25/18

University of Stavanger

FACULTY OF SCIENCE AND TECHNOLOGY

SUBJECT: PET 535: MODERN WELL DESIGN

DATE: SEPTEMBER 10 , 2015

TIME: 0900 - 1300

AID: CALCULATOR

THE EXAM CONSISTS OF 6 PAGES

REMARKS: PLEASE STATE ASSUMPTIONS

Problem 1: Design of the Production Casing

We will design the production casing of a well. The following data applies:

9-5/8 in. 47 lbs/ft P110	
Weight:	68.73 kg/m
Burst strength:	651 bar
Collapse:	366 bar
Tension:	6590 kN
Mud weight:	1,60 s.g. on in/outside of csg.
Inner diam.	220,5 mm
Setting depth:	2909 mMD, 2350 mTVD
Depth next hole:	3341 mMD, 2655 mTVD
Cemented interval:	2131 – 2909 mMD, 1800 - 2350 mTVD
Produktion packer at	2414 mMD, 2000 mTVD
Gas density negligible.	
bar x cm^2 = daN	

The well is vertical down to 1000 m, followed by a sharp build up. From 1000 m to the bottom assume a constant inclination of 45 degrees.

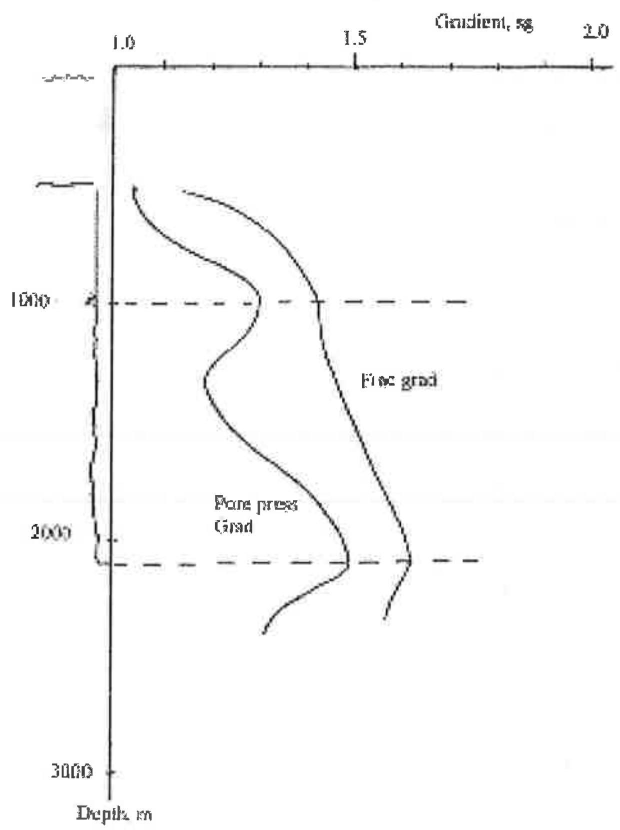
Assume that the well is drilled from a jack-up rig with 25 m airgap. Use the enclosed prognosis. Please write all assumptions.

a) Prepare a figure of the well and define two criteria for burst of the production casing, and determine the safety factor.

b) Decide a criterion for collapse and determine the factor of safety.

a) Determine the total weight in air of the casing string, and the buoyed weight in the well. Determine the factor of safety. Bending may be neglected.

d) The reservoir has a vertical extent of 50 m. Propose a drilled length below the reservoir. Explain why.



Problem 2: Casing strength

The following casing types are available:

Size(in):	Grade, weight(lb/ft):	Outer diam.(mm):	Inner diam.(mm)
20	P110, 133	508	475,7
13-3/8	K55,88.2	346.1	314.3
10-3/4	N80, 60.7	273	245.4
7	L80, 20	177.8	164

a) Compute the burst strength of each casing. List the casings from strongest to weakest in burst.

b) Are these casings suitable for use in the same well? Explain which of the casings could be replaced, and indicate if it should be stronger or weaker.

c) A closed pipe is pressurized from the inside. Define two failure modes, and show which failure mode is dominating.

Problem 3: Hydraulics

a) In the hydraulic system of the drilling rig, is the flow mostly laminar or mostly turbulent? Provide you answer with an example.

b) Which parameter contributes mostly to the pressure drop, viscosity or density of the drilling fluid? Explain.

c) Comparing ordinary rotary drilling with drilling with a motor, are there any differences. If yes, identify one important difference.

d) The drill string is changed from 3.5 in to 5 in in a well. Identify three improvements in the hydraulic system.

e) Define an equation for mechanical power and one for hydraulic power. Define the variables.

Problem 4: Mud weight optimalization

a) Define the two classical limits for the mud weight. What are the failure mechanisms?

b) Using a simple fracturing equation, define the new optimization criterion presented in this course. What is this criterion called?

c) Define two advantages of using this criterion. Also define two concerns.

d) In the figure on the following page propose a mud weight schedule.

Problem 5: Temperature induced pressures

One problem with subsea wellheads is the potential of trapped pressures. The pressure inside the B-annulus may increase due to thermal effects. In the following you are asked to investigate this as follows:

a) Show the relationship between pressure increase and temperature increase. Explain the conditions for the equation.
b) Assume that the coefficient of thermal expansion is $3x10^{-4}$ (1/°C), and the compressibility coefficient is $-3x10^{-5}$(1/bar). Compute the pressure increase if bottomhole temperature remains constant but the surface temperature has increased 100 °C

Some Formulas

$P(bar) = 0.098 \times d(s.g.) \times D(m)$

$P_3 = Cq^m$

$P_2 = \rho q^2/2A^2 0.95^2$

Index:	Equation:	Criterion:	Fraction parasitic pressure loss:	Flow rate:
1	qP_2	Max. HP	1/(m+1)	$P_1/C(m+1)$
2	$q\sqrt{P_2}$	Max. jet impact	2/(m+2)	$2P_1/C(m+2)$
3	$q3/2\sqrt{P_2}$	New A	3/(m+3)	$3P_1/C(m+3)$
4	$q^2\sqrt{P_2}$	New B	4/(m+4)	$4P_1/C(m+4)$
5	$q^{5/2}\sqrt{P_2}$	New C	5/(m+5)	$5P_1/C(m+5)$

$A = q\{\rho/2P_2\}^{1/2}/0.95$

Using the units of: density(kg/l), flowrate (l/min) and pressure (bar), the nozzle area in in^2 can be obtained by dividing the equation above with 122.4.

$d_{RKB1} = d_{RKB2}D/(D-\delta h)$

$LOT = 2\sigma_a - P_o$

$P_{wf}(\gamma) = P_{wf}(0) + {}^1/_3\,(P_o - P_o^*)\sin^2\gamma$

$P_{wf}(0) = \{P_{wf}(\gamma) + (\sigma_o - 1/2P_o)\sin^2\gamma\}/\{1 + 1/2\sin^2\gamma\}$

$\Delta\sigma_a = \Delta P_o(1-2\nu)/(1-\nu)$

$\Delta P_{wf} = \Delta P_o(1-3\nu)/(1-\nu)$

$P_{burst} = 2\sigma_{tensile}\, t/D_o$

$P_{collapse} = \{2CE/1 - \nu^2\}\{1/(D_o/t - 1)^2 D_o/t\}$

$(\sigma_t/\sigma_{yield}) = 1/2(\sigma_a/\sigma_{yield}) \; +/-\{1 - 3/4(\sigma_a/\sigma_{yield})^2\}^{1/2}$

$\rho = (d_p D - 1.03h_w)/(D - h_f - h_w)$

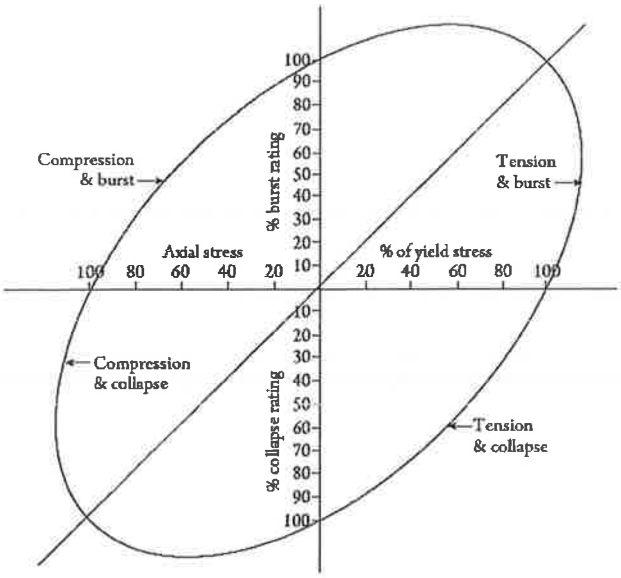
$$d_{wf2} = d_{wf1}\frac{D_1}{D_2} + d_{sw}\frac{D_{w2} - D_{w1}}{D_2}$$
$$D_2 = D_1 + (D_{w2} - D_{w1}) + (D_{f2} - D_{f1})$$

$$D_2 = D_1 + (D_{w2} - D_{w1}) + (D_{f2} - D_{f1}) + \left(\frac{d_{ob1}}{d_{ob2}} - 1\right)(D_1 - D_{w1} - D_{f1})$$

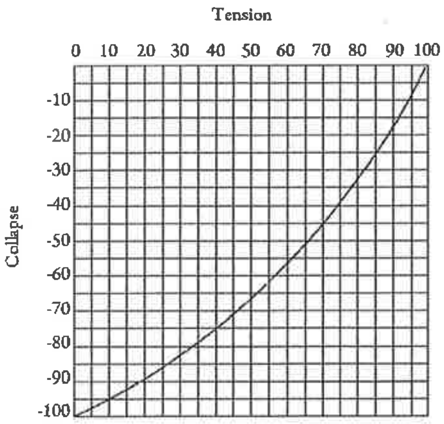
$$\frac{\Delta V}{V} = \frac{1}{2}\alpha\Delta T$$
$$\Delta P = \left(\frac{-1}{c}\right)\frac{\Delta V}{V}$$

Units

1 bar = 14.5 psi = 10^5 Pa
1 ft = 0.3048 m = 12 in
1 lb_f = 0.454 kp = 4.45 N



Compression
& burst
Tension
& burst
% burst rating
Axial stress
% of yield stress
100 80 60 40 20
20 40 60 80 100
10 20 30 40 50 60 70 80 90 100
Compression
& collapse
% collapse rating
Tension
& collapse



Tension
0 10 20 30 40 50 60 70 80 90 100
Collapse
-10 -20 -30 -40 -50 -60 -70 -80 -90 -100

Problem 5: Data normalization

You are planning a subsea infill well in a production field. Your design is based on data from the production platform which has a wellhead elevation of 120 m. You are going to use a jackup drilling rig with a air gap of 40 m. The water depth is 300 m. The data from the production platform are:

Pore press. Grad.(sg)	0.82	0.90	0.95	1.10	1.15	1.20
Depth(m)	500	700	900	1100	1300	1500

a) Define the normalization equations.

b) Normalise the pore pressure gradient to drillfloor level and sea level. Show all three curves in a plot.

c) Connect each data point with a curve for the three reference levels. Explain the meaning of this curve. What do we call this curve?

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