UNIS

The University Centre in Svalbard

Exam
AT-327 Arctic Offshore Engineering
Monday 2nd December 2019, hours: 09.00-13.00

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Permitted aids: Dictionary between English and mother tongue. Approved particular simple calculator. This set of problems consists of 4 pages. Five problem sets are presented; you must answer all 5 problem sets. In case of obvious mistakes or omissions in the problem sets, make your own assumptions.
The exam questions should be answered in: *Norwegian, English, Danish or Swedish.*

Problem Set 1 (20 %)

Ice roads:
For roads on floating ice it may be necessary to increase the bearing capacity by thickening the ice. Normally this is done by flooding the ice cover by sea water. Assume that a wind is blowing over the wetted surface. The vertical sensible heat flux per unit area Q is given by:

$$Q = \rho_{air} \cdot c_{air} \cdot St \cdot u \cdot (T_s - T_\infty)$$

where

$\rho_{air} = 1.27\ \text{kg/m}^3; c_{air} = 1\ \text{kJ/kg°C}$; Stanton number $St = 1.7 \cdot 10^{-3}$
T_s – surface temperature (°C); T_∞ – air temperature; u – wind velocity;
$l_f = 333\ \text{kJ/kg}$ (latent heat of fusion for ice)
Assume:
$\rho_{ice} = 900\ \text{kg/m}^3, T_s = -2\ °\text{C}, T_\infty = -20\ °\text{C}, u = 15\ \text{m/s}$

a) Explain the physics and the assumptions made in this process?
b) Calculate the time it takes to freeze a 4 cm thick ice layer on top of the ice under these conditions?

Problem Set 2 (20 %)

Production and transport of hydrocarbons:
Proposed production structures:
1. Earth island
2. Gravity base structure, vertical walls (i.e. D = 100 m)
3. Gravity base structure, sloping walls (i.e. D = 100 m at the mean water level, slope angle α = 30°)
4. FPSO with turret loading (i.e. 250 m long, beam 33 m, draft 12 m)

Water depth: 30 m.
Make assumptions as required.

a) Discuss briefly limitations (cons) and advantages (pros) with the proposed oil production concepts (1-4) for the Arctic Offshore?

b) Not all concepts (1-4) are complete with respect to transport (export). Discuss briefly possible hydrocarbon export solutions?

Problem Set 3 (20 %)

Ice physics:

a) Explain the process of desaliniation of sea ice?
b) The brine pockets, as shown in Figure 3.1, is migrating downward in the ice. What conditions are required for brine pockets to migrate upwards in the ice?

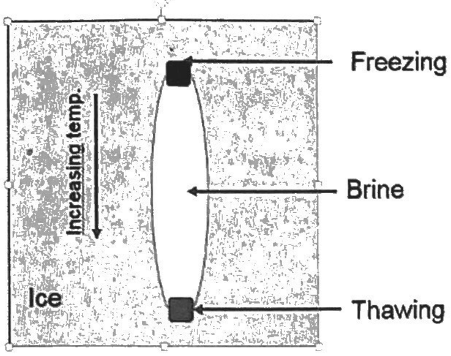

Figure 3.1. Brine pocket.

c) Typically the salinity profile of first-year sea ice shows a "C-shape" profile as shown in Figure 3.2. Explain the process behind this shape?

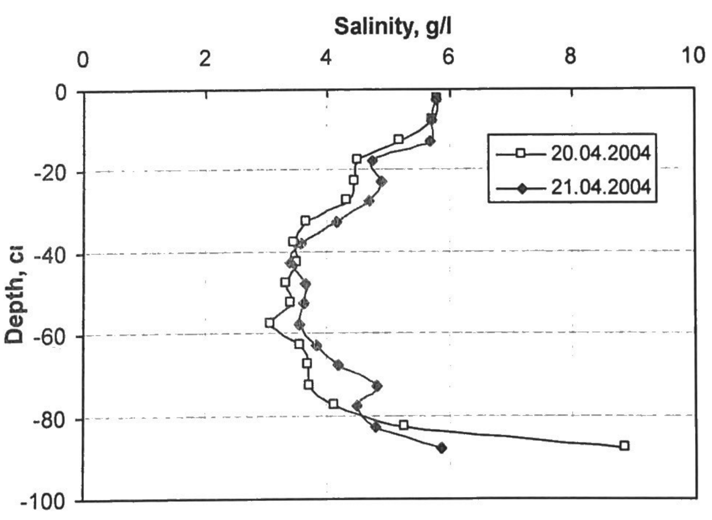

Figure 3.2. Typical sea ice salinity profile.

d) Sketch the corresponding salinity profile for multi-year sea ice?

Problem Set 4 (20 %)

Dynamic ice-structure interaction:

You obtained the response measurements from a gravity based offshore platform during a severe dynamic ice-structure interaction event (Figure 4.1). The data shows the structural displacement at the ice action point. The first natural frequency of the structure is 1 Hz.

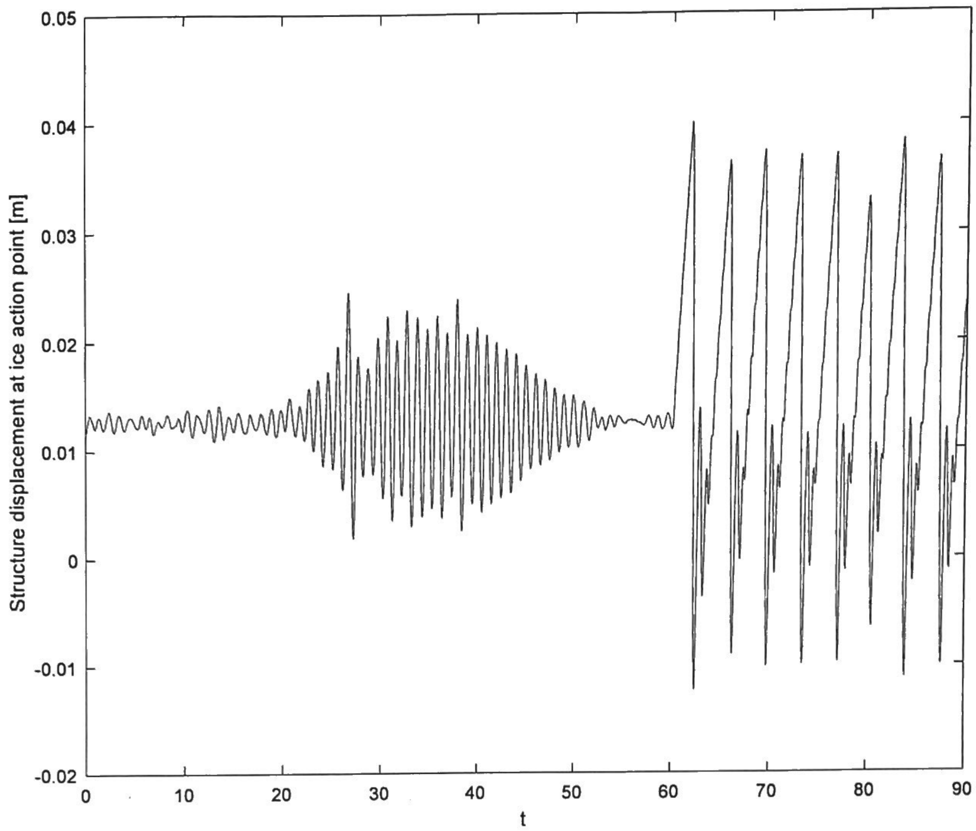

Figure 4.1. Response measurements from an offshore structure interacting with level ice. Time t in seconds.

a) Describe which regimes of ice-induced vibrations occurred indicating (1) the time interval for each regime and (2) the characteristics of the regime you used in identifying it?

b) Given that the ice thickness and strength were constant during the event, sketch the ice speed as a function of time corresponding to the observed structural response. (magnitudes are not required, it is about the relative difference between the regimes)?

Problem Set 5 (20 %)

Icing problems:

a) (30% weight). Explain shortly process of wet icing with periodic sea spray. List main heat fluxes and their contribution to the overall heat balance equation in this case?

b) (70% weight). Consider a vessel in the Barents Sea. The air temperature is -7 °C, the wind speed is 20 m/s. Interaction of the vessel with waves creates spray with duration of 2 seconds and period of 60 seconds. During the spraying event the spray flux to the structure is 100 g/(m^2s). The temperature of the coming spray is equal to the sea temperature which is 2° C. The sea water salinity is 35 ppt. The percentage of water entrapped into the ice accretion is 30% and the ice accretion density is 917 kg/m^3.

Assume that evaporative heat flux is equal to the convective heat flux. The Nusselt number is defined as $Nu = 0.03 \mathrm{Re}^{0.8}$, where Reynolds number $Re = \frac{V \cdot D}{\nu}$, V is the wind speed, D is the characteristic linear size of a structural element. Estimate power required to keep the window on the supply vessel free of ice. The size of the window is 0.5 m on 0.5 m?

Some equations and constants:

$S_b = -0.0182 * T_f$ salinity of water film

$\nu = 13 \cdot 10^{-6} \frac{m^2}{s}$ is the kinematic viscosity of air

$k_a = 0.024 \frac{W}{(m \cdot K)}$ is the thermal conductivity of air

$c_w = 4000 \frac{J}{(kg \cdot K)}$ is the specific heat capacity of water

$l_f = 3.4 \cdot 10^5 \frac{J}{kg}$ is the latent heat of fusion of water

$h = \frac{Nu k_a}{D}$ is the convective heat transfer coefficient