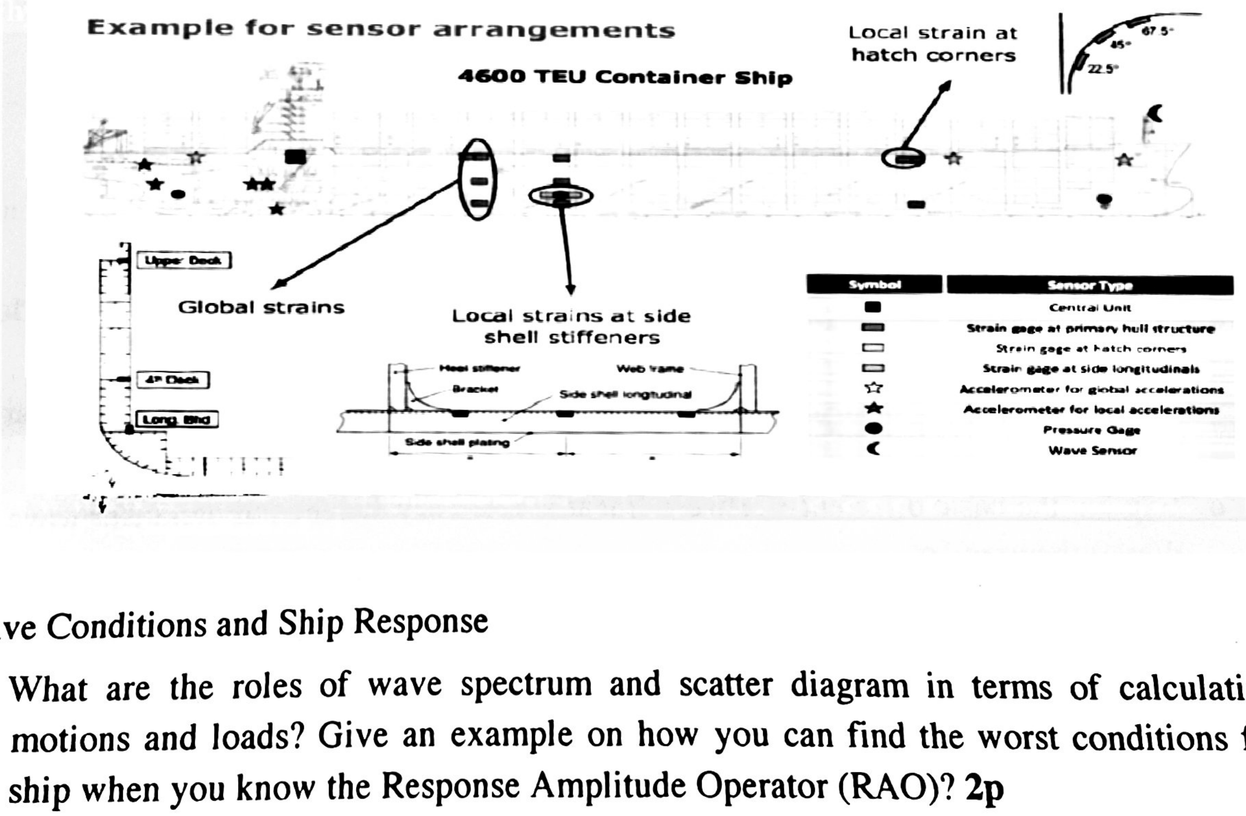
1ST MID-TERM EXAM, SHIP DYNAMICS

Ship Dynamics for Design, Sea Surface description and Equations of Motion

Time: 04.04.2018, 10:00-13:00 hrs., Room 118 Konetekniikka 3

Answers in English only. Remember: clear writing, short answers and use of the right terminology is required. ***Return the questions!***

1. Ship Dynamics for Design – general principles
   a. What are the key areas of the subject of ship dynamics in terms of design, i.e. why is it needed? **2p**
   b. If you have 4 uni-axial and 1 tri-axial accelerometer to measure ship motions how would you position those to get all 6 degrees of freedom of the ship accurately measured? Sketch these on the figure given below. Use commonly used notations/terms to describe rigid hull motions. **1.5p**
   c. Following on from (b.) above briefly explain whether (and if applicable how) the instrumentation would change for the case of an icebreaking tanker and a standard bulk carrier. **0.5p**
   d. Would there be any difference between the sagging and hogging bending moments and why? Which IACS URS requirement defines this envelope of loads? Use sketches. **2p**



2. Wave Conditions and Ship Response
   a. What are the roles of wave spectrum and scatter diagram in terms of calculating motions and loads? Give an example on how you can find the worst conditions for ship when you know the Response Amplitude Operator (RAO)? **2p**
   b. What is the basic difference between the ISSC and ITTC spectrum (*brief explanation*) ?
   c. The ISSC wave spectrum is defined as:

$$S_w(\omega)=0.11\left(\frac{2\pi}{T_z}\right)^4\frac{H_{1/3}^2}{\omega^5}e^{-\frac{0.44}{\omega^4}\left(\frac{2\pi}{T_z}\right)^4}$$

For T_Z = $7s$ and $H1/3$ = 2.6m the RAO of the bending moment of the ship is given by frequency and a corresponding RAO vector [ton²/m²]:

$$\omega_{RAO}=\{\ 0.3\quad 0.4\quad 0.5\quad 0.6\quad 0.7\ \},$$

$$RAO=\{\ 0\quad 4\cdot10^9\quad 2\cdot10^9\quad 3\cdot10^9\quad 0\ \}$$

Calculate the response spectrum. **1.5p**

d. Define what is a freak wave? Why a freak wave cannot be calculated with a standard wave spectrum and scatter diagram? **2p**

3. Controlling Ship Dynamics

a. Explain physically how we can achieve hull motion reduction. Explain the positive and negative features of 4 different systems that may be used for motion reduction. **2p**

b. Explain the physics (sequence of events) on how the rudder of a single propeller ship produces the turning moment? When the ship turns what other motion components become active apart from yaw? **2p**

c. Compare: *(a)* constant and controllable pitch propeller characteristics and their adequacy *(b)* the use of podded propulsion versus a traditional propeller solution. For each (a) and (b) present your results on a table with prons and cons. Discuss the practicality of each technology (i.e. whether it apples or not and why) for the ship you study in your group design exercise. **2p**

4. Short Term Response

a. Why ship short-term response is evaluated from 0.5 to 3 hours and long-term response for 25 years? Give physical / design related and mathematical reasoning? **2p**

b. Explain / sketch the wave formation mechanisms of wind-generated waves. What do we mean when we say that the sea state is fully developed? **2p**

c. Explain the energy content of waves. How can you estimate the energy using linear wave theory? **1p**

d. Explain the basic difference between linear wave (Airy Wave) and nonlinear wave (Stokes Wave) theories **1p**

5. Equations of Motion

a. Name and sketch the rigid body ship equations of motion in waves. Explain the physical meaning of Newton's 2nd law of motion with application to ship dynamics. Write down this combined equation of motion and name each of the terms. **2p**

b. What is the difference between Quasi Static Response, Dynamic Response and Resonance response. **2p**

c. How can we physically assess damping? Name 3 cases corresponding to damping induced response for a 1 dof system. Sketch the displacement versus time dynamic response curve for a 1 dof system for which $\zeta < 1.0$. **2p**

Bonus Question

a. The problem of linear ship motions in waves is approached by considering 3 types of forces in addition to the restoring forces of hydrostatic origin. What are they used for? Name them and define them **(2p)**

b. Name the six degrees of freedom representing the motions of a ship in waves. Define added mass and damping. Draw the roll, heave and sway RAO of added mass and damping for a typical box like ship section **(2p)**

c. Draw the typical patterns of Heave and Pitch RAOs for a typical symmetric section. What is defined as wave matching region and what would be the influence of wave matching region on pitch response (*explain physically by drawing the RAO at different L/lamda ratios in way of the wave region*)? **(2p)**

Equations

$$E = \frac{1}{2}\rho g \zeta^2 = \frac{1}{4}\rho g \zeta^2 + \frac{1}{4}\rho g \zeta^2$$

$$\zeta(x,y,t) = \sum_i \zeta_i(x,y,t)$$

$$\langle \zeta(x,y,t) \rangle = 0, \langle\ \rangle = mean$$

$$\langle \zeta^2 \rangle = \sum_i \langle \zeta_i^2 \rangle, \langle \zeta_i^2 \rangle = \text{variance}$$

$$S_{yy}(\omega) = |H(\omega)|^2 S_{xx}(\omega)$$

$$n = \frac{T}{2\pi}\sqrt{\frac{m_2}{m_0}}$$

$$m_k = \int_0^\infty \omega^k S(\omega) d\omega$$

$$\phi = -\zeta V_c \frac{\cosh k(z+h)}{\sinh kh} \sin k(x - V_c t)$$

$$R = k\int_0^\infty S(\omega) d\omega, k = 2 \text{ or } 8$$

$$\hat{z} = \sqrt{\ln \frac{n}{\alpha}} \sqrt{R}$$

$$\overline{\omega}_1 = \frac{m_1}{m_0} = \frac{\int_0^\infty \omega S(\omega) d\omega}{\int_0^\infty S(\omega) d\omega}$$