FACULTY OF SCIENCE AND TECHNOLOGY

SUBJECT:	**PET100 DRILLING**
DATE:	**xx.02.2019**
TIME:	**09:00 – 13:00 (4 HOURS)**
AID:	**Approved calculator**

Universitetet i Stavanger

THE EXAM CONSISTS OF TOTAL 15 PAGES: 6 PAGES WITH EXERCISES, 1 PAGE WITH FORMULAS, 7 PAGES WITH TABLES AND 1 PAGE WITH ANSWERSHEET FOR MULTIPLE-CHOICE QUESTIONS.

NB! ANSWERSHEET FOR MULTIPLE-CHOICE IS TO BE HANDED IN WITH THE REST OF THE ANSWERS.

NOTICE: All the 4 exercises is given equal weight, i.e each count 25%. Quickly read through all the exercises before you start. Use your time well, so that each part gets the necessary time.

EXERCISE 1 Axial load

A vertical well is to be drilled down to 2400m on a fixed platform. The mud used for drilling has a density of 1210 kg/m^3, and a viscosity of 10 cP. The drill pipe to be used is a 5 1/2", 21.9 lb/ft, premium grad E with FH joints. We will have a 7.5" drillcollar of 150m, 181.7 kg/m with ID 3.00".

a) **1.** Calculate the maximum axial load on the drill string without mud circulation.
   2. Calculate the safety factor against yield.

b) One can assume the nozzle force to be equal to 5 kN.
   1. What will then be the reactive force on bit (WOB) when we want the neutral point to be at 2/3 h_{dc} from bottom?
   2. Why do we want the neutral point to be 2/3 h_{dc} from bottom?

c) It is necessary to have mud circulation while drilling. The pump pressure being used is maximum 320 bar gauge. The drill bit requires a torsional moment of 3 kNm. The combined safety factor should be at least 1.2 during the drilling operation. What is the maximum frictional moment allowed to occur between the wellbore wall and the drill string?

   Hint: use the combined safety factor formula.

d) The drawworks are set up with a traveling block containing 6 sheaves, and the combined weight of the hoisting equipment is said to be 3000 kg. The total friction factor is 1.04. When tripping from current depth (2400m) with a motor power of 750 kW and efficiency 0.95:
   1. What is the force acting on the fastline?
   2. What is the velocity of which the fastline travels?
   3. What is the velocity of which the drillstring is being lifted?

Multiple-choice 1 Axial load

1. What is the effective axial load on the neutral point?
   a) $F_E = F_A$
   b) It is the limit stress of pipe
   c) The average of pipe length
   d) $F_E = 0$

2. What is the major component of the drillstring?
   a) Drillpipe
   b) Drillcollar
   c) Drillbit
   d) Mudpump

3. What are "Slips" used for in the rotary system?
   a) Suspend pipe in the rotary table when making/breaking a connection
   b) To decrease the wall friction between wellbore and pipe
   c) Extend the lifecycle of drillbit by projecting the right path
   d) Reduce cost of maintenance

4. What is the velocity of the dead-line?
   a) $v_D = C_D \sqrt{\frac{2 \cdot \Delta P_D}{\rho_m}}$
   b) $v_D = F_F \cdot \frac{k_T - 1}{1 - k_T^{-n}} \cdot W \cdot \Delta t$
   c) $v_D = 2 \times v_F$
   d) $v_D = 0$

EXERCISE 2 Fluids and pumps

For the drilling of the well in exercise 1 we want a circulation rate of 2000 liter/min. The frictional pressure drop from the mudpump to the top of the drill string is 0.9 bar, frictional pressure drop in annulus is 11 bar.
Well data: Vertical well, depth 2400m, drill collar length is 150m.
Mud data: density 1210 kg/m^3, viscosity 10 cP.

a) Calculate the frictional pressure drop from the top of the drillstring down to the nozzles. [Use the attached tables and formula containing N_2 and N_3 values]

b) During drilling we want a minimum pump pressure of 320 barg.
   1. Calculate the largest nozzle pressure drop, and show that this corresponds to about 84% of the total pump pressure. Is this acceptable?
   2. How large is then the nozzle force? ($C_D = 0.95$).

Inner nozzle diameter for five nozzle numbers are:

No. 10: 6.938 mm	No. 12: 8.525 mm	No. 14: 10.113 mm
No. 11: 7.731 mm	No. 13: 9.319 mm	

c)

1. 4 equally sized nozzles will be installed. What nozzle number should you use?
2. If we want the nozzle force to be 7 kN, what nozzle number should you then choose?

From b) we want the mudpump to deliver a minimum of 320 barg. We have been provided with Triplex mudpumps with the following properties:

Stroke:	10" (inch)	Volume efficiency:	0.97
Power input:	1150 kW	Mechanical pump efficiency:	0.85
Topspeed:	130 stroke/min	Transmission efficiency:	0.78
Bushing:	4.5, 5, 5.5, 6 og 6.5"	Electric motor efficiency:	0.92

d) Which bushing do we have to choose in order to have high enough pump pressure?

e)

1. What will be the maximum pump pressure using this bushing?
2. How many mud pumps are needed in order to get the desired flowrate of 2000 liter/min?

Multiple-choice 2 Fluids and pumps

1. What will happen to the flowrate if we use a bushing which is double the size?
   a) Flowrate increases by a factor of 2
   b) Flowrate decreases by a factor of 3
   c) Flowrate increases by a factor of 4
   d) Flowrate decreases by a factor of 2

2. If the nozzle diameter decreases (while all other parameters are equal), what will this lead to?
   a) The frictional pressure drop in annulus will increase
   b) The frictional pressure drop in annulus will decrease
   c) The nozzle pressure drop will decrease
   d) The required pump pressure will increase

3. Which of the following is a thumbrule regarding the mud velocity through the nozzles?
   a) Over 100 km/h
   b) Over 100 km/s
   c) 47% - 64% of the velocity in the drill string
   d) 47% - 64% of the pump pressure

4. The cost of the mud is what percentage of the total cost of the well?
   a) 2-5%
   b) 5-10%
   c) 10-15%
   d) 15-20%

EXERCISE 3 Casing

After drilling to a depth of 2400m below the wellhead (fixed platform) in a vertical well we will set a 13 3/8" casing. The formation pressure at 2400m was measured to 320 barg. We will continue with the same mud density (1210 kg/m^3), and it is estimated that the loss of mud to a possible low-pressure zone will empty maximum 40% of the casing. The required safety facotrs are 1.8 for tear-off, 1.5 against bursting and 1.2 against collapse. Density of any gas in annulus is assumed to be 170 kg/m^3. When mud is still for a long period of time it can degenerate into a density of 1060 kg/m^3 (weight material falls out, but not salt).

a)

1. Draw a sketch and calculate the maximum burst pressure in a possible gas kick situation.
2. At which depth is the strain (bursting pressure) on the casing at its greatest? Explain
3. Draw a sketch and calculate the maximum collapse pressure in a possible fracture and loss of mud to the low-pressure zone.
4. At which depth is the strain (collapse pressure) on the casing at its greatest?

During cementing, a cement paste with a density of 1525 kg/m^3 is used. The fluid used to pump/push the cement down the casing has a density of 1035 kg/m^3 (mud to be used for further drilling). It is cemented up 500m below the wellhead. We assume «worst case» where the cement paste during pump-down will fill up the casing completely.

b)

1. Calculate the maximum bursting pressure and maximum collapse pressure when cementing. Draw a sketch of both scenarios.
2. At which depth is the strain on the casing at its greatest? Explain.

c)

1. What is now the dimensioning burst and collapse pressures?
2. Find the lightest casing that meets the pressure requirements.
3. Calculate the safety factor against burst and collapse.

d)

1. Calculate the axial load, both for degeneration of mud and during cementing.
2. Calculate the safety factor against tear-off, both for degeneration of mud and during cementing.
3. What is the dimensioning axial load?

(Hint: Internal volume can be calculated from the table value of the inner diameter, or from the capacity, which in the table is defined as liters per meter).

Multiple-choice 3 Casing

1. Why is secondary cement jobs usually called "squeeze cement jobs"?
    a) Because the cement pump must squeeze the pipe to increase its diameter
    b) Because they involve cement being forced through holes and perforations
    c) Because they involve cement being sucked back into the cement pump
    d) Because they involve cement being sucked back into the mud pump

2. Which casing is usually applied for completion of the well?
    a) Surface casing
    b) Intermediate casing
    c) Production casing
    d) None of the above

3. What is the main method of securing the liner in the well?
    a) Anchoring it inside previous casing string
    b) Hanging it from the top of the well
    c) Gluing it into the formation
    d) Melting it into the formation

4. Which of the following phenomena decreases the axial load compared to the axial load in mud?
    a) Overpull when casing is stuck
    b) Plug bumping pressure
    c) Lost circulation
    d) Higher mudweight

EXERCISE 4 Kick calculations

During drilling of the vertical well in exercise 1 to a depth of 2400m below the wellhead the mud level in the return tank increased more than expected. We stop drilling, shut off the pump and seal off the BOP, 54 seconds after we assume the kick started. (Mud data: 2200 liter/min, 1210 kg/m^3, 10 cP). We measured an increase of volume in the return tank of 9.2 m^3. The pressure at the top of annulus, just beneath the BOP, was measured to be 28 bar. The shut-in drill pipe pressure was measured to be 22 bar.

Length of drill collar:	150 m
Inner volume of drillstring:	15.5 m^3
Inner volume of annulus:	152 m^3

a)

1. What is the formation pressure at 2500m?

2. The killmud should give a safety margin of 10 bar at the bottom of the well. What density should our killmud have?

b) From a nearby well we have received information about the reservoir fluid, which is oil with some dissolved gas. The density of which was measured to be 725 kg/m^3.

1. How high up in the well is there reservoir fluid?

We want to use «driller´s method» to kill the well. During these type of situations we want a lower pump rate and we choose a pump rate of 650 liter/min. The viscosity of the kill mud is 26 cP.

c) Calculate

1. The time needed to displace the drillstring volume.

2. The time needed to displace the annulus volume.

3. The time needed to kill the well using this method (total time).

d) **1.** What is the frictional pressure drop in the drillstring under mud circulation with the old mud?
2. What is the nozzle pressure drop during circulation with old mud?
3. What is the frictional pressure drop in the drillstring during mud circulation with kill mud in the entire drillstring?
4. What is the nozzle pressure drop during circulation with kill mud?
5. Draw a graph showing the standpipe pressure during the entire process (use calculated numerical values).

Multiple-choice 4 Kick calculations

1. If we instead had used “engineer´s method” to kill this well, how much faster could we have killed the well?
    a) 3h 53min
    b) 2h 45min
    c) 4h 16 min
    d) 23 min

2. Which of the following does NOT cause the mudweight to be reduced during normal operations?
    a) Solids removal
    b) Lost circulation
    c) Excessive dilution of the mud
    d) Gas cutting of the mud

3. What does BOP stand for?
    a) Bleed Out Preventer
    b) Blow Out Power
    c) Blow Out Preventer
    d) Black Oil Pressuriser

4. Which of the following is NOT a primary indicator of a kick?
    a) Flow rate increase
    b) Pit volume increase
    c) Improper hole fillup during trips
    d) Drilling break