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Estimation of Optimal Weather Routing of a Ship using the Result of Model Test and Weather data

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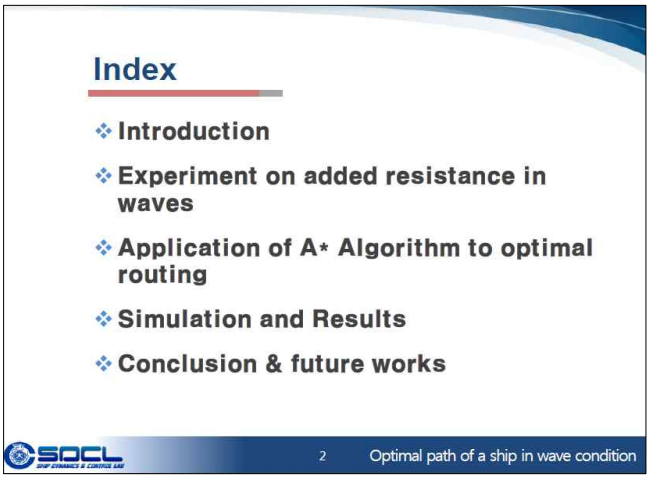
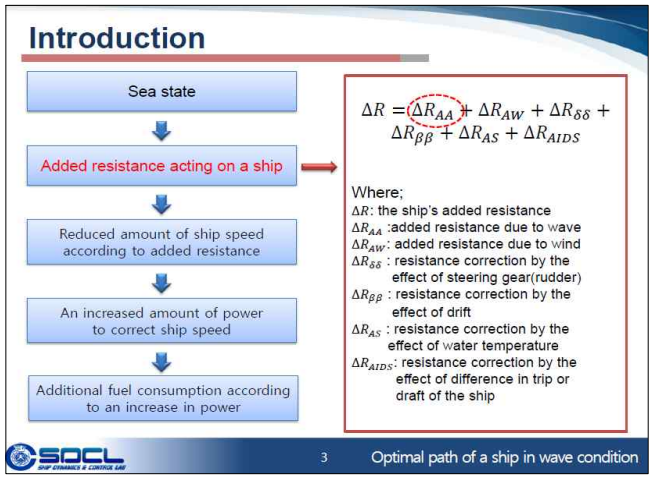
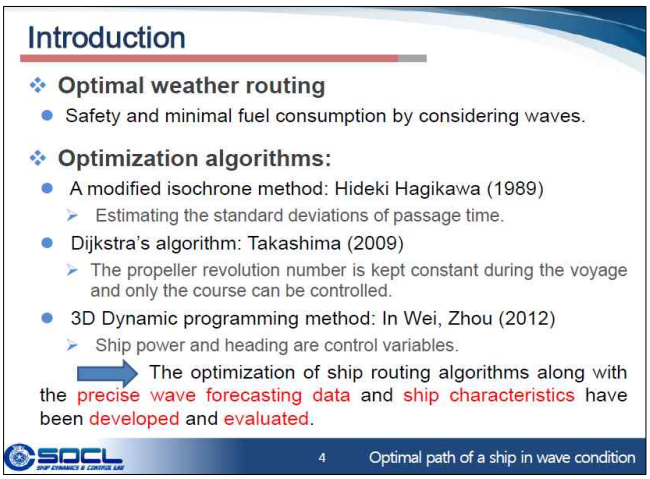
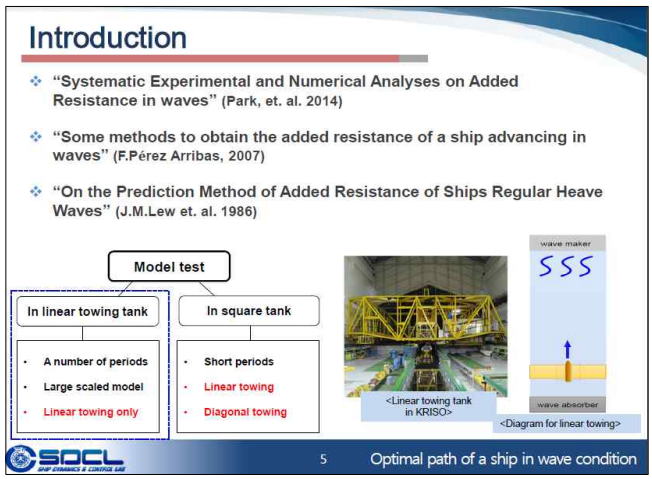
요 약 : 최적기상항로 추정의 주요 평가지수중 하나인 파랑중 부가저항의 모형시험을 이용하여 실해역의 불규칙파중 부가저항을 도출하였으며, 이를 평가지수로 갖는 A*알고리듬을 도입하여 최적기상항로를 추정하였다.

핵심용어 : 최적기상항로(Optimal weather routing), 파랑중 부가저항(Added Resistance in waves), A*알고리듬(A* algorithm)









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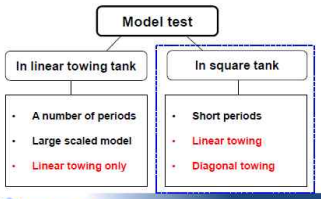
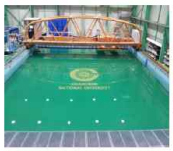
Introduction

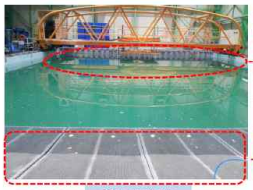
- "Systematic Experimental and Numerical Analyses on Added Resistance in waves" (Park, et. al. 2014)
- "Some methods to obtain the added resistance of a ship advancing in waves" (F.Pérez Arribas, 2007)
- "On the Prediction Method of Added Resistance of Ships Regular Heave Waves" (J.M.Lew et. al. 1986)




<Square tank in CWNU>

<Diagonal towing in Square Tank>

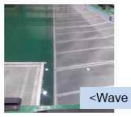
Test facility


<Square tank>

Item (unit)	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

<Principal dimensions of the square tank>


<Wave maker>

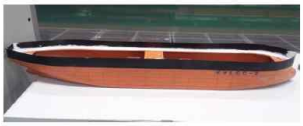

<Wave absorber>

Item (unit)	Description
Type	Piston
Plate number	28
Max. wave height (cm)	20
Max. wave length (m)	3

<Principal dimensions of the wave maker>

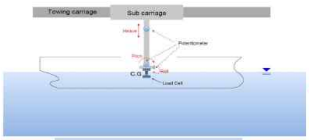
Target model ship

- KVLCC2


<Actual figure of a model ship>

Item (unit)	Real	Model
Scale ratio	1	223
L_{BP} (m)	320	1.435
B (m)	58	0.2601
D (m)	20.8	0.02819
∇ (m^3)	312622	0.02819
C_B	0.8098	0.8098
LCB (%)	3.48	3.48
Design speed (m/s)	7.97	0.534

<Principal dimension of KVLCC2>



<Diagram for installing a model ship>

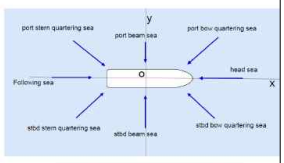
Surge, sway and yaw : fixed
Heave, roll and pitch : free

Regular wave properties

- Wave parameters & wave incident angles

A/L_{BP}	μ (°)	T (s)	ω (rad/s)	λ (m)	λ / L_{BP}
0.0035	180 135 90 45 0	0.62	10.14	0.60	0.42
		0.67	9.38	0.70	0.49
		0.72	8.78	0.80	0.56
		0.80	7.85	1.00	0.70
		0.88	7.17	1.20	0.84
		0.91	6.89	1.30	0.91
		0.96	6.55	1.435	1.00
		0.98	6.41	1.50	1.05
		1.04	6.02	1.70	1.18
		1.11	5.70	1.90	1.32
		1.13	5.55	2.00	1.39
		1.21	5.18	2.30	1.60
		1.29	4.87	2.60	1.81
		1.34	4.69	2.80	1.95
		1.39	4.53	2.30	2.09

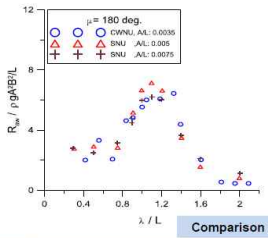
<Regular wave parameters>



<Definition of wave incident angles>

Comparison of the results

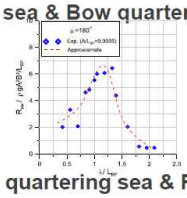
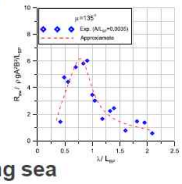
- Head sea condition
- Comparison between the results in CWNU and SNU
- To verify the availability of the test results → guaranteed



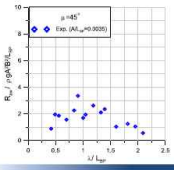
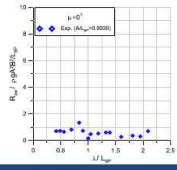
Comparison of the results

Added resistance in waves

- Head sea & Bow quartering sea

- Stern quartering sea & Following sea

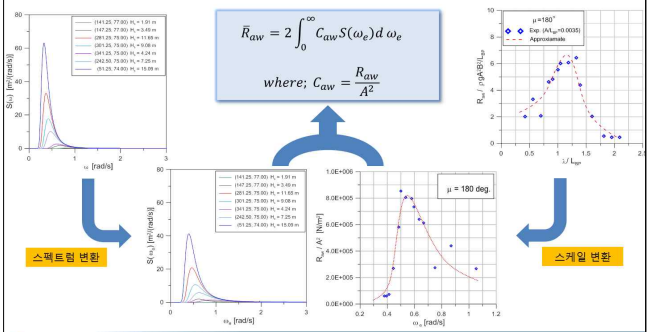



Added Resistance in Irregular Waves

Application of test results

$$\bar{R}_{aw} = 2\int_0^{\infty} C_{aw} S(\omega_e)\, d\,\omega_e$$

$$where;\ C_{aw} = \frac{R_{aw}}{A^2}$$



A* Algorithm

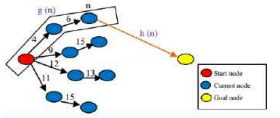
History

- Dijkstra, E.W. (1959) : Dijkstra's algorithm
- Nilsson, N (1964): Dijkstra's algorithm improve → A1
- Raphael, B (1967): A1 improve → A2
- Hart, E (1968): the new optimal algorithm A*

Evaluation Function

- Using path-cost g(n) and heuristic value h(n) to evaluate shortest path to goal.

f(n) = g(n)+ h(n)



Sample illustration of the A Algorithm*

Application of A* algorithm

Optimization routing

- Control variable is a ship speed.
- Respect to minimize fuel consumption and sailing time.
- Evaluation f(n) of a node by combining waves data forecast with characteristics of the ship.
- Discrete grid size 1.25^{o}x 1^{o}

Evaluation function of a node i+1

$$f_{i+1} = g_{i+1} + h_{i+1}$$

- Path cost value

$$g_{i+1} = g_i + g_{i,i+1}$$

$$g_{i,i+1} = R_{aw,i+1}$$

- Heuristic value

$$h_{i+1} = R\arccos(\sin\phi_{i+1}\sin\phi_{Dest} + \cos\phi_{i+1}\cos_{Dest}\cos\Delta\lambda)$$

Simulation

Departure

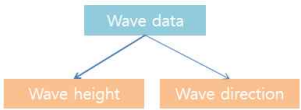
- Pusan, Korea

Destination

- San Francisco, US

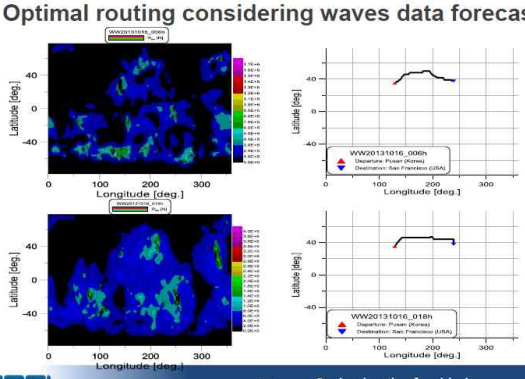
Waves data forecast from GRIB file

- WW20131016_006h
- WW20131016_018h
- WW20131016_030h



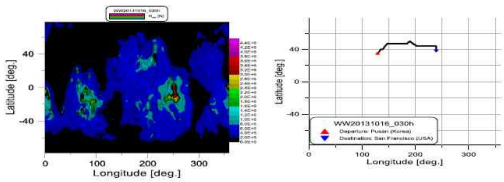
Results

Optimal routing considering waves data forecast



Results

Optimal routing considering waves data forecast



No. Data	Distance (nm)	ETA (hour)	Compare
Great Circle	4946.37	319	-
WW20131016_006h	5553.19	358	12.27%
WW20131016_018h	5821.00	376	17.67%
WW20131016_030h	5687.26	366	14.98%