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MAX-DRILL, DRILLING PERFORMANCE OPTIMIZATION PROCESS. SIGNIFICANT IMPROVE IN GEOTHERMAL DRILLING PERFORMANCE

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ABSTRACT

Performance drilling is a big challenge in Oil & gas and geothermal drilling. Industry is trying to find the best way of understanding bit selection, motor, downhole survey, drilling parameter, ect. Objective is to reduce drilling cost by spent less drilling rig time.

Chevron develops drilling optimization process call "Max Drill" which is wildly used in many businesses all over the world in oil and gas drilling. Geothermal Business also utilizes Max Drill process, specific for geothermal drilling which is understand as, a hard rock, low pressure and high temperature. As per April 2013, Salak campaign completed 6 steam cap producer(Included 1 multi lateral), two Deep liquid producer, one work over , and two brine injector wells (totally 10 drilling wells and one work over) with in 11 month of operation , which is approximate 3-4 month faster than the estimation. One of key factor is due to implementing "Max Drill" Process.

The paper has objective to demonstrate to Geothermal Drilling industry understand the use of Drilling engineering and process to improve drilling performance.

BACK GROUND

The required to improve drilling performance, as an operation cost reduction initiative, is an industry goal. Engineer, management, crew need to understand of performance drilling. Drilling industry in both oil and gas and geothermal today believe that the new technology meaning to a newly research, without understanding the need of natural. For instance, the required to drilling faster need to pay for higher cost of down hole tools, advance drilling bit design, or newly technology in the research lab. The faster ROP or better drilling performance of competitor is due to rock softer or easier to drill the wells.
The requirement of understanding natural of rock, mechanism to destroy, selecting equipment and tools, and process of performance drilling for geothermal industry will be described in this paper.

Max Drill, performance drilling, Process

MAXDRILL is a systemized data driven approach to *drilling Performance Improvement*, based on the identification and re-mediation of flounders/dysfunctions, either in the planning stages of an operation, or real time during the execution phase. It focuses on a relentless and continuous and re-engineering of the planning and execution phases of the drilling operation. The keys components of max Drill are listed below:

1. System definition and analysis
2. Flounder identification and re-mediation
3. Real time execution
4. Continuous re-engineering

GEOTHERMAL DRILLING

The geothermal energy is required heat source for producer steam which is generally, located in volcanic area. The wells are required to drill deep to main reservoir with high temperature. In general, the rock in geothermal producer field is volcanic (igneous) rock, such as tuff, andesite lava, Brescia, granite, etc. The rock is hard and brittle which is required energy to destroy. Additionally, geothermal system is usually located in a low pressure system which is always experience in lost circulation, stuck pipe, and many of hole problem. The challenges in geothermal drilling are:

- Takes place in an environment of prolific lost circulation resulting in hole cleaning challenges and stuck pipe risks.
- Limited geological data
- Derived from the earth's crust most often encounters bottom hole temperatures that can exceed 500°F (260°C)

- Hard, abrasive, and sometimes difficult to drill formations are also the norm in geothermal drilling, Igneous rock, such as Tuff, Andesite Brescia, Lava (est. avg of 20-25k psi compressive strength)

Geothermal Well design

The well designs in geothermal required surface casing with cement in annulus. The big hole size is required, due to reduce pressure lost in production hole section. The Standard bit/casing size for Chevron Geothermal illustrate below:

Table 1: Illustration a standard well design for Chevron Geothermal.

Section	Bit Size	Casing size	Well Inclination	TD Depth (feet)
Conductor		30”	vertical	100-180
Intermediate 1	26”	20”	vertical	1400 - 2000
Intermediate 1	17 ½”	13 3/8”	0 to 50	3000 - 4000
Production Liner 1	12 ¼”	10 ¾”	30-60	5000 - 7000
Production Liner 2	9 7/8”	8 ½”	30-60	6000 - 11000

BHA design

Due to the objective to hit wells targets which is far away from PAD location, the down hole directional drilling tools, such as Rotary Steerable, motor, MWD is required to be able to control directional drilling.

Managing hole problem

Due to the low pressure in geothermal system, the lost circulation is anticipation to happen, if the annulus ECD is higher than fracturing pressure and pore pressure. Therefore, the technique of using light weight mud, such as aerated or form drilling is benefit to geothermal drilling. When the lost circulation occurs, the high flow rate is required to maintain to remove cutting out of bottom hole to prevent the stuck pipe. The drill string RPM is also required to ensure that the cutting has been removes out of bottom hole.

Performance qualifier

When drilling a well, the system and operation are required to meet objective of drilling hole to the target. Therefore, the objective of drilling has to be listed and priority base on requirement. The performance qualifier (Explain in SPE paper number 119826) is required to apply. For geothermal drilling, the performance qualifier is listed, base on ranking as followed:

1. Drilling long section with trouble free
2. Eliminate stuck pipe, avoid lost BHA
3. Hit target box
4. High Rate of penetration

Once the performance qualifier is quantified, the list of equipment, parameter and procedure are:

- Drilling with high flow rate to remove cutting out of bottom hole
- Trying with maximize air mud ratio, to light ECD in annulus
- Required Down hole motor and MWD to be able to control directional drilling
- Apply optimize drilling pipe RPM , to keep cutting remove
- Selecting the drilling bit to meet objective

APPROCHING MAX DRILL SYSTEM

1. System definition and analysis – Knowing the objective of drilling each section. Base on well design of Chevron geothermal, design and objective of each section are as followed:
26” section – Drill 1000-2000 feet in vertical
17 ½” section- Directional drills from zero to 30-60 degree
12 ¼”, 9 7/8” and 7 7/8” section – Drill in geothermal reservoir production zone with anticipate of hot, lost circulation, stuck pipe potentials.

After knowing objectives, then team will set performance ranking. The paper using sample of 17 ½” and 12 ¼” as sample:

17 ½” – Complete build from zero degree and build angle in one bit trip. Therefore, performance ranking are listed as a sequence below:

- Trouble free
- Directional
- One bit trip
- ROP
- Bit dulled condition

12 ¼” – Objective is to drill in hot and low pressure zone which is anticipated. In general, geothermal drilling is target to hit fracturing; the target box is big compare to oil and gas well. Performances ranking for production zone drilling are:

- Trouble free (hole cleaning , avoid stuck)
- Long bit life
- ROP
- Directional
- Bit dulled condition

2. Flounder identification and re-mediation – Knowing limitation of system, such as maximum top drive, drilling pipe torque capacity, maximum flow rate and pressure.

Drilling engineer identifies and capture lesson learn as a continuous improvement.

17 ½" section: Due to the objective of building from zero degree to 30-60 degree of well inclination is hard rock environment. It was observe and found that directional driller has to push a high WOB when sliding which is cause a high side force to bit and stabilizer. The lesson learn from 2010-2011 Darajat drilling campaign found the stabilizer worn in almost every wells and required two bit trips for drilling 2000-3000 foot which is short. Additionally, the bit dulled shows the highly worn on the side of TCI bit.

Figure 1: Illustration stabilizer and bit dulled wore on side.

Engineering approached- Bit vendor suggested using non aggressive bit for longer life due to formation abrasiveness. However, Chevron decided to change a higher abrasive resistance, hard facing on stabilizer material. And request to add 50 – 100 % diamonds enhance on TCI bit.

The result – After implement from engineering approach, stabilizer has long life which can slide a high WOB and meet directional objective. The 100% diamond enhance on TCI bit also improving ROP and bit life. The 17 ½" achieved single bit trip for drilling 2000-3000 feet regularly.

Figure 2: Illustration stabilizer and bit improve after implement Max Drill.

Production drilling section (12 ¼", 9 7/8" and 7 7/8"): In this section, the well design in general is in tangent which some time required correction (steering). Most of drilling time is on drilling mode. However, the high flow rate and air required to circulation for hole cleaning, therefore, the down hole motor is running with high RPM which can effect to lateral vibration and abrasive ware on side.

Engineering approached- Due to high RPM, the TCI bit has observed abrasive worn on side. The bit vendor has been requested to improve diamond enhance on side and request for more insert count on outer row.

The result – The TCI bit regularly in a good condition and always pull out due to bearing life limited.

Figure 3: Illustration the bit dulled before implement max drill on left, and improvement after engineering approach on the right side.

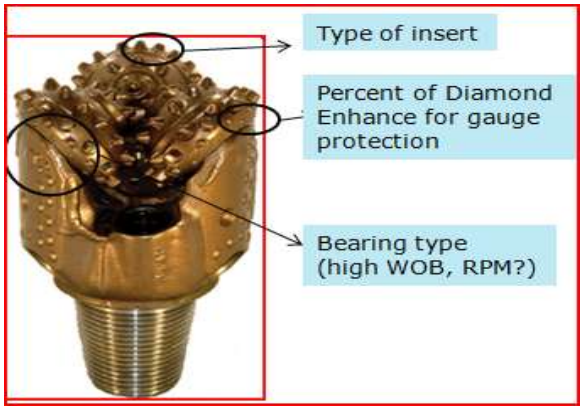

Figure 4: Illustration the component of TCI bit

3. Real time Execution – The rig crew regularly conduct the "Drill off test" to find the best drilling parameter. Objective is not only to find the best ROP, but also to improve longer bit/BHA life from vibration mitigation.

The drilling with TCI bit in geothermal reservoir finding a high lateral vibration when running high RPM and in sufficiency WOB. The describe in the figure 5 which is illustrate one sample from the Drill off test. In any RPM test (180, 190 and 200 down hole RPM), the higher WOB at 45-50 K lbs result to lower torque and gain ROP.

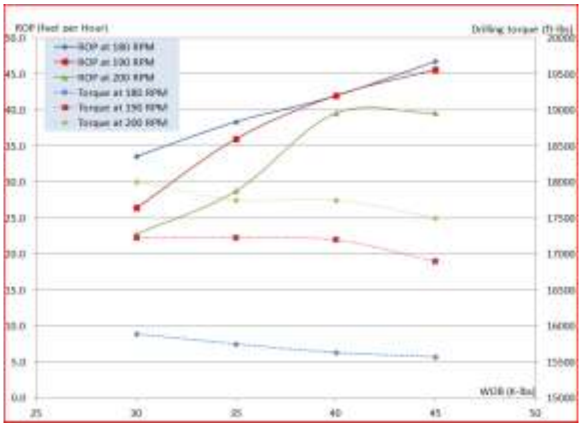

Figure 5: Illustration the Drill off Test to find the best drilling parameter(WOB vs ROP and vs Torque)

The result of the Drill off test in this sample can illustrate that in a same system design (bit/BHA) can find differences ROP and vibration. The lower ROP found when apply low weight and high RPM (Found 23 feet per hours). And the high ROP can be achieve by put higher WOB and lower RPM (found 46 feet per hours). In this case, ROP can be double and mitigation vibration (lower magnitude torque) when drilling in the same formation if understand the right drilling parameter.

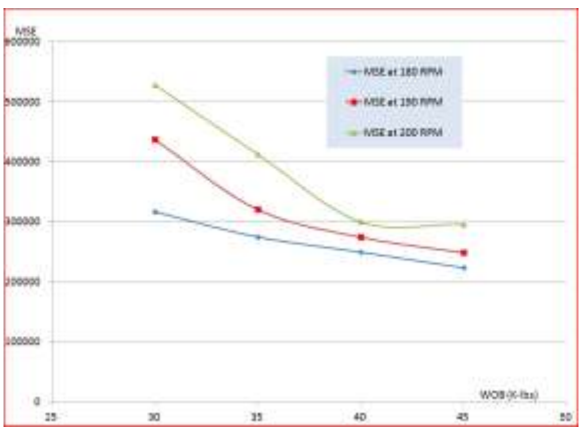

Figure 6: Illustration the Drill off Test to find the best drilling parameter (WOB vs MSE)

The efficiency of drilling can be found by using MSE value which is a common describe the energy input to destroy rock. The MSE has equation as below:

$$MSE = \frac{WOB}{Ab} + \frac{120 \times \pi \times RPM \times Torque}{Ab \times ROP}$$

Ab = Bore hole area ($\pi \times D \times D / 4$)
D is representing bit diameter

The chart from Drill off test above describe the lowest MSE (energy in put to destroy rock) found at 45 K WOB with low RPM which is the operation flounder point.

4. Continuous re-engineering – The bit dulled, drill off test result, performance qualifier and objective has been review regularly. The well planning process is using performance optimization as regular basis. The TCI bit does not follow recommendation base on IADC code (such as 435,537, etc), but rather select base on observation, dulled and performance objective.

THE ACTUAL RESULT

The Max Drill process stated implement in Chevron Geothermal since Darajat Drilling campaign in 2010-2011, and Salak Drilling campaign 2012-2013. The look back in Darajat found improving average 6.8 days per well which estimation of average 800,000 US $ per day improving, comparing to the previous Darajat Drilling campaign.

Table 2: Illustration Performance matrix in Darajat and Salak drilling campaign comparison.

Average	**2007-2008**	**2010 - 2011**	**Variance**
Well MD	7560	7242	- 318 ft
Drilling days (hours per 100 feet)	27.3 8.7	20.5 6.8	- 6.8 days
Flat time	6.25	4.9	- 1.35 days
Other time	5.2	4	-1.2 days
Location	7.5	8.2	+ 0.7 days
Unscheduled event	10.1	12.5	+ 2.4 days

The 2012-2013 Salak Drilling campaign

Average	**2006-2007**	**2008-2009**	**2012 - 2013**
Well MD	6540	6854	7193
Drilling days (hours per 100 feet)	14.8 5.43	18.4 6.44	11.8 3.94
Flat time	6.33	6.45	4.83
Other time	2.3	1.7	3.2
Location	8.7	9.2	7.7

The Salak 2012-2013 Campaign performance describe a significant improving performance in Drilling days comparing to the previous drilling campaign. This campaign accomplish drilling average 300 feet deeper than previous campaign but +/- 7 days faster.

CONCLUSION

1. Set a clear performance objective before drilling a well or section of well
2. Using Performance Qualifier before bit/BHA design
3. Identify system definition, and knowing system flounder (limitation)
4. Optimization by using engineering analysis, using database as component.
5. Optimize drilling parameter by using Drill off Test to find the best parameter
6. Keep lesson learn, take bit / BHA photo for look back process for continues improvement.

NOMENCLATURE

ROP - Rate of Penetration
TD - Total Depth
MD - Measure Depth
TVD - True Vertical Depth
BHA - Bottom Hole Assembly
MWD - Measure while Drilling
ECD - Equivalent Circulating Density
WOB - Weight on Bit
MSE - Mechanical Specific Energy

REFERENCES

Graham Mensa Wilmot, Panurach Dumrongthai (2009),"Performance Drilling–Definition, Benchmarking, Performance Qualifier, Efficiency and Value ," *SPE*