Casing design of the KY slim hole well in “X” Geothermal field

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ABSTRACT

Geothermal exploration activities including exploration drilling are important stages in a geothermal project. The high uncertainty of the amount of reserves and costs incurred in geothermal projects is a reason for investors to be reluctant to invest at this stage. One alternative is to use slim hole drilling technology instead of using standard hole or big hole technology. Slim hole drilling technology has long been applied in Indonesia in 1993 but has not continued its application. In 2015, slim hole drilling technology began to be used again at the Ijen geothermal field, East Java. Therefore, it is necessary to review the slim hole drilling, especially the casing design and hoisting rig capacity. The purpose of this study is to design a casing for slim hole KY well drilling, namely determining the casing seat at each depth, calculating the thermal stress value which is considered in calculating burst, collapse, and tension pressures. In addition to the casing design, rig sizing calculations were carried out, especially hoisting rig capacity in field X using slim hole reflection well data in the Ijen area, East Java. The results obtained are the determination of the minimum casing setting depth for the production liner 1500 m grade L-80, production casing 680 m, grade L-80, surface casing 240 m grade K-55, and conductor casing 30 m grade K-55, the results of thermal stress analysis, the maximum temperature obtained in the production casing is 425.3°F and the production liner is 426.67°F.

Keyword: Exploration Drilling; Geothermal; Casing Design

INTRODUCTION

Exploration activities on the geothermal industry are the first stages in geothermal development projects and play an important role in the longevity and continuation of such a geothermal industry. One of the activities carried out on the exploration phase was drilling (Daniel Adityatama, 2019). The drilling of exploration is one of the activities of the high-cost phase of exploration and of high uncertainty. The high costs that must be incurred on exploration operations as well as high uncertainty are a major consideration for investors’ choice of the slim hole (small diameter) exploratory drilling technology. In Indonesia, the first slim hole geothermal exploration technology was successfully applied to in 1970 and not continued to develop until 2015, the slim hole’s exploratory drilling technology was once again used in the intelligence field (east Java). At the very least, the exploration of slim hole in Indonesia, the study aims to prepare the drilling of the exploratory well of slim hole the geothermal hole that is focused on the design of the casing (seating completion, thermal stress analysis, burst load, collapse load, and tension load).

METHODOLOGY

The purpose of this study is to determine the casing shoes setting depth, thermal stress on casing design of geothermal slim hole well, determine the grade of the casing strength, and calculate the burst load, collapse load, and tension load. The data used are BPD pressure (boiling point depth pressure), BPD temperature (boiling point depth temperature), hydrostatics and pore pressure gradients of the reference well in the X geothermal field. The factor to consider is the G data survey of geology to determine the point of exploration. The combination can also be judged by pressure formation, geology, the depth of the bottling well hole, the temperature of the formation, and the thermal stress factor.
which results in the closing to casing grade and casing weights of a geothermal exploration well. The design of the casing is included in the larger casing, the weight casing, and also the composite Settings. These things need to be considered to calculate the pressure loads of the burst, collapse, and the axial that caused the casing to be able to survive while drilling into an exploration or production. Another factor to consider is the corrosion factor that can occur in the casing. The design of the casing is a significant factor in the success or failure of an exploratory well at drill. For the expense incurred, the design of the casing was siced or considered at about 20-30% of the total cost of an exploratory well or production well to be drilled (Abdirazak Omar Moumin, 2013).

RESULT AND DISCUSSION
1. Geothermal casing shoes depth selection
In determining the depth of the casing in the slim hole exploration well in field X, here by determining the pressure and temperature boiling point depth (BPD) (John Lubuva, 2018) fracturing pressure and pore pressure at a certain depth with a known water level value of 307 m below sea level and a top of reservoir located at a depth of 1,000 m. The purpose of installing the production casing above from the top of the reservoir is to prevent swelling clay from occurring in the production casing series. To determine the value of the BPD temperature, obtained from the leak of test (LOT) data from other wells which is valid data. For the value of the BPD pressure, it is obtained from the BPD temperature based on the depth of the well obtained from the steam table where there is an increase in the BPD temperature and also the BPD pressure after passing the water level depth limit of 307 m. Based on the minimum casing shoe depth method, the determination of the casing shoe depth is only divided into 3 position intervals (sections), namely conductor casing, surface casing, and production casing. Production liners are not included in the determination of the casing position because after installation of the production casing where the casing shoe depth is 680 m, the liner will then be used to a total depth of 1,500 m.

1. Conductor Casing
Conductor casing is installed as an initial step in the design of casing for slim hole exploration wells in field X. Conductor casing is installed before the rig enters the drilling zone and is installed using a hammer pounded into the ground. For the conductor casing it has a depth of 30 m TVD (98.42 ft) for the minimum casing shoe depth.

2. Surface casing
Surface casing is the second series that is installed in the slim hole exploration well in field X. Where, the function of the surface casing itself is to place the Blow Out Preventer (BOP). According to the casing seat chart, the depth of the surface casing is 240 m TVD (787.4 ft) for the minimum casing shoe depth.

3. Production casing
Production casing is the longest casing series and is placed in the productive zone. Where, this production casing is cemented from the bottom of the hole to the surface. According to the casing seat chart for the slim hole exploration well in field X, the minimum casing shoe depth is at a depth of 680 m TVD (2,230.9 ft).

4. Liner
For the casing design for this slim hole exploration well, a liner is used in the productive layer which has the advantage that no cementing is needed. The liner here is installed from a depth of 700 m (minimum casing shoe depth for production casing) suspended to a depth of 1,500 m where this depth is the total depth drilled.

Figure 1. Graphic of determining casing seat for KY Geothermal slim hole exploration well on field “X”

Figure 2. Graphic of BPD Temperature and BPD Pressure reference well
2. Thermal Stress Analysis
Thermal stress analysis is only carried out on the production casing and production liner because the hot fluid only passes through the production casing and production liner. Meanwhile, parts of the conductor casing and surface casing are not calculated for thermal stress because the fluid does not pass through the section because the casing condition at that time was already cemented.

a. Thermal stress production casing
In the production casing, here we use steel for the casing. Where, for steel itself, it has a Young’s modulus of $1.1 \times 10^{11}$ N/m² converted to psi of 15,954,151.15 psi and the thermal coefficient ($\beta$) of steel is $5.67 \times 10^{-6}$ F⁻¹.

The calculation of the thermal stress value in the production casing is as follows:
- Maximum temperature: 460.4°F
- Embedding temperature: 100°F
- Temperature difference: 360.4°F
- Tension ($\sigma$): $\beta \times E \times \Delta T$

Or:

| Temperature (F) | Degradation | Reduction (%) | Degradation (Psi) | $\sigma$ |
|----------------|-------------|---------------|-------------------|----------|
| 200            | 0.93        | 7             | 74400             | 224.00   |
| 300            | 0.88        | 12            | 70400             | 400.00   |
| 400            | 0.83        | 17            | 66400             | 600.00   |
| 460.4          | 0.7998      | 20.02         | 63984             | 720.80   |
| 500            | 0.78        | 22            | 62400             | 800.00   |
| 600            | 0.73        | 27            | 58400             | 100.00   |

Table 1. Decreased yield strength in 7” production casing

b. Thermal Stress Production Liner
In the production liner, here we also use steel for the liner. Where, for steel itself, it has a Young's modulus of $1.1 \times 10^{11}$ N/m² converted to psi of 15,954,151.15 psi and the thermal coefficient ($\beta$) of steel is $5.67 \times 10^{-6}$ F⁻¹.

The calculation of the thermal stress value on the production liner is as follows:
- Maximum temperature: 582.1°F
- Embedding temperature: 100°F
- Temperature difference: 482.1°F
- Tension ($\sigma$): $\beta \times E \times \Delta T$

Or:

| Temperature (F) | Degradation | Reduction (%) | Degradation (Psi) | $\sigma$ (tension) |
|----------------|-------------|---------------|-------------------|-------------------|
| 200            | 0.93        | 7             | 74400             | 2000.00           |
| 300            | 0.88        | 12            | 70400             | 4000.00           |
| 400            | 0.83        | 17            | 66400             | 6000.00           |
| 460.4          | 0.7998      | 20.02         | 63984             | 8000.00           |
| 500            | 0.78        | 22            | 62400             | 8000.00           |
| 582.10         | 0.7389      | 26.11         | 59115             | 9642.14           |

Table 2. Decreased yield strength in 4½” production liner
Figure 4. Temperature vs tension graphic for Tmax Determination in 4 ½” production casing

Burst Load, Collapse Load, Tension, and Safety Factor

In this part, it will discuss load calculation of casing which functions rather than load calculation casing is to determine the value of the burst and collapse, and the tension of each casing seat there from the conductor casing, surface casing, production casing and production liner and calculate the safety factor for each casing section (John Lubuva, 2018).

\[ P_{burst} = 0.875 \times \left( \frac{2 \times Yp \times t}{D} \right) \]  
(1)

Description:
- \( Yp \) = yield strength from pipe (psi)
- \( t \) = pipe thickness (inch)
- \( D \) = outside diameter of pipe (inch)

The formula above is to calculate the burst load rating. And for collapse load rating formula is

\[ P_{collapse} = Yp \times \left( \frac{F}{D/t} - G \right) \]  
(2)

Description:
- \( Yp \) = yield strength of pipe (psi)
- \( F \) = API transition 1
- \( G \) = API transition 2

Safety factor (SF) is a value that has been determined to allow and ensure that the performance of a casing will always be greater than the expected load. The safety factor itself has different values depending on the operating company and also certain situations. Safety factors for casings that are minimally acceptable or used (NZS, 1991) are:

a. Internal yield (burst) design factors 1.5-1.8
b. Collapse design factors 1.2
c. Tensile design factors 1.5-1.8
d. Compressive factor 1.2.

a. Surface Casing 9 5/8”

For the calculation of the surface casing design with the data obtained is:

- Casing size (OD) = 9
- Type = K-
- 55
- Yield strength = 55,000
- ID = 8
- 2/3”
Weight ppf = 48
Depth m TVD = 240

787.4 ft TVD
BPD pressure =
14.62 psi
BPD temperature =
212°F
Thickness =

½Table 4. Calculation result for collapse load rating and burst load rating surface casing 9 5/8”

| Surface Casing 9 5/8” |   |
|-----------------------|---|
| Burst rating (Surface)| 6793 psi |
| Burst rating (CSD)    | 4415.5 psi |
| Burst load (Surface)  | 603 psi |
| SF                    | 7.55 |
| BPD                   | 620 psi |
| SF                    | 7.12 |
| Collapse rating (Surface) | 1440 psi |
| Collapse rating (CSD) | 1154 psi |
| Collapse load (Annular of cement, mud inside casing) | 300 psi |

| Tension Load |   |
|--------------|---|
| Tension rating | 757722 lb |
| Tension load | 237717.44 lb |
| SF           | 5.71 |

| Burst and Collapse (rating and load) |   |
|--------------------------------------|---|
| Burst rating (CSD)                   | 6250 psi |
| Burst load @surface                  | 5678 psi |
| SF                                   | 3.48 |
| Burst load @CSD                      | 1331 psi |
| SF                                   | 4.27 |

Figure 5. Collapse and burst rating vs collapse and burst load surface casing 9 5/8”

**Table 5.** Calculation result for collapse load rating and burst load rating production casing 7”

**b. Production Casing 7”**

For the calculation of the production casing design with the data obtained is:

**Casing size (OD)** = 7”

**Type** = L-80

**Yield strength** = 80,000

**ID** = 6-3/8”

**Weight** ppf = 23

**Depth** m TVD = 680

2,230.97 ft TVD
BPD pressure = 495.13 psi
BPD temperature = 465.7°F
**Thickness** = ½

Figure 6. Tension rate vs tension load surface casing 9 5/8”

**Figure 5.** Collapse and burst rating vs collapse and burst load surface casing 9 5/8”

**Figure 6.** Tension rate vs tension load surface casing 9 5/8”
Figure 8. Tension rate vs tension load production casing 7"

3. Production Liner 4 ½"
For the calculation of the production liner design with the data obtained is:

Casing size (OD) = 4 ½”
Type = -
Yield strength = 80,000 psi
ID = 4”
Weight = 12-3/5 ppf
Depth = 1,500 m TVD
902.23 ft TVD
BPD pressure =
4921.26 psi
BPD temperature = 582.1ºF
Thicknes = ⅛

Table 6. Calculation result for collapse load rating and burst load rating production liner 4 ½”

| Production Liner L-80 4 1/2 | Burst rating  (Surface) | Burst rating (CSD) |
|-----------------------------|-------------------------|--------------------|
| Tekanan Burst               | 7778                    | 5727.92            |
| Tekanan Collapse            | 5408                    | 3982.7             |
| Tensile load                | 267036                  | 27693.1            |
| Tensile load + Overpull     | 27693.1                 | 127693.1           |
| SF                          | 2.09                    |
CONCLUSION
Based on the results and discussion, it can be concluded as follows:
1. Determination of casing design Shoe depth is divided into 3 intervals (sections) starting from 30 m for conductor casing, 240 m for surface casing, 680 m for production casing, and installation of production liners from casing shoe depth to production casing 680 m to a depth of 1,500 m.
2. The results of the thermal stress analysis carried out on the production casing and production liner sections obtained the maximum temperature in the production casing of 425.3 °F and on the production liner of 426.67 °F. The maximum temperature is used to determine the casing grade used, namely L-80 in the production casing and production liner with a yield strength value of 80,000 psi.
3. Burst and collapse pressures, and tensile loads in each casing section based on the resulting thermal stress analysis, namely burst pressure > collapse pressure and the safety factor value generated by design > from the safety factor of the company's procedures. The burst, collapse, and tensile load pressures on the surface casing, production casing, and production liner are 4,792 psi each; 3,466 psi; 757.222 lbs; 6,250 psi; 3,664 psi; 525,236 lbs and 7,778 psi; 5,408 psi; 267,036 lbs. safety factor that has taken into account the situation when the annulus is full of cement, mud in the casing; the annulus is filled with cement, water in the casing; and annulus filled with cement, empty casing, on the surface casing, production casing, and production liner each 5.51; 6.57; and 2.09.

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