MEC-E4001 Winter Navigation

EXAMINE 19.02.2020
Time: 09-12
Class rooms: K215 (K1), Otakaari 4

(Answers either in Finnish or English)

Question 1:

You are responsible for the development of a new icebreaking polar research vessel concept with the following key technical characteristics:

Length, design waterline:	120.0 m
Beam, design waterline:	20.0 m
Design draught:	7.5 m
Propeller diameter	4.2 m

During hull form development, you calculated the following ice resistance components using Lindqvist's method:

Ice thickness [m]	Crushing [kN]	Bending [kN]	Submersion [kN]
0.2	6.2	6.2	65.9
0.5	38.5	24.7	164.7
0.8	98.7	49.9	263.5
1.1	186.6	80.5	362.3
1.4	302.2	115.6	461.1
1.7	445.6	154.7	559.9
2.0	616.7	197.4	658.6

In the first design iteration, the total propulsion power was 13000 kW. Based on CFD calculations, the corresponding open water speed would be 15 knots and bollard pull 140 metric tons.

You have a gut feeling that the selected propulsion power may not be enough to fulfil the client's icebreaking capability requirement – 2 knots in 1.5 m level ice with a 20 cm snow cover – and you have decided to uprate the propulsion power to 15000 kW.

Show through calculations that the vessel now achieves the specified icebreaking capability (2 points) and plot the corresponding h-v-curve (4 points).

Potentially useful formulae:

$R_c \propto H_{ice}^2 \qquad R_b \propto H_{ice}^{1.5} \qquad R_s \propto H_{ice} \qquad P(v_{ow}) \propto v_{ow}^3$

$T_B = K_E \times (P_D \times D)^{2/3}$

$T_{NET}(v) = T_B \times \left[1 - \frac{1}{3} \times \frac{v}{v_{ow}} - \frac{2}{3} \times \left(\frac{v}{v_{ow}}\right)^2\right]$

$H_{ice,equivalent} \approx H_{ice} + \frac{1}{3} \times H_{snow}$

$R_{ice}(H_{ice}, v) = [R_c(H_{ice}) + R_b(H_{ice})] \times \left(1 + 1.4 \times \frac{v}{\sqrt{g \times H_{ice}}}\right) + R_s(H_{ice}) \times \left(1 + 9.4 \times \frac{v}{\sqrt{g \times L}}\right)$

$\frac{y - y_0}{x - x_0} = \frac{y_1 - y_0}{x_1 - x_0}$ or graphic linear interpolation

Question 2:

The new Polar Class (PC) 5 icebreaking polar research vessel on your drawing board has a displacement of 10000 tons. After a lengthy negotiation, the client reluctantly agreed that the vessel's transit speed would be limited to 12 knots in regions where there's a possibility of encountering multi-year ice; after all, the ship can achieve a speed of about 16 knots at full power.

Using calculations, a) justify the selection of the initial ice class (3 points) and b) make a recommendation for a higher ice class (3 points).

Your structural engineer has defined the following design ice loads (normal force against shell) in the bow region for three different ice classes. It can be assumed that these figures include a reasonable safety factor. In addition, she has estimated the impact of reduced or increased scantlings on the vessel's steel weight.

Ice class	Steel weight impact	Design ice load
PC 6	-500 tons	11000 kN
PC 5		13000 kN
PC 4	+800 tons	15500 kN
PC 3	+1500 tons	18000 kN

Consider a design scenario where the vessel experiences a glancing impact in the bow. Use the energy-based ice forces method and assume a simple impact where all kinetic energy is expended in crushing. Mass reduction coefficient for this ice impact scenario is 2.0, ice crushing strength for 1 m² reference area can be taken as 2500 kPa, and the force-area relationship exponent is -0.5.

From the hull lines drawing, you have measured that the waterline opening angle at the impact point is 30 degrees and frame angle is 49.1° from vertical.

$$IE = \frac{p_0}{3+2\times ex} \times \left(\frac{1}{\sin\alpha \times \cos\alpha \times \sin\beta' \times \cos^2\beta'}\right)^{1+ex} \times \zeta_n^{3+2\times ex}$$

$$\tan(\beta') = \tan(\beta) \times \cos(\alpha)$$

$$KE_e = \frac{1}{2} \times \frac{M}{Co} \times V_n^2$$

$$F_n = p_0 \times \left(\frac{1}{\sin\alpha \times \cos\alpha \times \sin\beta' \times \cos^2\beta'}\right)^{1+ex} \times \zeta_n^{2+2\times ex}$$

Question 3:

What are the main reason for the diesel-electric propulsion system to be better in ice than the pure diesel engine. (6P)

Question 4:

What are the main additional design topics, you have to take into account when you design ships for ice comparing with the design for open water (6P)

Question 5:

Desribe the background and basic principles of the engine power requirements used in the Finnish-Swedish ice class rules. (6P)