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Ship Motion Analyses in Compact Wave Basin with Absorbing Wave-maker

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Analyses are presented of experimental ship motion in ring waves and focused transient waves at a new compact wave basin, AMOEBA (Advanced Multiply Organized Experimental BAsin). The basin, developed by the authors, enables the generation of arbitrary wave fields using 50 energy-absorbing wave-makers arranged around a basin. These analyses give frequency and directional characteristics of ship motion with fewer experiments than conventional basins using individual regular waves. A theory of ship motion analysis in ring waves and focused transient waves is proposed, and the validity of this analysis is tested with experimental results. A relationship between accuracy and basin size is also examined theoretically for practical analyses and experiments.

INTRODUCTION

Ship motion experiments, with ship models in wave tanks, are normally very time-consuming due to the reflection of wave energy by the walls of the experimental basin. Although Takezawa et al. (1988) proposed an experimental method of utilizing reflected waves from tank walls positively, reflected waves generally disturb experimental conditions. Consequently, we must finish measuring before a ship model encounters reflected waves, and we cannot carry out the subsequent experiment until the reflected waves completely disappear.

Large models (longer than 3 m) have often been used to obtain accurate results, but this adds to the time and power requirements. Large models are expensive to make and difficult to operate. The required size of the ship model depends on what is being measured. If only the 1st-order hydrodynamic forces and ship motions are required, the ship model can be miniaturized until surface tension becomes a significant factor.

The compact wave basin AMOEBA, which was developed by the authors (1995, 1998, 1999a and b) based on the wave energy-absorbing theory (1973, 1978, 1980, 1985 and 1987), has 50 energy-absorbing wave-making elements on the whole of the basin walls. This basin completely absorbs reflected waves and generates an arbitrary wave field indefinitely. The generation of an arbitrary wave field is based on the snake motion of segmented wave-makers (1984, 1994). In other words, the basin can generate the same conditions as an infinite wave field in an actual sea. The authors (2002) have investigated new experimental methods using this wave basin.

In this paper, we discuss methods of obtaining frequency response functions of ship motion from its time history data in ring waves or focused transient waves. Ring waves are multidirectional waves, composed of incident waves with the same amplitude and period arriving from all directions. The motions of a traveling ship in ring waves can be decomposed into regular motions of incident waves according to individual encounter wave periods. Consequently, the directional characteristics of ship motion can be obtained in a single experiment. On the other hand, focused transient waves are composed of incident waves with individual periods. Ship motions in focused transient waves can be decomposed into regular motions for each wave period. Thus, the frequency characteristics of ship motion can also be obtained in a single experiment. Combining these advantages, we can observe the direction and frequency characteristics of ship motion at the same time.

We propose a theory of ship motion analysis in ring waves and focused transient waves, and we tested the validity of this analysis with experimental results. We also examined theoretically the practical analyses and experiments in the large AMOEBA.

THEORY AND ANALYSIS OF FOCUSED TRANSIENT WAVES

Focused transient waves are generated by a linear summation of wave elements of individual periods. We are able to design focused transient waves with arbitrary wave frequencies. When the phase of waves propagating in the same direction agrees at a specific point in a basin, focused transient waves instantaneously appear at that point. Thus, focused transient waves enable us to obtain frequency response functions of ship motion at a specific point in a single experiment.

A time history of the wave elevation encountered by a ship model is expressed as $\zeta(t)$ at the center of gravity of the ship, and a time history of its ship motion (surge, sway, heave, roll, pitch, yaw) is described as $z(t)$. When these time histories are obtained in $-T/2 \le t \le T/2$, they are shown as:

$$\zeta(t) = \begin{cases} \zeta_T(t) & \text{in} \quad -\dfrac{T}{2} \le t \le \dfrac{T}{2} \\ 0 & \text{in} \quad |t| > \dfrac{T}{2} \end{cases} \tag{1}$$

$$z(t) = \begin{cases} z_T(t) & \text{in} \quad -\dfrac{T}{2} \le t \le \dfrac{T}{2} \\ 0 & \text{in} \quad |t| > \dfrac{T}{2} \end{cases} \tag{2}$$

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