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EFFECT OF IRREGULAR WAVES ON DYNAMIC ANALYSIS OF A SHIP AND A SUBMERGED PAYLOAD JOINTED WITH CABLES

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Introduction

Due to the complexities of sea environment, the investigation of ship dynamics has attracted the attention of many investigators. The current study investigates the dynamic of a floating vessel from which a submersible payload has been hung by two cables. In fact, under these conditions, the floating vessel is subjected to irregular sea waves and these wave excitations are transferred to the submersible payload through the cables. The correct prediction of payload pitch angle and its time rate of change and also its linear acceleration are the important parameters which affect the design criteria of the floating vessel.

In the present study, the coupled governing equations of motion for floating vessel and submerged payload have been solved for the heave and pitch directions. The dynamic cable tensions have been also computed. The hydrodynamic coefficients of the floating vessel and submerged payload have been obtained by using the strip theory. The JONSWAP wave spectrum has been used for studying the influence of irregular sea waves.

Problem Statement

In the present paper, the influence of irregular sea waves on dynamic behavior of the combined surface vessel and the submerged payload which is hung from the floating vessel by the aid of two cables has been investigated. The fact that cables are only under tension makes the dynamic response complicated. On the other hand, the accurate calculation of added mass, damping and restoring forces affects the accuracy of the simulation for both surface vessel and submerged payload. The schematic of the problem and the simulation model are shown in figures (1) and (2), respectively.

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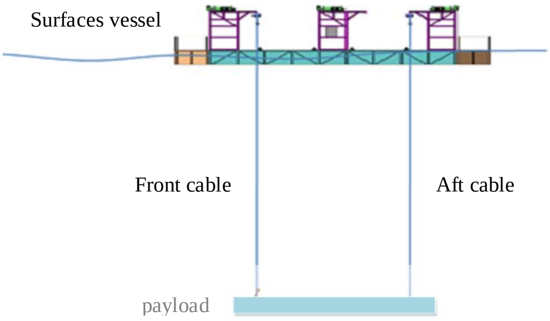

Fig. 1) schematic of surface vessel and submerged payload

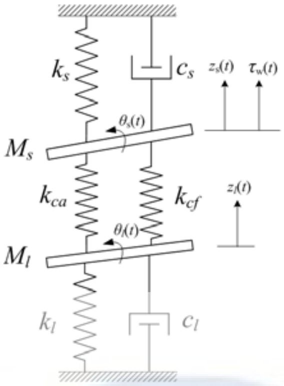

Fig. 2) mass-spring-damper model of the problem

Problem Formulation

For modeling purposes, we have used the two-dimensional mass-spring-damper system in heave and pitch directions. The coupled governing equations of the mass-spring-damper system of Fig. (2) are as follows:

$$\begin{gathered} A_{33s}\ddot{z}_s + B_{33s}\dot{z}_s + C_{33s}z_s + A_{35s}\ddot{\theta}_s + B_{35s}\dot{\theta}_s + C_{35s}\theta_s = F_w e^{iwt} - (T_{cf} + T_{ca}) \\ A_{53s}\ddot{z}_s + B_{53s}\dot{z}_s + C_{53s}z_s + A_{55s}\ddot{\theta}_s + B_{55s}\dot{\theta}_s + C_{55s}\theta_s = M_w e^{iwt} - M_{cf} + M_{ca} \\ A_{33s}\ddot{z}_l + B_{33l}\dot{z}_l + C_{33l}z_l + A_{35l}\ddot{\theta}_l + B_{35l}\dot{\theta}_l - Z_{HS} = T_{cf} + T_{ca} \\ A_{53l}\ddot{z}_l + B_{53l}\dot{z}_l + C_{53l}z_l + A_{55l}\ddot{\theta}_l + B_{55l}\dot{\theta}_l - M_{HS} = M_{cf} - M_{ca} \end{gathered} \tag{۱}$$

$$\begin{gathered} [A_l] = \begin{bmatrix} m - Z_{\dot{w}} & -mx_g - Z_{\dot{q}} \\ -mx_g - Z_{\dot{q}} & I_y - M_{\dot{q}} \end{bmatrix} \\ [B_l] = \begin{bmatrix} -Z_{w|w|} & -Z_{q|q|} \\ -M_{w|w|} & -M_{q|q|} \end{bmatrix} \end{gathered} \tag{۲}$$

The added mass and damping coefficients of the submerged payload have been determined using strip theory formulas. The corresponding hydrostatic force and moment of the submerged payload in pitch-heave plane are as follows:

$$\begin{gathered} Z_{HS} = -(W - B)\cos(\theta) \\ M_{HS} = z_g W\sin(\theta) - x_g W\cos(\theta) \end{gathered} \tag{۳}$$

In order to investigate the Sea State 3 conditions, the following values have been used in the JONSWAP wave spectrum:

$$H_s = 3\ m,\quad T_0 = 3.65\,s$$

Conclusions

Through solving the coupled governing equations of motion, the frequency response of surface vessel and submerged payload in both heave and pitch directions and also tension in both cables have been obtained. The results show that cable tension becomes zero in some specific periods of time. This has been shown in Fig. (3). This is due to the fact that cables can be only under tensile loading. Figure (4) shows the harmonic pitch response of floating vessel and submerged payload. As it can be seen from Fig. (4), the pitch response of submerged payload differs considerably with that of surface vessel. The results of the present study can be used in accurate designing of cable loading conditions as well as linear and angular accelerations of submerged payload and floating vessel.

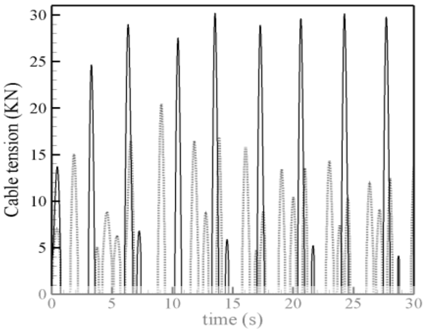

Fig. 3) temporal response of tension in front cable (solid line) and aft cable (dashed line)

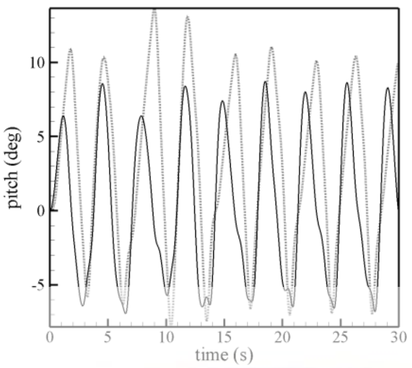

Fig. 4) harmonic pitch response of floating vessel (solid line) and submerged payload (dashed line) at modal frequency

References

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