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Identification of hydrodynamic coefficients for manoeuvring simulation model of a fishing vessel

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A B S T R A C T

The results of numerical and experimental investigations on the manoeuvring performance of a fishing vessel, typical for Mediterranean Sea, are here presented. PMM experiments were used for evaluating hydrodynamic derivatives and implementing the theoretical model. The simulation model was validated, both with zig-zag and spiral experimental model tests results in still water and compared with Tribon Initial Design module results.

1. Introduction

A safe ship with optimum hydrodynamic performance constitutes the major concern in ship research and design activity. Appealing to the concept of global safety the naval architect aims to obtain the optimum ship shape, which allows safe operation in given environmental conditions. Since the occurrence of dangerous situations may have undesirable or detrimental consequences, the critical situations should be carefully investigated and a deeper understanding of complex hydrodynamic phenomena is mandatory. Possible major accidents could be avoided by imposing certain restriction within operation procedures. In this respect, it is very important for the designer to use powerful hydrodynamic tools in order to investigate the ship performance and safety, starting with the initial design stage.

Statistics reported in the literature reveal that fishing is one of the most dangerous occupations. The hazardous conditions on board of fishing vessels result partly because the ship is a moving platform that often exposes fishermen to harsh working conditions, which are not generally experienced in other industrial activities. It has been recognized for many years that Mediterranean Sea constitutes a highly risky area for the daily operation of fishing vessels.

In order to apply theoretical calculations in different design stages, it is necessary to develop and validate the software programs by means of experimental tests. To this aim, the hydrodynamic characteristics of a fishing vessel model were experimentally investigated (Obreja, 2001). The body plan of the vessel "Città di Genova" is shown in Fig. 1, while the characteristics of the ship and the model (scale 1/12) are summarized in Table 1. The fishing vessel actually operates in Mediterranean Sea area.

The hydrodynamic derivatives were measured during the experimental campaign by means of standard PMM model tests in still water with the aim of developing a simulation model (Nabergoj et al., 2005). There are only a few full nonlinear simulation models of merchant ships e.g. VLCG tanker, ro–ro passenger, container, ferry, etc., known in literature (Bertram, 2000; Nielsen et al., 2001; Lee and Fujino, 2003).

The manoeuvring characteristics of a Mediterranean fishing vessel are here shown for the first time and, therefore, represent an important source of helpful tools for the ship designers. The numerical predictions obtained by implementing a nonlinear hydrodynamic model tuned with the obtained derivatives are successfully validated by experiment. Data provided by Tribon Initial Design module confirm the reliability of this commercial code.

2. Hydrodynamic model

The manoeuvrability concept gathers distinct nautical performances: course keeping, course changing, change of speed and stopping. Several theoretical models can be used to investigate horizontal ship motions in time domain. The main difficulty for their implementation is the availability of hydrodynamic forces applied on hull.

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Nomenclature

The subscript notation, except where otherwise stated, denotes the partial derivatives of the forces and moments with respect to motion parameters.
The prime superscript indicates the value of a non-dimensional item.

A_R rudder area
A_{WL} area of load waterline
B moulded breadth
C stability criterion
C_B block coefficient
C_W waterline area coefficient
D stock propeller diameter
GM_T transverse metacentre height
I_{zz} yaw inertia moment
L length between perpendiculars
L_{OA} length overall
N yaw hydrodynamic moment
R instantaneous radius of the trajectory
T_A draught at the aft perpendicular
T_F draught at the fore perpendicular
T_ϕ natural roll period
U ship speed
X surge hydrodynamic force
Y sway hydrodynamic force
Y_A aft sway hydrodynamic force
Y_{A0} amplitude of the aft sway hydrodynamic force
Y_F fore sway hydrodynamic force
Y_{F0} amplitude of the fore sway hydrodynamic force
Y_{Ain} in-phase component of the aft sway hydrodynamic force
Y_{Aout} out-of-phase component of the aft sway hydrodynamic force
Y_{Fin} in-phase component of the fore sway hydrodynamic force
Y_{Fout} out-of-phase component of the fore sway hydrodynamic force
∇ volumetric displacement
k_{xx} roll radius of gyration
k_{yy} pitch radius of gyration
k_{zz} yaw radius of gyration
m mass of the ship
r vertical component of the angular speed
$\dot{r}$ vertical component of the angular acceleration
t time
Δt time step
u longitudinal component of the ship's speed
$\dot{u}$ longitudinal component of the ship's acceleration
v lateral component of the ship's speed
$\dot{v}$ lateral component of the ship's acceleration
$\overline{v}_0$ total ship's speed in the origin of the coordinates system
x_G longitudinal centre of gravity
y_{0s} amplitude of the harmonic sway motion
z_G vertical centre of gravity
β drift angle
δ rudder angle
ϕ_A phase difference between excitation and hydrodynamic response, measured by aft dynamometer
ϕ_F phase difference between excitation and hydrodynamic response, measured by fore dynamometer
$\overline{\omega}$ total angular speed of the ship
ω_s circular frequency of the harmonic sway motion
ω_y circular frequency of the harmonic yaw motion
ρ water density
Ψ heading angle
Ψ_{0y} amplitude of the harmonic yaw motion

The origin O of the body coordinate system $Oxyz$ fixed in the ship is considered amidships and situated on the symmetry plane (Fig. 2). In ship manoeuvrability studies (Abkowitz, 1964; Triantafyllou and Hover, 2002) when vertical motions can be neglected, the system of differential equations of motions gets the following simplified form

$$X = m(\dot{u} - rv - r^2 x_G)$$

$$Y = m\left(\dot{v} + ru + \frac{\partial r}{\partial t} x_G\right)$$

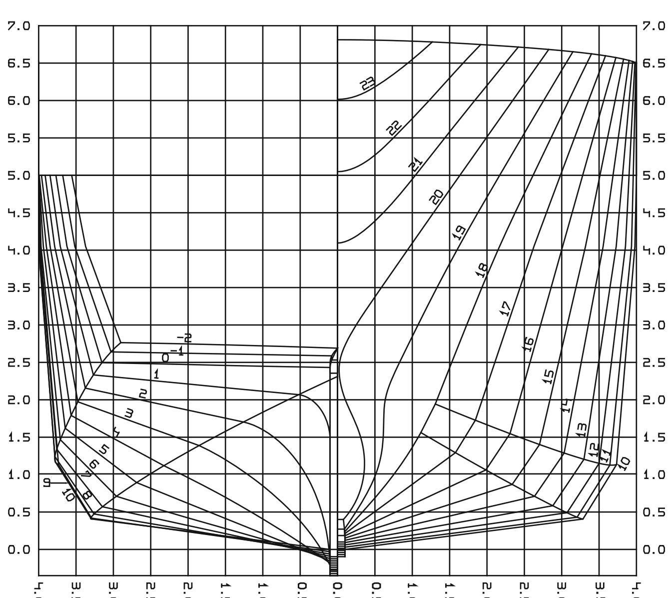

Fig. 1. Body plan of the fishing vessel "Città di Genova".

Table 1
Main characteristics of the ship and model (full load condition).

Main characteristics	Full scale	Model scale (1/12)
Length overall, L_{OA} (m)	32.7	2.725
Length between perpendiculars, L (m)	25.0	2.083
Moulded breadth, B (m)	8.0	0.667
Volumetric displacement, ∇ (m^3)	296.0	0.171
Draught at fore perpendicular, T_F (m)	2.42	0.202
Draught at aft perpendicular, T_A (m)	2.74	0.228
Longitudinal centre of gravity, x_G (m)	11.32	0.943
Vertical centre of gravity, z_G (m)	3.05	0.254
Transverse metacentre height, GM_T (m)	0.65	0.054
Block coefficient, C_B	0.574	0.574
Waterline area coefficient, C_W	0.819	0.819
Natural roll period, T_ϕ (s)	6.2	1.8
Roll radius of gyration, k_{xx} (m)	2.46	0.205
Pitch radius of gyration, k_{yy} (m)	6.78	0.565
Yaw radius of gyration, k_{zz} (m)	6.9	0.575
Area of load waterline, A_{WL} (m^2)	163.74	1.137
Stock propeller diameter, D (m)	1.8	0.15
Rudder area, A_R (m^2)	2.88	0.02
Ship speed, U	12kn	1.8m/s