Comparison between Use of Hammer Bits and Roller Cone Bits on Conventional Land Rigs, a Case Study of the Menengai Field

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Abstract:-**Drilling speed of the top section (26" hole to a depth of 80m and $17^1/_2$" from a depth of 80m-400m) has been a challenge in the Menengai geothermal field with low rate of penetration as per intended target. This section is generally hard formation with frequent drilling fluids losses.**

Use of the standard roller cone bits on these sections causes a lot of vibrations on the rig leading to frequent breakdowns of the equipment (rotary table and top drive system) leading to downtime; hence, longer drilling periods and high maintenance cost.

Loss of circulations while drilling the top section leads to cement plugs to heal the losses, use of more loss circulation material (LCM) and drilling mud. This increases the time taken to drill these sections due to wait on cement to cure and overall well costs.

Introduction of the hammer bit on the conventional land rigs in the Menengai geothermal field was viewed as potential solutions to the challenges experienced with the standard roller cone bits. This study sought to compare the performance of two-bits across four wells in order to establish whether the hammer bit has any advantage over the roller cone.

Results shows that the hammer bit had a high average rate of penetration (ROP) of 2.2019 meters per hour on the 26" hole and $17^1/_2$" hole section as compared to an average ROP of 0.376 meters per hour for the roller cone bit. The hammer bit presented other advantages including low/minimum vibrations transmitted to the rig equipment, less drilling fluids used and minimum downtime hence minimum maintenance costs. The study recommends that the hammer bit be adopted for drilling all wells' top sections in Menengai geothermal field.

Keywords: **Hammer bit, air drilling, percussion drilling, conventional land rig, drilling fluid, rate of penetration, rotary table, top drive system, roller cone bit, drilling fluids, loss circulation material (LCM), cement plugs.**

I. INTRODUCTION

They are different types of bits used in the drilling field these are;

I. Those that break the rock
II. And for coring purposes

In this paper we will focus on two types of bits used to break the rock i.e. roller bits and air hammer bits.

A. Roller Cone Bits

Roller cone bits consist of three cones turning independently and are assembled on three arms joined together by a welding constituting the body of the tool. Several types of bearings are used (rollers with or without sealing, stages of friction, system of lubrication, etc.). These tools work mainly in compression. The roller cutter element of bit is fitted with a chain of teeth that are designed to crush rocks in a single bit rotation (Lyons, 2009). Significant improvements have been made to the roller bits such as introduction of nozzles, tungsten carbide inserts, lubricated & sealed bearings, diamond shells, and journal bearing. The purpose of these improvements is to increase the rate of penetration (ROP) and life span of the tool; thus, reduce the cost of drilling.

Figure 1: Roller bits: Tungsten carbide inserts and steel toothed bits

The introduction of nozzles improve the bits efficiency by enhancing the hole bottom cleaning process (White, 1988). Consequently, there is improved removal of discrete chips from the hole before they are re-grounded resulting in higher ROP. The nozzles have also enhanced the bit cleaning process. Tungsten carbide among the toughest materials known; hence, the introduction of carbide inserts has improved the strength and durability of the bit (Lyons, 2009). The introduction of lubricated and sealed bearing has improved the lifespan of the bearing by reducing the rate of wear caused by friction between the bearing and rock cuttings. Introduction of diamond shells has also helped to improve bit durability by minimizing wear and gauge rounding under abrasive conditions. Introduction of journal bearing has optimized bit inserts penetration into the formation. Currently at the Menengai Project, the roller bits are used for drilling

26'', 17 ½'', 12 ¼'' and 8 ½'' holes with introduction of air hammer bit to increase ROP on the 26'' and 17 ½'' section holes.

B. Air Hammer Bit

While drilling with the hammer bit, the bit is situated down the hole in direct contact with the drill bit. The main role of the hammer is to transform energy provided by compressed air into piston kinetic energy, which is transferred to the drill bit through oscillating movements and mechanical impacts, and eventually, to the rock. The bit keeps rotating creating new impact positions resulting in fragmentation of rocks. The fragmented rocks are flushed from under the bit to the surface via the borehole annulus by compressed air that flows through the bit nozzles. The hammering mechanism is driven by air pressure; hence, the name "air" hammer bit. The method is widely used for drilling long holes for water wells, shallow gas and oil wells and for geothermal wells. In mining it is also developed for sampling using reverse circulation by a hydraulic or electric motor driven gear box called a rotary head that moves up and down the tower via a feed system generating the pull down required to give sufficient weight on the bit.

Figure 2: Hammer drill bits

The hammer drill system is not a very new technology. This drilling method was applied in oil and gas drilling operations at the beginning of the 20th century (Sliwa et al., 2015). However, the technology was replaced by the development of improved rotary rigs. The improvements made rotary bits faster and efficient than the standard hammer bits leading to the abandonment of the latter. In 1960, interest on hammer drilling system was revived with the introduction of high frequency, low energy hammers. Technological advancements made it possible for the hammer to make about 1800 strokes per minute making this drilling method more efficient (Okuchaba, 2008). However, the use of hammer drilling system remained a challenge as the bit welds could not withstand the hammering action resulting in deviation problems. To resolve the deviation issue, developers reduced the weight on the bit and its rotating bit, which ultimately reduced efficient and increased costs.

In the 1980s, design engineers working in the Arkoma Basin in the United States replaced the tricone bit with fixed bit that was connected to a hammering mechanism (Sliwa et al., 2015). They also fitted the hammering bit with diamond enhanced tungsten carbide (TC) inserts to improve their resistance to wear and enhance the penetration rates. However, limited durability remained a major problem as the drilling bit and spline section could still be separated during drilling causing the bit to fall down in the hole. In 1991, the design engineers developed a retaining device that eliminated the bit separation problem during drilling. The retaining device comprises of three retaining mechanisms. The primary retention mechanism is the retaining ring situated at the top of the bit. The second retaining mechanism is the sleeve placed between hammer case and the shoulder of the driver sub. The third retaining mechanism is a rope threaded machined on the bit and the retainer. This advancement made the hammering drilling system more efficient and is still in use today.

Figure 3: Hammer Drill Retaining Device

Literature suggests that air hammer bits have an advantage over roller bits when drilling hard rock and abrasive formations (Lyons, 2009). The hammer piston strikes the drill bit resulting in an efficient transmission of the impact energy and insignificant power losses with the whole depth. In addition, the impact from the air hammer provides an additional source of energy. The roller cone bit only has two sources of energy for destroying rock: the weight exerted on the bit by drill string and the force provided by the rotation of the bit. Apart from these two sources of energy, the air hammer drilling system derives additional energy from the impact of the oscillating piston.

According to Okuchaba (2008), the impact from the air hammer accounts for over 60% of the energy needed for rock destruction in hammer drilling system. Finger (1984) also found that that hammer bits drilled more than two times as fast as high weight on bit (WOB) rotary air drills and had a ROP that was three to six times faster in mining and oil fields. However, the study linked hammer bits with problems of high sensitivity to WOB and gauge wear. The quality of the study was also limited by the experimental design where the bits were tested in a controlled environment rather than real geological setting.

Besides high rate of penetration, Hung et al. (2015) associated hammering bits with improved hole geometry, larger and better cuttings, reduced drill string stress, and low cost per foot. However, pseudo-plastic behavior of cuttings can occur at high borehole pressures limiting the rate of penetration. Similarly, this study was conducted in an experimental environment using granite, anhydrite, basalt, and gabbro rock types, whose property differ from the trachyte rocks commonly found in the top section of Menengai geothermal field. In light of these limitations, a comparison between hammer bits and roller cone bits at the Menengai geothermal field is necessary to determine the technology that is best suited for the field.

II. LITHOLOGY

The lithology of a rock unit is a description of its physical characteristics visible at outcrop, in hand or core samples or with low magnification microscopy, such as colour, texture, grain size, or composition. In this paper, a comparison of the lithology of four wells, three drilled by a combination of tri cone bit and hammer bit, and one drilled by the Tri cone bit. This comparison was used to show that drilling occurred on almost similar rock surfaces; thus, giving a clear comparison between air hammer and tri cone bits on drilling the top section of the wells (0-80 Meters). The Lithology is shown Figure 4;

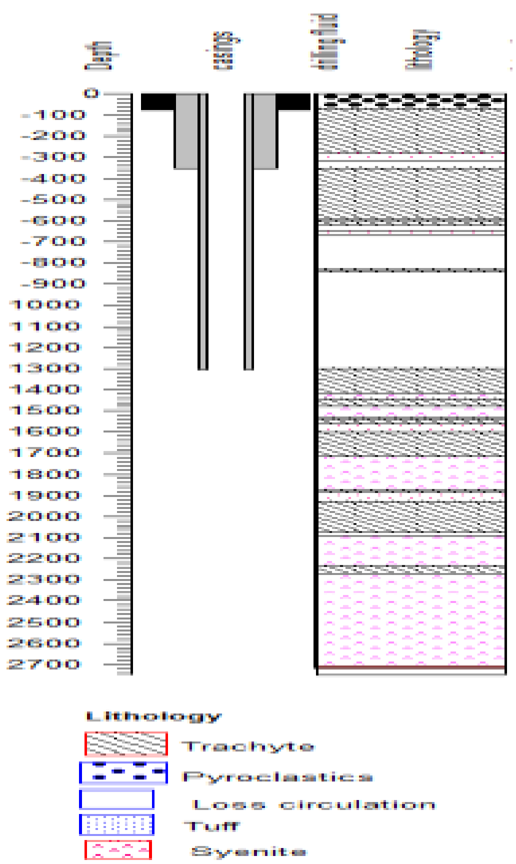

Figure 4: General lithology of the Menengai geothermal field.

The Menengai field formation under study (0-300m) comprised mainly of trachyte rocks with pyroclastic lenses. The formation has trachytic lava with thin overlying pyroclastic lenses of around 5 m. The formation is often blocky and with very fine grain size that gives it greater strength. The lava is generally fresh and unaltered due to its low susceptibility to alternations (Omondi, 2011). The low resistivity of these subsurface formations is associated with the maintenance of the geothermal properties of the region. Although the trachytic rocks are essential to the maintenance of the geothermal system, they are a hard formation to drill. Huge losses of circulation are usually experienced. Due to the blocky nature of the lava in this section, drilling challenges like cave-ins are experienced and therefore cement plugs are done in some of the sections.

III. METHODOLOGY

The study sought to compare the performance of the hammer bit with that of the standard Tri cone roller bit across four wells: MW-01, MW-10A, MW-13, and MW-21. Data regarding these wells was obtained from company records. The study sought to compare the rate of penetration of the two bits as well as conduct a cost analysis.

IV. RESULTS

A. Comparison of ROP for the Wells

Analysis of the rate of penetration (ROP) of tri cone bit and Hammer bit is presented in Table 1;

Table 1: Comparison of Tri-cone and Hammer Bit

Well	Bit Type	Meters Drilled	Drilling Hours	Average ROP (M/HR)
MW-01	Reed 26" Tricone	66.27	78	0.8496
	24" Air Hammer	49.77	35	1.4220
MW-10A	Reed 26" Tricone	29.33	78	0.3760
	24" Air Hammer	45.69	20.75	2.2019
MW-13	Reed 26" Tricone	48.77	127	0.3840
MW-21	Reed 26" Tricone	25.28	70	0.3611
	24" Air Hammer	49.77	35	1.4220

As illustrated in Table 1, the MW-01 well was drilled using both the tri cone bit and air hammer bit. The tri cone bit drilled a total of 66.27 meters in 78 drilling hours translating to an average rate of penetration (ROP) of 0.8496 m/hr. The hammer bit drilled a total 49.77 meters in 35 hours translating to an average ROP of 1.4220 m/ hr. This data shows that the hammer bit had an upper hand in the drilling of the top section of the Well.

The MW-10A well was also drilled using a combination of the tri cone bit and the air hammer bit. The tri cone bit drilled a total of 29.33 meters in 78 drilling hours translating to an average ROP of 0.3760. On the other hand, the air hammer bit drilled a total of 45.69 meters in 20.75 drilling hours translating to an average ROP of 2.2019. The hammer bit also had a higher ROP than the tri cone roller bit in this well.

The MW-13 well was also drilled using the tri cone roller bit only. The bit drilled a total of 48.77 meters in 127 drilling hours translating to an average ROP of 0.3840. This average ROP is lower than that recorded by the air hammer bit in wells MW-01 and Mw-10A.

The MW-21 well was drilled using a combination of a 24" Air hammer drill and Reed 26" Tri cone bit. The tri cone bit drilled a total of 25.28 meters in 70 drilling hours translating to an average ROP of 0.3611 meters per hour (m/hr). On the other hand, the air hammer bit drilled a total of 49.77 meters in 35 drilling hours translating to an average ROP of 1.4220 m/hr. These results clearly indicate that the hammer bit had a high rate of penetration for this particular well. Table 2 presents a summary of data from the four wells

Table 2: Summary of Data from the Four Wells

	Tricone Bit	Hammer Bit
Total Meters Drilled	147.768	177.80
Total Drilling Hours	393	80.75
Average ROP (for all wells)	0.376	2.2019

As Table 1 illustrates, the hammer Tricone roller bit drilled a total of 147.768 meters in a total of 393 hours translating to an average ROP of 0.376. On the other hand, the hammer bit drilled a total of 177.80 meters in 80.75 hours translating to an average ROP of 2.2019. The ROP for the hammer drill is 5.9 times higher than that of the tri cone bit. These findings are consistent with previous studies such as Finger (1984) and Hung et al (2015), which also found that the air hammer bit had a higher rate of penetration than the tri cone bit albeit in experimental environments.

Figure 5 presents a more elaborate comparison of the performance of the tri cone bit and the air hammer bit in drilling the top sections of the four wells (MW-01, MW-10A, MW-13, and MW-21).

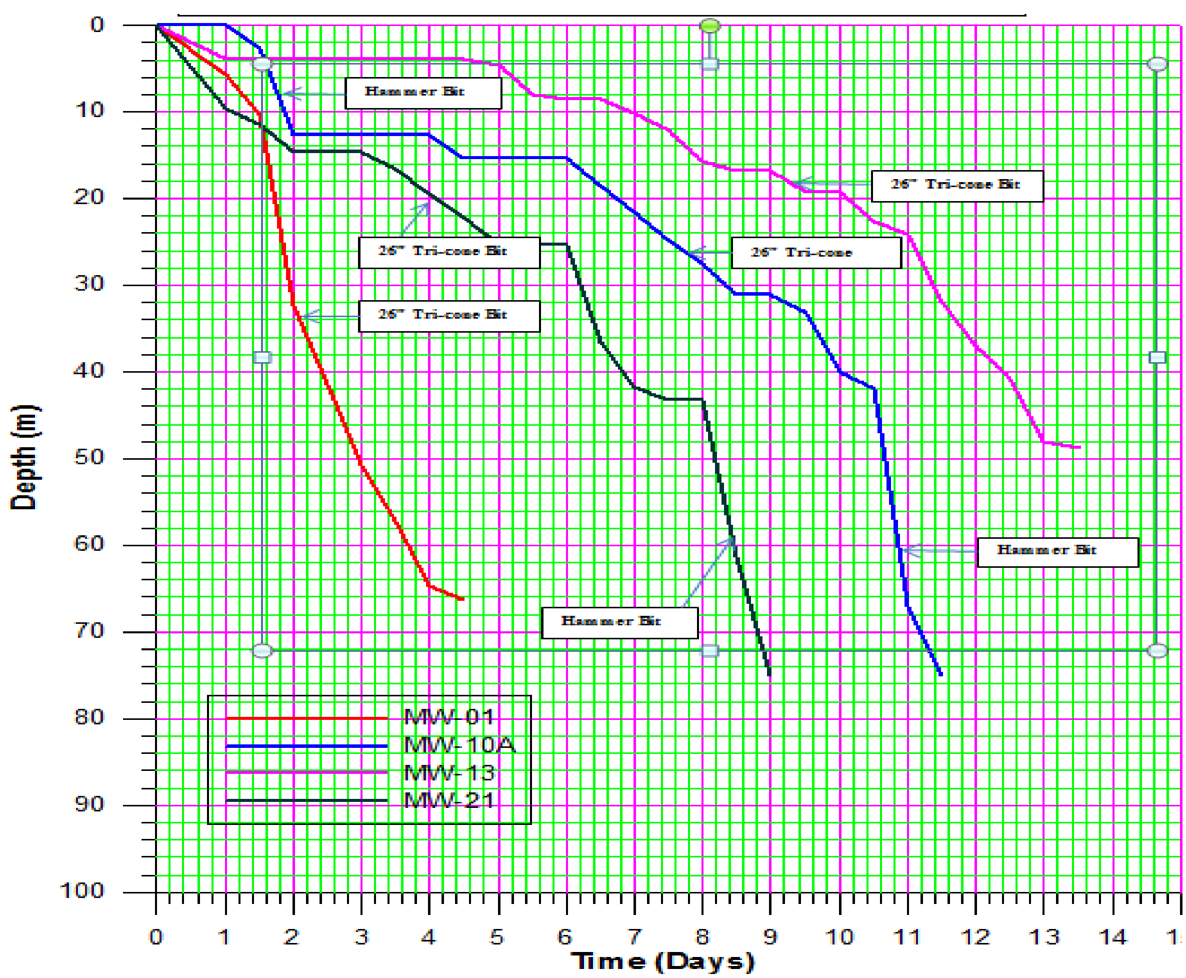

Figure 5: Comparison of Hammer and Tri Cone Bits for the Four Wells

As the graph illustrates, well MW-10A that was drilled using the air hammer bit in the top 10 meters had a steeper slope than the other three wells that were drilled using the tri cone bit in the top 10 meters. The air hammer bit also out performed that tri cone bit below the 40 M depth as illustrated by the slopes for MW -10A and MW-21. These results provide a more accurate evaluation of performance of the two bits as it compares the rate of penetration at the same depth. The introduction of the hammering effects changes the mode of rock destruction mechanism resulting in higher rate of penetration.

B. Cost Analysis

There are few, if any, drilling operations in the world where cost is not an important consideration. Cost is important! It is our responsibility as drilling people to accomplish the tasks before us at an optimum cost, which is the minimum cost to safely develop the reserves and produce the assets at an optimum level. The drilling operation must be cost effective.

The effectiveness of various drilling techniques must be measured in total cost or in cost per unit of length drilled. The cost per unit of length can be calculated using the following formula.

$$CT = \frac{Cb + Cr(t+T)}{F}$$

Where CT = Cost per foot or meter

Cb = Bit cost

Cr = Hourly rig cost

F = Footage drilled, feet or meters

T = Trip time (hours)

t = Rotating time (hours)

Taking well MW-21 information for example, we have the following information;

26" tri-cone insert bit:

Cost per bit = $40,000

Cost of rig = $ 500/hr

Rotating hours = 70

Trip time = 0.75 hrs

Footage = 82.94 ft (25.28 m)

Average penetration rate = 1.234ft/hr (0.376 m/hr)

24" air hammer bit:

Cost per bit = $100,000 (Bit + hammer assembly)

Cost of rig = $ 500/hr

Rotating hours = 35

Trip time = 0.75 hrs

Footage = 163.29 ft (49.77 m)

Average penetration rate = 7.22 ft/hr (2.2019 m/hr)

Cost per foot for the 26" tri-cone insert bit:

$$CT = \frac{40{,}000 + 500(70 + 0.7)}{82.94} = \$908/\ ft(\$2{,}978/\ m)$$

Cost per foot for the 24" air hammer bit:

$$CT = \frac{100{,}000 + 500(35 + 0.7)}{163.29} = \$722/\ ft(\$2{,}368/\ m)$$

Table 3: Summary Comparison of Hammer Bit and Tri Cone Roller Bit

S/N	24'' AIR HAMMER BIT	26"TRI CONE BIT
1.	Does not require drilling mud (Bentonite)	Requires Drilling Mud
2.	Uses Air drilling compressors minimum of 3 (3450cfm) at a time i.e. more Volume is required than pressure so as to lift the cuttings	Doesn't require air drilling compressors
3.	Air hammer bit is expensive to procure (about **$114,000**)	Less expensive to procure (about **$40,000**)
4.	Maintenance cost involved	No maintenance done
5.	Low maintenance cost on BHA due to minimal vibrations transmitted to the string	Higher maintenance cost on BHA due to high vibrations transmitted to the string
6.	Minimal vibrations transmitted to the rig/Minimal WOR	High vibrations experienced causing breakages to the Top drive, Kelly bushing, and rotary table; hence, high wait on repairs
7.	Minimal Weight on Bit used during drilling	Requires higher Weight on Bit to drill
8.	Has a lower operating cost per foot (**$722/ft**)	Has a high operating cost per foot (**$908/ft**)
9.	Higher ROP	Low ROP
10.	Less contact time with rock; hence, less bit abrasion and longer bit life.	More contact with rock; hence, high bit abrasion and shorter bit life.

V. CONCLUSION

Based on findings, the study concludes that the hammer bit is the most appropriate for drilling the top section of wells at the Menengai Geothermal Fields. Since the top formation section of the Menengai geothermal field is characteristically hard formation, it is recommended that 26'' hammer bits be used for the surface hole and $17^1/_4$" hammer bits for the intermediate holes so as to reduce the drilling days spent on these two sections. Findings have showed that although the hammer bit is expensive to procure and maintain, it has higher ROP which saves on drilling cost. It also cause minimal vibrations on the string thus reducing the risk of breakdown and associated downtime and repair costs.

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