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On the prediction of weight distribution and its effect on seakeeping

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Abstract

During the design of any ship it is normal to assess its seakeeping behavior. Whether numerical or experimental methods are used, they require accurate knowledge of the ship's radii of inertia, usually only calculable in the latter stages of design. Various estimation methods are available to predict the radii of gyration earlier in the design process, but this paper shows that they frequently fail to predict the correct value. A semi-empirical estimation method, suitable for use in the early stages of design, has been proposed in earlier work by the authors and was found to give good predictions of the eventual radii of inertia. This paper expands the range of ships against which this method was validated from five to nine (and sixteen total conditions). The method continues to provide good predictions of the radii of inertia over this increased range of ships, and remains suitable for use during the basic design stage.

Keywords

Radii of inertia; Weight distribution; Prediction method; Seakeeping; Ship motions

Nomenclature

$A_{lateral}$	[m]	Projected side area of ship
a_{xx}	[m]	Roll added mass radius of gyration
B	[m]	Beam of ship
b	[m]	Breadth of item
c	[-]	Roll radius of inertia coefficient
c_{eff}	[-]	Ratio between I_{eff}/I_{solid}
D	[m]	Depth of ship
DWT	[tonne]	Dead weight
DXF	[-]	file format for 3D objects
GT	[-]	Gross tonnage
H	[m]	Effective depth
h	[m]	Height of item
IGES	[-]	file format for 3D objects
IMO	[-]	International Maritime Organisation
I_{solid}	[ton·m^2]	Solid inertia of item
I_{eff}	[ton·m^2]	Effective inertia of fluid in tank
I_{xx}	[ton·m^2]	Roll inertia
I_{yy}	[ton·m^2]	Pitch inertia
I_{zz}	[ton·m^2]	Yaw inertia
k_{xx}	[m]	Roll radius of gyration
k_{yy}	[m]	Pitch radius of gyration
k_{zz}	[m]	Yaw radius of gyration
LCG	[m]	Longitudinal centre of gravity
LNG	[-]	Liquefied natural gas
LPG	[-]	Liquefied petroleum gas
LT	[LT]	Long ton (1016 kg)
L_{pp}	[m]	Length between perpendiculars
m	[tonne]	Mass of item
MAPE	[%]	Mean absolute percentage error
r	[m]	Radial distance from item to reference point
R	[-]	correlation coefficient
STEP	[-]	file format for 3D objects
T	[m]	Draught at midship
TEU	[-]	Twenty-foot equivalent unit
VCG	[m]	Vertical centre of gravity
x	[m]	x-distance from item to reference point
y	[m]	y-distance from item to reference point
α	[m^2]	Roll radius of inertia coefficient
β	[-]	Roll radius of inertia coefficient
Δ	[tonne]	Displacement of ship

Introduction

A ship's mass radii of inertia strongly influence its seakeeping performance. For example, the pitch radius of inertia (k_{yy}) affects pitch motions and therefore also vertical accelerations, deck wetness and added propulsive resistance in waves. The roll radius (k_{xx}) and yaw radius (k_{zz}) of inertia have a similar influence on roll, yaw and transverse accelerations, affecting comfort and the loads acting on cargo.