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Viscous Forces Acting on a Semisubmersible Oscillating with Low Frequency in Regular Waves

K. Otsuka, T. Kiku and Y. Ikeda*
Department of Naval Architecture, University of Osaka Prefecture, Sakai, Japan

ABSTRACT

In order to predict low-frequency viscous forces on a semisubmersible moving with large amplitude and low frequency, it is necessary to know the viscous forces acting on cylindrical members of it. To get fundamental information on the viscous forces, force measurements are carried out of a lower-hull cylinder slowly oscillating in regular waves and a circular cylinder oscillating with two different frequencies. The results show that the low-frequency hydrodynamic coefficients significantly depend on two parameters, $Kc^* = U_L T_W/D$ and U_W/U_L, where T_W, D, U_W and U_L are period of wave-frequency component, representative diameter of the cylinders, maximum velocity of wave-frequency component and maximum velocity of low-frequency component, respectively. Low-frequency viscous forces acting on a semisubmersible are predicted by summing up two-dimensional viscous forces acting on the cylindrical members. Force measurements of a semisubmersible model oscillating with low frequency in sway and surge modes are also carried out in regular waves. Viscous effects on the low-frequency hydrodynamic forces acting on the semisubmersible are discussed on the basis of the comparison between the predicted and experimental results.

INTRODUCTION

Low-frequency and large-amplitude horizontal motions of moored floating structures are induced at resonant frequencies of the mooring system by low-frequency second-order wave drift forces. To predict the low-frequency motion, the low-frequency damping forces should be accurately estimated. Wichers et al. (1982a, 1982b, 1984) reported that the low-frequency hydrodynamic damping force on a moored vessel increases in waves as compared with that in still water, and this influence of waves on the low-frequency damping force was called wave damping. Hereafter, Saito et al. (1984) and Faltinsen et al. (1986) called it wave drift damping in order to distinguish it from the linear radiation wave damping with incident wave frequency.

For a semisubmersible with a small waterplane area and consisting of cylindrical members, it is considered that the effect of radiated waves due to low-frequency motions on the damping is negligibly small as compared with the viscous effect. Saito et al. (1988) and Kinoshita et al. (1989, 1991) pointed out that viscous damping is important as well as wave drift damping in the case of a semisubmersible. Viscous effects on low-frequency hydrodynamic forces acting on a moored offshore structure or its members were experimentally investigated by Ando et al. (1984), Koterayama et al. (1986, 1988, 1989), and others. They measured the low-frequency hydrodynamic coefficients of the structures, and showed that the low-frequency added mass is also affected by viscous forces induced by incident waves.

Koterayama et al. (1988) pointed out that the low-frequency drag coefficient of a moored structure depends on "reduced velocity," which is defined by $U_L T_W/D$. Kinoshita et al. (1989) showed that the ratio of the wave particle velocity to the velocity of low-frequency motion U_W/U_L is another important parameter. Ikeda et al. (1990) studied the mechanism of generation of low-frequency viscous damping force on a cylinder oscillating with two different frequencies, and they called the reduced velocity Kc^* as a kind of Kc number, because this parameter represents the difference of displacement (or Kc number) of the high-frequency motion between the forward swing and the successive backward swing at the moment when the low-frequency motion has the maximum speed. They also experimentally confirmed that the low-frequency viscous damping depends on two parameters, $U_L T_W/D$ and U_W/U_L, as shown by Kinoshita et al. (1989). Detailed characteristics of the low-frequency hydrodynamic coefficients, however, have not been clarified insofar that they can be used for design and analysis of ocean structures.

The purpose of this paper is to predict low-frequency viscous forces acting on a semisubmersible oscillating in regular waves by summing up the two-dimensional viscous forces acting on the cylindrical members. Force measurements of the cylindrical members, a lower-hull cylinder oscillating with low frequency in regular waves and a circular cylinder oscillating with two different frequencies, are summarized in the first part of this paper. In the second part, force measurements of a semisubmersible model forced to make sway or surge motion in regular waves are described, and the contributions of viscous forces to the total low-frequency hydrodynamic forces acting on the semisubmersible are discussed on the basis of the comparison between the predicted and experimental results.

LOW-FREQUENCY VISCOUS FORCES ACTING ON CYLINDRICAL MEMBERS

The hydrodynamic coefficients in plane oscillatory flow are generally used to predict the wave forces acting on a vertical member like a column, because vortex shedding patterns around a vertical member are almost two-dimensional, and the flow field around it can be approximated by that in plane oscillatory flow. On the other hand, in the case of a horizontal member like a lower hull, hydrodynamic coefficients of it are significantly different from those in plane oscillatory flow due to the orbital flow effect. Ikeda et al. (1988) reported that wave forces acting on the lower hulls of a semisubmersible in beam seas decrease rapidly to about half of those in plane oscillatory flow at Kc of about 2.5 due to the interaction between the vortex shedding and the orbital flow in

*ISOPE Member.
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KEY WORDS: Low-frequency damping, low-frequency added mass, viscous effect, cylindrical members, semisubmersible.