Experimental Study on Force and Yaw Moment Acting on Ship in Regular Wave with Various Wave Direction

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Abstract : *Ship maneuvering performance is usually estimated in calm water conditions which provide valuable information about the ship maneuvering characteristics at the early design stage. However, the course-keeping ability and the maneuvering performance of a ship can be significantly affected by the presence of waves when ship maneuvers in real sea condition. Therefore, it is necessary to understand the maneuvering behavior of a ship in waves in the viewpoint of ship safety in the design stage. In this study, the force and yaw moment acting on a moving ship in regular waves with different wave length and wave direction will be performed in the square wave tank in Changwon National University. The results of this study can be used to help a person to design a ship hull with the best ship maneuverability in waves and disseminate knowledge on predicting ship maneuvering in regular waves in various wave directions.*

Keywords : *Model test, Wave Force, Yaw Moment, Ship Maneuvering in Wave*

Introduction

❖ **Ship maneuvering performance**

- is usually estimated in calm water conditions which provide valuable information about the ship maneuvering characteristics at the early design stage.
- However, the course-keeping ability and the maneuvering performance of a ship can be significantly affected by the presence of waves when ship maneuvers in real sea condition.
  - Therefore, it is necessary to understand the maneuvering behavior of a ship in waves in the viewpoint of ship safety in the design stage.

❖ **According to ITTC (2008)**

- Ship maneuverability in waves is of vital importance for navigation safety of seagoing ships.

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Previous work

- Yasukawa and Adnan (2006)
  - measured added resistance, steady drifting lateral force and yaw moment acting on an obliquely moving ship in regular waves.
- Xu et al. (2007)
  - conducted an experimental research on ship maneuverability in waves which included a series of PMM tests in waves to measure the forces on the model.
- Skejic et al. (2008)
  - developed the unified theory of seakeeping and maneuvering of ships in regular waves
- Seo et al. (2011)
  - have investigated the numerical analysis on ship maneuvering coupled with ship motion in waves.
- In this study, the force and yaw moment acting on a moving ship in regular waves.

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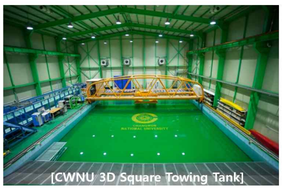
Test facility

❖ **CWNU's 3D Square Towing Tank**

- Main application
  - Ship resistance, ship maneuvering in wave test
  - PMM test for model ship and under water vehicle
  - Performance test of underwater vehicle etc ..
- XY carriage, yaw table



[CWNU 3D Square Towing Tank]

[Main specifications of 3D Square Towing tank]

Item	value
Length [m]	20
Breadth [m]	14
Water/Tank Depth [m]	1.5/1.8
Max. towing velocity [m/s]	1.0
Max. length of a model ship [m]	1.5

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Test condition

- Principal particulars

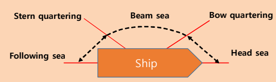
Item	Unit	Full	Model
Scale	-	1	230.000
Lpp	m	230	1.000
Lwl	m	232.5	1.011
B	m	32.2	0.140
D	m	19	0.083
T	m	10.8	0.047
Displacement	m^3	52030	0.004
LCG	m	111.6	0.485
Weight	kg	53330750	4.276
GM	m	0.6	0.0026
Speed	knots	24	1.583
Speed	m/s	12.35	0.814
Fn	-	0.26	0.26

- Rudder angle
  - 0°, 10°, 20°, 30°

- Wave condition

Lamda/L	Lamda [m]	Freq. [rad/s]	Period [s]	Real Wave height [m]	Scale Wave height [m]	Scale Wave height [cm]	h/Lambda
0.4	0.4	12.41	0.51	1.88	0.0082	0.82	0.020
0.6	0.6	10.13	0.62	1.88	0.0082	0.82	0.014
0.8	0.8	8.78	0.72	1.88	0.0082	0.82	0.010
1.0	1.0	7.85	0.80	3.25	0.0141	1.41	0.014
1.2	1.2	7.17	0.88	3.25	0.0141	1.41	0.012
1.4	1.4	6.63	0.95	3.25	0.0141	1.41	0.010
1.6	1.6	6.21	1.01	4.00	0.0174	1.74	0.011
1.8	1.8	5.85	1.07	4.00	0.0174	1.74	0.010
2.0	2.0	5.55	1.13	4.00	0.0174	1.74	0.009

- Wave direction
  - 0°, 45°, 90°,135°, 180°



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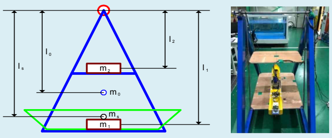
Pre-test

Inertia test

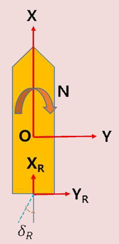
- Using inertia swing



Input, measurement	Weight 1	Weight 2	Ship
m[kg]	2	2	4.268
l[m]	0.94	0.445	0.924
T[s]	1.869	1.810	1.898
C	-5.354	12.968	

Item	Value
A	-84.65
B	7.3533
Is [kgm^2]	**0.2587**
Is_estimation [kgm^2]	0.2668
Error [%]	3.02

Coordinate system

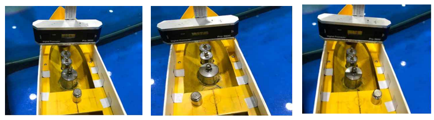


Pre-test

Ballasting

Inclining test

Items	Model
Scale ratio	230.000
Mass [kg]	4.268
GM [m]	0.0026
Moved weight [kg]	0.05
Lever ly [m]	0.03
Heel angle (deg.)	7.70



Items	Measured value [deg.]	Heal angle [deg.]	Error [%]
Start point measured	-0.05	-	-
Move weight to Port	7.52	7.57	1.67
Move weight to Starboard	-7.76	7.71	0.15

$$GM = \frac{wl_y}{W \bullet \tan\phi}$$

$$\phi = \tan^{-1}\left(\frac{wl_y}{W \bullet GM}\right)$$

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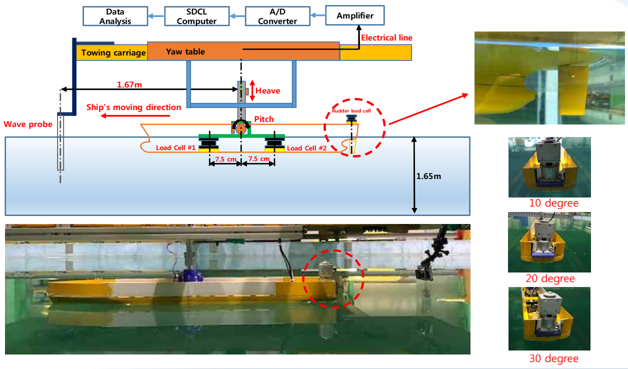
Experimental setup



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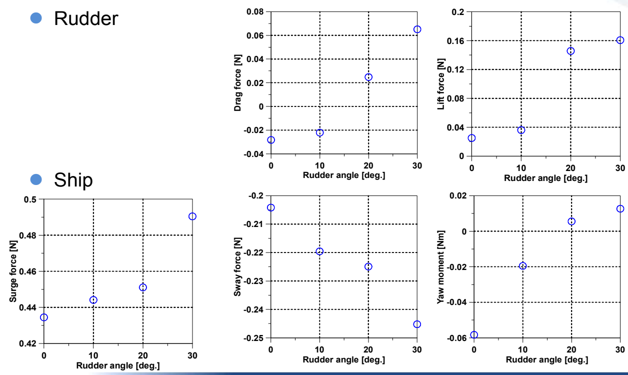
Force in Calm water

- Rudder
- Ship



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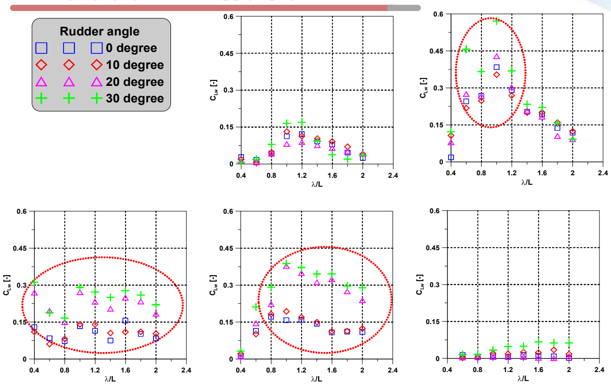
Lift coef. in wave



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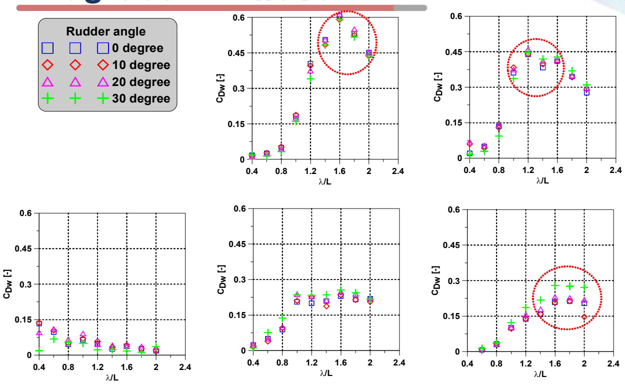
Drag Coef. in wave



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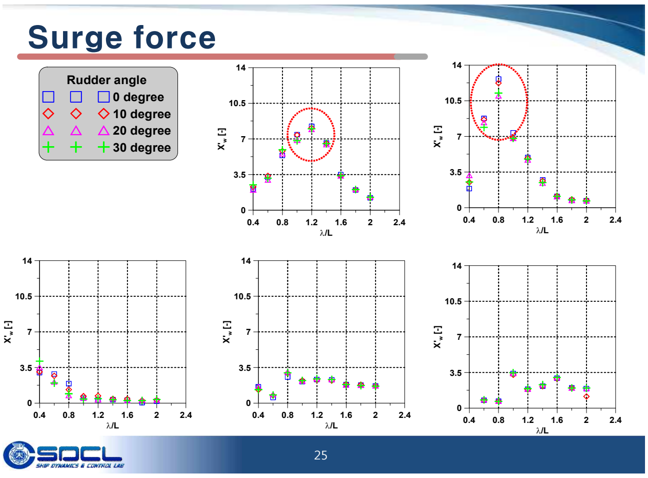

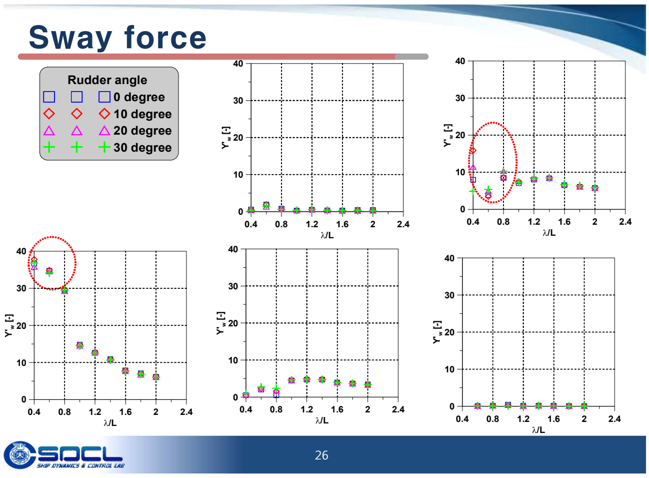

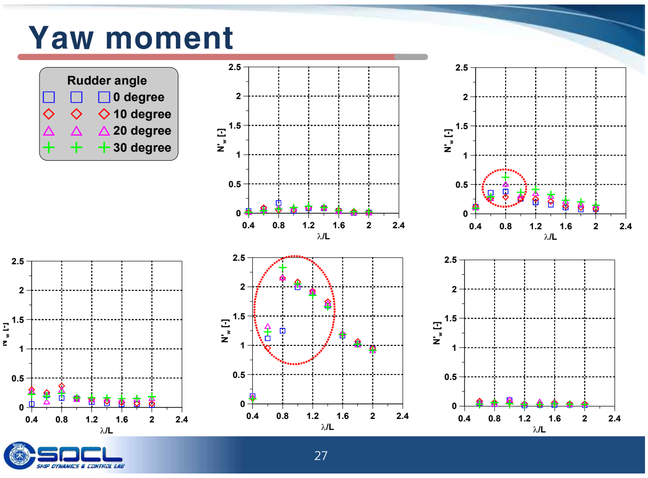

Conclusion

- The force acting on ship hull in regular waves was carried out in CWNU's model basin. A large number of test runs was performed at the test conditions as follows:
  - Forward speed: 0.814 m/s
  - Incident angle of wave: 180º, 135º, 90º, 45º, 0º
  - Wave frequency: 9 frequencies are selected in the frequency domain where the wave energy is concentrated
- The effect of wavelength and wave direction have a clear effect on the force, yaw moment acting on ship hull and lift force and drag force acting rudder.
  - For rudder
    - ✓ Drag force becomes largest in head sea, it becomes smallest in beam sea condition.
  - For model ship
    - ✓ Force and yaw moment acting on ship becomes large in short wavelength, and it decrease when wavelength increases.

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