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Identifying Casing While Drilling (CwD) Potential in Geothermal Scenario Along with Economics

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ABSTRACT

Geothermal energy is a prospective candidate for fulfilling future energy demand from renewable energy sources. The extraction of this energy mandates the drilling of a well into the formation containing high-temperature. Casing While Drilling (CwD), a method of simultaneous drilling and casing a wellbore with tubular called 'casing', evolves as an answer to arrest numerous drilling problems by decreasing the flat time for drilling, improving wellbore stability and integrity by 'plastering effect', preventing pipe stuck-up and reduced risk of well-control. In addition, it has proven to be beneficial in lowering environmental footprint with smaller rigs and enhancing rig floor safety due to lesser tubular handling. This paper discusses the working of CwD and examines the effects of certain modifications in design parameters corresponding to the geothermal environment that allows CwD to drill a geothermal production well (typically has large diameter) with negligible drilling problems. In recent time, it can be counted as a remarkable techno-economic solution for drilling community in the geothermal domain. Directional drilling with level 3 CwD also extensively discussed for the high-temperature and high strength formation to achieve maximum economic benefits in geothermal project. The paper shortlisted certain challenges that need to be addressed instantly to harness maximum potential from CwD. At last, the paper provides insight into the economics of CwD that demonstrates its reliability for proved geothermal prospects.

1. INTRODUCTION

Earth is a huge storage house of numerous energy sources ranging from hydrocarbons to renewable geothermal energy. Extraction of these energy sources involves drilling of hole in various geological formation. Technology for drilling has undergone a great transformation from the ancient spring pole to percussion cable-tools to rotary drilling that it can drill several miles into the earth (Epikhin, 2015). Although, drilling process is almost similar everywhere, each geological formation presents unique set of challenges. Geothermal formations are high temperature, hard, abrasive, highly fractured and under-pressure in nature and therefore, it makes drilling more difficult with rate of penetration and bit life are typically low.

Generally, drilling process is accomplished using tubulars called 'drill pipe' and drill bit. However, since a decade ago, drilling companies started experimenting another type of tubulars called 'casing' to drill wells (Velmurugan et al., 2015). The reason for this conversion is that the latter provides better drilling efficiency than the former and has many other advantages. The commercial acceptance of CwD technology by the oil and gas industry began in the 1990s after which concrete developments have taken place in this technology (Pavkovic et al. 2016).

At present, there are four types/levels of CwD used for drilling as shown in figure 1;

Type 1: Liner drilling with non-retrievable system

In this, the BHA needs to be retrieved once the liner hanger has been set and then it is cemented. Liner drilling has been successfully practiced in the Gulf of Mexico to mitigate hole instability problem (Torsvoll et al. 2010).

Type 2: CwD with non-retrievable system

Non-retrievable CwD is simple in its operation and application when compared to the others. One of the several limitations of the system is that it can only drill a straight hole with no directional control. Analysis shows that it is a viable drilling method for industrial implementation in fields where top hole sections are covered by permafrost (Aleksandrov et al. 2015).

Type 3: CwD with retrievable system

CwD with retrievable system is very advanced having the ability of directional trajectory control and logging with retrievable BHA while keeping the casing string at the bottom. To retrieve BHA, either a drill pipe or a wireline operation can be used while independently continuing the reciprocation of only casing string to avoid the potential problem of being stuck.

Type 4: Liner drilling with retrievable system

Liner drilling has similarities to CwD in which a complete casing string from the surface is replaced by shorter length casing joints extended up to the last casing shoe and the liner string is lowered by a running and setting tool on a drill pipe. On the completion of the drilling, the non-retrievable system is able to set liner hanger after which cementing is done.

Till 2002, operators had drilled more than 2000 wellbore sections using casing in which 1020 intervals were vertical wells drilled with casing and non-retrievable bits, about 620 were drilled with partial liners and more than 400 used retrievable BHA for vertical drilling and about 12 used retrievable BHA for directional drilling (Shepard et al. 2002). This data and experience of using CwD for hydrocarbon proves its excellent reliability and performance in all kind of situations and thus, recommends its application for geothermal environment with certain changes.

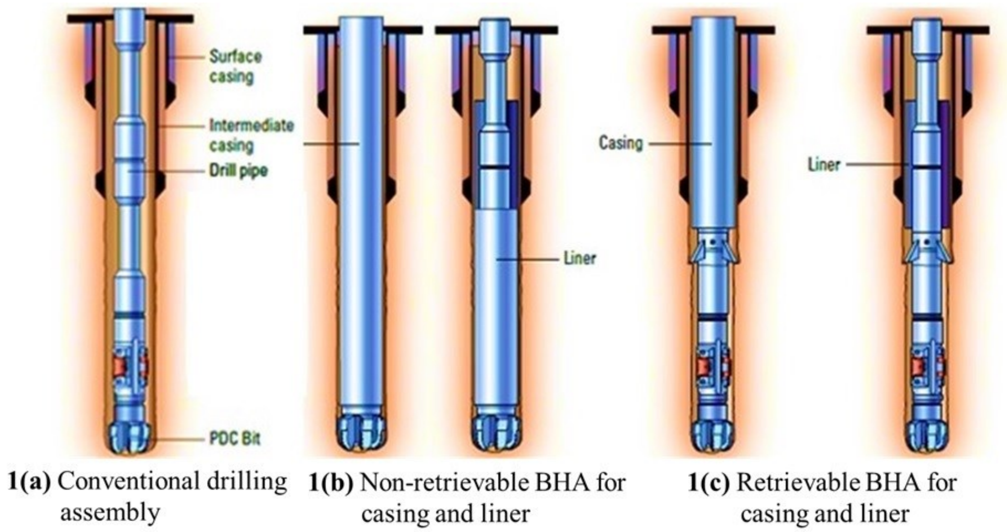

Figure 1: Types of CwD system (modified from http://www.connection-mag.com/?p=4154)

2. CASING WHILE DRILLING

2.1 Working of CwD

In CwD, standard casing string is used to transmit rotary power to bit and to circulate drilling fluid - mud into well bore whereby simultaneous drilling and casing activities in the well bore are carried out. The casing for drilling can be a liner or a full length casing string up to the surface. The use of CwD overcomes the drawbacks of conventional drilling practices, like well bore instability and loss circulation, with the help of plastering effect (Abubakar et al., 2012). It leads to the formation of thin layer of mud cake that is strong enough to prevent fluid loss (Naveen and Babu, 2014). Same annular space across well bore allows CwD optimization of hydraulics that results in good hole size and efficient transportation of cuttings (Fisher et al., 2004; Karimi et al. 2011). The application of CwD with Managed pressure drilling gives a good control of Bottom Hole Pressure (BHP) thereby allowing drilling between the pore pressure and the fracture pressure to be carried out without damaging the formation (Balanza et al. 2015).

2.2 Equipments for CwD

1) CwD rig:

Casing Drilling uses a specially developed drilling rig or a conventional rig modified for casing drilling (ONGC, 2007). CwD rig has Casing Drive System (CDS) below top drive that provides connection, rotation and circulation of casing string. Also, new smaller rig for CwD requires less horsepower and fuel as effective hole cleaning can be done with less pumping pressure due to lesser annular space. Furthermore, it produces less emission, operates in small location and transported more easily and quickly than larger conventional rig (IADC, 2015).

2) Casing Drive System (CDS):

The CDS, powered by top drive hydraulic control system, holds the full weight of casing string and applies torque for drilling and make up connections. The casing string is attached to the top drive via a casing drive system without screwing it into the top casing connection (Domala et al. 2015).The use of CDS and power slips makes casing connections faster and minimizes rig floor activity while making connections and assuring floor safety (Warren et al. 2004).

3) Casing String:

In CwD the drill string consists of pipes called 'casings'. Casings are of similar grade, class and sizes that are normally used in conventional drilling. In Casing String, BHA is attached to Drill-Lock Assembly (DLA) located above the casing shoe joint and plays a vital role during insertion and retrieval of tools from the bottom. The components of BHA are made to pass though the casing string used for drilling having an under-reamer or a hole enlarger and mud motor. This results in less power than the optimum to steer the under reamer and bit.

4) Other accessories:

Major CwD accessories used for handling the casing and CwD operations are listed below;

A. Pump Down Displacement Plug (PDDP): PDDP is an accessory used for preventing U-tube effect in cementing operation of CwD.

B. Multi-lobe torque ring: Multi-lobe torque ring ring provides positive make up shoulder to increase torque capacity when installed in standard API - Buttress Threaded Connections (BTC).

C. Wear resistant couplings: Wear resistant couplings are mainly used to protect casing from excessive abrasion during drilling.

D. Centralizers: In CwD, centralizers provide positive centering of casing string for cementing operation in vertical and deviated wells.

E. Warthog: The warthog, a casing running and reaming tool, helps in setting up casing to TD despite the presence of potential hole problems such as bridges, doglegs, sloughing formations and deviated holes.

F. Torque monitoring device: Torque monitoring device located at rig floor is used to monitor connection assembly torques.

3. CWD FOR GEOTHERMAL ENVIRONMENT

Successful implementation of CwD in oil and gas industry for more than 25 years provides opportunities for its exaggerated use in other domains like geothermal formation. Use of CwD in geothermal formation provide several advantages and at same time, needs several consideration for its full potential utilization. Two major advantages offered by CwD for geothermal drilling are as follows;

a. Proper cement displacement:

In geothermal wells, the tendency of drilling fluids to degrade or gel at higher temperatures and thus, this situation makes cement displacement more difficult. This leads to poor bonds between casing and cement in certain areas. The problem becomes more dangerous in geothermal wells as repeated starting and stopping of production leads to casing failure due to thermal cycling in section un-supported by cement. In addition, thermal expansion of water pockets behind casing exerts enough pressure to buckle the casing. Although, use of CwD cannot eliminate this problem, it improves quality of cement displacement by rotation and reciprocation of cement string during pumping operations.

b. Lost circulation:

The perennial problem in geothermal drilling is loss of drilling fluid in highly fractured formation found in many reservoirs. Fractures are common in geothermal because hard rock formation in seismically active areas tend to fractured and required flow rates in economically attractive geothermal projects dictates flow from fractures. Apart from this, lost circulation leads to many severe problems such as drilling without returns cause formation pressure to be unbalanced, which can allow the hole wall to fall in and this will create stuck up, twist offs, or even loss of hole. CwD avoids this problem by plastering effect. In plastering effect, rotation of casing string and smaller annular space cause drill cuttings to be smeared into the borehole wall as shown in figure 2. Experiments indicates that low radial clearance (casing to hole diameter ratio less than 0.7) and lower tangential contacts angles can increase plastering benefits and therefore it will provides better protection against lost circulation problem.

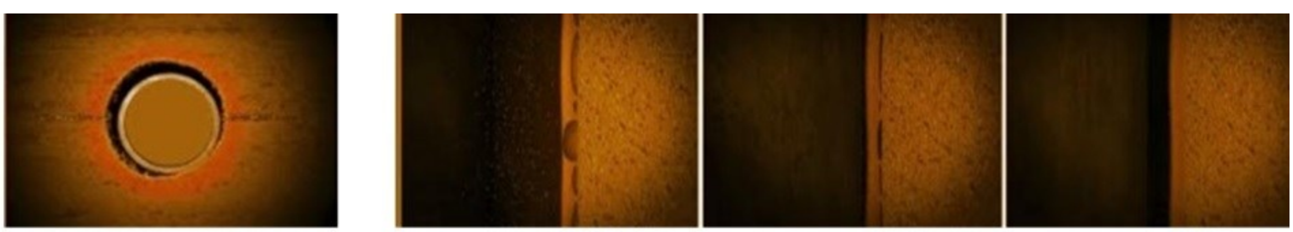

Figure 2: Plastering effect during CwD (modified from IADC 2015)

Use of CwD in geothermal drilling requires several consideration to be addressed, which are as follows;

a. Hard formations:

Geothermal formations are much harder than normal oil and gas formations. In CwD, the annular space behind casing is very less and therefore, casing wear very fast due to its periodic contact with formations. Thus, this affects well planning procedure and casing design requires highest attention. In addition, harder formation tend to lower rate of penetration and proper bit selection needed in all four types of CwD as mention in introduction part.

b. Tool failures:

Geothermal formation's high temperature environment diminishes performance of several drilling and logging tools. Retrievable CwD type uses wide range sensors and therefore high temperature has highest impact on this weak point. However, present days several efforts are going on to find material in which these sensors are placed to insulate the effect of temperature. In addition, high temperature causes problem with mud circulating system and therefore, it is advisable to use special mud cooling system.

c. Corrosion:

Geothermal brines are extremely corrosive in natures and with the aid of high temperature, they can provide disastrous effect by fatigue failures of tubing. Corrosion inhibiting chemicals used to prevent corrosion; however, it will increase cost of drilling.

d. Vibration problems:

Rotation of drill string at natural resonant frequency produces vibrations that can cause downhole tool damage, fatigue failure as washout, tool joint failure etc. There are three types of vibration namely, axial, torsional and transverse. However, the most severe type is transverse vibrations. The cost of drilling a well can increase approx. two fold because of vibration related problems such as lost time while pulling out of hole, fishing, poor quality of hole and many more. Proper operation of drilling parameters (like WOB, RPM etc.) allows driller to avoid vibration problems.

4. DIRECTIONAL DRILLING WITH CWD

From different types of CwD, retrievable CwD commonly used to provide direction control in directional drilling. It is known as type 3/ level 3 CwD. It is mainly consists of Bottom Hole Assembly (BHA) connected to casing string by a tool known as DLA. It provides two types of locking mechanisms viz. axial lock and torsional lock. The force applied from the surface sets the axial lock, releases the running tool and the rotation engages torsional lock.

In last decade, Positive Displacement Motor (PDM) used with type 3 CwD for drilling a directional well. However, use of PDM presents several problems such as 'motor stall', poor quality of borehole and few others. Therefore, Rotary Steerable System (RSS) seen as viable alternative of PDM for directional, high-angle, horizontal and extended reach wells. A RSS unit for CwD consists of bias unit, applies side force for direction changes and control unit, contains electronic sensors like gyroscopes and accelerometer. A lithium battery pack is provided to power the control unit sensor. Casing string with RSS assembly is given in figure 3. Testing with RSS technology in casing drilling improves operational efficiency by eliminating PDM's drawbacks.

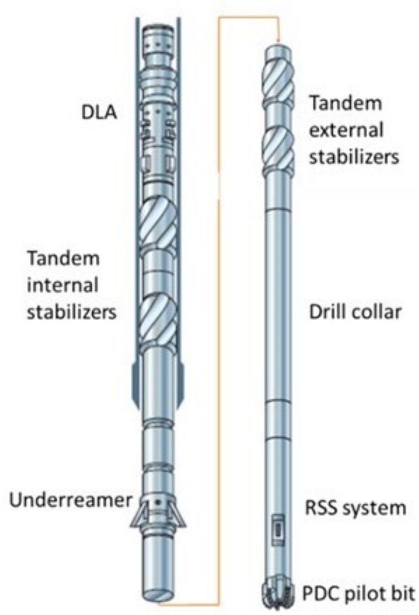

Figure 3: Use of RSS in CwD (modified from Pavkovic et al. 2016)

5. ECONOMICS

The main goal of CwD for geothermal well is to drill large diameter geothermal well with minimal cost and satisfying quality and safety concerns. The day work rate for a drilling rig is very high (Well cost study, 2015). So, it is very important that every moment of the rig is used in drilling rather than wasting time in tubular handling or doing secondary activity such as recovering from pipe stuck up, tripping in or out for logging purpose. Kipsang et al. 2015 describes cost model for geothermal wells in detail and in that, we highlighted some of costs as shown in Table 1, which can be reduced through use of CwD:

Table 1: Cost data of normal geothermal well

Description	**Unit**	**Total** ($)
Pre-spud costs		
Drillsite preparation	Fixed	70,000
Rig mobilisation, demobilisation and transport[A]	One-off	420,000
SUM		490,000
Daily operating costs		
Rig rental with crew	Day rate	1,893,000
Rig rental with crew-standby[B]	Day rate	350,000
Air compressors, balanced drilling	Day rate	9,500
Cementing equipment	Day rate	8,000
Rental tools, fishing	Day rate	0
Maintenance Engineering	From table	24,000
Drill stem inspection	Fixed	300,000
Transportation and cranes	Day rate	0
BOP rentals + H2S alarms	Day rate	0
Directional drilling equipment rentals	Day rate	1,250
Welding services and others	Day rate	0
Water Supply	Day rate	0
Waste disposal, clean-up and site maintenance	Day rate	0
Lodging, catering (Camp and food)[C]	Day rate	82,030
SUM		2,667,780
Drilling consumables		
Rock Bits	From table	182,000
Drilling Detergent	From table	46,000
Diesel & Lubricating Oil	From table	736,424
Cement	From table	39,674
Cement additives	From table	3,967
Drilling mud[D]	From table	170,610
SUM		1,178,676
Casing and wellhead		
Casing	From table	556,718
Casing accessories and consumables	From table	29,350
Wellhead Equipment	From table	79,550
SUM		665,618
Services		
Drilling supervision	From table	30,000
Civil Engineering	From table	6,000
Site Geologist	From table	12,000
Geological services	From table	9,000
Reservoir Engineering	From table	6,000

Planning and logistics	From table	12,000
Logging services	Fixed	30,000
SUM		105,000
Non-productive time[E]		
Fishing	Day rate	
Lost Circulation	Day rate	
Others	Day rate	
SUM		0
TOTAL		5,107,074
15% CONTINGENCY[F]		766,061
PROJECT TOTAL		5,873,135

The reasons for highlighted cost savings can be summarized as follows,

A: CwD rig is smaller compared to normal rig and therefore transported to drill site with less number of truck-loads.

B, C: Less tubulars handing requires smaller crew and thus lodging and catering expenditure can be minimized.

D, E: With plastering effect of CwD, loss circulation problem became very small and additional mud cost is eliminated.

F: Less complexity of tools and procedures minimizes failures in system and contingency fund requirement.

In addition, CwD eliminates capital cost related to drill pipe. Lesser tubular handling at the rig site further reduces the NPT of rig. As standard casing joint length is 40 ft, drillers make about 25% fewer connections compared to standard drill pipe joint of approx. 30 ft length. In casing drilling, after drilling to TD, casings are already in place and thus, the time related to tripping out of drill string and running in permanent casing is abolished. Therefore, if we consider the above scenarios, casing drilling results in 45% NPT reduction. (Fontenot et al. 2005).

This discussion indicates that CwD has good potential for reduction in cost along with drilling time, which are major factors in geothermal well budget.

6. SHORT TERM CHALLENGES

Major challenges associated with CwD are as follows:

A. High torque and drag: As casing is larger in diameter and heavier when compared to drill pipe, the torque required to rotate the casing string to TD is often high.

B. Hydraulics: As the annular clearance in CwD is very small compare to conventional drilling practices, it requires a redesigning of hydraulic. As higher ECDs are hard to manage at greater depth, even with optimal mud rheology and reduced flow.

C. Tripping casing: Saving tripping time is prolific advantage, Bit for CwD needs to be designed in a way that it completes drilling up to a minimum casing depth in one run. Otherwise, the whole casing string must be pulled out to change the bit. Thus, proper bit selection is a prerequisite to reduce tripping time.

D. Managing stick out: In retrievable BHA, the benefits of CwD are not seen until the bottom most casing reaches the formations concerned. Thus, if the directional/logging BHA extends 90 ft past the casing shoe and the RoP is 30 ft hr^{-1}, three hours of drilling is required before any benefit of plastering effect (reduction in losses) is seen. This is very important factor in case of geothermal drilling.

E. Capital cost: Though CwD showed reduction in daily drilling cost in every areas, capital investment for CwD rig is still higher. Thus, it requires cost efficient manufacturing of major CwD rig equipment like CDS and hydraulic catwalk.

The above challenge needs to be addressed for improving CwD performance in geothermal drilling.

7. CONCLUSION

We know that drilling for hydrocarbon and geothermal energy has several similarity. However, it has many differences due to high temperature environment, hard rock strength, highly fractured rocks and dimensions of geothermal wells. These differences poses several challenges and CwD has ability to reduce challenges to major extent as summarized below;

- CwD has capability for extensive reduction in NPT and cost. Thus, it is very beneficial for low-budget geothermal projects.
- Good quality cement job allows company to produce geothermal energy for log time without suffering with large maintenance.
- Plastering effect in CwD provides barrier to lost circulation and therefore, it helps to reduce drilling problems.
- However, extreme temperature's tool failures and corrosion are widely spread drilling problems that needs to be solved to achieve highest success with CwD.

8. ACKNOWLEDGEMENT

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