Wash Waves Generated by High Speed Displacement Ships*

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ABSTRACT

It is difficult to compute far-field waves in a relative large area by using one wave generation model when a large calculation domain is needed because of large dimensions of the waterway and long distance of the required computing points. Variation of waterway bathymetry and nonlinearity in the far field cannot be included in a ship fixed process either. A coupled method combining a wave generation model and wave propagation model is then used in this paper to simulate the wash waves generated by the passing ship. A NURBS-based higher order panel method is adopted as the stationary wave generation model; a wave spectrum method and Boussinesq-type equation wave model are used as the wave propagation model for the constant water depth condition and variable water depth condition, respectively. The waves calculated by the NURBS-based higher order panel method in the near field are used as the input for the wave spectrum method and the Boussinesq-type equation wave model to obtain the far-field waves. With this approach it is possible to simulate the ship wash waves including the effects of water depth and waterway bathymetry. Parts of the calculated results are validated experimentally, and the agreement is demonstrated. The effects of ship wash waves on the moored ship are discussed by using a diffraction theory method. The results indicate that the prediction of the ship induced waves by coupling models is feasible.

Key words: wash waves; wave generation model; wave spectrum method; Boussinesq type equation wave model; motions of moored ship

1. Introduction

Wake waves generated by high speed ships may cause detrimental impacts on the coastal environment by damaging shorelines and banks. Wash waves in shallow water may have effects on water plants and animals. In recent years, complaints from smaller vessels moored along the banks of inland waterways due to the unexpected motions caused by the wash waves of passing ships have increased with the increase of high speed ships. Often such effects occurred due to operation of fast ferry services, it is significant to predict wash effects in an early stage to reduce/avoid the harmful effects. With the growing awareness of wake washes to the high-speed service, the environment and so on, many naval architects and scholars have conducted the researches on the washes. Macfarlane et al. (2008) analyzed the erosion to the banks by the washes generated by small ships in sheltered waters,
and provided that the single criteria is not enough to evaluate the washes; Ghani et al. (2008) described the experimental results of a patrol, and also gave some discussion on the numerical calculation results; Macfarlane (2009) conducted an experimental investigation into the correlation of model scale wave wake measurements against full scale trials results for a catamaran operating at low length Froude numbers; Benassai (2010) discussed the wake wash waves generated by high speed crafts observed at some distance away (typically one or multiple ship lengths) from the line of travel of the vessel both numerically and experimentally; Yaakob et al. (2012) presented results of a parametric study of catamaran hull form to obtain low wake wash hull form configurations or low speed inland waterway boats by CFD simulation and model experiments; Didenkulova (2013) investigated the potential benefits of wake analysis by means of a time-frequency technique (windowed Fourier transform), and analyzed the characteristic properties of different vessel wake signals. Pinkster (2004, 2009), van der Hout et al. (2011) calculated the effects of a passing ship on moored ships; Bunnik et al. (2009) used RANS method to analyze the responses of moored ships in waves due to the passing ship considering the effects of viscosity, and discussed the effects of the navigation angle of the passing ship; Luth et al. (2011) described the full scale test carried out to develop the missing relation between the wash induced motions of a moored vessel and the hindrance. As known to all, it is difficult and costly to measure the full scale data for each ship, and it is hard to change the wave characteristics of ships after being produced, so predicting the waves and the effects correctly in the ship design phase is an attractive choice. But there are many problems in calculating the washes of a ship, the dimensions of waterways are always very large, the affected subjects are sometimes far from the passing ship, the width of waterways is always variable, and the topography of the waterways is complex, thus it is hard to find a kind of method to obtain the satisfactory results of waves and the effects of the passing ships. Using coupled methods seems to be an attractive choice, the calculating area is divided into several parts, models are applied for each part of the area, and each model only needs to include the physics for the specific part.

A stationary wave generation model combined with a spectrum method is used to calculate the wake waves of passing ships in deep water with constant water depth (in other words, the effects of variation of waterway bathymetry can be ignored in this condition). Wave spectrum method is a kind of method that calculates the wave spectrum by analyzing the known wave heights, and then the wave height at any point of the field can be obtained by reconstruction of the wave spectrum. Calculated and measured wave data both can be used as the input for this method, which makes it feasible to obtain the washes of ships by doing experiments or using wave generation model in relative small regions. But often, variations of waterway width or depth may cause changes to the far field wave pattern, which need to be taken into account and resolved. When the depth, width or cross section of the waterway varies along the path of the ship, the flow field is unsteady principally, which cannot be considered in above-mentioned coupled method. Therefore, a stationary wave generation model combined with a separate wave propagation model (Boussinesq type equation wave model) is adopted. The Boussinesq type equation wave model used in this paper is a 2D horizontal model for the computation of wave propagation in time domain. The geometry (bathymetry, harbour walls), nonlinear wave-wave interaction, wave breaking, wave run up, wave shoaling, refraction, and diffraction