Liner Drilling'' (RLD). The RLD can be

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viewed as an evolution in the drilling liner technology. It will be similar to the Retrievable Casing Drilling, which employs the use of a BHA, and can be retrieved through the casing. The retrievable liner is tipped to be capable of providing directional control, which will in turn ensure its application in directional wells.

3.2 Discussion

The RLD can simultaneously drill and case the wellbore. Its concept stems from the casing drilling process. RLD uses surface tools similar to those employed in retrievable casing drilling. The downhole tools mainly comprise a BHA, which could be retrieved with the aid of a wireline or drill pipe after disconnecting the liner. The BHA will include a component probably a rotary steerable system to provide directional control for directional wells applications. Other components to be added to the BHA are an assembly locking mechanism, extendible bit, pilot bit, positive displacement motor (PDM), stabilizer and measurement while drilling (MWD) tool. Additionally, the BHA would have the ability to run core bit with barrels and core while liner drilling. Fig 19 below shows a well schematic for the Retrievable Liner Drilling (RLD) concept. The schematic is used to demonstrate how the RLD concept can be used in drilling the well initially drilled with the CwD concept at the Lobo field in the case study previously discussed. The upper section of the formation is drilled to depths 1250 ft and 7250 ft and cased off with 9⅝'' and 7'' casings respectively. No wellbore issues are expected since there is no deviation from the initial casing drilling performed. However, drilling through the bottom interval of the formation requires the use of a conventional drill pipe. This drill pipe bears the drilling loads and also transports the BHA to the target depth. A 4'' pilot bit is attached to the end of the BHA and it drills the initial pilot hole. The 6.25" extendible bit, located above the pilot bit, drills the well bore to the TD. After drilling this section, a 4.5'' liner is hung in the 7'' casing and a top packer is set in place. The liner is as competent as a full string casing and it secures the wellbore after it is set. The drill string can then be retrieved from the wellbore. The rotary steerable system shown in Fig. 19 is included in the BHA design for directional wells to provide deviation control.

The locking assembly is a special tool that connects the BHA to the casing and it also transfers the torsional, axial and pressure loads from the BHA to the drill string. The drill string is connected to the liner with the aid of a linerhanger. The position of the liner inside the 7'' casing limits the depth to be drilled with the liner. In the Retrievable Liner Drilling (RLD) concept, the liner is placed in suspension and rotated with the aid of a drill pipe, unlike the Casing Drilling concept, where the casing string extends back to the wellhead. The tools used in the retrievable liner drilling would have the capability to withstand any torque exerted on the liner. The tools setting would be designed to accommodate the pressures encountered during the drilling process.

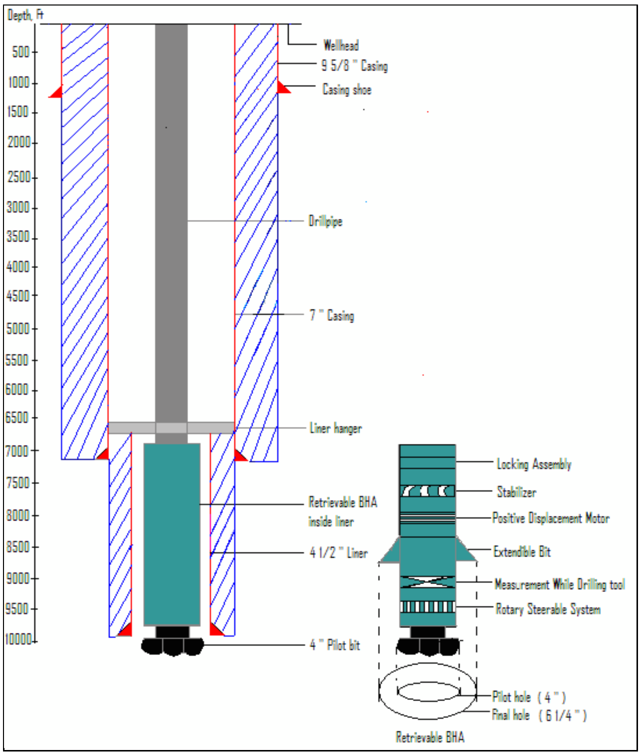

Fig. 19: Well Schematic for a Retrievable Liner Drilling System

The merits of the retrievable liner as opposed to full casing strings are discussed as follows:

3.2.1 Cost

Reduction in cost is a very important factor considered in the O&G industry. It is also pertinent to note that when opting for cost effective operations in the industry, the integrity of the process under question is not in any way compromised. The liner does not extend to the wellhead as compared to full casing string. Huge savings in cost is made in eliminating joints of casing string. For example, the cost of running and setting a 4.5'' liner at a depth interval of 2750ft instead of running a casing string to the surface generates a saving of about 4/5th of the total price of the casing. The cost of casing strings used in drilling a well contributes to about 30% of the total well cost. This goes a long way to show how much cost reduction could be realized from replacing full casing strings with liners.

3.2.2 Wellhead Design

The retrievable liner system is more attractive in well completions with wellhead having limited space for the accommodation of casing hangers. For example, considering the case study previously discussed, a great challenge would have been faced if the wellhead was designed to contain only three strings - two for casing and one for production tubing. With the liner system, there would not be a need for the liner to be run to the surface. It will have the liner hung from the previous casing string. The 4.5'' casing used in the case study is replaced with a 4.5'' liner and hence have it hanger set on the 7'' casing.

3.2.3 Subsea Well Control

Well control is an important aspect of any drilling operation. It involves the maintenance of a constant bottom hole pressure within the wellbore, to prevent the influx of formation fluids into the wellbore in order to avoid a kick. A kick usually occurs when the hydrostatic pressure of the drilling mud is less than the pressure of the formation. It also arises during trips with in flow of fluids resulting from an inability to keep the hole full and swabbing. Although no subsea well was drilled at the Lobo field, there are some drilling situations that require the need to shear the pipe for proper well control purposes. With the use of casing in subsea completion for such a situation, it is extremely difficult to change the rams in the subsea without removing the stack. Retrievable liner drilling would involve the use of drill pipes to surface above the hanger and this could be managed with standard subsea wellhead equipment. Subsea well control equipment includes subsea BOP stack, temporary and permanent guide bases and marine riser.

3.2.4 Oil Recovery

Oil recovery is usually carried out to regain extra reserves in a given reservoir. Some of these oil recovery options demand the wellbore to be stimulated with the use of completion equipment. In such a case, a liner rather than a casing will be used.

3.3 Limitations to Retrievable Liner Drilling

The challenges limiting the application of liner drilling are:

- The ability to set and reset the liner hanger for retrieval, and still maintain the integrity of the hanger.
- The maximum distance, which the liner can drill considering string torque, max load and tortuous formations.
- The potential damage to the inside of the casing during setting and unsetting of the liner hanger.

4. CONCLUSION

This study focused on the present application of casing drilling and its future development. Casing drilling is a reliable drilling technique, which improves drilling performance compared to the conventional drilling technique. A literature review was done to highlight the attainable methods of carrying out this drilling practice by the oil and gas industry, throwing some light on the challenges associated with its execution. A study was also undertaken with the aim of improving the retrievable casing drilling concept by investigating retrievable liner drilling.

Prior to casing drilling, wells were drilled with the conventional drilling method, which has been faced with drilling challenges. These problems range from wellbore incidents and drilling hazards to NPT (Non Productive Time) and finally, an overall high cost of well production, which have been reduced to the barest minimum by the use of casing drilling technology. The case study discussed in this report, further highlights the benefits of Casing While Drilling (CwD). In a bid to fully utilize the merits associated with casing drilling, a study was undertaken to determine the practicability of applying the concept of retrievable liner drilling. The idea behind looking into this development is to further capture reductions in overall well costs and also explore areas where the application of the casing drilling method has been restricted.

In conclusion, the retrievable liner drilling is viable and can be applied as a suitable drilling technique. By adopting this drilling method as an alternative to the current casing drilling technique, it will be anticipated that the operator will not only achieve huge cost reductions but also improve drilling performance and maximize recoverable reserves.

5. RECOMMENDATIONS

In order to ensure a successful application of the retrievable liner system, the following should be taken into consideration.

- The use of expandable liner hanger in place of normal liner hanger.
- The expandable liner hanger is more beneficial than the latter in drilling through depleted formations or formations with high tortuous sections.
- The application of torque and drag analysis to the liner system.
- The designing of the liner (specifically the coupling) to ensure it can withstand the drilling loads occurring where it will be set.
- Provision of casing wear accessories similar to those used in full string casings to prevent excessive liner wear, which in turn decreases the tendency of the liner to fail due to burst and/or collapse.
- The ability to connect and disconnect the liner whenever the BHA needs to be retrieved or run into the hole. It will ensure the BHA is not only retrieved when the total depth is reached but also when the need for tool change is required.

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