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Global hydroelastic analysis of ultra large container ships by improved beam structural model

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ABSTRACT: *Some results on the hydroelasticity of ultra large container ships related to the beam structural model and restoring stiffness achieved within EU FP7 Project TULCS are summarized. An advanced thin-walled girder theory based on the modified Timoshenko beam theory for flexural vibrations with analogical extension to the torsional problem, is used for formulation of the beam finite element for analysis of coupled horizontal and torsional ship hull vibrations. Special attention is paid to the contribution of transverse bulkheads to the open hull stiffness, as well as to the reduced stiffness of the relatively short engine room structure. In addition two definitions of the restoring stiffness are considered: consistent one, which includes hydrostatic and gravity properties, and unified one with geometric stiffness as structural contribution via calm water stress field. Both formulations are worked out by employing the finite element concept. Complete hydroelastic response of a ULCS is performed by coupling 1D structural model and 3D hydrodynamic model as well as for 3D structural and 3D hydrodynamic model. Also, fatigue of structural elements exposed to high stress concentration is considered.*

KEY WORDS: Hydroelasticity; Container ship; Beam theory; Restoring stiffness; Finite element method.

INTRODUCTION

The increase in the world trade has largely contributed to the expansion in sea traffic and building Ultra Large Container Ships (ULCS) up to 20,000 *TEU*. Structure design of such large ships is at the margin of the classification rules. Due to increase in size and speed the natural frequencies of the hull girder can fall within the range of encounter frequency of wave load. Several important issues affecting ULCS have been identified, i.e. nonlinear quasi-static hydrodynamic loading, springing, slamming, green water and whipping. These problems have been analysed within EU FP7 Project Tools for Ultra Large Container Ships (TULCS) (Malenica et al., 2011). For the needs of preliminary design beam model of hull girder has been developed, which is described in this paper (Senjanović et al., 2014a). It is based on the advanced theory of thin-walled girders (Senjanović et al., 2009). Beam finite element is derived which includes bending, shear, torsional and warping stiffness properties. Also, contribution of transverse bulkheads to the hull stiffness is analysed as well as effectiveness of relatively short engine room structure.

In addition problem of restoring stiffness formulation is considered and a consistent formulation is presented, which is worked out by employing the finite element concept (Senjanović et al., 2013). Application of the developed theoretical achievements is illustrated by numerical examples of the contemporary ships.

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BEAM STRUCTURAL MODEL

Outline of the advanced theory of thin-walled girders

Development is based on the Timoshenko beam theory. The total beam deflection, w, consists of the bending deflection, w_b, and the shear deflection, w_s, i.e., Fig. 1.

$$w = w_b + w_s \, . \tag{1}$$

The shear deflection is a function of w_b

$$w_s = -\frac{EI_b}{GA_s}\frac{\partial^2 w_b}{\partial x^2} \, , \tag{2}$$

where E and G are the Young's and shear modulus, respectively, while I_b and A_s are the moment of inertia and shear area of cross-section, respectively. The angle of cross-section rotation is caused by the bending deflection

$$\varphi = \frac{\partial w_b}{\partial x} \, . \tag{3}$$

The cross-sectional forces are the bending moment

$$M = -EI_b \frac{\partial^2 w_b}{\partial x^2} \tag{4}$$

and the shear force

$$Q = GA_s \frac{\partial w_s}{\partial x} = -EI_b \frac{\partial^3 w_b}{\partial x^3} \, . \tag{5}$$

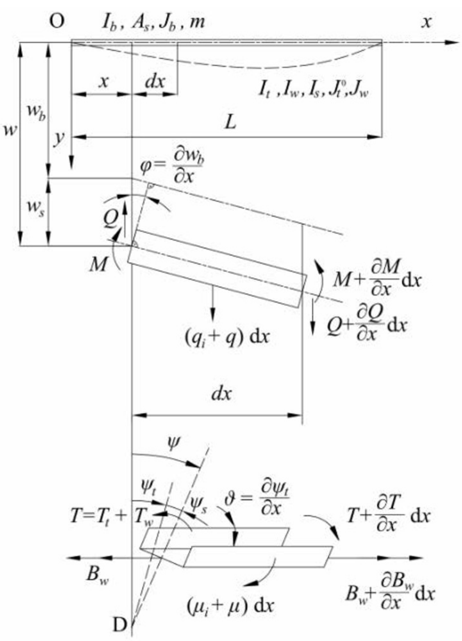

Fig. 1 Beam bending and torsion.