WAVE DRIFT DAMPING AND LOW-FREQUENCY OSCILLATIONS OF AN ELLIPTIC CYLINDER IN IRREGULAR WAVES

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SUMMARY

Wave drift damping of low-frequency oscillations of moored bodies was introduced by Wichers and Huismans (1984). Later papers conclude that this is an important damping force for low-frequency lengthwise oscillations of slender bodies, where viscous damping turns out to be very small. In the present account we study damping of low-frequency oscillations of a moored body in an irregular sea. We apply the damping force

$$\dot{x}\alpha(k_L)a^2(t,x) \tag{1}$$

where $\dot{x}$ and x denote respectively low-frequency velocity and position of the body. α is a function of the wave number k_L of the wave group of the incoming waves. a^2 is given by

$$a^2(t,x) = \sum_{m=1}^{N} |A_m|^2 + \sum_{m=1}^{N} \sum_{\substack{n=1 \\ n\neq m}}^{N} A_m A_n^* \exp(i((\omega_m-\omega_n)t+(k_m-k_n)x)) \tag{2}$$

where t denotes time, A_m denotes complex amplitude, ω_m intrinsic frequency and $k_m=\omega_m^2/g$ wave number of wave component number m. A star denotes complex conjugate. Applying narrow-banded power spectrum of the incoming waves, the first part of (1), i.e.

$$\dot{x}\alpha(k_L)\sum_{m=1}^{N}|A_m|^2 \quad (3)$$

corresponds to the wave drift damping. The new term, which is accounted for here, is the time-dependent damping term

$$\dot{x}\alpha(k_L)\sum_{m=1}^{N}\sum_{\substack{n=1\\n\neq m}}^{N}A_mA_n^*\exp(i((\omega_m-\omega_n)t+(k_m-k_n)x)) \quad (4)$$

The slowly varying force is calculated in the frame of reference following the slowly varying position of the body. Thus, also slowly varying frequency of encounter of the incoming waves is introduced.

The body is a slender elliptic cylinder which is submerged and is moored by linear springs. The major axis is horizontal, and the cylinder is restricted to move along a horizontal frictionless constraint. The flow around the cylinder is two-dimensional.

The power spectrum of the incoming waves is given by a narrow-banded Gauss curve spectrum or Pierson-Moskowitz spectrum. The slowly varying force is then computed by the approximation due to Marthinsen (1983). Thus, the value of the slowly varying force is found from the mean second order force upon a submerged cylinder in a weak uniform current and regular waves, which is treated in Grue and Palm (1985). The equation of motion is solved by numerical integration. It is demonstrated that the time dependent damping does not cause resonance. The numerical calculations show that the time-dependent damping slightly increases the total damping. Also the mean horizontal displacement of the body becomes slightly reduced due to this damping term.

REFERENCES

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Discussion

Papanikolaou: I have to remark on the employed method by Wichers that it doesn't consider the full nonlinear phenomenon, e.g. by including the second-order velocity potential due to the wave-body motion interaction, but is based on simplifying assumptions which can lead to wrong predictions for the desired second-order wave damping.

Grue: As Prof. Papanikolaou remarks the applied method doesn't consider the full second order solution. Formally, the wave drift damping is a third order effect since the slowly varying velocity of the body is small. However, it is found that this third order effect strongly influences the value of the slow drift force and introduces an important damping. This indicates that also other higher order effects should be examined closely. If, however, the moored body has a resonance at a very small frequency, the contribution to the slow drift forces from the higher order potentials are very small. In this case the presented theory will be valid.

Falnes: In his talk, Sclavounos reported a positive vertical drift force for a fixed submerged cylinder. In the discussion Evans mentioned that over the oscillating submerged Bristol Cylinder a negative vertical drift force was predicted. Grue found that in his case the horizontal drift force may be strongly influenced by the velocity of the cylinder. Is it possible that this influence is sufficiently strong to change the sign of the drift force?

Grue: The horizontal velocity of the submerged body has a large effect on the mean horizontal force. Obviously, when the body moves in the same direction as the incoming waves, with a sufficiently large speed, the mean horizontal force is directed against the motion of the body, which means that the sign of the drift force has changed. In the other case, where the body moves against the incoming waves, the sign of the drift force never changes. For long incoming waves the value of the drift force is always increased due to the forward speed. For moderate and short incoming waves, however, the value of the drift force reduces due to the forward speed. This leads to negative "wave drift damping", and is true for submerged cylinders of different cross sections.