MODULE II : MANEUVERABILITY

Topic: Estimation of Hydrodynamic derivatives by Theoretical/Empirical Methods

Question 1

An estimate for linear damping derivatives can be made from the relations: $Y_v' = -\pi(T/L)^2$; $Y_r' = 0.5\pi(T/L)^2$; $N_v' = -0.5\pi(T/L)^2$, $N_r' = -0.25\pi(T/L)^2$. Consider two shops having same length of L=200m. The first ship is wider and shallower with B=40m, T=12m, and the second ship is narrower but deeper with B=30m, T=16m. Both have same C_B of 0.70 (so that both have same displacement). Estimate the derivatives and hence the stability criterion and comment on the stability characteristics of the two hulls.

Answer:

$m' = \dfrac{\rho LBTC_B}{0.5\rho L^3} = \dfrac{2BTC_B}{L^2} = 16.8\times10^{-3}$ for both ships.

ship 1:

$$Y_v' = -\pi\left(\frac{T}{L}\right)^2 = -11.309\times10^{-3}$$

$$Y_r' = +0.5\pi\left(\frac{T}{L}\right)^2 = 5.655\times10^{-3}$$

$$N_v' = -0.5\pi\left(\frac{T}{L}\right)^2 = -5.655\times10^{-3}$$

$$N_r' = -0.25\pi\left(\frac{T}{L}\right)^2 = -2.827\times10^{-3}$$

Stability index:

$$c = N_r'Y_v' - N_v'(Y_r' - m') = [(-2.827)(-11.309) - (-5.655)(5.655 - 16.8)]\times10^{-3}$$
$$= -31.055\times10^{-3} < 0$$

Thus this ship is directionally unstable.

Ship 2:

$$Y_v' = -\pi\left(\frac{T}{L}\right)^2 = -20.106\times10^{-3}$$

$$Y_r' = +0.5\pi\left(\frac{T}{L}\right)^2 = 10.053\times10^{-3}$$

$$N_v' = -0.5\pi\left(\frac{T}{L}\right)^2 = -10.053\times10^{-3}$$

$$N_r' = -0.25\pi\left(\frac{T}{L}\right)^2 = -5.027\times10^{-3}$$

Stability index:

$$c = N_r'Y_v' - N_v'(Y_r' - m') = [(-5.027)(-20.106) - (-10.053)(10.053 - 16.8)]\times10^{-3}$$
$$= +33.039\times10^{-3} > 0$$

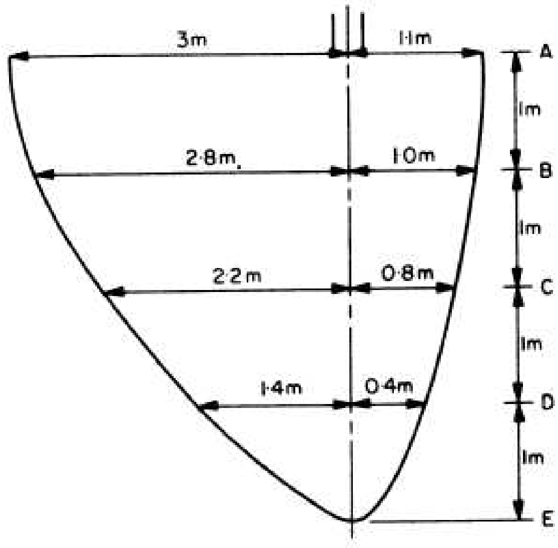
Thus this ship is directionally stable

Thus is seen that an increased T/L improves stability.

Topic: Control Surface and Rudder

Question 2

Calculate the force, torque and bending moment at stock for the spade rudder shown in the figure below, for rudder angle of 35 deg. and ship speed of 20 knots. Assume that force on the rudder can be approximated by the formula $21.1\,A_R V^2\delta$ where A_R is rudder area, and CP is 0.31 times the chord length from the leading edge.



Answer:

Referring to the figure, integrations are performed using Simpson's 1st rule (1,4,1 rule) :

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9
Level	Total Chord Length (m)	S.M	F (area) (2)*(3)	Lever Below stock	F(moment) (4)*(5)	c.p. aft of leading edge	c.p. aft of axis	F(torque) (4)*(8)
A	4.1	1	4.1	0	0	1.27	0.17	0.70
B	3.8	4	15.2	1	15.2	1.18	0.18	2.74
C	3.0	2	6.0	2	12.0	0.93	0.13	0.78
D	1.8	4	7.2	3	21.6	0.56	0.16	1.15
E	0	1	0	4	0.0	0.0	0	0.00
$\sum$			32.5		48.8			5.37

Area or rudder $A_R = \frac{1}{3} \times 1 \times 32.5 = 10.83\ m^2$

CP aft of axis : 5.37/32.5 = 0.165 m

CP below stock = 48.8/32.5 = 1.502 m

Force on rudder = $21.1 \times 10.83 \times (20 \times 0.5144)^2 \times 35 = 847 \times 10^3\ N = 847 kN$

Bending moment at stock = $847 \times 10^3 \times 1.502\ N = 1.272\ \ MN\ m$

Torque = $0.165 \times 847 \times 10^3\ \ Nm = 140\ kN\, m$