MANOEUVRING PREDICTION OF OFFSHORE SUPPLY VESSEL

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To my beloved mother, whose prayers always afforded me to accomplish this work,

to my dear wife and my kids Syazwa, Iqah, Afiq, Haekal and Faris

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ABSTRACT

International Maritime Organization (IMO) standard for ship manoeuvrability have hastened the need for more accurate prediction of ship's manoeuvrability at the early design stage. There are many methods available for manoeuvring prediction such as free running model test, captive model test and etc, however these methods are expensive and time consuming. As alternative the numerical simulation method with parameters determined from a database is taking place the current principal approach. This thesis presents a manoeuvring prediction of Offshore Supply Vessel (OSV) which includes the development of the time domain simulation programme. As being OSV, manoeuvring ability is very critical aspect in order to avoiding collision and grounding especially in harbour and offshore operations such as tow and tug. Thus, early prediction of OSV manoeuvring characteristic is essentially important. Manoeuvring time domain simulation programmed was developed by using Matlab Simulink software. Hydrodynamic derivatives and coefficients are calculated from proven Kijima formulae and then be incorporated to the simulation program. Prediction vessel swept paths were obtained by double integrating acceleration in surge, sway and yaw axis. Validation of the prediction results were carried out by comparing with full-scale sea trial results. It is found that some discrepancy to the prediction results can be improved by relative sensitivity studies on simulation parameters. The result of improved prediction tool shows a good agreement to the sea trial results. Hence manoeuvring prediction by numerical approximate formula is reliable and economic to be used as a prediction tool in early design stage.

ABSTRAK

Kewujudan piawaian olahgerak kapal daripada *International Maritime Organization (IMO)* telah mengesa ke arah keperluan meramal olahgerak kapal dengan tepat pada peringkat rekabentuk lagi. Terdapat banyak kaedah yang boleh digunakan seperti ujian model bebas, ujian model tertawan dan sebagainya, tetapi kebanyakannya melibatkan kos yang tinggi dan masa yang panjang. Kaedah simulasi berangka yang mana parameter ditentukan daripada pangkalan data telah menjadi alternatif kepada kaedah yang sedia ada. Tesis ini memaparkan kajian ramalan olahgerak ke atas Kapal Bekalan Luar Pantai yang mana melibatkan program simulasi. Sebagai Kapal Bekalan Luar Pantai, aspek olahgerak adalah menjadi kritikal untuk mengelakan pelanggaran dan terkandas terutamanya yang melibatkan operasi di dermaga dan luar pantai seperti menarik, menunda dan sebagainya. Oleh itu, kebolehan meramal ciri-ciri olahgerak kapal pada peringkat awal rekabentuk adalah sangat penting. Program simulasi olahgerak telah dibuat menggunakan perisian Matlab Simulink. Pekali hidrodinamik dikira berdasarkan rumus anggaran Kijima dan seterusnya di integrasikan ke dalam program simulasi. Ramalan ke atas laluan kapal boleh diperolehi dengan pengamiran berganda ke atas pecutan kapal di dalam paksi pusuan, huyung dan rewang. Proses pengesahan keatas keputusan ramalan olahgerak dilakukan melalui perbandingan dengan keputusan olahgerak ujian laut. Perbezaan terhadap keputusan ramalan boleh diperbaiki dengan melakukan proses bandingan sensitif keatas parameter simulasi. Penambahbaikan terhadap program simulasi telah menghasilkan keputusan yang agak tepat berbanding keputusan olahgerak ujian laut. Oleh itu, ramalan olahgerak kapal berdasarkan pendekatan rumus anggaran berangka boleh diguna pakai dan menjimatkan kos di dalam menentukan ciri-ciri olahgerak kapal pada peringkat awal rekabentuk.

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LIST OF SYMBOLS AND ABBREVIATIONS

Abbreviation

CFD	–	Computational Fluid Dynamics
DE	–	Design and Equipment
DMI	–	Danish Maritime Institute
DOF	–	Degree of Freedom
IMO	–	International Maritime Organisation
ITTC	–	International Towing Tank Conference
MMG	–	Mathematical Model Group
MSC	–	Maritime Safety Committee
PMM	–	Planar Motion Mechanism
RANS	–	Reynolds Averaged Navier-Stokes
SNAME	–	Society of Naval Architects and Marine Engineers
UTM	–	Universiti Teknologi Malaysia
WG	–	Working Group

Latin Symbols

a_1, a_2, a_3	–	Constants
Ae/Ao	–	Expanded blade area ratio
a_H	–	Rudder to hull interaction coefficient
A_R	–	Rudder area
B	–	Ship breadth
bR	–	Rudder beam
$C1$, $C2$, $C3$	–	Constants for propeller
CB (Cb)	–	Block coefficient

C_N	–	Normal force coefficient
C_P	–	Prismatic coefficient
C_{PA}	–	Prismatic coefficient, after body
C_{tp}	–	Constant
C_{WA}	–	Water plane area coefficient, after body
C_{WPA}	–	Water plane area coefficient
D_P	–	Propeller diameter
ea	–	Fullness of aft run
F	–	Force
F_N	–	Normal force acting on rudder
g	–	Acceleration due to gravity
H	–	Water depth
hR	–	Rudder height
h/T	–	Under-keel clearance
I_{ZZ}	–	Moment of inertia of the ship around Z-axis
J_{ZZ}	–	Add moment of inertia around Z-axis
J	–	Advance coefficient
k	–	Hull aspect ratio
K_R	–	Aspect ratio of rudder
K_T	–	Thrust coefficient
K_Q	–	Torque coefficient
LOA	–	Ship length overall
L_{PP}	–	Length of the ship between perpendiculars
m	–	Mass of ship
m_x	–	Added mass in X-directions
m_y	–	Added mass in Y-directions
N	–	Yaw moment acting on ship
n	–	Propeller revolution
N'_β	–	Partial derivative of N with respect to β
N'_r	–	Yaw moment due to yaw motion
$N'_{\beta\beta}$	–	Partial derivative of N with respect to β
$N'_{\beta\beta r}$	–	Partial derivative of N with respect to β and yawing

$N'_{\beta rr}$	–	Partial derivative of *N* with respect to β and yawing
N'_{rr}	–	Yaw moment due to yaw motion
P	–	Propeller pitch
P/D_P	–	Propeller pitch ratio
T	–	Draught
t_P	–	Thrust reduction coefficient in straight forward moving
t_R	–	Coefficient for additional drag
r	–	Yaw rate ($r = d\psi / dt$)
r'	–	Dimensionless turning rate $[r' = r(L/U)]$
u	–	Velocity in x-direction (surge)
$\dot{u}$	–	Acceleration in *x*-direction (surge)
U	–	Total ship velocity
U_R	–	Rudder inflow velocity
v	–	Velocity in *y*-direction (sway)
$\dot{v}$	–	Acceleration in *y*-direction (sway)
w_P	–	Effective wake fraction coefficient at propeller location
w_{PO}	–	Effective wake fraction coefficient of propeller in straight running
x,y,z	–	Local co-ordinate system, body-fixed
x_o, y_o, z_o	–	Global co-ordinate system
X	–	Force in *x*-direction acting on ship
x_H	–	The distant between the centre of gravity of ship and centre of lateral force
x_G	–	Centre of gravity (positive if forward of amidships)
X_P	–	Propeller thrust
X_R, Y_R, N_R	–	Rudder forces and moment
x_R	–	The distant between the centre of gravity of ship and centre of lateral force
X'_{uu}	–	Non-dimensional ship resistance
$X'_{\beta r}$	–	The change of ship resistance due to β and yaw motion or partial derivative of *X* with respect to β and yawing
Y	–	Force in *y*-direction acting on ship

Y'_{β}	–	Partial derivative of Y with respect to β
Y'_{r}	–	Sway force due to yaw motion
$Y'_{\beta\beta}$	–	Partial derivative of Y with respect to β
$Y'_{\beta\beta r}$	–	Partial derivative of Y with respect to β and r (yawing)
$Y'_{\beta rr}$	–	Partial derivative of Y with respect to β and yawing
Y'_{rr}	–	Sway force due to yaw motion
Z	–	Numbers of blades

Greek Symbols

α_R	–	Effective ruder angle
β	–	Drift angle at the centre of gravity *C.G.*
δ	–	Rudder angle
γ_R	–	Flow straightening factor
ρ	–	Density of fluid
σa	–	Aft fullness metric
ψ	–	Heading angle

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CHAPTER 1

INTRODUCTION

1.1 Background

Manoeuvring characteristic of Offshore Supply Vessel (OSV) are very important criteria as her mission of operation demands high manoeuvrability ability and to make sure ship can be operates in what ever situation and location. Manoeuvrability ability of OSV is very critical aspect especially in harbour, offshore operations such as tow and tug in order to avoiding collision and grounding. In general, low speed vessels with high block coefficient such as OSV are known to have bad manoeuvring characteristic because of the full hull form with small length to beam ration. A successful manoeuvring is interpreted as the ability to get the ship to go anywhere, from straight ahead without any rudder action to tight turning with significant rudder action.

In December 2002, International Maritime Organization (IMO) has adopted the Resolution MSC.137 (76) "Standards for Ship Manoeuvrability". This standard was developed for maritime safety and to ensure safe operation of ships at sea. In order to apply with the IMO manoeuvring standards, the ability to predict manoeuvrability of OSV at the design stage is essentially important.

IMO standards provide criteria on the ship turning ability, yaw checking ability, course keeping ability and stopping ability. To meet this requirement, the more accurate design tool is desired for the prediction of manoeuvring motions such as turning circle and zig-zag manoeuvre. In addition, it is too late to improve the design once the vessel has been built.

1.2 Problem Statement

There are several methods available to assess the manoeuvring criteria of a vessel. The criteria is analyzing base on the vessel's swept path. Sea trial and free running model test are the straightforward methods to obtain its criteria. However these methods are expensive. Simulation methods could also be use to analyze manoeuvring criteria either by incorporating the hydrodynamic coefficients obtained from captive model test or empirical formula. The captive model test often incurs heavy expenditures in equipment, testing time and cost. Whereas in practical, both time and cost are limited in the early design stage, thus the execution of extensive model test on every ship is practically beyond possibility.

As alternative, nowadays the numerical simulation method with parameters determined from a database is taking place the principal approach under the present circumstances. On the other hand the reliability and accuracy of numerical simulation are required to be validated with full-scale sea trial results. The establishment of cheaper and accurate manoeuvring prediction tools based on numerical approach is essentially important in order to built ship to comply with IMO manoeuvring standard. As such this paper described a manoeuvring prediction study based on numerical simulation method which did not require a series of model tank test.

1.3 Objective

The objectives of this thesis are:

a) To predict manoeuvring performance of Offshore Supply Vessel (OSV) by using numerical approach simulation programme.

b) To validate manoeuvring characteristic obtained from simulation programme with full-scale sea trial results and proposed improved to simulation programme if necessary.

1.4 Scope

The scope of this thesis is listed as shown below:

a) The vessel investigate is based on design data of a "60M Offshore Supply Vessel (OSV)".

b) Determined hydrodynamic coefficients from hull form data by using semi-empirical formula.

c) Ship motion study is limited to 3 degree of freedoms which are surge, sway and yaw.

d) Manoeuvring performance parameter study is limited to turning circle and zig-zag manoeuvre.

e) Develop numerical simulation programme by using Matlab Simulink software.