A VBM Research Based on Segmented Model Tests and Numerical Simulations for a River-to-sea Ship

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ABSTRACT

The river-to-sea ship structure tends to be flat due to limited draft of river channels. Its weakened vertical stiffness may cause slamming and wave induced vibrations. In this paper, in order to investigate the vertical bending moment (VBM) in this kind of ship, a segmented elastic model test was carried out. For comparison, numerical simulations based on three dimension (3D) potential theory and 3D hydroelastic theory were performed. And rule-based results were also given. Results indicate that, wave induced vibrations, springing and whipping would contribute more than 50% to the composed VBM in this ship. Considering effects of hydroelasticity, long term forecast of VBM based on 3D potential theory are larger than rule-based results.

KEY WORDS: segmented model tests; hydroelasticity; springing; slamming; VBM

INTRODUCTION

Due to draft limitations of inner river channels, river-to-sea ships are always wide and flat. Slamming and springing which may frequently occur under rough sea states would cause high-frequency response of the ship hull, which may damage the structure strength and reduce ship’s lifespan. On the other hand, the officially released rules special for river-to-sea ships have not attracted much attention due to its small scale. Liu (2013) has investigated the slamming of river-to-sea ship. Geng (2014) has carried out segmented model tests for river-sea ship in China. In order to investigate wave induced vibrations in ship hull, and provide reasonable wave bending moments for the flat river-to-sea ship, a segmented model test on river-sea ship was carried out. Results were compared to numerical results obtained from 3D potential theory, 3D hydroelastic theory and rule-based formula.

3D HYDROELASTIC FREQUENCY-DOMAIN ANALYSIS

According to traditional calculation method, ship is regarded as rigid body without structural deformation in wave loads prediction. Such rigid assumption is accurate enough for wave load prediction for ordinary ship. However, for structure with weak stiffness, the hydroelastic theory is necessary in the process of wave load prediction. Hydroelastic theory is a way to analyze dynamic response when hull vibration occurs. The motion and load response are calculated based on the forced vibration equation for the ship sailing in waves. Based on this theory, ship hull is elastomer, and its high frequency vibration response in waves can be calculated from higher order vibration modes and rigid motions. China Ship Scientific Research Center (CSSRC) has developed software THAFTS for 3D linear frequency-domain hydroelastic calculation.

The Basic Equation of Structural Dynamics

$$M\ddot{x} + C\dot{x} + Kx = P + F + G$$

where $M$ is the total mass matrix of the system; $C$ is the total damping matrix; $K$ is the total stiffness matrix of the system; $x$ is the total nodal displacement array of the system; $P$ is the external force on structure; $F$ is the concentrated force on structure; $G$ is the nodal forces array equalled to body force on structure.

The inherent frequency and natural mode of vibration $(r=1, 2, \ldots, N)$ is the order of vibration modes) can be obtained from modal analysis. With consideration of structure characteristic, the $1^\text{st}$, $2^\text{nd}$, $\ldots$, $m^\text{th}$ movements and deformation modes are withdrawn from the modal shape vector for the investigation on ship’s overall vibration. Nodal displacement mode shapes are discrete as:

$$D = [D_1, D_2, \ldots, D_m]$$