Casing Design for Casing/Liner while Drilling

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Abstract – *Drilling and Completion procedures are time consuming operations after which an oil well can start production. The time consumed by these operations are known as nonproductive time(NPT). Cutting on NPT is every Petroleum engineer's goal. Casing/Liner while drilling is a very good option to precisely minimize the time invested in drilling and completion procedures. This study presents a Casing Design procedure for Casing/Liner while drilling. The selected casing would be able to withstand the loads during drilling and production.*

Key Words: Liner while Drilling, Casing while Drilling, Casing Design.

1.INTRODUCTION

Looking at the current crisis experienced by the petroleum industry and the fall in the prices of crude oil, it is very important to reduce the NPT to increase profits. Also, the days of easy oil are gone by, drilling and exploration in areas which were earlier considered to be "problematic zones" have become unavoidable. While exploring in such zones it is observed that the wellbore collapses before casing and after the drill sting has been pulled out. Casing/liner while drilling helps mitigate both the problems mentioned above.

1.1 Casing while Drilling

Casing while drilling is a type of drilling where, instead of using a conventional drill sting made up of drill pipes, the drill string comprises of the casing. After a particular section is drilled only the BHA is pulled out i.e. in case of a Retrievable BHA. The casing is place and can be cemented, where as in conventional drilling tripping out is required. This helps save time and also deal with the 'thief zones'.

One major disadvantage of casing while drilling is that it requires rig modifications which is again a costly affair. Hence Casing while drilling is a good option only in specific areas.

1.2 Liner while Drilling

In Liner while drilling operations the drill pipes are attached to the liners which are connected to the BHA. This method of drilling is particularly used to avoid the problematic zones. A well can drilled in the conventional manner until just above the thief zone after which Liner while drilling can be employed.

Liner while drilling needs minor rig modification, which can be installed and uninstalled in quickly. Hence, Liner while drilling is a very viable and effective method to reduce NPT and deal with thief zones.

2. Methodology

First step towards the casing design procedure for C/LWD is the initial well data,

- Overburden gradient
- Mud weight
- Temperature gradient & surface temperature
- Formation fluid density
- Formation fracture gradient
- Pore pressure gradient
- Well profile and casing sections

These parameters will help in the determination of the Drilling window

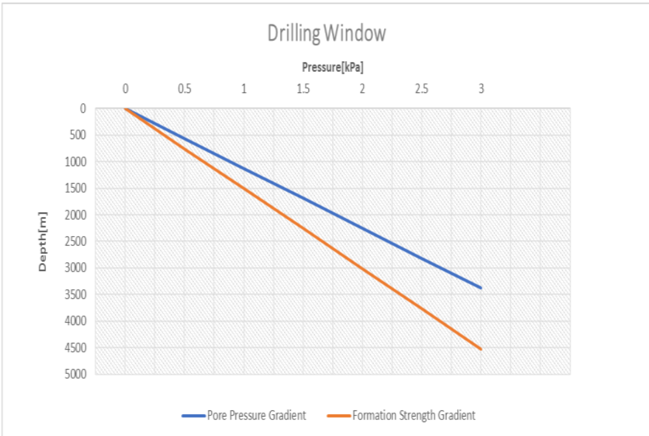


Figure -1: Drilling window

2.1 Casing Design Load (worst scenario case)

Assuming that the well profile has three sections of casing,

- Surface
- Intermediate
- Liner

Collapse load is first calculated for the surface casing, collapse at the surface will be zero.
Collapse at the casing shoe,
= Mud gradient * Depth of casing shoe(Dcs)
Hence,design collapse load will be,
= Collapse at casing shoe * F.O.S

F.O.S for collapse is generally 1.1-1.25

Burst load, the burst load at casing shoe
= internal pressure – external pressure
Where,
Internal pressure = Fracture gradient * Dcs
External pressure = Fresh water gradient * Dcs

Design Burst at cs = F.O.S * Burst load at cs
F.O.S for burst load is generally 1.2-1.8
Burst load at surface,
= internal pr * exp [(g*M(h2-h1))/(Z*R*Tavg)] * F.O.S
Similar procedure has to be followed for the other two sections of casings.

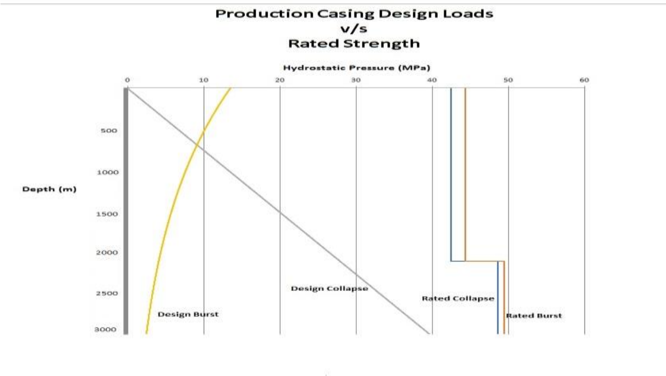
2.2 Casing selection based on uniaxial loading

Based on the calculated worst case collapse and burst loads, casing steel grades have to be selected from API-5CT. The selected casing steel grades have to be then checked for their Collapse and burst strength to see if they can withstand the expected design loads.
If we start with surface casing, the D/t ratio is to be calculated first,
D/t = Diameter/nominal thickness

D/t ratio will help to choose the Collapse strength formula and constants based on which range the ratio falls in i.e Plastic,Elastic or Transition rage formulae.
Assuming its transition range we carry forward the calculations,

Collapse strength, PT = Yield strength * [(F/(D/t)) – G]
Burst strength, p = 0.875 [(2Yp * T)/D]

Same procedure is to be repeated for intermediate and liner sections. A plot of design loads vs production loads would let us know if the casing steel grade withstands the uniaxial loading criteria.



2.3 Axial Loading

Axial load is to be calculated separately for each section of casing,

Axial Load = Buoyed Unit Weight * Depth
Where, Buoyed Unit Weight in lblft

$$\text{Wt of casing in air} * \left(1 - \left(\frac{\text{Density of mud}}{\text{density of steel}}\right)\right)$$

To convert it to newtons multiply by 32.17/4.448

Axial load in hold section = buoyed wt*depth*COS angle
Design Axial Load = Axial load * 1.8 (F.O.S)
Axial load due to bending,
= Young's Modulus * (r/R)
r = outer radius of casing in the bent section
R = radius of curvature of well bore.

Total Axial Load = Axial load at top of hold section + Axial load due to Build-up section + Axial load due to bending
Design Axial load = total axial load * F.O.S
If the design axial load is less than the Yield strength of the material then the steel grade can withstand the load.

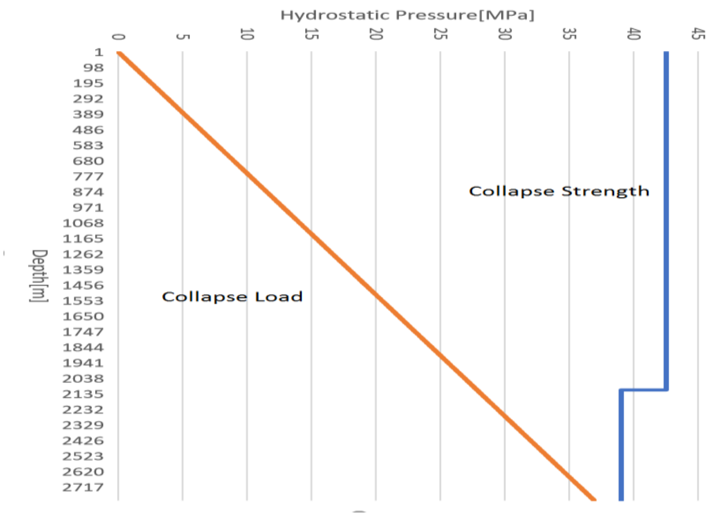
2.4 Combined Loading

Collapse with axial load

$$Y_{Pa} = [\sqrt{1 - 0.75(sa/yp)2 - 0.75(sa/yp)}]*yp$$

Sa= total axial load without F.O.S
Yp= yield strength of steel grade

Collapse(rated) strength, PT = Y_{Pa} * [(F/(D/t)) – G]
A graph Design load vs Rated strength plotted to check if the casing steel grade withstands the design collapse.



Plot of Design Load vs. Rated Strength for Collapse

2.5 Von Mises Analysis for Burst Loading

Axial load due to bending,
= Young's Modulus * (r/R)

r = inner radius of casing in the bent section

R = radius of curvature of well bore.

Total Axial Load = Axial load at top of hold section + Axial load due to Build-up section + Axial load due to bending

Design Axial load = total axial load * F.O.S

Further axial stress, hoop stress and radial stress are calculated for every 30m

Axial stress(A) = (4*Axial load)/(pi*(D_O-D_I)

Hoop stress(H)

$= [(r_i^2+(r_i^2 r_o^2)/(r_o^2- r_i^2)]p_i - [(r_o^2+(r_i^2 r_o^2)/(r_o^2- r_i^2)]p_o$

Radial stress(R)

$= [(r_i^2-(r_i^2 r_o^2)/(r_o^2- r_i^2)]p_i - [(r_o^2+(r_i^2 r_o^2)/(r_o^2- r_i^2)]p_o$

Then calculate the Von Mises Stress

$=[(R-H)^2+(A-R)^2+(H-A)^2]^{1/2}/ 2$

If the calculated VM stress is lesser than the Yield strength of the steel grade then the casin can withstand the stress.

Torque and Drag Analysis

T & D analysis can be done on the basis of the soft string or the standard model i.e. Johancsik equations

$F_n = F_0 + \Sigma[(s_i-s_{i-1})wi \cos((a_{i-1}+a_i)/2)+m_iN_i]$

$T_n= T_o + \Sigma r_i\ m_iN_i$

$N_i = (s_i-s_{i-1})\{[wi \sin((a_{i-1}+a_i)/2)+F_i((a_{i-1}+a_i)/ (s_i-s_{i-1}))]+[\sin((a_{i-1}+a_i)/2) F_i((b_{i-1}-b_i)/ (s_i-s_{i-1}))]$

Where,

F_i axial load at node I, N
w buoyed specific weight of casing, N
s distance coordinate measured depth, m
m friction coefficient
a inclination angle, radians
b azimuth angle, radians
T torque, Nm

2.6 Axial Loading due to Drag Forces

Total Axial load = F_n + Axial load due to bending

If Total Axial load * F.O.S < yield strength, then the casing grade can withstand the loads.

Collapse including Drag forces,

$Y_{Pad} =[\sqrt{1-0.75(sa/yp)2-0.75(sa/yp)}]*yp$

Sa = axial load including drag

Using Y_{Pad} to find collapse load,

$PT = Y_{Pad} * [(F/(D/t)) - G]$

If PT is within the design collapse, then the operator may consider the casing steel grade for the casing of the well section.

3. CONCLUSIONS

This procedure can be used for casing design for Casing/Liner while drilling. The inclusion of whirling and buckling analysis and surge and swab loads will make it more realistic. Also Torque and Drag analysis can be carried out by using Stiff string model and a comparative study can be done.

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