

# EXPERIMENTAL RESEARCH ON SHIP MANEUVERABILITY ACCORDING TO LOADING CONDITION

\* THANH NHAT NAM NGUYEN \*\*IM NAMKYUN \*\*\*VAN LUONG TRAN

\* Graduate school of Maritime Transportation System, Mokpo National Maritime University, Mokpo, 530-729, Korea  
 \*\*, \*\*\* Division of Maritime Transportation System, Mokpo National Maritime University, Mokpo, 530-729, Korea

**Abstract :** In December 2002, International Maritime Organization (IMO) has adopted the Resolution MSA.137(76) Standards for the Ship Maneuverability. For applying the standards, we have to estimate and evaluate the Maneuverability of a ship at the design stage in difference of trim and displacement as accurate as possible. In this paper, the effect of loading condition on the ship Maneuverability was investigated through 3 methods : numerical simulation, free running model ship and real ship data. Firstly, We carried out numerical simulation, free running model ship experiments and real ship experiments at ballast condition, half loaded condition and full loaded condition with difference of trim.. Secondly, by comparing these results of 3 methods, we draw out the trend of ship Maneuverability due to the change of trim and displacement of a ship.

**Key words:** ship maneuverability, loading condition

## Introduction

IMO Maneuvering Standards are to be applied at full loaded even keel condition

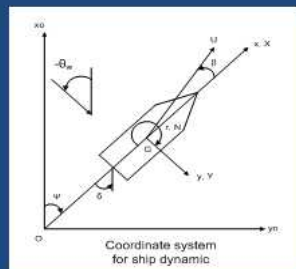
The ship is generally operated not only in full loaded condition but also in half loaded condition or ballast condition with difference of trim

The effect of loading condition on Ship Maneuverability must be taken in account

In this research, numerical simulation and free running model ship experiments were carried out and then compared with real ship test results to draw out the tendency of ship maneuverability according to loading condition.

S.I.M.A.C

## Numerical Simulation Model Ship



Type	SAENU RI
Length (m)	103
Breadth (m)	15.6
Depth (m)	7.3
Draft (m)	5.4
Displacement (T)	4600
Speed (knot)	15
Propeller type	Fixed pitch
No of Blades	4
Diameter (mm)	3.800
Rudder type	Semi-balanced

S.I.M.A.C

## Mathematical Model

**Mathematical Model for External Forces and Moment**

$$\begin{cases} (m + m_x) \dot{u} - (m + m_y) v \dot{r} = X \\ (m + m_y) \dot{v} + (m + m_x) u \dot{r} = Y \\ (I_x + I_{ax}) \dot{r} = N \end{cases}$$

$$\begin{cases} X = X_p + X_r \\ Y = Y_p + Y_r \\ N = N_p + N_r \end{cases}$$

**The External Forces and Moment Acting on the Hull**

$$\begin{cases} X_p = X_{p0} + X_{p1} + X_{p2} \\ Y_p = Y_{p0} + Y_{p1} + Y_{p2} \\ N_p = N_{p0} + N_{p1} + N_{p2} \end{cases}$$

**Propeller Force**

$$X_p = \rho \cdot C_p \cdot D^4 \cdot n^3 \cdot K_T \cdot U^2$$

**Rudder Force and Moment**

$$\begin{cases} X_r = -(1 - \sigma_r) \rho \cdot S_r \cdot l \cdot U^2 \cdot \delta \\ Y_r = -(1 + \sigma_r) \rho \cdot S_r \cdot l \cdot U^2 \cdot \delta \\ N_r = -(\sigma_r + \sigma_{r0}) \rho \cdot S_r \cdot l^2 \cdot U^2 \cdot \delta \end{cases}$$

Where :

- \*HPR : symbolize ship's hull , propeller and rudder
- \*m, m<sub>x</sub>, m<sub>y</sub> : mass of ship, x & y components of added mass of ship
- \*u, v : ship's speed
- \*r : yaw rate of ship
- \*X, Y : x, y components of external force
- \*N : moment about z-axis
- \*X<sub>p</sub>, Y<sub>p</sub>, N<sub>p</sub> : non dimensional external force and moment
- \*k<sub>T</sub> : thrust deduction rate
- \*k<sub>R</sub> : resistance increase ratio due to the rudder-on-hull interaction
- \*k<sub>1</sub>, k<sub>2</sub> : added ratio of sway force due to the rudder-on-hull interaction
- \*x<sub>H</sub> : non dimensional distance from midship to the acting location of rH

S.I.M.A.C

## Scenario

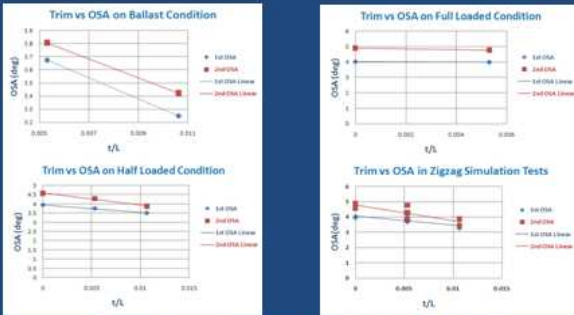
Test	Index	Ballast Condition			Half Loaded Condition			Full Loaded Condition	
		Normal trim	Big trim	Even keel	Normal trim	Big trim	Even keel	Normal trim	
10°/10° Egeng p=0	Draft(m)	4.0	4.0	4.3	4.3	4.3	4.3	5.4	5.4
	Trim(m)	0.5	1.0	0.0	0.5	1.0	0.0	0.5	0.5
	Disp(T)	3081	3081	3919	3919	3919	4600	4600	4600
10°/10° Egeng r=0	Draft(m)	4.0	4.0	4.3	4.3	4.3	4.3	5.4	5.4
	Trim(m)	0.5	1.0	0.0	0.5	1.0	0.0	0.5	0.5
	Disp(T)	3081	3081	3919	3919	3919	4600	4600	4600

S.I.M.A.C

First author: \* nhatnam44@yahoo.com

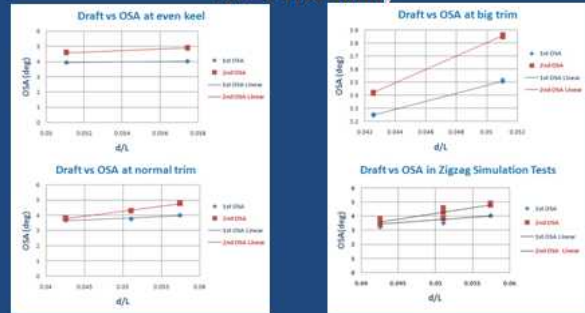
Corresponding authors : \*\* namkyun.im@mmu.ac.kr, \*\*\* tranvanluong@vamaru.vn

### Summary of the Effect of Trim on Ship Maneuverability



\*The overshoot angle decreases when the trim of ship increases  
 \*Rate of change of OSA due to Trim effect decreases when draft increases

### Summary of the Effect of Displacement on Ship Maneuverability



\*The overshoot angle increases when the draft of ship increases  
 \*Rate of change of OSA due to Draft effect increases when trim increases

### Main Particulars of Free Running Model Ship

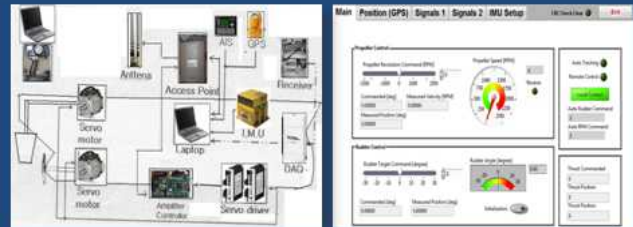


	Ship	Model
Scale ratio	1	1/100
Type	Tanker Ship	Tanker Ship
Design speed (m/s)	7.973	0.7973
L.B.P (m)	320	3.2
B (m)	58.0	0.58
Depth (m)	30.0	0.3
Draft (m)	20.8	0.2080
Displacement (m <sup>3</sup> )	312737.5	0.3127

Rudder		Propeller	
Type	Horn	Type	FP
S of rudder (m <sup>2</sup> )	273.3	No. of blade	4
Lat. area (m <sup>2</sup> )	136.7	D(m)	9.86
Turn rate (deg/s)	2.34	P/D (0.7R)	0.721
		Ae/A0	0.431
		Rotation	Right hand
		Hub ratio	0.155

### Overview of the System



System flow chart of Free Running Model Ship      Main screen of operating program

### Scenario

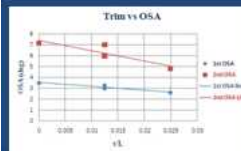
	Df (m)	Da (m)	Trim (m)
Ballast	0.08	0.08	0.00
Half Loaded	0.12	0.12	0.00
	0.10	0.14	0.04
Full Loaded	0.08	0.16	0.08
	0.18	0.18	0.00

### Environment

Time	Humidity (%)	Wind course	Wind speed (m/s)	Pressure (atm)
3pm	76	WSW	2.8	1007.5
4pm	77	WNW	3.0	1007.3
5pm	81	NW	3.9	1007.7
6pm	91	NW	3.0	1008.4
7pm	97	NW	2.0	1008.8



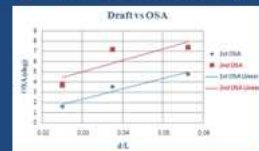
### Effect of Trim on Ship Maneuverability



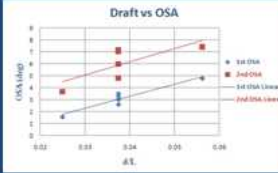
\* The overshoot angle decreases when the trim of ship increases  
 \*The course keeping and yaw checking abilities in big trim is better than in small trim

### Effect of Displacement on Ship Maneuverability

\* The overshoot angle increases when the draft of ship increases  
 \* The course keeping and yaw checking abilities in small draft is better than big draft

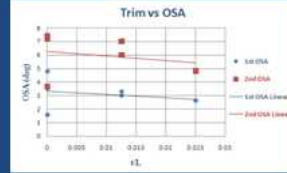


## Summary of the Effect of Loading Condition on Ship Maneuverability



Effect of draft

- The overshoot angle increases when the draft of ship increases
- The overshoot angle decreases when the trim of ship increases



Effect of trim

## Main Particulars of SAE YU DAL



Type	SAE YU DAL
Length (m)	102.7
Breadth (m)	14.5
Width (m)	9.5
Draft (m)	5.1
Displacement (T)	3644
Speed (knot)	15
Propeller type	Fixed pitch
No of Blades	4
Diameter (mm)	3,060
Area Ratio	0.63
Rudder type	Semi-balanced

## Location



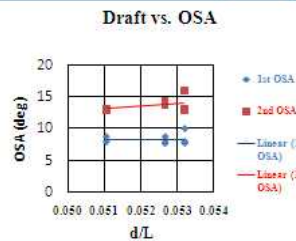
## Scenario

	East China Sea	Luzon West Coast	Luzon west Coast
Experiment cases	4	4	2
Df (m)	4.40	4.20	4.40
Dr (m)	5.60	5.70	5.20
Draft (m)	5.00	4.95	4.80
Trim (m)	1.20	1.50	0.80

## Results

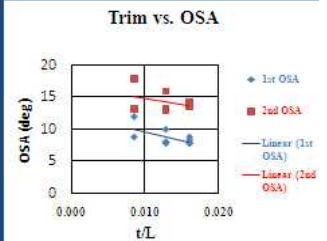
Draft (m)	4.80	4.80	4.95	4.95	4.95	4.95	5.00	5.00	5.00	5.00
Trim(m)	0.80	0.80	1.50	1.50	1.50	1.50	1.20	1.20	1.20	1.20
1 <sup>st</sup> OSA	8.80	8.00	8.30	7.80	7.80	8.80	10.00	7.80	8.00	8.00
2 <sup>nd</sup> OSA	13.30	13.0	13.80	14.20	13.70	14.40	16.00	13.30	13.00	13.00

## Real Ship Experiment Results



Effect of Displacement on Ship Maneuverability

- The overshoot angle increases when the draft of ship increases
- The overshoot angle decreases when the trim of ship increases



Effect of Trim on Ship Maneuverability

## Comparison of 3 Method's Results



## Conclusion

These experimental results are agreed with previous research.

The overshoot angle increases when the draft of ship increases

The course keeping and yaw checking abilities of ship in small draft is better than in big draft

The rate of change of OSA due to trim effect decreases when displacement increase

The overshoot angle decreases when the trim of ship increases

The course keeping and yaw checking abilities of ship in big trim is better than in small trim.

The rate of change of OSA due to draft effect increases when trim increases