

Fatigue Failure Analysis of Bottom Hole Assembly during the Drilling of H-E1 and H-Q1 Wells in the Hululais Geothermal Field

(Analisis Fatigue Failure Pada Bottom Hole Assembly Dalam Pemboran Sumur H-E1 dan H-Q1 di Lapangan Panas Bumi Hululais)

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Abstract

In drilling operations it is intended to be able to conduct drilling quickly without causing damage to the drilling equipment and be able to produce good quality wells. Failure on the drilling pipe or bottom hole assembly (BHA) ranks results from loading that exceeds the maximum strength limit of the material. In this study, the calculation of the load on the downhole motor, where in the depth of the drill 512 meters failure occurs in the form of broken downhole motor. Based on the analysis conducted, at a depth of 494 meters the value of the hookload has increased quite high at 131.8 klb, while the maximum allowable hookload value is 121 klb, this indicates an overpull of 10.8 klb and based on the calculation of the drag value, a drag is obtained 38.8 klb while the maximum drag value is 28 klb, the difference between the actual drag value and the maximum allowable drag value is 10.8 klb, so it can be concluded that the failure that occurs in BHA # 10 is due to a drag that exceeds the maximum limit of 10.8 klb.

Keywords: Geothermal, Drilling, Bottom Hole Assembly, Fatigue, Failure

Sari

Dalam operasi pemboran diinginkan agar mampu melakukan pemboran dengan cepat tanpa menimbulkan kerusakan pada peralatan pemboran serta mampu menghasilkan kualitas sumur yang baik. Failure pada rangkaian pipa pemboran atau bottom hole assembly (BHA) terjadi akibat adanya pembebanan yang melebihi batas maksimum kekuatan material. Dalam penelitian ini dilakukan perhitungan beban pada downhole motor, dimana pada kedalaman bor 512 meter terjadi failure berupa terputusnya downhole motor. Berdasarkan analisis yang dilakukan, pada kedalaman 494 meter nilai hookload mengalami kenaikan yang cukup tinggi yaitu 131,8 klb, sedangkan nilai maksimum hookload yang diizinkan adalah 121 klb, hal ini menunjukkan terjadi overpull sebesar 10,8 klb dan berdasarkan perhitungan nilai drag, diperoleh drag 38,8 klb sedangkan nilai maksimum drag adalah 28 klb, selisih nilai drag aktual dengan nilai drag maksimum yang diizinkan adalah 10,8 klb, sehingga dapat disimpulkan bahwa failure yang terjadi pada BHA #10 adalah karena adanya drag yang melebihi batas maksimum sebesar 10,8 klb.

Kata-kata kunci: Panas bumi, Pemboran, Bottom Hole Assembly, Keausan, Kerusakan

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I. INTRODUCTION

The increase of the amount of world energy demand has an impact on the availability of oil and gas energy reserves. Therefore, in order to be able to support the energy needs new and / or renewable and environmentally friendly energy sources are needed. Technological developments and advances have had a positive impact on the discovery of alternative energy, namely the discovery of geothermal energy. Along with the development of energy utilization in the world, geothermal energy is considered to have many advantages, such as: renewable, environmentally friendly and relatively low cost when used by the community because the output generated from this energy is electrical energy, but not the drilling operation itself. Drilling

operations in geothermal wells require substantial costs, so an effective and efficient technology is required to achieve the most economical geothermal drilling costs. The main challenges of geothermal well drilling are high pressure and temperature or better known as high pressure and high temperature (HPHT), then the type and character of rocks, where the majority of rocks in geothermal fields are igneous and metamorphic rocks, and hot reservoir gas earth that is corrosive. Therefore drilling equipment that is capable / resistant to these conditions is needed.

A drilling operation is designed to complete a drilling project quickly without causing damage to drilling equipment and is able to produce a good quality well. Damage / failure in the drill pipe and

Bottom Hole Assembly (BHA) is caused by the imposition of excessive stress / stress on the drill pipe circuit. Drill pipe failure is often occurred in drilling of ultra-deep well at complex geological conditions [1]. Statistics indicate that about 50% of drillstring failures resulted from fatigue. Most drillstring failures occur on drillpipe and drill collar connectors or upset transition areas [2, 3]. Fatigue is a gradually ongoing process, which brings along permanent structural changes on a localized level. Fatigue happens due to fluctuating or repeated strain at stresses having their maximum values well below the material yield strength used in designing the static limits of the drillstring [4]. Knowledge of the fatigue characteristics is necessary in order to achieve the analysis of dowhole tools under dynamic loads and reliable application of equipment without failure [5]. In this research, we will focus on calculating the load on the BHA which results in fatigue failure, where the application of the correct load / parameter will affect the service life and reduce the costs and drilling operation time.

II. METHOD

2.1 Data

The data needed in this research is in the form of actual data of drilling parameters, bottom hole assembly / BHA data, drilling plan data, and literature study. The data used in this study is obtained from PT Pertamina Geothermal Energi. This research was conducted on two wells located in Bengkulu Province. Drilling parameter data and BHA well data used are H-E1 and H-Q1 wells. In drilling a well, of course there are very many drilling parameter data and there are also a number of BHA that are used, in this study, in the H-E1 well the researchers only used data based on the initial depth of the well to the depth where the failure occurred. As for the H-Q1 well, the data used is adjusted to the data used in the H-E1 well. This is done to compare failure data with normal data (without failure).

2.2 Procedure

The initial stage in analyzing fatigue failure at BHA is to conduct a reference study that aims to find out the theories that cause fatigue. The next step is to collect the actual data of drilling parameters used in the field related to the failure that occurred. Then do the parameter calculations based on the existing fatigue failure theory. After the calculation results are obtained, the next step is to compare the calculation values with the actual data and reference study data. After that, the optimum parameter values and results are obtained.

The data processing in this study can be seen in the flow chart Figure 1. This research begins by collecting data, in the form of drilling data (hookload, WOB, torque, and measured depth),

BHA data, and mud motor specification data. Calculating theoretical load values, including: maximum overpull, maximum Weight on bit (WOB), buckling load, bending stress, tensile stress, torque, and drag load. If the actual hookload value exceeds the allowable hookload value (motor specifications) and / or the actual torque load value is greater than the permissible torque value, failure will occur in the form of broken downhole motor or mud motor. If the actual load of the hookload and torque does not exceed the maximum allowable load, the BHA circuit is safe. The estimated value obtained is the maximum planning value that can be achieved when drilling takes place.

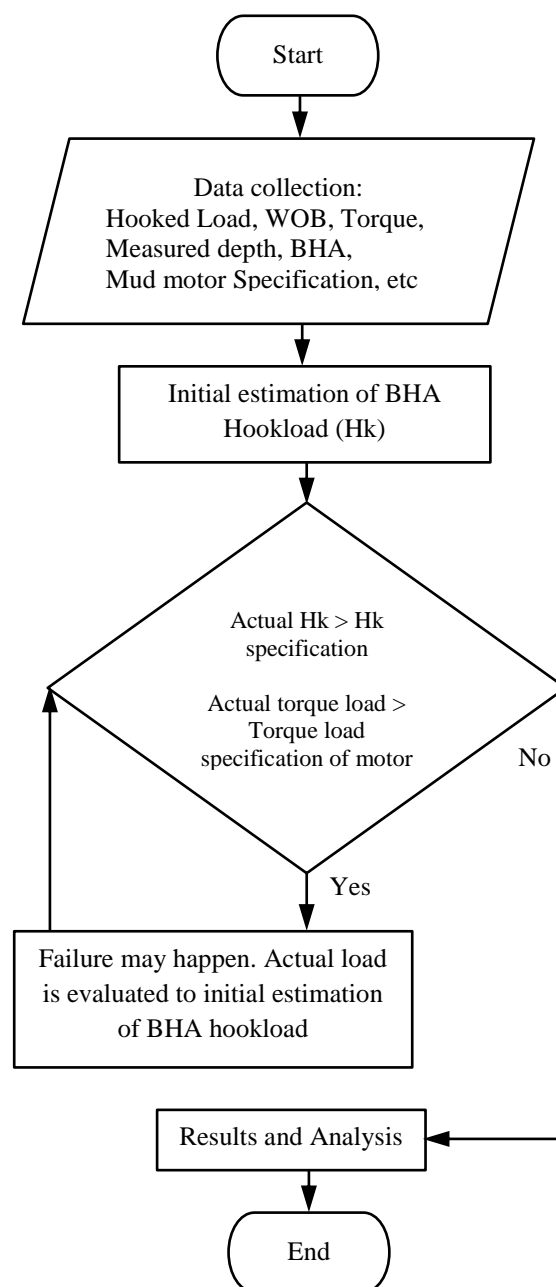


Figure 1. Flow Chart of the Research

2.3 Calculation

Hookload parameter is used to determine the maximum tensile stress when tight holes or stuck pipes occur [6]. Hookload is calculated using the following equation,

$$Hk = W_{\text{string}} \times BF \quad (1)$$

$$W_{\text{string}} = \text{Weight per foot} \times L \quad (2)$$

where

- Hk = hookload, lb
- W_{string} = string weight in air, lb
- BF = buoyancy factor
- L = length of string, ft

In stuck pipe conditions, the operator has to know how much additional tension, or pull can be applied to the string before exceeding the strength of the drill pipe. This parameter is known as overpull, since it is the pull force over the weight of the string. Therefore, the maximum overpull is defined as

$$\text{Maximum overpull} = Y - Hk \quad (3)$$

where

Y = yield strength, lb

Maximum weight on bit (WOB) is the maximum load that can be applied to the bit before failure happen. WOB can be calculated using the following equation

$$\text{WOB} = SF \times W_{\text{BHA}} \times BF \quad (4)$$

where

- WOB = weight on bit, lb
- SF = safety factor
- W_{BHA} = BHA Weight in air, lb

Buckling load is a force that works vertically on a drill string. This buckling load causes the pipe to bend due to pressure from above, in this case the pressure is to produce WOB [6], as in Figure 2.

Dawson and ley, 1984 [7] introduced buckling load (FC) calculation in a rotated state. The equation is as follows,

$$F_c = 550 \sqrt{\frac{I \times Bf \times (65.5 - MW) \sin \theta}{D_h - D_{tj}}} \quad (5)$$

$$I = \frac{A}{16} (OD^2 + ID^2) \quad (6)$$

$$A = 0.7854 (OD^2 - ID^2) \quad (7)$$

where

- FC = Critical buckling (lb)-
- I = Moment of Inertia (in⁴)
- Bf = Buoyed weight per foot (lb/ft)
- θ = Borehole inclination
- A = Cross sectional area of pipe, in²
- D_H = Hole Diameter (in)
- D_{TJ} = Tool joint diameter (in)

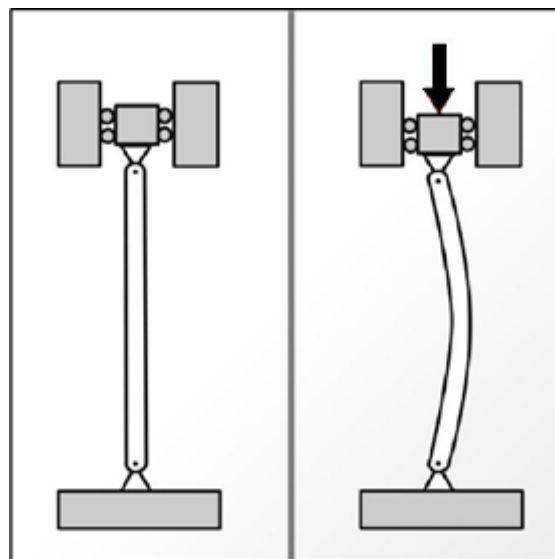


Figure 2. Buckling load occurs due to vertical pressure [6]

Drag load occurs due to the addition of the inclination of the wellbore that makes the drillstring to lean on the wall of the wellbore. When tripping in / out of the string, the friction is generated between the drill pipe and the wall. It causes the effect of compressive drag and tension drag on the drillpipe. The following equation can be used to estimate the drag load,

$$D = W_m \times L \times f \times \sin \theta \quad (8)$$

where

- D = drag load, lbf
- W_m = buoyant weight = string weight (lb) x BF (lb/ft)
- L = string length, ft
- f = friction factor = 0.33

III. RESULTS AND DISCUSSION

Table 1 shows the results of the calculation of the BHA load in the H-E1 well. Based on calculations that have been done, the hookload load of BHA # 2, BHA # 4, BHA # 5, BHA # 7, BHA # 8, and BHA # 9 are still within the allowable load

limit. While for BHA # 10 at 494 m depth, the calculated load value of 93 klb, actual value of 131.8 klb, and the maximum limit value is 121 klb. This means that in BHA # 10 there was an overpull of 10.8 klb. This can be seen also in the actual drag load that occurs in the downhole motor that is 38.8 klb, where the maximum value of drag is 28 klb so this difference shows that the downhole motor is overloaded 10.8 klb from the maximum allowable drag load.

Table 2 shows the results of the calculation of the BHA load in the H-Q1 well. Based on the calculations that have been made on the BHA used at H-Q1 well, we get hookload, WOB, drag, torque, buckling load, tensile stress, and bending stress that do not exceed the maximum allowable load. Accordingly, the drill pipe equipment used in the well does not undergo fatigue or even failure.

IV. CONCLUSIONS

From the results of the analysis from 4 wells to improve performance by strategy from KPI target as the objective to achieve performance.

1. In H-E1 wells, the values of hookload load, WOB, torque, buckling load, tensile stress, and bending stress at BHA # 1, BHA # 2, BHA # 3, BHA # 4, BHA # 5, BHA # 6, BHA # 7, BHA # 8, and BHA # 9 that were used during drilling did not experience a load that exceeds the maximum allowed. Therefore in this BHA failure does not occur. Whereas the downhole motor failure that occurred in BHA # 10 H-E1 well was due to an overpull of 131.8 klb, where the value was greater than the maximum hookload value of 121 klb. The load exceeds the permitted limit of 10.8 klb.
2. In H-Q1 wells the value of hookload load, WOB, torque, buckling load, tensile stress, and bending stress on BHA used during drilling also do not experience a load that exceeds the maximum allowable limit so that this BHA does not fail.
3. In calculation or actual value, hookload load, buckling stress, and tensile stress tend to increase as the depth of the hole increases.

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Table 1. Calculation of BHA Variables of H-E1

Variable	BHA#2			BHA#4			BHA#5			BHA#7			BHA#8			BHA#9			BHS#10		
	Depth 154.16 ft			Depth 190.24 ft			Depth 272.24 ft			Depth 393.6 ft			Depth 760.96 ft			Depth 826.56 ft			Depth 1620.23 ft		
	P	A	M	P	A	M	P	A	M	P	A	M	P	A	M	P	A	M	P	A	M
Hookload, klb	28.56	62.81	121	28.98	62.81	121	43.52	71.41	121	53.71	91.91	121	69.75	93.01	121	86.93	119.90	121	93	131.80	121
Buckling Load, klb	1.74	1.74	-	1.72	1.72	-	2.72	2.72	-	4.8	4.8	-	18.23	18.23	-	20.8	20.8	-	27.25	27.25	-
Tensile Stress, klb/in ²	7.6	7.6	-	7.71	7.71	-	11.58	11.58	-	15.67	15.67	-	18.56	18.56	-	22.17	22.17	-	24.75	24.75	-
Bending Stress, klb/in ²	17.46	17.46	-	17.46	17.46	-	17.13	17.13	-	16.73	16.73	-	16.43	16.43	-	16.01	16.01	-	15.7	15.7	-

Table 2. Calculation of BHA Variables of H-Q1

Variable	BHA#1			BHS#2		
	Depth 396.88 ft			Depth 1649.84 ft		
	P	A	M	P	A	M
Hookload, klb	69.06	89.48	121	92.57	106.67	121
Buckling Load, klb	3.34	3.34	-	22.04	22.04	-
Tensile Stress, klb/in ²	18.3	18.3	-	22.06	22.06	-
Bending Stress, klb/in ²	16.45	16.45	-	16.38	16.38	-