Evaluation of Springing-Induced Hull Girder Loads for Ultra Large Containership and Ore Carrier

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ABSTRACT

Linear springing responses are numerically evaluated in the design spiral for ultra large containership and large ore carrier. Numerical methods used in the present work are based on the modal superposition and the coupling of whole ship finite element model (3D FEM model) in structure regime and three-dimensional hydrodynamic model (3D panel model) in hydrodynamic regime. Springing-induced as well as wave-induced vertical, horizontal and torsional moments produced on the hull girders were calculated for a wide range of wave encounter frequencies. It is shown that for the ultra large containership the first and second modes of the combined torsional and horizontal vibrations of the hull contributed to the first peak of springing response and its energy is large enough to have impact on the structural behavior of the ship. On the contrary, for the large ore carrier the torsional modes of hull vibrations were negligible at high wave frequencies so that they impose little effect on the spring response of the ship.

KEY WORDS: Springing responses; ultra large container ship; large ore carrier; 3D FEM model; 3D panel model; modal superposition; torsion; vertical bending;

INTRODUCTION

The importance of hydro-elasticity has emerged in ship design practice because of excessive hull girder vibrations which are frequently reported to be partly responsible for the fatigue damage and reduction of the vessel life in seagoing ships. It is well known that this high order of hull vibrations is partly attributed to springing response which is caused by the resonance between structural natural frequencies of a ship and wave encounter frequencies. According to the rapid increase in size and speed of modern cargo carriers, the structural natural frequencies tend to approach the range of the wave encounter frequencies. Subsequently those large ships are more vulnerable to the springing response than smaller ships. This context forced the ship designers in shipyard to pay attention to the numerical calculations of springing response and the inclusion of the springing-induced response in the structural design of the ship hulls.

As far as the mathematical modeling is concerned the most popular methods are based on the so called modal decomposition approach (e.g. see Bishop & Price (1979)). Within this approach the structural response is decomposed into a series of dry structural natural modes and the coupling is performed after defining the hydrodynamic boundary value problems (BVP) for each of these modes. The solution of these BVP’s gives the corresponding hydrodynamic coefficients (added mass, damping and excitation) which are combined with those of rigid body and the extended fully coupled motion equation is built. The solution of the motion equation gives the amplitudes of the different modes of motions from which the RAO’s of any particular structural response can be deduced. As far as the structural model is concerned and since only the first few structural modes will have dynamic type of responses, the simplified non-uniform beam model is usually employed. There are several disadvantages of the beam model, the most important being that for complicated structures (container ship, multihull, etc.) it is not very representative and on the other side it does not give the direct access to the local stresses which are essential for fatigue analysis. That is why the 3D FEM model of the ship structure is preferred and this model is used in this paper. Recent advances on the different hydroelastic models can be found in the reference (JEME).

In the present work the linear springing responses are numerically evaluated for an ultra large containership and a large ore carrier to investigate the different structural behavior of the two ships. In general, for large containerships, the lowest natural modes are predominated by the coupling of horizontal and torsional modes while the ones for the ordinary merchant ships are associated with vertical bending modes. The numerical methods used in the present work are based on the recent Bureau Veritas’ R&D work on the modal superposition and coupling of 3D FEM model and 3D hydrodynamic model using the diffraction - radiation theory.

THEORETICAL BACKGROUND

Here below we briefly recall the basic principles of the numerical model used in this study. In contrast to the well known rigid body seakeeping model, the hydroelastic model basically extends the motion representation with the additional modes of motion/deformation chosen as a series of the dry structural natural modes. We write: