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An advanced theory of thin-walled girders with application to ship vibrations

I. Senjanović*, S. Tomašević, N. Vladimir

University of Zagreb, Faculty of Mechanical Engineering and Naval Architecture, I. Lučića 5, 10000 Zagreb, Croatia

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The paper presents an outline of the advanced theory of thin-walled girders. The improvement includes shear influence on torsion as an extension of shear influence on bending. The analogy between bending and torsion is recognized and pointed out throughout the paper. Complete differential equations of coupled flexural and torsional vibrations for a prismatic girder are derived. In addition, the 8 d.o.f. beam finite element, utilizing the energy approach, is constituted with stiffness and mass matrices, and load vectors. The paper describes determining of geometrical properties of multi-cell open cross-sections by employing the strip element method. Numerical procedures for vibration analyses are outlined. Furthermore, dry natural vibrations of a VLCS (Very Large Container Ship) are analysed by 1D FEM model as a prerogative for hydroelastic analyses of these relatively flexible vessels. Influence of transverse bulkheads is taken into account by increasing torsional stiffness of the ship hull proportionally to their deformation energies. Validation of 1D FEM model is checked by correlation analysis with the vibration response of the fine 3D FEM model.

* Corresponding author. Tel.: +385 16168142; fax: +385 16156940.
E-mail address: ivo.senjanovic@fsb.hr (I. Senjanović).

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Nomenclature

A	cross-section area
A_i	integration constants
A_s	shear area
a_k, b_k, c_k, d_k, e_k, f_k,	coefficients of shape functions
B_w	warping bimoment
b	one half of bulkhead breadth
C	energy coefficient
c	eccentricity
E	Young's modulus
E_{tot}	total energy
f	normal stress flow
G	shear modulus
g	shear stress flow
H	ship height
I_b	moment of inertia of cross-section
I_s	shear inertia modulus
I_t	torsional modulus
I_w	warping modulus
i, j, k	indexes
J_b	moment of inertia of distributed mass
J_t^0, J_t	polar moment of inertia of distributed mass about centre of gravity and shear centre
J_w	bimoment of inertia of distributed mass about warping centre
L, l	length
M	bending moment
m	distributed mass
n	mode number
Q	shear force
q	distributed load
T	torque
T_t	torsional torque
T_w	warping torque
t	time
U	strain energy
w	deflection
w_b	bending deflection
w_s	shear deflection
u, v	membrane displacements
x, y, z	coordinates
z_C, z_S, z_G	coordinate of centroid, shear centre and gravity centre
$[C]$	damping matrix
$[D]$	elasticity matrix
$[K]$, $[k]$	stiffness matrices
$[L]$	deformation matrix
$[M]$, $[m]$	mass matrices
$[T]$	transformation matrix
$\{F\}$, $\{f\}$	force vectors