International Journal of Offshore and Polar Engineering
Vol. 1, No. 4, December 1991 (ISSN 1053-5381)

Decomposition of Low-Frequency Hydrodynamic Forces Acting on a Floating Vessel Moored in Ocean Waves

Takeshi Kinoshita
Institute of Industrial Science, University of Tokyo, Tokyo, Japan

ABSTRACT

Decomposition of ship resistance in still water has traditionally been one of the most important problems for naval architects, especially in case of model experiments. Model tests of a ship advancing in waves are more realistic than similar tests in still water as an added resistance acts on the hull due to the waves. But they are simpler compared with a real floating vessel slowly oscillating in waves, because the advance speed is constant. Further in the latter case the vessel has not necessarily a streamlined shape and the oscillating speed is very small. Then the viscous effects may play an important role in the low-frequency hydrodynamic forces, relatively to added mass and damping. In this paper, decomposition of these low-frequency hydrodynamic forces is discussed, and the results of forced oscillation tests in waves for models of typical floating structures are presented. The contribution of each component to the slow drift motion in irregular waves is demonstrated by time-domain simulation.

INTRODUCTION

A moored floating structure exhibits a highly tuned resonance of motions that generally occurs at very low natural frequencies in the horizontal plane. The slowly varying second-order wave drift force is one of the most important excitations of this resonance. Estimation of the structure's maximum excursions caused by this resonance motion is now being recognized as essential in the design of mooring systems.

The perturbation approach with potential flow and small wave slope assumptions usually gives a good estimate of the motion responses of floating bodies to first-order wave excitations, provided viscous roll damping is applied. However, it is not known whether it can give a good estimate of slow drift motions due to second-order wave excitation. In fact, viscous damping is relatively large compared with radiation wave damping in any mode of slow drift motions. Characteristics of another potential orientated damping (wave drift damping) which dominate, together with viscous damping, are still not clarified.

The objective of this paper is to determine equations of motion which include low-frequency hydrodynamic forces, and to clarify characteristics of the low-frequency hydrodynamic forces, namely, low-frequency damping and added mass, experimentally. In other words, it is to determine a mathematical model for slow drift motions in waves.

HYDRODYNAMIC FORCES

The following hydrodynamic forces concern the motion of a floating vessel moored in waves:

a) Wave frequency exciting forces, added mass and wave radiation damping

Because forward speed by slow drift motion is very small, the wave frequency wave exciting forces, added mass and wave radiation damping can be evaluated by the linear diffraction-radiation theory using panel methods without forward speed. The total number of elements to get reliable results depends on the shape of the offshore structures. It may vary from 500 to 1500, for example. However, it is limited by the capacity of the computer. Comparative studies were performed by ISSC (Eatock Taylor and Jefferys, 1986) and ITTC (1984, 1987). These hydrodynamic forces can be evaluated in a reasonable number of elements for a usual type of floating offshore structure, except where there is heaving added mass in some semisubmersibles.

The computed added mass is almost constant for all frequencies of slow drift motion. However, the added mass in fact may be affected by vortex shedding in the case of non-streamlined shapes of structures. Then it depends on the Reynolds number, the Keulegan-Carpenter number (K_c) and the surface roughness.

The wave radiation damping is negligibly small compared with other damping, such as viscous or wave drift damping for slow drift motion.

b) Mean and slowly varying wave exciting forces

The slowly varying wave exciting forces are commonly evaluated by the second-order potential theory. Maruo (1960), Newman (1967) and Molin (1979) developed the momentum method for the mean drift forces and moments in regular waves, in which the second-order potential does not result. Pinkster (1979) introduced the method of direct integration to obtain the slowly varying drift forces and moments. Matsui (1989) showed the contribution of the second-order potential on the drift forces and moments for several types of structures.

Kudou (1977) confirmed that the computed mean drift forces in regular waves of a sphere and a spheroid were in good agreement with measured ones. The slowly varying drift forces and moments are hard to measure, because they must be measured by an apparatus which will allow for model motions at the wave frequency, but not at the low frequency; otherwise we have to assume a linear transfer function between the motions and the wave excitation (Kato and Kinoshita, 1990).

When the incident wave amplitude is large relative to the cross-sectional dimensions of the hull components, viscous effects may contribute to drift forces. The effect is of third order, which

---

Received January 25, 1991: revised manuscript received by the editors September 26, 1991. The original version (prior to the final revised manuscript) was presented at The First International Offshore and Polar Engineering Conference (ISOPE-91), Edinburgh, United Kingdom, August 11-16, 1991.

KEY WORDS: Slow drift motion, slow drift oscillations, wave drift force, wave drift damping, drag coefficient, added mass.