Thesis for the *Doctor of Engineering*

A Maneuverability Study on Container Ship with Four Degree of Freedom in Shallow Water

January 2020

Graduate School of Changwon National University
Department of Eco-Friendly Offshore Plant FEED Engineering
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Thesis Supervisor: ***Yoon Hyeon Kyu***

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Nomenclature

α_q	Volume fraction
α_y	x- coordinates of the center of Y_{vdot}
β	Drift angle
Ω	Vector of rotational velocities
δ	Rudder angle
ε	Strain rate
ρ	Fluid density
μ	Molecular viscosity
μ_t	Eddy molecular viscosity
η	Position vector
η_0	Open water efficiency
ϕ	Roll angle
σ_k, σ_ω	Prandtl numbers
τ_{ij}	Reynolds stress tensor
τ_{RB}	Vector of rigid body force and moment
τ_H	Vector of hydrodynamic forces and moment
τ_{HS}	Vector of hydrostatic force
τ_P	Vector of propulsion force
τ_R	Vector of rudder force and moment
τ_w	Wall shear stress
ν	Kinematic viscosity
ν_t	Turbulent eddy viscosity
$\forall$	Control volume
ψ	Heading angle

Γ_ϕ	Diffusion coefficient
A	Area
a	Acceleration
B	Ship breadth
C_B	Block coefficient
C_μ	Coefficients
f	Vector of body forces per unit mass
D_P	Propeller diameter
i	Unit vector
g	Gravitational acceleration constant
n	Propeller revolution
p	Roll rate
R	Radius
r	Yaw rate
r_g	Vector of distances to the center of gravity
u	Velocity vector
u	Surge velocity
V	Speed of ship
v	Sway velocity
h	Water depth
I_x	Moment of inertia with respect to x-axis
I_y	Moment of inertia with respect to y-axis
I_z	Moment of inertia with respect to z-axis
J	Advance ratio
K	Hydrodynamic roll moment
K_Q	Propeller torque coefficient
K_T	Propeller thrust coefficient

L_{PP}	Ship length between perpendiculars
l_x	z coordinates of center of X_{udot}
l_y	z coordinates of center of Y_{vdot}
m	Ship mass
N	Hydrodynamic yaw moment
n	Propeller rate of revolution
p	Roll velocity
$P_{0.7}$	Propeller pitch at $0.7rp$
Q_0	Open water propeller torque
R	Resistance
r	Yaw velocity
Re	Reynolds number
T	Ship draft
T_0	Open water thrust
T_P	Thrust of propeller behind ship
t	time
t_p	Thrust deduction
u	Longitudinal velocity
V_P	Propeller inflow speed
V	Volume
w_p	Wave fraction coefficient
X	Longitudinal hydrodynamic force
x	Longitudinal coordinate
Y	Transverse hydrodynamic force
y	Transverse coordinate
y_+	Non-dimensional wall distance
z	Vertical coordinate

Superscript

•	Rate of change
′	Dimensionless value

Abbreviation

CFD	Computational Fluid Dynamics
DOF	Degree Of Freedom
FRMT	Free Running Model Test
IMO	International Maritime Organization
KCS	KRISO Container Ship
KRISO	Korea Research Institute of Ships and Ocean Engineering
KVLCC	KRISO Very Large Crude-oil Carriers
RANS	Reynolds-Averaged Navier-Stokes
RPM	Revolution Per Minutes
VOF	Volume Of Fluid
SIMPLE	Semi-Implicit Method for Pressure-Linked Equations
SNAME	The Society of Naval Architects and Marine Engineering
URANS	Unsteady Reynolds-Averaged Navier Stokes

ABSTRACT

A Maneuverability study on container ship with four degree of freedom in shallow water

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With the continuous increase in ship's size combined with the generally slower increase in the size of waterways, the need for the prediction of ship maneuvering in shallow waterways continues to attract attention from the international scientific community. In this study, the maneuvering characteristics of the 3-DOF maneuvering motion of container ship considering roll motion in shallow water are predicted. The RANS-based approach are used to produce the maneuvering coefficients through the simulation of various constrained motions such as forward running, static drift, static heel, circular motion, the combined motions, and the pure roll motion. The maneuvering simulations of the 3-DOF maneuvering model coupled with roll motion are done for evaluating the ship behaviors in the medium shallow water condition. The results show that the roll motion has a significant decrease on the while the ship movement trajectory has a significant increase when the ship operates in the shallow waterway. The prediction of the roll motion and maneuvering characteristics are in good agreement with those of free running model tests, indicating that the CFD simulation has compromising capability to predict the maneuvering derivatives and the 4-DOF ship maneuvering motion in shallow water as well.

KEYWORDS: Container ship, RANS method, 4 Degree of Freedom, Maneuvering characteristics, Shallow Water.

국문 요약

천수역에서 컨테이너선의 4 자유도 운동 기반 조종성능 연구

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선박의 크기가 지속적으로 증가하고 있는 반면 수로의 크기는 상대적으로 느리게 증가함에 따라 얕은 수로에서의 선박 조종에 대한 예측 필요성이 국제적으로 계속 증가하고 있는 추세이다. 본 연구는 얕은 해역에서의 횡동요 운동을 고려한 컨테이너 선의 3 자유도 운동의 조종 특성을 예측하였다. RANS 기반 접근법은 직진 운동, 정적 표류 운동, 정적 횡경사 운동, 선회 운동, 조합 운동, 순수 횡경사 운동과 같은 다양한 구속된 운동 조건에서 시뮬레이션을 수행하여 조종성미계수를 추정하는데 사용된다. 횡동요 운동을 포함하여 3 자유도 조종모델을 활용한 조종 시뮬레이션은 천수 조건에서 선박 조종성능을 평가하기 위해 수행된다. 시뮬레이션 결과로 선박이 천수 수로에서 운항 할 때 선박의 움직임 궤적이 크게 증가하는 반면 횡동요 운동은 크게 감소하는 결과를 보여준다. 횡동요 운동 및 조종 특성의 예측은 자유항주 모형시험 결과와 일치하며, CFD 시뮬레이션을 통하여 천수 조건에서의 조종성미계수와 4 자유도 선박 조종 운동을 예측할 수 있는 있음을 언급하고자 한다.

주제어:

컨테이너선, RANS 기법, 4 자유도, 조종특성, 천수역

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