

Casing Design using the Maximum Load Method on Offshore Development Wells

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ABSTRACT

Pore pressure and fracture gradient analysis is needed to plan the casing setting depth and to determine the number of casing sections that will be run into the drilling well. The maximum load method was used to design the casing for the Furak well. The purpose of this casing design is to avoid burst, collapse, tension and biaxial problems during drilling operations. Furak well is an offshore development well which is planned to be drilled. The total depth of when measured from the rotary table is 9840 TVD, and measured from sea bed 9332 TVD to seawater depth 442 ft. The casing setting depth for conductor casing is 502 ft from the seabed and recommended conductor casing string diameter 20 Inc., grade H-80 pounder 94 lbf, connection type with short thread coupling (STC). The casing setting depth for the surface casing is 1987 ft from the seabed and recommended surface casing string diameter 16 Inc., grades are top of casing grade N-80 pounder 84 lbf, middle of casing grade K-55 pounder 75 lbf, and bottom of casing grade H-40 pounder 65 lbf, connection type with short thread coupling (STC). The casing setting depth for the intermediate casing is 5962 ft from the seabed and recommended intermediate casing string diameter 10.75 Inc., grades are top of casing grade N-80 pounder 55.5 lbf, middle of casing grade K-55 pounder 45.5 lbf, and bottom of casing grade H-40 pounder 40.5 lbf, connection type with short thread coupling (STC). The casing setting depth for the production casing is 9332 ft from the seabed and recommended surface casing string diameter 7 Inc., grades are top of casing grade P-110 pounder 38 lbf, middle of casing grade HCN-80 pounder 32 lbf, and bottom of casing grade L-80 pounder 26 lbf, connection type with long thread coupling (LTC).

Keywords: casing design, maximum load, burst load, collapse load, tension load, biaxial load.

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1. Introduction

Casing planning is an important aspect in drilling activities oil, gas and geothermal in onshore and offshore. Especially for offshore drilling and production, the depth of seawater will also affect for the casing design (Kotow, et. al., 2018). Casing string that is run into the borehole must be based on the standard classification set by the America Petroleum Institute (API5CT., 2005). The main objective of the casing design is to obtain a casing string that can protect the well during drilling operations continued in the production operation phase for a long period of time (Fertl., 1975). Pore pressure and fracture gradient analysis is needed to plan the casing setting depth and to determine the number of casing sections that will be run into the drilling well (Chukwudi, et. al., 2018). Burst loads, collapse loads, tension loads and biaxial loads are planned after determining the casing setting depth (Large. et. al., 1997). Drilling fluid (mud and cement) properties, rate of penetration, trajectory and formation properties are also other factors that can affect casing during drilling (Cahill, et. al., 2021). Temperature, pressure, salt content and non-salt content can affect the casing during production (Coker, et. al., 2020). To drill deep and ultradeep offshore wells that often encounter narrow and challenging operating windows used controlled annual mud level (CAML) is a managed-pressure drilling technology, to control the bottomhole

pressure (BHP) during drilling operations uses a submersible pump to change the liquid level in the riser (Nguyen, et. al., 2017). In general, there are two methods commonly used in casing design, including the maximum load method and the minimum load method (BG Group., 2001). The results of calculations using these two methods will be seen according to the safety factor (SF) which is the safety number of the minimum ratio of casing resistance based on manufacturing, in order to obtain optimal and efficient casing resistance (Moughalu, et. al., 2020). Safety factors based on API standards for casing loading are: burst = 1.1, collapse = 0.85 – 1.125 and tension = 1.6 - 1.8. (Rubiandini., 2012)

2. Literature review

2.1 Casing

Casing is steel pipe specially designed for oil, gas and geothermal wells. The casing is designed based on specifications so that when used it can perform its function properly for multi-zone in vertical wells, directional wells and horizontal wells (Bravkova, et. al., 2017). However, the problem that often arises when drilling and workovers for horizontal, multilateral and deep wells is casing wear (Soong, et. al., 2017). Casing drilling technology, used for wells with geological complications, such as lost circulation or wellbore instability of various nature, this allows to

reduce the time for well construction, reduces the risk of accidents and non-productive time associated with the complication zone (Usmanov, et. al., 2021). In general, the types of casing used include: conductor casing, surface casing, intermediate casing, production casing and liner casing (Herriot-Watt., 2005). Based on American Petroleum Institute (API) standards, casing classification based on specifications includes: diameter, nominal weight, grade and range length (Moore., 1986).

a. Specification of casing diameter

The casing diameter specification includes the casing outside diameter (OD) and the nominal casing wall thickness which defines the unit weight properties. The casing diameter is divided into 3 types, namely outside diameter (OD), inside diameter (ID), and drift diameter (Bourgoyne, et. al., 1986).

b. Specification for nominal weight of the casing

The specification of the nominal weight of the casing is the average weight of a casing and its couplings in unit length. The nominal weight and thickness of the casing determine a large measure of the inner diameter and volume capacity of the casing. The thicker a casing at the same size means the heavier the casing will be and also the thickness of the casing can determine the price of the casing if it is thicker and heavier (Adams., 1985).

c. Specifications of coupling

Coupling specifications can be distinguished based on diameter, grade and thread shape. Several types of casing are reviewed from the coupling and thread according to the API including: round thread coupling (long thread coupling (LTC) and short thread coupling (STC), butress thread coupling, and extreme line thread coupling based on a comprehensive scenario in order to sget optimal results (Pereira, et. al., 2020).

d. Specifications of casing length

The casing length specification is based on standardization classified by the API, and it is possible to adapt it to the needs of the application such as: range 1 with a length of 16 – 25 ft, range 2 with a length of 25 – 34 ft, and range 3 with a length of more than 34 ft (Rabia., 2002).

e. Specifications of casing grade

Casing grade specifications are based on the quality or strength of the material quality of a casing. Each grade has a different chemical composition, so the value of the physical property it has is also different. The higher the grade value of the casing, the higher the yield strength value it has will be. Examples of casing grades are H-40, J-55, K-55, C-75, L-80, N-80, P-110 and V-150. All grades have different diameters, burst ratings, collapse ratings and tension ratings (Bourgoyne, et. al., 1986).

2.2 Design Casing

a. Burst load

Burst load comes from wellhead pressure, mud hydrostatic pressure originating from the drilling fluid column which rises due to the gas column in the well, pressure during cementing and stimulation and if the pressure from within cannot be held by the strength of the casing, the casing will burst, this event called bursting pressure or burst pressure causes the casing to burst (Chineke, et. al., 2021).

b. Collapse load

Collapse pressure is the pressure from outside the casing which comes from the formation pressure which is large enough when the casing is in the well, to measure the formation pressure from the outside is very difficult, so in the calculation to determine the collapse pressure the hydrostatic pressure of the drilling mud is used. If the influence of the pressure outside the casing is greater than the pressure inside, the casing will collapse (Liu, et. al., 2020).

c. Tension load

Tension load is the tensile load caused by the weight of the casing string hanging below it and the largest tension load is experienced by the casing at the surface. The weight of the casing series in the air will be heavier than the casing series in the wellbore due to the effect of the buoyancy factor exerted by the mud on the casing string (Cayeux, et. al., 2021).

d. Biaxial load

In planning the casing, the effect of tension on the collapse reduction is taken into account, but it can also occur in a combination of forces acting on the casing such as burst or collapse loads that occur simultaneously with tension or compression loads. The presence of tension will reduce the collapse resistance and increase the burst resistance. While compression will reduce burst resistance and increase collapse resistance (Romero, et. al., 2020).

3. Methodology

3.1 Data Collection

Furak well is an offshore development well which is planned to be drilled. The total depth of when measured from the rotary table is 9840 TVD, and measured from sea bed 9332 TVD to seawater depth 442 ft. Pore pressure and fracture gradient analysis, hole geometry and drilling mud plans and casing setting depth designs have been made and can be seen in Table 1.

The hole geometry plan for the conductor section with a bit size (hole diameter) of 24 inc used a casing with a size of 20 inc, mud 8.5 ppg depth of 1010 ft from the rotary

table and 502 ft from the seabed. The hole geometry plan for the conductor section with a bit size (hole diameter) of 17.5 inc used a casing with a size of 16 inc, mud 9.4 ppg depth of 2595 ft from the rotary table and 1987 ft from the seabed. The hole geometry plan for the conductor section with a bit size (hole diameter) of 14.75 inc used a casing with a size of 10.75 inc, mud 10 ppg depth of 6470 ft from the rotary table and 5962 ft from the seabed. The hole

geometry plan for the conductor section with a bit size (hole diameter) of 8.75 inc used a casing with a size of 7 inc, mud 9.4 ppg depth of 9840 ft from the rotary table and 9332 ft from the seabed (Azi., 2020)

Table 1. Furak well plan for design casing

Well	Casing setting depth from rotary table (ft)	Casing setting depth from seabed (ft)	Type of casing	Mud plan (ppg)	Hole geometry plan	
					Hole size (in)	Casing size (in)
Furak	1010	502	Conductor	8.5	30	24
	2595	1987	Surface	9.4	20	16
	6470	5962	Intermediate	10	14.75	10.75
	9840	9332	Production	11.3	8.75	7

3.2 Diagram Research

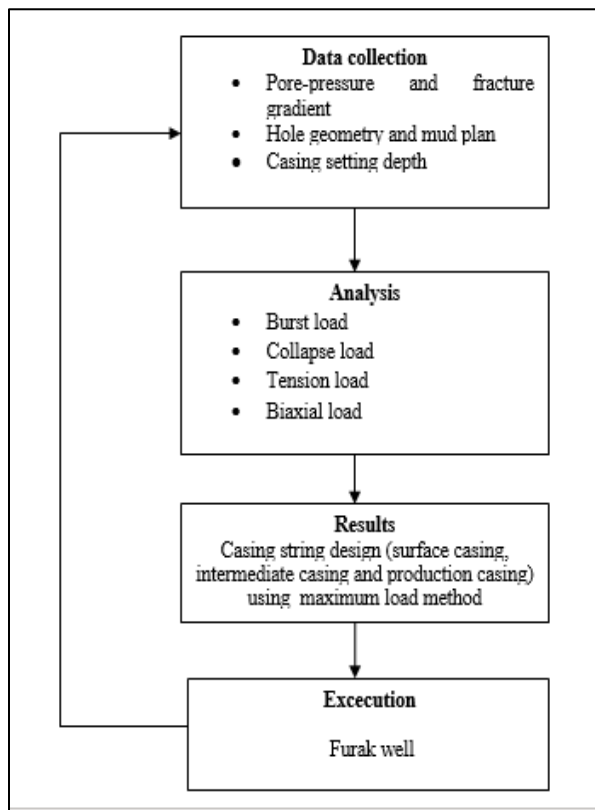


Figure 1. Diagram research casing design Furak well.

4. Result and Discussion

4.1 Conductor Casing

The casing setting depth for conductor casing is 502 ft from the seabed with a formation pressure of 480 psi, and an equivalent mud weight (EMW) of 8.5 ppg. Hole geometry 24 inc, outside diameter casing surface 20 inc, with short thread coupling (STC) connection type. The recommended conductor casing string grade H-80 pounder 94 lbf, burst rating 1530 psi, collapse rating 520 psi and tension rating 1077000 lbf.

4.2 Surface Casing Design

The casing setting depth for the surface casing is 1987 ft from the seabed with a formation pressure of 1100 psi, and an equivalent mud weight (EMW) of 9.4 ppg. Hole geometry 20 inc, outside diameter casing surface 16 inc, with short thread coupling (STC) connection type. The recommended surface casing string grades are top of casing grade N-80 pounder 84 lbf, middle of casing grade K-55 pounder 75 lbf, and bottom of casing grade H-40 pounder 65 lbf.

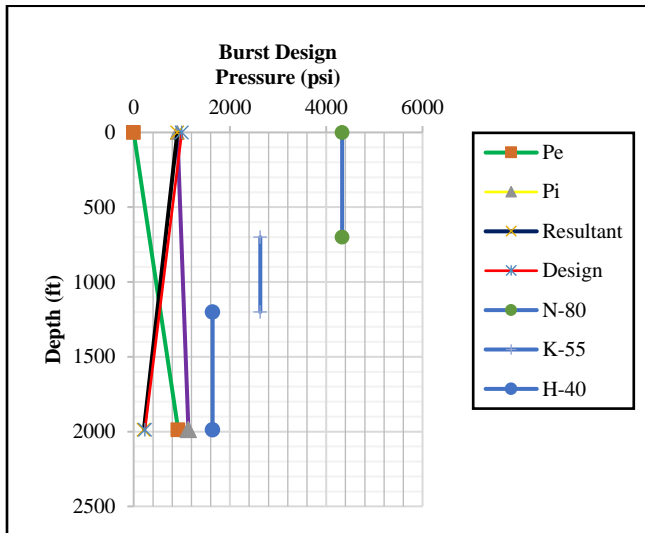


Figure 2. Burst design for surface casing.

The safety factor for the burst load is 1.1 and the casing selected must have a strength exceeding the burst design, so that it is safe to use. Top of casing grade N-80 pounder 84 lbf burst rating 4330 psi, middle of casing grade K-55 pounder 75 lbf burst rating 2630 psi, bottom of casing grade H-40 pounder 65 lbf, burst rating 1640 psi.

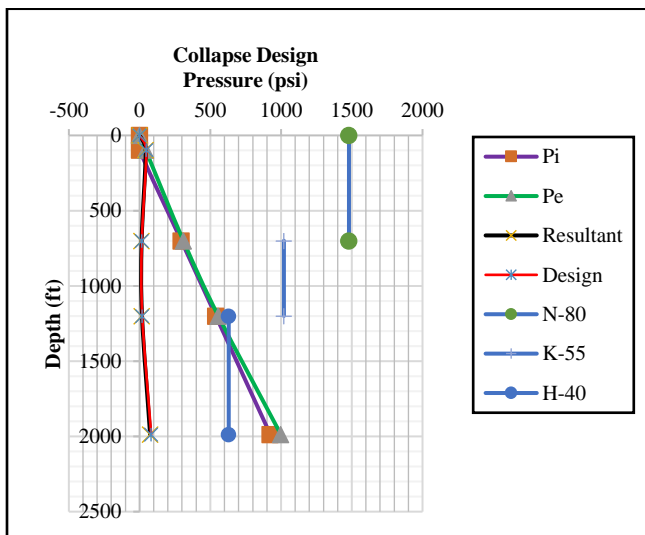


Figure 3. Collapse design for surface casing.

The safety factor for the collapse load is 1.1 and the casing selected must have a strength exceeding the burst design, so that it is safe to use. Top of casing grade N-80 pounder 84 lbf collapse rating 1480 psi, middle of casing grade K-55 pounder 75 lbf collapse rating 1020 psi, bottom of casing grade H-40 pounder 65 lbf, collapse rating 630 psi.

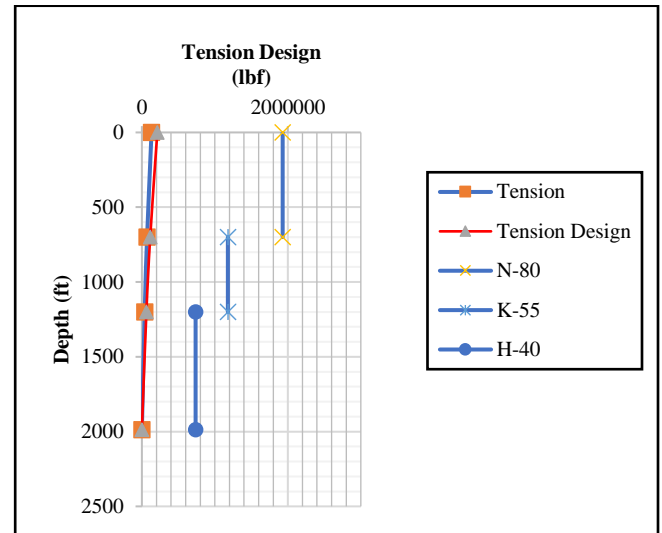


Figure 4. Tension design for surface casing.

The safety factor for the tension load is 1.6 and the casing selected must have a strength exceeding the tension design, so that it is safe to use. Top of casing grade N-80 pounder 84 lbf tension rating 1929000 lbf, middle of casing grade K-55 pounder 75 lbf tension rating 1178000 lbf, bottom of casing grade H-40 pounder 65 lbf, tension rating 736000 lbf.

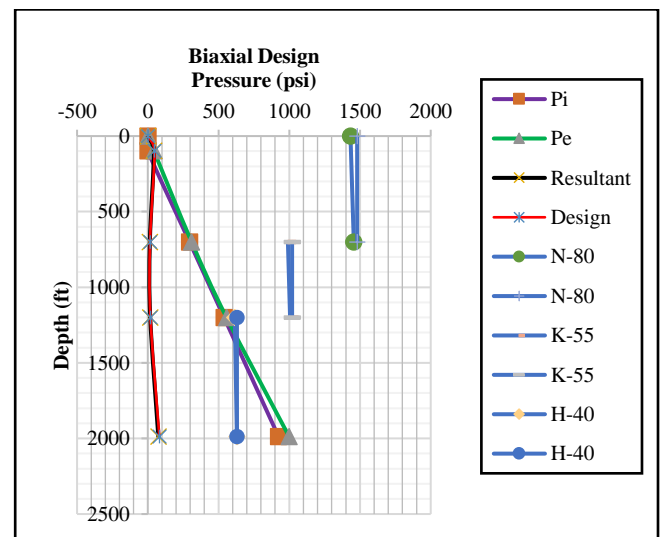


Figure 5. Biaxial design for surface casing.

4.3 Intermediate Casing Design

The casing setting depth for the intermediate casing is 5962 ft from the seabed with a formation pressure of 2977 psi, and an equivalent mud weight (EMW) of 10 ppg. Hole geometry 14.75 inc, outside diameter casing surface 10.75 inc, with short thread coupling (STC) connection type. The recommended surface casing string grades are top of casing

grade N-80 pounder 55.5 lbf, middle of casing grade K-55 pounder 45.5 lbf, and bottom of casing grade H-40 pounder 40.5 lbf.

design, so that it is safe to use. Top of casing grade N-80 pounder 55.5 lbf collapse rating 4020 psi, middle of casing grade K-55 pounder 45.5 lbf collapse rating 2090 psi, bottom of casing grade H-40 pounder 40.5 lbf, collapse rating 1390 psi.

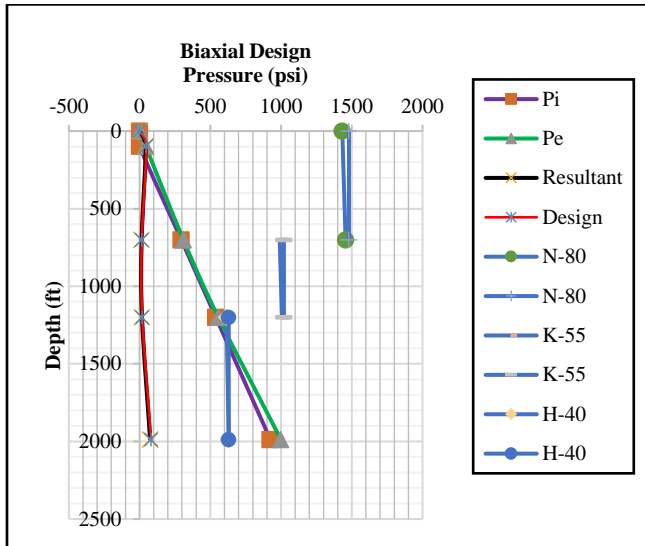


Figure 6. Burst design for intermediate casing.

The safety factor for the burst load is 1.1 and the casing selected must have a strength exceeding the burst design, so that it is safe to use. Top of casing grade N-80 pounder 55.5 lbf burst rating 6450 psi, middle of casing grade K-55 pounder 45.5 lbf burst rating 3580 psi, bottom of casing grade H-40 pounder 40.5 lbf, burst rating 2280 psi.

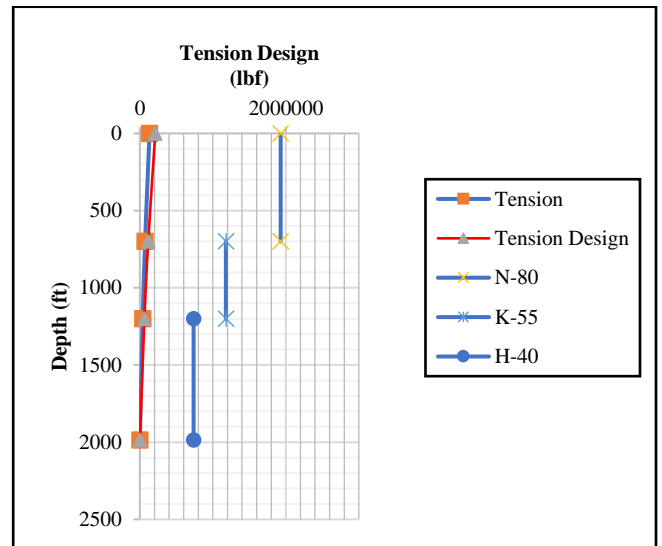


Figure 8. Tension design for intermediate casing.

The safety factor for the tension load is 1.6 and the casing selected must have a strength exceeding the tension design, so that it is safe to use. Top of casing grade N-80 pounder 55.5 lbf tension rating 1276000 lbf, middle of casing grade K-55 pounder 45.5 lbf tension rating 715000 lbf, bottom of casing grade H-40 pounder 40.5 lbf, tension rating 457000 lbf.

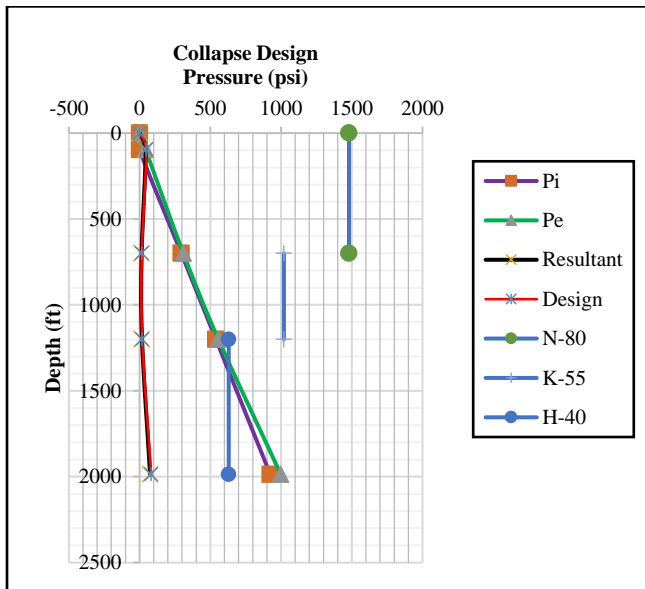


Figure 7. Collapse design for intermediate casing.

The safety factor for the collapse load is 1.1 and the casing selected must have a strength exceeding the collapse

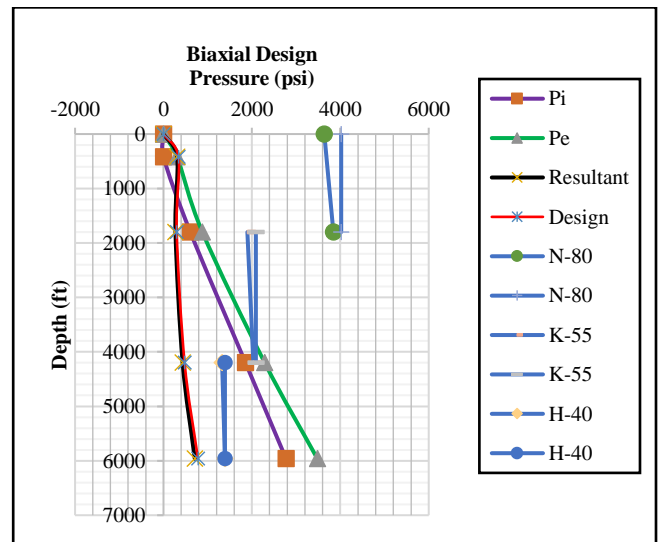


Figure 9. Biaxial design for intermediate casing

4.4 Production Casing Design

The casing setting depth for the production casing is 9332 ft from the seabed with a formation pressure of 4480 psi, and an equivalent mud weight (EMW) of 11.3 ppg. Hole geometry 8.75 inc, outside diameter casing surface 7 inc, with long thread coupling (LTC) connection type. The recommended surface casing string grades are top of casing grade P-110 pounder 38 lbf, middle of casing grade HCN-80 pounder 32 lbf, and bottom of casing grade L-80 pounder 26 lbf.

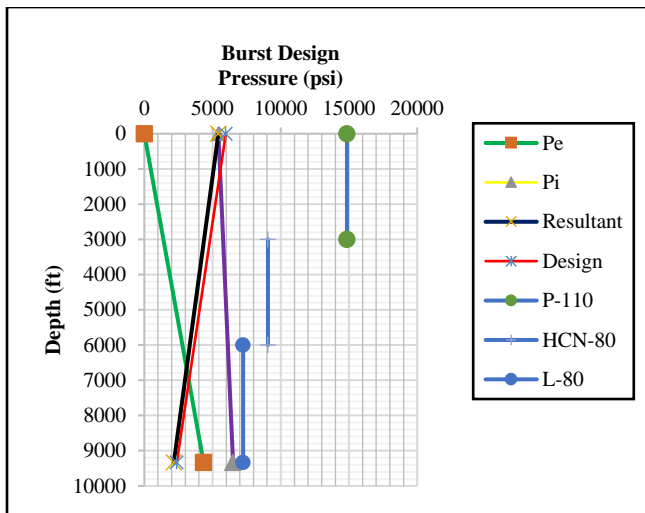


Figure 10. Burst design for production casing.

The safety factor for the burst load is 1.1 and the casing selected must have a strength exceeding the burst design, so that it is safe to use. Top of casing grade P-110 pounder 38 lbf burst rating 14850 psi, middle of casing grade HCN-80 pounder 32 lbf burst rating 9060 psi, bottom of casing grade L-80 pounder 26 lbf, burst rating 7240 psi.

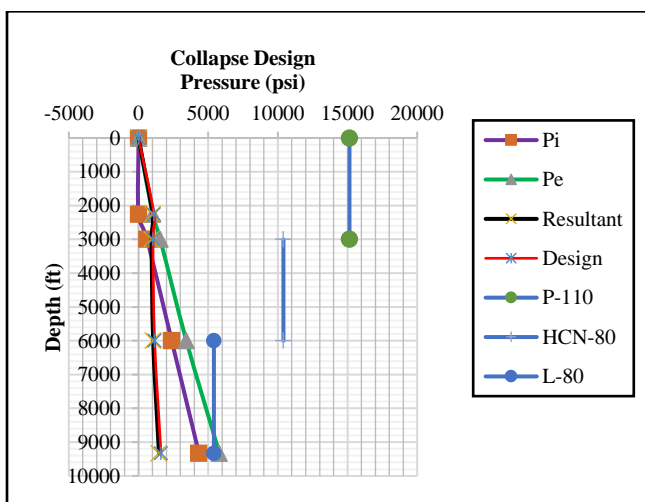


Figure 11. Collapse design for production casing

The safety factor for the collapse load is 1.1 and the casing selected must have a strength exceeding the collapse design, so that it is safe to use. Top of casing grade P-110 pounder 38 lbf collapse rating 15140 psi, middle of casing grade HCN-80 pounder 32 lbf collapse rating 2090 psi, bottom of casing grade L-80 pounder 26 lbf, collapse rating 5410 psi.

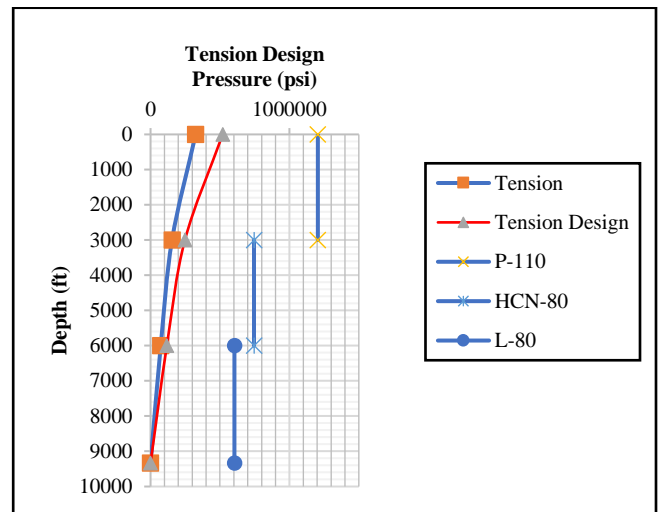


Figure 12. Tension design for production casing.

The safety factor for the tension load is 1.6 and the casing selected must have a strength exceeding the tension design, so that it is safe to use. Top of casing grade P-110 pounder 38 lbf tension rating 1205000 lbf, middle of casing grade HCN-80 pounder 32 lbf tension rating 745000 lbf, bottom of casing grade L-80 pounder 26 lbf, tension rating 604000 lbf.

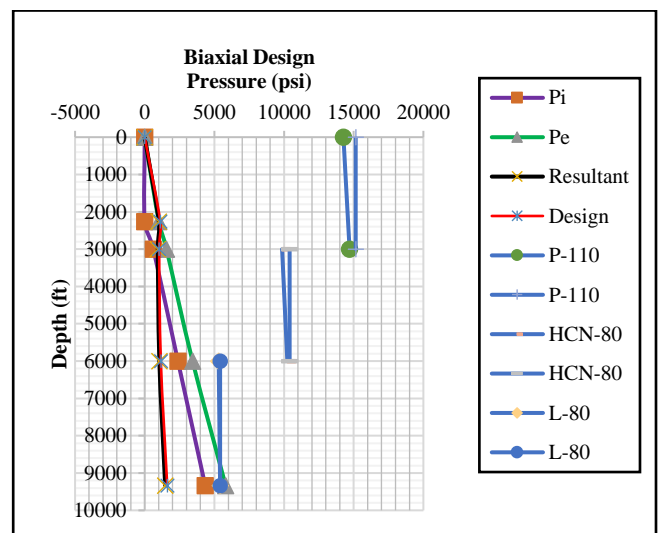


Figure 13. Biaxial design for production casing

5 Conclusion and Future Research

5.1 Conclusion

- a. The casing setting depth for conductor casing is 502 ft from the seabed with a formation pressure of 480 psi. The recommended conductor casing string grade H-80 pounder 94 lbf, connection type with short thread coupling (STC) and outside diameter casing 20 inc.
- b. The casing setting depth for the surface casing is 1987 ft from the seabed with a formation pressure of 1100 psi. The recommended surface casing string grades are top of casing grade N-80 pounder 84 lbf, middle of casing grade K-55 pounder 75 lbf, and bottom of casing grade H-40 pounder 65 lbf, connection type short thread coupling (STC) and outside diameter casing 16 inc.
- c. The casing setting depth for the intermediate casing is 5962 ft from the seabed with a formation pressure of 2977 psi. The recommended surface casing string grades are top of casing grade N-80 pounder 55.5 lbf, middle of casing grade K-55 pounder 45.5 lbf, and bottom of casing grade H-40 pounder 40.5 lbf, connection type short thread coupling (STC) and outside diameter casing 10.75 inc.
- d. The casing setting depth for the production casing is 9332 ft from the seabed with a formation pressure of 4480 psi. The recommended surface casing string grades are top of casing grade P-110 pounder 38 lbf, middle of casing grade HCN-80 pounder 32 lbf, and bottom of casing grade L-80 pounder 26 lbf, connection type long thread coupling (LTC) and outside diameter casing 7 inc.

5.2 Future Research

This research can be used as a reference in the development of offshore fields, especially for Furak wells.

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