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Improved Bottom Hole Assembly Design at Field Dieng, Indonesia

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ABSTRACT

The bottom hole assembly (BHA) is designed based on various factors: hole geometry, mud weight, loads and forces, safety factor, components (drill collar, heavy weight drill pipe/HWDP, jars, etc.), inclination and direction, formation rocks (hardness and lithology). The study presented here discusses the lesson learned of BHA design and performance of drilling geothermal well HCE-28A in Field Dieng, Indonesia. The well is characterized with high temperature up to 316°C, pressure up to 15.7 MPa, presence of corrosive substances (CO_2, H_2S, and chloride) and environment (pH 4-5), and hard formation rocks. Major problems, such as high dogleg severity (DLS), tight hole, stuck pipe, and loss circulation occurred during drilling operation of this well. Such problems affected the BHA performance. This study was focused on BHA performance at depth 1,500-2,100 m MD in 12 ¼" hole section. Five BHA in this hole section were selected for the analysis.

The result of this study improves the design of BHA and the quality of the borehole according to the requirement from the reservoir and production point of view. The results and the lessons learned are used in designing BHA for the next well drilling campaign in this Field.

1. INTRODUCTION

Following are factors that must be considered in designing the drill string, including BHA and drill pipe [Koger (1998); IADC (2007):

(1). Hole geometry

The first consideration when designing the drill string is the hole geometry, including depth, and diameter of the bit.

(2). Mud weight

A further consideration is the maximum and minimum mud weight. This is related to the buoyancy factor calculation during downhole operation.

(3). Safety factor

Safety factor is determined to prevent the stresses from causing deformation or failure. The safety factor used in the tensile strength calculation that can be either the safety factor method or overpull.

(4). Drill collar weight
(5). Drill pipe adjusted weight
(6). Kelly
(7). Heavy weight drill pipe (HWDP)
(8). Drill pipe
(9). Other considerations

Basically, the other considerations discuss the initial physical properties and their degradation over time. Based on Mitchel (1995), two forces (wall force and centrifugal force) and one torsional dampening should be calculated in designing BHA, particularly for deviated well. The wall force is a result of buoyed weight and sine of the inclination angle of the hole, the centrifugal force is an orbital motion of the BHA produced by rotation, and the torsional dampening caused by the drill bit, stabilizers, and the rotation of the BHA and drill pipe.

Based on Koger (1998), following particular other considerations should also be considered: stuck pipe, dogleg severity (DLS), placement of jars, corrosion. Cycle fatigue is one of the most common causes of drill pipe failure. The amount of fatigue damage depends on four aspects that are the suspended tensile load of the string below the dogleg, the severity of the dogleg, the number of cycles the pipe rotated in the dogleg, the condition of the string and the corrosiveness of the drilling fluid. The DLS is calculated with following equation (Lyons et al., 2016):

$$DLS = \{cos^{-1}[(\cos I_1 x \cos I_2) + (\sin I_1 x \sin I_2) x \cos(A_2 - A_1)]\} x \frac{30}{CL} \quad (1)$$

where DLS, CL, I_1, I_2, A_1, A_2 are dogleg severity, °/30 m, course length or distance between survey points (m), inclination (angle) at upper survey points (m), inclination (angle) at upper survey points (m), inclination (angle) at upper survey points (m), and inclination (angle) at upper survey points (m).

Drilling jars are located in the BHA and their main purpose is to assist in freeing stuck drill pipe. BHA is designed to make sure the jars are run in tension. BHA will be divided into the assembly below the jars and above it.

(10). The BHA is also designed according to the purpose of the operation, such as slick BHA (composed only of drill collars), fulcrum BHA (used to build the inclination during drilling), pendulum BHA (used to drop the inclination during drilling), packed BHA (used to hold the inclination during drilling), directional BHA (used to drill the hole according to the designed direction and inclination), and other purposes. Several variables affect the BHA's performance, such as rugosity (hole enlargements) of the well, formation rock (hardness and lithology), formation dip, torque while drilling, drag during trip, stabilizer, drill collar wear, and mud cake (Mitchel, 1995).

The study presented here took a case from well HC-28A. The well is located in Field Dieng, Indonesia. This field has been operated for more than 20 years (Darma, (2016). The well is characterized with high temperature up to 316°C, pressure up to 15.7 MPa, presence of corrosive substances (CO_2, H_2S, and chloride) and environment (pH 4-5), and hard formation rocks. The study started with the collection, quality assurance (QA), and quality control (QC) of data (Geo Dipa, 2019; Marbun, 2013). The available data was limited. The collected data including actual well trajectory, actual well schematic, drilling parameter (weight on bit/WOB and torque), loss circulation zone, BHA, and daily drilling report (DDR). Further, data calculation and analysis were performed, including the rate of penetration (ROP) and lithology. The estimated compressive strength of the formations rock was not available. This data was obtained from the literature study [Dincer et al. (2004); Perras and Diederichs (2014). The analysis of the study was focused on depth 1,500-2,100 m MD in 12 ¼" hole section, since major problems occurred during drilling operation in this hole section. Five BHA in this depth range were selected for the analysis. The analysis included the BHA performance according to the problems that occurred (high DLS and loss circulation), the effect of buoyancy factor due to partial and total loss circulation, and formation rocks. The study was concluded with lesson learned that is useful for BHA design in future well drilling campaign. Figure 1 shows the methodology.

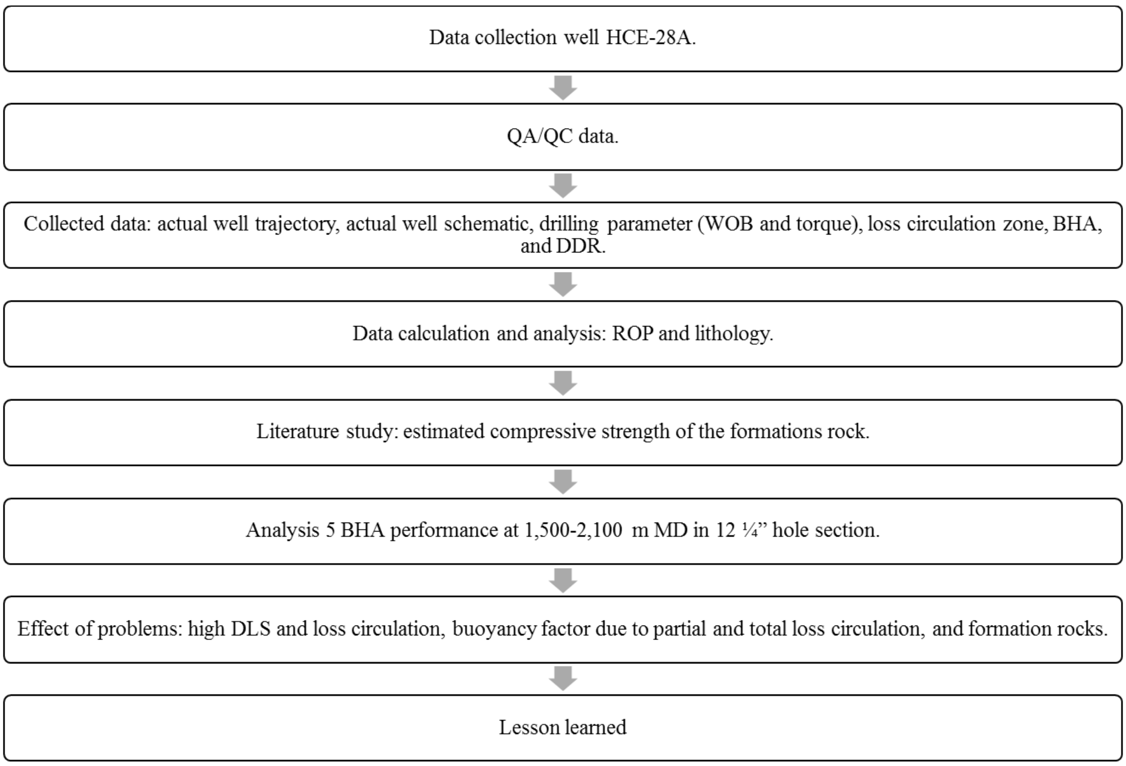

Figure 1: Methodology

2. RESULT AND DISCUSSION

2.1 Summary of the well

Well HCE-28A is a production and directional well. Figure 2 shows the well trajectory and Figure 3 shows the well schematic (Geo Dipa, 2019; Marbun, 2013).

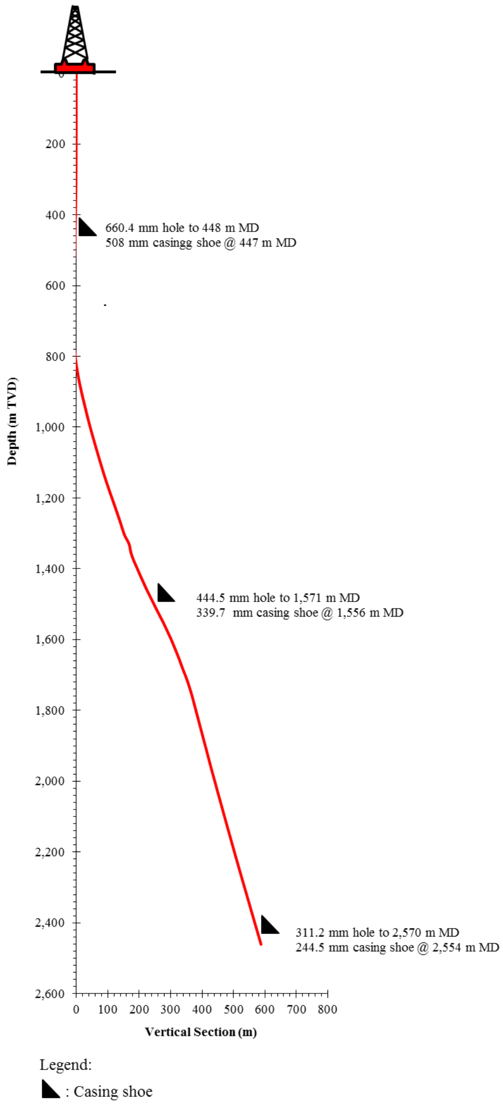

Figure 2: Trajectory of Well HCE-28A (Geo Dipa, 2019; Marbun, 2013)

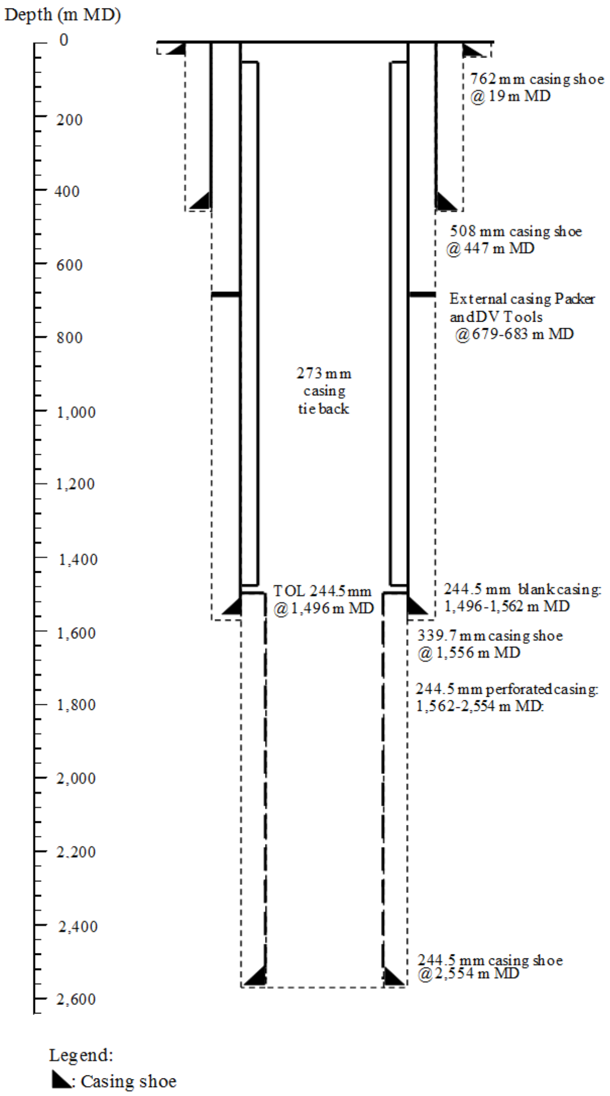

Figure 3: Schematic of Well HCE-28A (Geo Dipa, 2019; Marbun, 2013)

2.2 List of BHA

Following table shows the selected five BHA used for the analysis in this study. The BHA were used at depth 1,500-2,100 m MD in 12 ¼” hole section.

Table 1: List of selected BHA used for analysis (Geo Dipa, 2019; Marbun, 2013)

BHA	**A**		**B**		**C**		**D**		**E**	
Specification	**Name**	**Length (m)**	**Name**	**Length (m)**	**Name**	**Length (m)**	**Name**	**Length (m)**	**Name**	**Length (m)**
	Bit	0.3	Bit	0.3	Bit	0.3	Bit	0.3	Bit	0.3
	Mud motor	7.92	Near Bit (NB) stabilizer	1.7	NB Stab	1.7	NB Stab	1.84	NB Stab	1.84
	Float sub string	0.72	Monel	9.47	Pony Monel	3.34	Pony Monel	3.34	Pony Monel	3.34
	UBHO sub	0.82	String stabilizer	1.77	Roller Reamer	2.16	Roller Reamer	2.16	ST stab	1.76
	Monel	9.47	Drill collar	46.71	Monel	9.47	Monel	9.47	Monel	9.47
	Drill Collar	46.71	Jars	10.69	Stab	1.85	Stab	1.85	Stab	1.85
	Jars	10.69	X/O	1.34	Drill Collar	46.71	Drill Collar	46.71	Drill Collar	46.71
	X/O	1.34	HWDP	277.54	Jar	10.73	Jar	4.62	Jar	4.62
	HWDP	277.54			X/O	1.34	X/O	1.34	X/O	1.34
					HWDP	277.54	HWDP	277.54	HWDP	268.28
Total Length (m)	355.51		349.52		355.14		349.17		339.51	
Start Depth (m)	1,574		1,574		1,792		1,792		1,846	
End Depth (m)	1,634		1,634		1,846		1,846		2,086	
Notes and problems	BHA: drilled 12 1/4" hole section. Partial loss circulation and total loss circulation occurred.		BHA: wash and ream. Worked on tight hole at 1,619 m MD until pipe free. The cement plug was set at 1,583 m MD, side track hole was drilled.		BHA: drilled 12 1/4" hole section.		BHA: wash and ream. Work on tight hole and stuck pipe at 1,698 m MD by using air drilling and jar until pipe free.		Work on stuck pipe at 2,074 m MD by using air drilling until pipe free. Partial loss circulation occurred.	

2.3 Analysis and review

Figure 4 shows the analysis result of BHA performance. The figure consists of collected data (WOB, torque, loss circulation, and BHA), calculated and analyzed data (ROP, DLS, and lithology), and estimated compressive strength of formation rocks from literature study (Geo Dipa, 2019; Marbun, 2013; Dincer et al., 2004; Perras and Diederichs, 2014). The DDR was also reviewed and analyzed to define the drilling problems, such as loss circulation, tight hole, and stuck pipe. In this study, the zones with DLS above 2^o/30 m were categorized as high DLS zones.

The five BHAs were selected according to zones where major problems occurred. Table 2 shows the analysis of loss circulation zones, loss circulation rate and type, DLS, and buoyancy factor. When partial loss circulation occurred, only a certain volume of mud in the hole that supported the BHA and drill pipe (buoyancy force), while when total loss circulation occurred, there was no buoyancy force from drilling fluid. These problems affected the axial and lateral loads, including fluctuate WOB, tension, compression, high bending, and potential risk of buckling of the BHA. The BHA was designed with buoyancy force from the drilling fluid, while at these depths, the actual loads were higher than the design plan due to loss circulation problem. This was aggravated by the high DLS zones, tight hole, and stuck pipe occurrence. The cutting which was not circulated out of the well due to loss circulation, the vugular rocks, and the brittle formation rocks, contributed to the tight hole and stuck pipe occurrence. The tight hole and stuck pipe occurrence were not only during the drilling operation, but also during washing, reaming, and survey. In addition, the hardness and type of formation rocks affected also the BHA performances. According to the lithology analysis, there are two types of formation rocks. The upper section is highly argilically altered to weakly-moderately propylitically altered pyroclastics intercalated with thin andesite lavas. Meanwhile, in the lower section of the lithology there is highly propylitically altered andesite complex or microdiorite. Based on the literature study, these formation rocks have the same range of compressive strength, 38.5 to 112.7 MPa. Eventually, all of these problems compromised the borehole quality and caused problems in the next operation: running casing, liner, and completion equipment.

Table 2: Lost circulation analysis (Geo Dipa, 2019; Marbun, 2013)

Depth (m MD)	Loss circulation rate (m^3/hr)	Loss circulation type	DLS (degree/30 m)	Buoyancy factor analysis
1,504	4.05	Partial loss circulation	1.61	Close to 1
1,549	6.04	Partial loss circulation	0.87	
1,564-1,565	9.22-9.41	Partial loss circulation	1.71	
1,571-1,575	4.76-18.34	Partial loss circulation	1.71	
1,596	63.59	Total loss circulation	2.76	1
1,615-1,634	0.69-17.57	Partial loss circulation	1.21-2.35	Close to 1
1,859	15.3	Partial loss circulation	2.44	
1,864-1,866	3.3-12.45	Partial loss circulation	2.44	
1,923-1,924	39.44-26.15	Partial loss circulation	0	
2,014-2,029	0.2-12.89	Partial loss circulation	0.36	

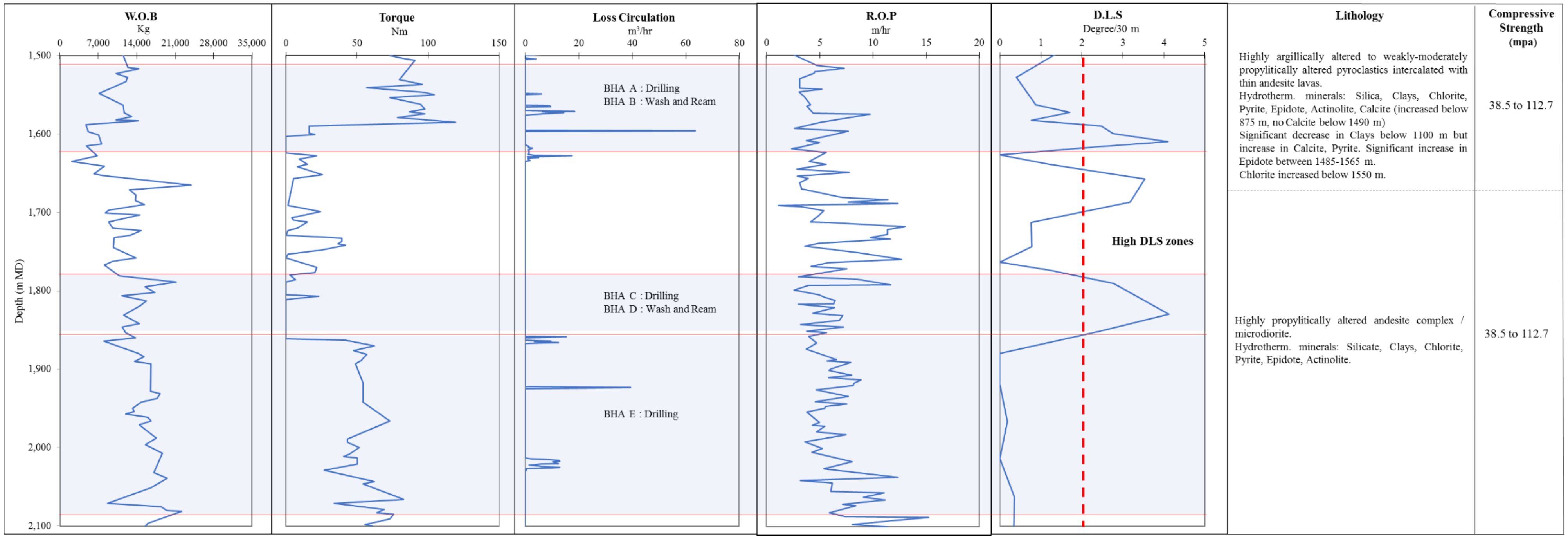

Figure 4: Collected data including drilling parameter (weight on bit/WOB and torque), loss circulation zone, and BHA. Data calculation and analysis including ROP and lithology. The estimated compressive strength of the formations rock from literature study. The analysis depth: 1,500-2,100 m MD in 12 ¼” hole sectin (Geo Dipa, 2019; Marbun, 2013; Dincer et al., 2004; Perras and Diederichs, 2014)

3. CONCLUSION

Based on the analysis, the following lessons learned can be recommended:

(1). The formation rocks and loss circulation zones are parameters that cannot be designed. The parameters that can be changed and designed to improve the drilling performance are hole geometry, BHA design, drilling parameter, mud type, and drilling operational procedure.
(2). Aside from hole geometry, mud weight, loads and forces, safety factor, components (drill collar, heavy weight drill pipe/HWDP, jars, etc.), inclination and direction, formation rocks (hardness and lithology), the lesson learned analyzed in this study is included in BHA design of next well drilling campaign in this Field.
(3). When drilling through loss circulation zones, precautions should be taken to control the drilling parameter in order to reduce the potential problems, such as high DLS, tight hole, and stuck pipe due to cutting accumulation in borehole. One of the suggestions is to reduce the ROP when drilling encounters trouble zones, such as loss circulation.
(4). According to the trouble zones encountered during drilling in this well, particular modification in planning and operational procedure can be proposed. These include controlling drilling parameter, reducing the stand by time (do not stop operation such as circulation or rotation for too long), and other solutions.
(5). Precautions should be taken in drilling operational procedure, such as washing, reaming, or taking survey, since major problems (loss circulation, tight hole, and stuck pipe) occurred in this operation, not only while drilling.

LIST OF ABBREVIATIONS

BHA	=	Bottom hole assembly
DLS	=	Dog leg severity
KOP	=	Kick off point
NB Stabilizer	=	Near Bit Stabilizer
ROP	=	Rate of penetration
WOB	=	Weight on bit
X/O	=	Crossover

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