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Ship Springing Analysis for Very Large Container Ship

Jung-Hyun Kim and Yonghwan Kim
Department of Naval Architecture and Ocean Engineering, Seoul National University, Seoul, Korea

Byoung-Chul Kang
DSME R&D Institute, Daewoo Shipbuilding and Marine Engineering, Seoul, Korea

Yooil Kim
Department of Naval Architecture and Ocean Engineering, Inha University, Incheon, Korea

This paper considers the analysis of ship springing which is based on a hybrid BEM-FEM method to couple the boundary value problems of two distinct domains: fluid and structure. A strong-coupling scheme is applied to solve fluid-structure interaction by using a fixed-point iteration scheme. This study focuses particularly on the observation of computational results for the different beam modeling of ship structure and different structural damping. Even though the same computer code is applied, the computational results can be dependent on the user and the modeling of computational parameters such as grids, beam modeling and external forces. The ship model considered in this study is a very large containership. The computed motion RAO and the load signal time-histories are compared with experimental data, and the agreement and discrepancy are described. This kind of observation may help us to understand the uncertainty level of numerical analysis in ship springing analysis.

INTRODUCTION

Hydroelastic hull-girder vibrations referred to as springing and whipping have come to be real engineering issues with recent strong demands for larger and faster ships than ever before. As ship size is getting larger, the occurrence probabilities of springing and whipping are getting higher in general, and consequently more potential fatigue damage can be easily predicted. The primary mechanisms of springing and whipping are basically the same, but the excitation characteristics are very different. Springing is excited by ocean waves, while whipping is the transient response of hull-structure due to impulsive slamming force.

This study focuses on ship springing. If the lowest natural frequency of global ship structure is far higher than the dominant frequency range of ocean wave spectrum, springing will be negligible in ship design. However, the recent trend of building very large container ships makes springing one of significant sources of global ship vibration. Therefore, an influence of springing on fatigue loading should be taken into account quantitatively in the design of ship structure. The prediction of springing has been attempted numerically and experimentally by many researchers in marine engineering. The numerical and experimental attempts and findings are well summarized by Storhaug (2007). However, a complete theory for an analytical or numerical approach which is reliable in springing amplitude assessment is not yet developed. The experimental approach is regarded as reliable, but some concerns in experimental uncertainty and limitation of ship models are still not fully solved.

Early numerical approaches for springing analysis were based on linear 2D strip theory combined with 1D beam approximation for ship structure (e.g. Bishop and Price, 1979; Jensen and Dogliani, 1996). Recent numerical approaches can be found in the works of Malenica and Tuitman (2008), Iijima et al. (2008) and Kim et al. (2009). They employed 3D panel methods, including nonlinear restoring and Froude-Krylov forces. In springing analysis, the evaluation of nonlinear forces is very important, since these forces can be a main portion of springing excitation. Meanwhile, Malenica and Tuitman and Iijima et al. extended their structural model to a 3D finite element model for their modal approaches.

A 3D model can provide an accurate representation of the dynamic elastic behavior of ships and a direct evaluation of stress, but it is not available in the early design stage. Instead, a 1D finite element model may meet practical needs in the early design stage. Despite the recent improvement of hydrodynamic and structural analyses, the considered nonlinear forces being considered are still deficient in obtaining reliable magnitudes of high-order excitations. Further, structural damping remains in high uncertainty. For such reasons, numerical and experimental approaches for the springing prediction should supplement each other.

The present study considers the numerical analysis of the springing response of a 10,000 TEU containership by using the fully-coupled springing analysis program, WISH-FLEX (Kim et al., 2011). Particularly, this paper compares numerical results with the experimental results of the model tests done by MOERI/KORDI, investigating the influence of different computational parameters and beam models.

The numerical analysis employs a 3D Rankine panel method for solving the hydrodynamic problem and a 1D finite element method for the dynamic elastic behavior of the ship. High-order excitation is considered by calculating nonlinear restoring and Froude-Krylov forces at an actually wet body surface. The present 1D beam approach takes into account the warping distortion by adopting the Vlasov assumption and coupling between horizontal bending and torsion. The present approach can capture the complicated dynamic elastic behavior of a so-called thin-walled open section beam.

In the present computation, two different mass representations —lumped mass and consistent mass—are applied, and the corresponding results are compared. Further, the results for different structural damping values are examined, which is a matter of high uncertainty in real ship application. In a real engineering problem, the same target ship can be differently modeled by users, and

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