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Application of a Free-Surface-Type Antirolling Tank on an Ultralarge Container Ship

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In this study, a free-surface-type antirolling tank (ART) for an ultralarge container ship is discussed. The location and dimensions of the tank are determined by considering general arrangements of the target container ship. The number, position, and solidity ratio of baffles inside the tank are decided by following the existing recommendations. The effects of two kinds of internal baffles are compared. Both computational fluid dynamics analysis and experimental study of bench tests are employed to assess the hydrodynamic effectiveness of the ART on roll motions. Results of analysis such as amplitude and phase of the tank moment and roll response amplitude operators (RAOs) are compared. Maximum roll reductions of 40% at the resonance frequency range are obtained for the target ship of an ultralarge container ship.

INTRODUCTION

As the cargo capacity of container ships keeps increasing, the rolling performance of those ships emerges as a new concern among ship owners and shipbuilders. Ultralarge container ships have low block coefficients to achieve reduced resistance, but they have pronounced bow flare and a flat transom stern to secure more cargo space. The characteristics of such a hull form result in increased transverse metacentric height (GM); hence the ship becomes more vulnerable to the roll resonance during operation.

There are many types of roll-reducing devices, as summarized in Table 1. The proper roll reduction device is selected by considering many factors such as the roll reduction ratio, the effective speed, and impacts on ship design. For container ships, the bilge keels and the free-surface-type antirolling tank (ART) are mostly preferred because less space is needed to install the roll-reducing device. Recently, the ART has been considered more attractive for container ships.

A number of researchers have reported on how to design effective ARTs for ships. Comparisons of the characteristics of U-tube-type and free-surface-type ARTs with bench tests are found in Zdybek (1979). Many experiments with free-surface-type ARTs were performed at MARINTEK, and recommendations for ART design were established (Faltinsen and Timokha, 2009). The effects of baffles on ART performance were also investigated (Lee and Vassalos, 1996), and the roll performance of a model ship equipped with ART was evaluated by Hong et al. (2012). Research was also performed to investigate the sloshing of the tank, which is a very important phenomenon in the fluid behavior of the ART. An experimental study on the hydrodynamic impact for two-dimensional models was also carried out (Kim et al., 2009). Furthermore, coupled motion of a rigid barge with a partially filled tank was studied with a pulsating Green's function approach (Lee et al., 2009).

Type	Roll reduction (%)	Speed	Impact on design
Active fins	60∼90	> 12 knots	Significant space required
Rudder roll	40∼60	> 12 knots	Additional steering gear design needed
Bilge keels	10∼20	All speeds	Increased resistance
Passive tanks	40∼75	All speeds	Water weight approximately 1%∼2% of displacement

Table 1 Comparison of various roll reduction devices

Although there have been several experiments on the application of the ART, most target ships are not ultralarge container ships. Therefore, quantitative research on roll reduction for ultralarge container ships using a free-surface-type ART is still needed.

In this study, a free-surface-type ART for ultralarge container ships is discussed. The stabilizing effect of this type of ART was investigated through numerical and experimental approaches by using a tank model only. The interaction effects between the ship motion and the ART were not considered. The amplitude and phase of tank moment were obtained, and then roll response amplitude operators (RAOs) of the ship were calculated through postprocessing.

DESCRIPTIONS OF ART

The stabilizing performance of ART is influenced by the tank size, geometry, location, and fluid level. From the viewpoint of roll reduction, the width of the ART should be designed to be as wide as possible, and the length should be chosen so that the

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KEY WORDS: Antirolling tank, ultralarge container ship, baffle, computational fluid dynamics analysis, bench test, roll motion.