**DET TEKNISK – NATURVITENSKAPELIGE FAKULTET**

Universitetet i Stavanger

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| **SUBJECT:** | **PET100 BORING** |
| **DATE:** | **28.02.2020** |
| **TIME:** | **09:00 – 13:00 (4 Hours)** |
| **AID:** | **Approved Calculator** |

**THE EXAM CONSISTS OF 19 PAGES IN TOTAL;** 7 PAGES WITH TASKS, 1 PAGE WITH FORMULAE, 10 PAGES WITH TABLES AND 1 PAGE WITH ANSWER SHEET TO THE MULTIPLE CHOICE QUESTIONS.
**NB! THE ANSWER SHEET MUST BE TORN OFF AND DELIVERED TOGETHER WITH THE REST OF THE EXAM ANSWERS.**

***NOTE: All 4 tasks count equally, i.e. each task counts 25%. Quickly read through the whole exam before beginning to solve the questions, and figure out if there is anything that needs to be clarified with the teacher. Plan your time usage so that each section gets the necessary time and attention.***

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## *TASK 1 Axial load*

A vertical well will be drilled down to 3400m below drillfloor on a fixed platform. The mud density is 1230 kg/m$^3$, and the viscosity is 25 cP. We're going to use 4.5", 20.00 lb/ft, premium grade G105 drillpipe, with NC50(IF) connections. We will also use 150m of 6.75" drill collar, with inner diameter of 2.75"..

a)
1. Calculate the maximum axial force before the mud circulation starts.
2. What is the safety factor against yielding?

b)
1. We're assuming a reaction force from the nozzles of 6kN. What is the maximum WOB we can allow while drilling, if standard safty margin is to be fulfilled?
2. Give a short explanation for the standard safty margin.

c) During drilling we will have a WOB of 90kN and the a turque of 4kNm. The friction between the drillstring and the formation results in a tourque of 18kNm. The mudpump delivers a pressure of 350 barg. The pressure between the pump and the top of the drillstring can be neglected. What will be the minimum safty factor during drilling process?

d) The travelling block has 6 pulleys and a friction factor of $k_T = 1.042$. The total mass of the travel block and hoisting equipment is 7300 kg. The lift manages to lift the 250 tons BOP with a velosity of 0.3 m/s. Lifting cable being used has a yield point of 920 kN. The transmission efficiency from motor to cable drum is 75%.

1. What will be the force in the fastline when the drill string is pulled out of hole at 3400m depth?
2. How long time does it take to lift one stand (3 times a drillpipe length of 11.5 m)?
3. What is the maximum power (kW) of the motor that is running the lift?

***Multiple choice Task 1 Axial load***

1. Most drilling rigs are required to operate in remote locations where a power supply is not available. They must therefore have a method of generating the electrical power which is used to operate the systems mentioned above. The electrical power generators are driven by:
   a) Gasoline/petrol engines
   b) Gas engines
   c) Diesel engines
   d) Large battery packs

2. Which statement describes buoyancy correctly?
   a) The force acting from the formation towards the drill bit
   b) The force which makes up the elastic tension in the drill string
   c) The weight of drillpipe immersed in drilling fluid
   d) The weight of the displaced fluid

3. Where will the neutral point be if we stop circulating mud and stop drilling?
   a) 1/3 $h_v$ down from the top of the drill collar
   b) The top of the drill collar
   c) The top of the drill string
   d) The bottom of the drill collar

4. Which of the alternatives is not one of the main functions of the drillstring?
   a) To provide a conduit for petroleum fluids to the rig
   b) To suspend the bit
   c) Transmitting rotary torque from the kelly to the bit
   d) To provide a conduit for circulating drilling fluid to the bit

5. How is the relation between the number of pulleys in the travel block and the number of pulleys in the crown block?
   a) The travel block has the same number of pulleys as the crown block
   b) The travel block has one pulley more than the crown block
   c) The crown block has one pulley more than the travel block
   d) Only the crown block has pulleys

***TASK 2 Pumping***

When drilling the well in task 1, we would like to have a flow rate of 2000 litres/min. The frictional pressure drop from the mud pumps to the top of the drill string can be neglected. The frictional pressure drop in the annulus is 16 bars.
Welldata: Vertical well, 3400m depth, length of drill collar is 150m.
Fluid data: Density 1230 kg/m$^3$, Viscosity 25 cP.

a) What is the frictional pressure drop inside the drillstring from the top down to the nozzles in the drillbit? (Use the attached tables)

b) During drilling we wish to have a pump pressure of at least 350 barg.

1. Show that the maximum nozzle pressure is about 163 bars and calculate the velocity of the mud jet from the nozzles. Is this an acceptable value?
2. What is the nozzle force? (CD = 0.95).

c) Three nozzels of same type and size will be used in the drillbit. Which one of the following nozzels should be used to reach as close nozzle pressure as calculated in part b? The inner diameter for available nozzels are:
Nozzle No. 9: 7.144 mm, No. 10: 7.938 mm, No. 11: 8.731 mm, No. 12: 9.525 mm, No. 13: 10.319 mm and No. 14: 11.113 mm.

According to b) we want our mudpump to deliver at least 350 barg. A triplex mud pump with the following data is available:

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| Stroke: | 12" (inch) | Volume efficiency: | 0.98 |
| Electric Power in: | 1250 kW | Mechanical pump efficiency: | 0.86 |
| Topspeed: | 140 strokes/min | Transmission efficiency: | 0.82 |
| Liners: | 4.5" | Electric motor efficiency: | 0.93 |

d)
1. What is the maximum volume flowrate from the mud pump with the data given above?
2. What is the maximum pump pressure?
3. Is it enough with just one mud pump or do we need more? If so, how many?

***Multiple Choice Task 2 Pumping***

1. What is the impact of a longer stroke in the pump?
   a) Volume rate increases, pump pressure decreases
   b) Volume rate decreases, pump pressure decreases
   c) Volume rate decreases, pump pressure increases
   d) Volume rate and pump pressure are not affected by a longer stroke.

2. If the nozzle size increases (while everything else remains the same), what will be the consequences?
   a) Frictional pressure drop in the annulus will increase
   b) Frictional pressure drop in the annulus will decrease
   c) Frictional pressure drop in the nozzles will decrease
   d) The required minimum pump pressure will increase

3. Mud is a very important part in the oil- and gas industry. The cost of mud can be as high as?
   a) (1-5)% of the total cost of the well
   b) (10-15)% of the total cost of the well
   c) (20-25)% of the total cost of the well
   d) (30-35)% of the total cost of the well

4. Which statement is NOT correct?
   a) Duplex pumps are generally lighter and more compact than triplex pumps of similar capacity, and therefore are most suitable for use on offshore rigs and platforms

b) More power can be delivered using a triplex pump since higher pump speed can be used
c) The flowrate and pressure delivered by the pump depends on the size of sleeve (liner) that is placed in the cylinders of the pumps
d) Triplex pumps have the advantages of being lighter, give smoother discharge and have lower maintenance costs

5. Which one of these parameters the frictional pressure drop in the drillstring does NOT depend on?
   a) The rheological properties of the drilling fluid
   b) The length of the different drillstring sections
   c) The pressure drop in the annulus
   d) The inner and outer diameter of the drillcollar

***TASK 3 Dimensioning of Casing***

Having drilled to 3400m below the wellhead (on a fixed platform), we want to set a 9 5/8" casing. The fracturing pressure at 3400m depth was measured to 684 barg. The drilling of next section will also be conducted with the same mud density (1230 kg/m$^3$) and it is expected that due to loss of mud to possible low pressure zone, 30% of the casing volume will be emptied. The required safety factors are 1.8 against tearing, 1.3 against burst and 1.2 against collapse. A gas density of 320 kg/m$^3$ can be used for gas kick calculations. When mud is held for long, it can degenerate to a density of 1015 kg/m$^3$ (weighting particles fall out).

a)
1. Draw sketch and calculate the maximum bursting pressure at a possible gas kick situation.
2. At what depth is the load/strain on the casing maximum?

b)
1. Draw sketch and calculate the maximum collapse pressure at possible fracturing and loss of mud to the low-pressure zone.
2. At what depth is the load/strain on the casing maximum?

During cementing, a cement paste with a density of 1520 kg/m$^3$ is used. Pumping fluid (after cement) has a density of 1140 kg/m$^3$. The annular space between the casing and the formation will be cemented to 1900m depth below the well head. The cement paste volume used for cementing fills the casing completely before it is pumped into the annular space between the casing and the formation.

c)

1. Draw a sketch and calculate the maximum collapse pressure during cementing.
2. At what depth the maximum load occurs?
3. Is there any risk for fracturing while cementing?

d)

1. What are the dimensioning burst and collapse pressures?
2. Find the lightest casing you can use, which will withstand the pressures.
3. Calculate the safety factor for the burst and collapse pressure.

e)

1. Calculate the maximum axial load, both for the case with mud degeneration and for the case with cement.
2. Calculate the safety factor for the axial load, both for the case with mud degeneration and for the case with cement.
3. Which one of the cases is dimensioning?

*Multiple choice Task 3 Casings*

1. What is the main reason for cementing the casing?
   a) To be able to perforate the formation
   b) To prevent fluid flow between the casing and the wellbore wall
   c) To be able to fracture the formation
   d) To prevent the casing from sinking down the wellbore

2. Every casing section has a different diameter size for a variety of purposes. In which order are the standard casings usually placed and cemented in to the formation? (From largest diameter, to smallest diameter)
   a) Surface casing, conductor casing, intermediate casing, production liner, production casing
   b) Conductor casing, surface casing, intermediate casing, production casing, production liner
   c) Surface casing, conductor casing, intermediate casing, production casing, production liner
   d) Conductor casing, surface casing, intermediate casing, production liner, production casing

3. Which statement is NOT correct?
   a) Cement is used primarily as an impermeable seal material in oil and gas well drilling
   b) Cement is used to protect the casing from corrosive fluids in the formations
   c) The production casing is manufactured with relatively low burst and collapse tolerance
   d) The temperature and the pressures can be extreme in the reservoir sections, and since the production casing is used to secure the reservoir section, it must have the strength of withstanding harsh conditions

4. Which of these alternatives is NOT one of the considerations when determining the setting depth of the casing?
   a) Isolating lost circulation zones

b) Isolating the drill bit
c) Isolate troublesome formations
d) The need to isolate weak formations from high mudweights

5. Which pressure is usually greatest?
   a) The collapse pressure
   b) The pore pressure
   c) The burst pressure
   d) The formation pressure

***TASK 4 Kick***

When the drilling of the well in the previous tasks reached the depth of 3400m, the drilling was stoped due to incresing mud level in the mudpit. The mud flow rate was then 2000 l/min (Mud data: density of 1230 kg/m$^3$ and viscosity of 25 cP). The BOP was closed but due to certain problems the time and the increased mud level was not measured! However, after some time the pressure stabilized at an equilibrium with the reservoir and the shut in drill pipe pressure was measured to be 18 bar. The shut in casing pressure was measured to be 26 bar.

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| Lenght of drill collars: | 150 m |
| The volume of the whole drillstring: | 22.396 m$^3$ |
| The volume of the whole annulus: | 234.3 m$^3$ |

**a)**

1. What is the bottom hole pressure?
2. The kill mud should give a pressure margin of 9 bar at the bottom of the well. Determine the density of the kill mud.

The kill mud has a viscosity of 29 cP. Right before the kick was detected (at mud flow rate of 2000 l/min) the nozzle pressure drop was 158 bar. The wait and weight method was selected to circulate the reservoir fluid out of the well. For the circulation a mud flow rate of 700 l/minute was used. As soon as the pump started the pressure at top of the drillpipe increased from 18 to 63.1 barg.

**b)**

1. How long time does it take to circulate the drillstring?
2. How long time does it take to circulate the whole well?

**c)**

1. Use the given data (also from prior tasks) to calculate the pressure you have to regulate towards when circulating the content of the drillstring (while kill mud is filling the drillstring).
2. What value should the pressure at top of the drillstring have while circulating the content of the annulus?
3. Sketch a graph showing the drill pipe pressure as a function of circulating time while using the wait and weight method. Include calculated values.
4. How can we know that the inflow has been circulated out of the well?

***Multiple choice Task 4 Kick***

1. Which of the four alternatives is not one of the main indicators of a kick?
   a) Pit volume increase
   b) Flowing well with pups shut off
   c) Improper hole fill-up during trips
   d) Flow rate decrease

2. Is it possible to kill a well if you do not have a drillstring in it?
   a) Yes, if you use the so called "volumetric method"
   b) No, there is no chance to kill a well without having a drillstring in it
   c) Yes, if you use the so called "engineers method"
   d) Yes, if you use the so called "drillers method"

3. Which pressure is the most critical pressure to keep constant during a kick?
   a) The well head pressure
   b) The bottom hole pressure
   c) The annulus pressure
   d) The choke pressure

4. Which of the four alternatives is not one of the secondary barriers to the well?
   a) Mud pump
   b) BOP
   c) Casing and casing cement
   d) Wellhead

5. Which of the four alternatives is not one of the main reasons we get a kick?
   a) Swabbing
   b) Lost circulation
   c) Drilling with a high ROP
   d) Inaccurate estimates of pore pressure

# EQUATIONS GIVEN ON THE EXAM:

0,0254 m = 1''

$g = 9{,}81 \text{ m/s}^2$

$\rho_s = 7850 \text{ kg/m}^3$

- ***Tension in the fastline (deadline):*** $F_F = F_d = \frac{k_T - 1}{1 - k_T^{-n}} \cdot W$
- ***Frictional pressure drop in a circular pipe:*** $\Delta P_F = \frac{Q^{1{,}8} \cdot \rho^{0{,}8} \cdot \mu_p^{0{,}2}}{90163 \cdot D^{4{,}8}} \cdot \Delta L$
- ***Frictional pressure drop in an annular space:*** $\Delta P_F = \frac{Q^{1{,}8} \cdot \rho^{0{,}8} \cdot \mu_p^{0{,}2}}{70696 \cdot (D+d)^{1{,}8} \cdot (D-d)^3} \cdot \Delta L$

Units for $\Delta P_F$ [bar]: Q[Liter/min], ΔL [m], D & d [inch], density and viscosity relative to water

- ***Nozzle formulas:*** $v = C_D \sqrt{\frac{2 \cdot \Delta P_D}{\rho}}$ $(C_D = 0{,}95)$ /// $F_D = \dot{m} \cdot v = \rho \cdot Q \cdot v = \frac{\rho \cdot Q^2}{A_D}$
- ***Relative drillstring frictional pressure drop:*** $\Delta P_{F2} = \frac{Q_2^{1{,}8} \cdot \rho_2^{0{,}8} \cdot \mu_2^{0{,}2}}{Q_1^{1{,}8} \cdot \rho_1^{0{,}8} \cdot \mu_1^{0{,}2}} \cdot \Delta P_{F1}$
- ***Relative nozzle pressure drop:*** $\Delta P_{D2} = \frac{Q_2^2 \cdot \rho_2}{Q_1^2 \cdot \rho_1} \cdot \Delta P_{D1}$
- ***Initial drillstring pressure loss with kill rate:*** $P_{c1} = \Delta P_{F,m,2} + \Delta P_{D,m,2} + \Delta P_s$
- ***Final drillstring pressure loss with kill rate:*** $P_{c2} = \Delta P_{F,km} + \Delta P_{D,km}$
- ***Length of kick 1 ($V_k > V_{ann,dc}$):*** $L_K = L_{dc} + \frac{V_i + Q_m \Delta t - A_{ann,dc} L_{dc}}{A_{ann,dp}}$
- ***Length of kick 2 ($V_k \leq V_{ann,dc}$):*** $L_K = \frac{V_i + Q_m \Delta t}{A_{ann,dc}}$
- ***Height of kick:*** $h_k = \frac{P_{ann} - P_{dp}}{g(\rho_m - \rho_{kick})} \cdot \left[1 + \frac{Q_m \cdot \Delta t}{\Delta V_i}\right]$
- ***Density of inflow:*** $\rho_{kick} = \rho_m - \frac{P_{ann} - P_{dp}}{g \cdot h_k} \cdot \left[1 + \frac{Q_m \cdot \Delta t}{\Delta V_i}\right]$
- ***Mass balance:*** $\rho_1 \cdot V_1 + \rho_2 \cdot V_2 = \rho_m \cdot V_m$
- ***Combined safety factor during drilling:*** $\frac{1}{SF} = \sqrt{\left(\frac{P_i - P_o}{P_Y}\right)^2 + \left(\frac{F_E}{F_Y}\right)^2 + \left(\frac{M_R + M_F}{M_Y}\right)^2}$
- ***Safety factor under tension:*** $SF = \frac{F_Y}{F_A}$