DRILL BITS SELECTION ANALYSIS IN NON-CONSIGNMENT PROCUREMENT ARRANGEMENT IN GEOTHERMAL DRILLING PROJECT

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Keywords: *drill bits, drilling procurement, geothermal drilling.*

ABSTRACT

The drill bit is one of the most important tools in geothermal drilling operations. The main role of this tool is to crush or cut the rock. Unfortunately, the selection of the best available bit for a job can be determined only by trial and error. This is because bit selection refers to several factors, such as the formations and drilling parameters. In non-consignment procurement arrangements, drill bit selection shall be completed prior to the execution.

This paper explores the selection workflow and assumptions used in selecting drill bits for geothermal operation based on offset well and recent market reviews. Discussion covers drilling bit specifications and quantity determination for 3 wells in a drilling campaign. The results are recommendations for preferred drill bit selection in non-consignment procurement arrangement. Important data that must be recorded during drilling is also mentioned in the discussion. This is critical for drill bit selection optimization in future campaigns.

1. INTRODUCTION

Geothermal fields are different from oil and gas fields. The basic differences are on three major factors which are rock type, temperature, and pressure. Common rock types in geothermal reservoirs are igneous rocks and metamorphic rocks which include granite, granodiorite, quartzite, greywacke, basalt, rhyolite, and volcanic tuff. Compared to the sedimentary formations of most oil and gas reservoirs, geothermal formations are, by definition, hot (production intervals from 160°C to above 300°C) and are often hard (240+MPa compressive strength), abrasive (quartz content above 50%), highly fractured (fracture apertures of centimeters), and under-pressured. They often contain corrosive fluids, and some formation fluids have very high solids content. These conditions mean that drilling is usually difficult, rate of penetration and bit life are typically low, corrosion is often a problem, lost circulation is frequent and severe, and most of these problems are aggravated by high temperature. (Marbun, 2014)

The bit is one of the most important components that must be used in the drilling process. The main role of this tool is to crush or cut the rock. It is assembled on the bottom of the drill string and must be changed when it becomes excessively dull or stops making progress in depth. Most bits work by scraping or crushing the rock, or both, usually as part of a rotational motion. Everything on a drilling rig directly or indirectly assists the bit in crushing or cutting the rock. (Marbun, 2014).

Unfortunately, the selection of the best available bit for the job, like the selection of the best drilling fluid or drilling cement composition, can be determined only by trial and error. The most valid criterion for comparing the performance of various bits is the drilling cost per unit interval drilled. Since no amount of arithmetic allows us to drill the same section of hole more than once, comparisons must be made between succeeding bits in each well or between bits used to drill the same formations in different wells. The formations drilled with a given bit on a previous nearby well can be correlated to the well in progress using well logs and mud logging records. (Bourgoyne Jr., 1965).

2. BASIC THEORY

2.1 Drill Bits in Geothermal Drilling

A drilling bit is the cutting or boring tool which is made up on the end of the drill string. The bit drills through the rock by scraping, chipping, gouging, or grinding the rock at the bottom of the hole. Drilling fluid is circulated through passageways in the bit to remove the drilled cuttings. There are, however, many variations in the design of drill bits and the bit selected for a particular application will depend on the type of formation to be drilled. The performance of a bit is a function of several operating parameters, such as weight on bit (WOB), rotations per minute (RPM), mud properties, and hydraulic efficiency. An understanding of the design features of drill bits will be essential when selecting a drill bit for a particular operation.

There are, however, many variations in the design of drill bits and the bit selected for a particular application will depend on the type of formation to be drilled. Basically, there are three types of drilling bit:

- Drag Bits

  Drag bits (Figure 1) were the first bits used in rotary drilling but are no longer in common use. A drag bit consists of rigid steel blades shaped like a fish-tail which rotate as a single unit. These simple designs were used up to the year 1900s to successfully drill through soft formations.

Proceedings 42nd New Zealand Geothermal Workshop
24-26 November 2020
Waitangi, New Zealand
ISSN 2703-4275

Figure 1: Drag Bits (source: rotarypercussivedrill.com)

- Roller Cone Bits

  Roller cone bits or rock bits (Figure 2) are still the most common type of bit used worldwide. The cutting action is provided by cones which have either steel teeth or tungsten carbide inserts. These cones rotate on the bottom of the hole and drill hole predominantly with a grinding and chipping action. Rock bits are classified as milled tooth bits or Tungsten Carbide Insert (TCI) bits depending on the cutting surface on the cones. These bits allowed rotary drilling to be extended to hard formations.

(a) **(b)**

Figure 2: Roller Cone Bits: (a) Milled Tooth Bits; (b) TCI Bits (source: Hughes Christensen)

- Diamonds Bits

  The hardness and wear resistance of diamond made it an obvious material to be used for a drilling bit. The diamond bit is really a type of drag bit since it has no moving cones and operates as a single unit. The cutting action of a diamond bit is achieved by scraping away the rock. The diamonds are set in a specially designed pattern and bonded into a matrix material set on a steel body.

(a) **(b)** **(c)**

Figure 3: Diamonds Bits: (a) Polycrystalline Diamond Compact (PDC) Bits; (b) Natural Diamonds Bits; (c) Impregnated Bits (source: Hughes Christensen)

Geothermal drilling is traditionally challenged by hard and abrasive rock formation, with highly permeable fractured and/or faulted zones. This permeability is not only in reservoir structure, but also in overlying formation.

The main problem of geothermal drilling is low penetration rate of bits because of high torque friction, which is caused by subsurface conditions consisting of hard formation and high temperature affecting performance of the bit. The performance of the bit can be checked in history data usage of the bit. By evaluating the data, bit performance analysis can be made. The bit performance analysis depends on several variables such as bit type, bit design, formation characteristics, bit durability and drilling condition. If the bit is not used in accordance with the subsurface condition and formation, it will lead to an escalation of bit cost and ineffectiveness in geothermal well drilling. (Marbun, 2014).

2.2 Drill Bits Selection

It can be appreciated from the above discussion that there are many variations in the design of drill bits. The IADC has therefore developed a system of comparison charts for classifying drill bits according to their design characteristics and therefore their application. IADC code is short for "International Association of Drilling Contractors". The IADC Code for Tricone Bits defines its bearing design and other design features (shirt tail, leg, section, cutter). IADC Codes make it easier for drillers to describe what kind of rock bit they are looking for to the supplier. The most common IADC code used in HDD is such as 127, 517, 637 etc. Each digit has a different code.

- First Digit

  1, 2, and 3 designate Steel Tooth Bits with 1 for soft, 2 for medium and 3 for hard formations.
  4, 5, 6, 7, and 8 designate tungsten Carbide Insert Bits for varying formation hardness with 4 being the softest and 8 the hardest.

- Second Digit

  1, 2, 3, and 4 help further breakdown the formation with 1 being the softest and 4 the hardest.

- Third Digit

  This digit will classify the bit according to bearing/seal type and special gauge wear protection as follows:
  1 = Standard open bearing roller bit
  2 = Standard open bearing roller bit, air-cooled
  3 = Standard open bearing roller bit with gauge protection which is defined as carbide inserts in the heel of the cone
  4 = Sealed roller bearing bit
  5 = Sealed roller bearing bit with gauge protection
  6 = Journal sealed bearing bit
  7 = Journal sealed bearing bit with gauge protection

- Fourth Digit

  The following letter codes are used in the fourth digit position to indicate additional features:
  A = Air Application
  R = Reinforced Welds
  C = Center Jet
  S = Standard Steel Tooth
  D = Deviation Control
  X = Chisel Insert

E = Extended Jet
Y = Conical Insert
G = Extra Gage Protection
Z = Other Insert Shape
J = Jet Deflection

2.3 Procurement Common Practice

In oil/gas and geothermal drilling, drill bit selection is generally determined by trial and error and analysis of the use of drill bits in previous wells or offset wells. Therefore, the procurement used is generally using consignment basis. In addition, analysis on the selection of drill bits which depends on the subsurface conditions as described, the limitation in the analysis of the selection of drill bits for X Geothermal Field lies in the completeness of the offset wells drilling data that was conducted over a 20-year history.

It is wise to use consignment basis, where the geothermal company will only pay after they use the drilling bits. However, the consignment is not allowed by the lender and it is also not possible to order and pay for all wells. Therefore, in this paper is proposing the drilling bits specification and quantities for the first three wells each in X Geothermal Field. The rest will be ordered or requested by a geothermal company based on the first three wells performance.

3. DISCUSSION

3.1 Drill Bits Recommendation by Offset Wells Data

In the Offset Wells Report, an Analysis of drill bit performance was carried out on Offset Wells X Geothermal Field. From the drill bit performance analysis, conclusions can be summarized for drill bit recommendation that can be used in next drilling project in X Geothermal Field represented in the table below.

Table 1: Drill Bit Recommendation by Offset Wells Data

HOLE SECTION	DRILL BIT RECOMMENDATION (IADC CODE)
26"	415
	121
17-1/2"	535
	517
	515
	515M
	435M
12-1/4"	515M
	537
	447
8-1/2"	537X

The offset well data could also be analyzed to assess the performance of the drill bits that have been used. From the data below, it could be seen that the bits with IADC number 4XX and 5XX have good performance for drilling in hole section 17-1/2” and 12-1/4”, assessed from the average Rate of Penetration (ROP). The IADC 5XX bit also performs well when used in section 26”, this showed that the IADC 5XX bit can perform quite well in generally hard formation.

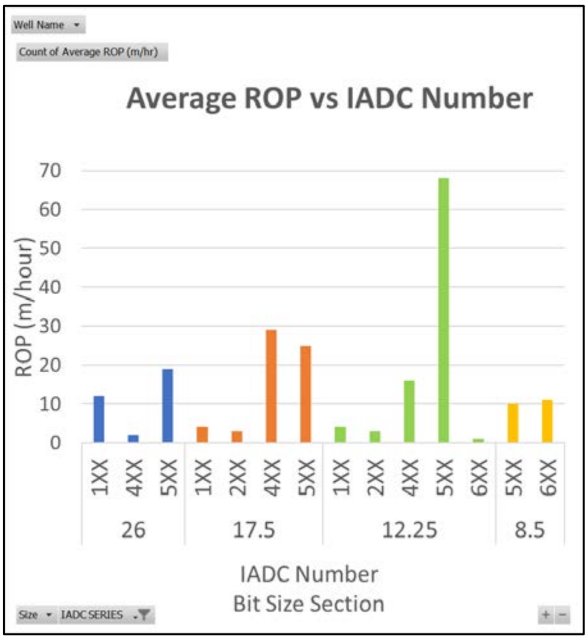

Figure 4: Average ROP vs IADC Number from Offset Wells Data

3.2 Drill Bits Recommendation by Vendors’ Data

In making bid documents for the next wells drilling project in X Geothermal Field, a market survey was conducted involving several vendors. The vendors also provided several reviews and recommendations for drill bits that can be used in the next wells drilling project in X Geothermal Field. The recommendations have been summarized in the table below.

Table 2: Drill Bits Recommendation by Vendors’ Data

Bit Size	IADC NUMBERS			
	Vendor A	Vendor B	Vendor C	Vendor D
26"	415	415	435	Hybrid Bit
	435	445	-	435
	-	115	-	-
17-1/2"	435	445	445	Hybrid Bit
	PDC	515	PDC	437
	-	135	-	-
12-1/4"	437	537	547	Hybrid Bit
	517	617	537	537
	537	PDC	517	-
	PDC	217	PDC	-

	PDC	-	-	-
8-1/2"	537	537	-	Hybrid Bit
	PDC	627	-	637
	PDC	217	-	N/C
9-7/8"	-	537	537	Hybrid Bit
	-	627	-	517
7-7/8"	-	537	617	Hybrid Bit
	-	617	-	627

3.3 Drill Bits Recommendation Summary

The method that was used in this report is drill bits selection based on recommendations that have been collected from several reviews, analysis and reports that have been done for the wells of X Geothermal Field. Recommendations for drill bits that can be used in the next wells drilling project in X Geothermal Field. The recommendations have been summarized in the table below.

Table 3: Drill Bits Recommendation Summary

Bit Size	IADC	Bearing	Gage Protection	Quantity for 3 wells
26"	415	Double seal bearing	50% TCI	3
	435	Double seal bearing	50% TCI	3
17-1/2"	537	Double seal bearing	50% DEI	2
	445	Double seal bearing	50% DEI	3
	435	Double seal bearing	50% DEI	3
	PDC	Double seal bearing	50% DEI	2
	Hybrid	Double seal bearing	50% TCI	2
12-1/4"	517	High temp. seal bearing	100% DEI	3
	537	High temp. seal bearing	100% DEI	3
	PDC	High temp. seal bearing	100% DEI	3
	Hybrid	High temp. seal bearing	100% DEI	2
8-1/2"	537	High temp. seal bearing	100% DEI	3
	627	High temp. seal bearing	100% DEI	2
	PDC	High temp. seal bearing	100% DEI	1
9-7/8"	537	High temp. seal bearing	100% DEI	2
7-7/8"	537	High temp. seal bearing	100% DEI	1
	617	High temp. seal bearing	100% DEI	1

In the 26” hole section, the most recommended drill bits are with IADC No. 415 and 435. Because it has a high durability to penetrate the 26” hole section. Hard and abrasive rock formation demands better protection on gauge surfaces. It is vital to the effectiveness of any bit as the gauge surfaces constantly ream the hole and are the subject of continuous abrasive wear. Protection on shirttails, heels and stabilizers are also vital as drill cuttings tend to build up around it and may cause premature bearing failure (Rifki, 2016).

In 17-1/2” hole sections, drill bits are recommended with IADC No. 435 and PDC because the formation is considered to be similar to the 26” hole section but will already enter the reservoir zone so it is recommended to use PDC bits.

In 12-1/4” hole sections, drill bits are recommended using IADC No. 517 and 537. Use of IADC No. drill bits 517 recommended 50% diamond protection, and IADC No. drill bits 537 recommended 100% diamond protection on leg and shoulder because it has entered the reservoir zone. IADC No. drill bits 517 can also be used to drill out cement.

Things to consider are that drill bits will be replaced when they are in a dull condition with a certain dull grade. The selection of drill bits must also pay attention to the condition of the BHA (mud motor), because durable drill bits are not necessarily compatible with the BHA.

4. CONCLUSION

The selection of drill bits at the beginning of the procurement phase will be complicated because the use of drill bits is analysed using trial and error. The use of drill bits also depends on the compatibility of the drill bits used with the formation being encountered. The analysis carried out in this report assumes analysis of offset wells and reviews from several vendors and consultants.

Therefore, this paper is proposing the drilling bits specification and quantities for the first three wells in X Geothermal Field. The rest will be ordered or requested by geothermal company based on the first three wells performance.

However, analysis needs to be done to assess the drill bits data used in the next wells drilling project in X Geothermal Field in order to obtain updated performance data and drill bit analysis so that optimal drill bit selection can be done.

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