

**Thesis for the *Doctor of Engineering***

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

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**Graduate School of Changwon National  
University  
Department of Eco-Friendly Offshore Plant FEED  
Engineering  
*Nguyen Tien Thua***

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

**Thesis Supervisor: *Yoon Hyeon Kyu***

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***Nguyen Tien Thua***

This thesis, written by *Tien Thua Nguyen*,  
has been approved as a thesis for the degree of  
*Doctor of Philosophy*.

Committee Chairman:

구봉국

Committee member:

윤건기

Committee member:

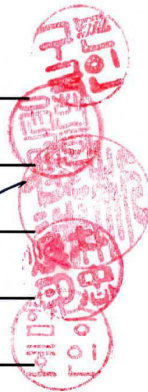
박주우

Committee member:

박중환

Committee member:

함승호



*December 2019*

**Graduate School of Changwon National  
University**

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## Nomenclature

$\alpha_q$	Volume fraction
$\alpha_y$	$x$ - coordinates of the center of $Y_{vdot}$
$\beta$	Drift angle
$\Omega$	Vector of rotational velocities
$\delta$	Rudder angle
$\varepsilon$	Strain rate
$\rho$	Fluid density
$\mu$	Molecular viscosity
$\mu_t$	Eddy molecular viscosity
$\eta$	Position vector
$\eta_0$	Open water efficiency
$\phi$	Roll angle
$\sigma_k, \sigma_\omega$	Prandtl numbers
$\tau_{ij}$	Reynolds stress tensor
$\tau_{RB}$	Vector of rigid body force and moment
$\tau_H$	Vector of hydrodynamic forces and moment
$\tau_{HS}$	Vector of hydrostatic force
$\tau_P$	Vector of propulsion force
$\tau_R$	Vector of rudder force and moment
$\tau_w$	Wall shear stress
$\nu$	Kinematic viscosity
$\nu_t$	Turbulent eddy viscosity
$\nabla$	Control volume
$\psi$	Heading angle

$\Gamma_\phi$	Diffusion coefficient
$A$	Area
$a$	Acceleration
$B$	Ship breadth
$C_B$	Block coefficient
$C_\mu$	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 $X_{u\dot{}}$
$l_y$	$z$ coordinates of center of $Y_{v\dot{}}$
$m$	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

Tien Thua Nguyen

Department of Eco-Friendly Offshore

Plant FEED Engineering

Graduate School of

Changwon National University

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

Tien Thua Nguyen

친환경 해양플랜트 FEED

공학과정

창원대학교 대학원

선박의 크기가 지속적으로 증가하고 있는 반면 수로의 크기는 상대적으로 느리게 증가함에 따라 얇은 수로에서의 선박 조종에 대한 예측 필요성이 국제적으로 계속 증가하고 있는 추세이다. 본 연구는 얇은 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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