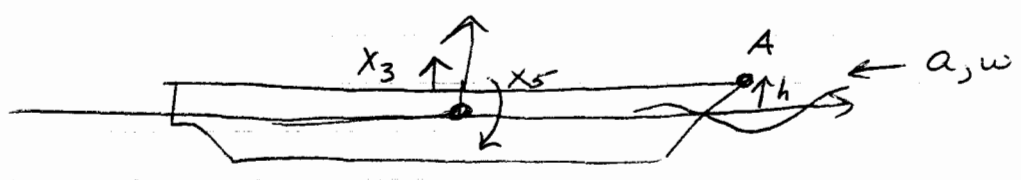Coupled Motions & Seakeeping : Complex Events

① Water on Deck

Design ⟹ need to choose h so that we have only so much water on deck

Assumptions ⟹ Incident wave is not significantly diffracted @ A

⟹ Ignore steady elevation (equilibrium ship position)

⟹ Assume Linear motions

$$\eta(x_1, t) = a\, e^{i(\omega t + kx_1)}$$

$x_1 ⟹$ inertial reference ⟹

$$x = x_1 - ut$$

$$\eta(x, t) = a\, e^{i(\omega_e t + kx)}$$

where $\omega_e = \omega + kU$

$$\eta(x_A, t) = \hat{\eta}_A\, e^{i\omega_e t} = a\, e^{i(\omega_e t + kx_A)}$$

$$\eta(x = 0, t) = \hat{\eta}_{\emptyset}\, e^{i\omega_e t} = a\, e^{i\omega_e t}$$

$\uparrow$ midships

$$⟹ \hat{\eta}_A = \hat{\eta}_{\emptyset}\, e^{ikx_A}$$

phase shift

Relative Distance from A to free surface

$$Z_A(t) \simeq h - \eta_A + x_3 - x_A x_5$$

equilibrium pt ↑

wave height

heave

pitch • distance from center of pitch to pt. A

Let $Z_1(t) = \eta_A - x_3 + x_A x_5$ such that

when $Z_1(t) > h$ then bow is under water (submerged)

$$\hat{Z}_1(\omega) = \hat{\eta}_A - \hat{x}_3 + x_A \hat{x}_5$$

$$\hat{x}_3(\omega) = H_3(\omega_e) \hat{\eta}_\emptyset \qquad \text{heave amplitude}$$

$$\hat{x}_5(\omega) = H_5(\omega_e) \hat{\eta}_\emptyset \qquad \text{pitch amplitude}$$

$$\hat{Z}_1(\omega) = \underbrace{\left\{ e^{ikx_A} - H_3(\omega_e) + x_A H_5(\omega_e) \right\}}_{} \hat{\eta}_\emptyset$$

$$S_{Z_1}(\omega_e) = \left| H_{Z_1}(\omega_e) \right|^2 S_\eta(\omega_e)$$

incident waves @ encounter frequencies

$$H(\omega_e) = e^{ik\,x_A} - H_3(\omega_e) + x_A\, H_5(\omega_e)$$

This is a <u>COMPOSITE EVENT</u>!

The relative phase term is very important

We can use the spectrum for deck

elevation, $S_{z_1}(\omega_e)$, to get

Rate that water exceeds level h (on avg.)

$$\therefore\quad \bar{\eta}(h) = \frac{1}{2\pi} \sqrt{\frac{M_2}{M_0}}\; e^{-h^2/2M_0}$$

M_0, M_2, M_4 are moments of Spectrum $S_{z_1}(\omega_e)$