On the Current Correction Method of Sea Trial Tests

Myung-Soo Shin*, Moonjin Lee*, Daeyoul Kang**, Soo-Won Jung***

* Korea Institute of Ocean Science & Technology

** Samsung Heavy Industries

*** Daewoo Shipbuilding & Marine Engineering Co. Ltd

7th Asian Shipbuilding Experts' Forum (ASEF)
Nov. 7, 2013

KIOST
KOREA INSTITUTE OF
OCEAN SCIENCE & TECHNOLOGY
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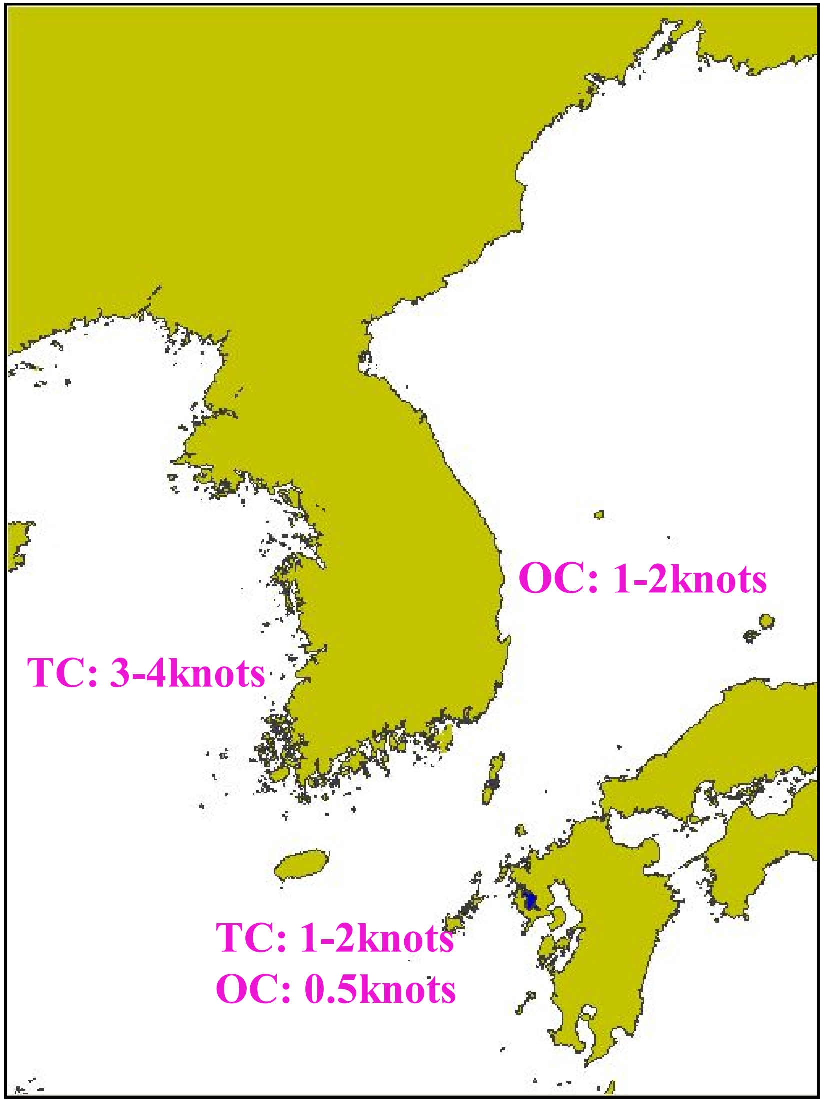
Introductions

- Near Korean Peninsula, the speed of currents are very strong. To improve the accuracy of sea trial tests, the accurate method for the current speed is very important.

- By the Minutes on ISO/TC 8/SC 6/WG 17 3rd Meeting on 2013-09-16/17 in London
  - The group agreed to include both **Iterative method** and **Mean of means** method.
  - Iterative Method
    - three (3) different power settings + additional double runs around EEDI power ; 4 double runs
  - Mean of means method
    - Five (5) double runs at three (3) different power settings are required ; over 5 double runs

- To validate the Iterative method, the comparison between the current simulation and estimated current in sea trial test by BSRA method is discussed.

Simulation of Real Time Currents



- Currents speed near Korean Peninsula is in the range of 1 – 4 knots usually.
- Currents are composed of three components
  - OC : Oceanic Currents
  - TC : Tidal Currents
  - WDC : Wind Driven Currents

Currents = OC + TC + WDC

Current Simulation : Tidal Currents

- Momentum and Continuity Equations

$$\frac{\partial U}{\partial t} + U\frac{\partial U}{\partial x} + V\frac{\partial U}{\partial y} + g\frac{\partial \zeta}{\partial x} - fV + \frac{kU\sqrt{U^2+V^2}}{D+\zeta} = 0$$

$$\frac{\partial V}{\partial t} + U\frac{\partial V}{\partial x} + V\frac{\partial V}{\partial y} + g\frac{\partial \zeta}{\partial y} + fU + \frac{kV\sqrt{U^2+V^2}}{D+\zeta} = 0$$

$$\frac{\partial (D+\zeta)}{\partial t} + \frac{\partial U(D+\zeta)}{\partial x} + \frac{\partial V(D+\zeta)}{\partial y} = 0$$

- Previous Tidal Currents Prediction

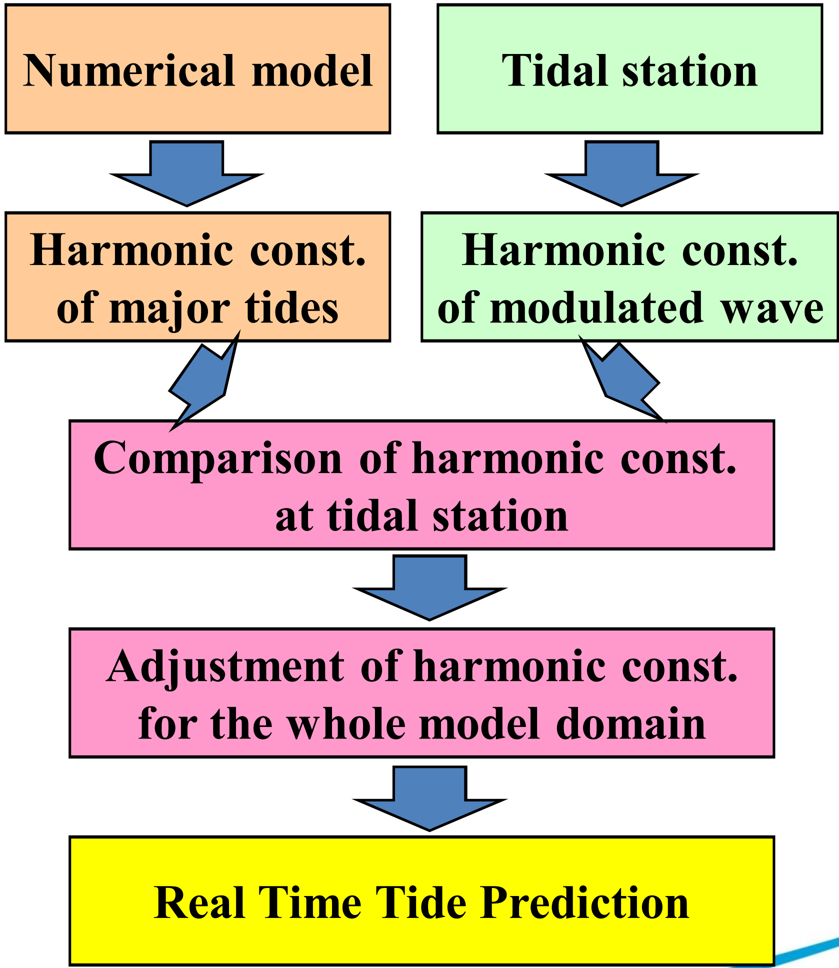
$$U(t_r) = \sum_{k=1}^{4} f_k(t_r) A_{Uk} \cos\{\omega_k - \phi_{Uk} + v_k(t_r) + u_k(t_r)\}$$

$$V(t_r) = \sum_{k=1}^{4} f_k(t_r) A_{Vk} \cos\{\omega_k - \phi_{Vk} + v_k(t_r) + u_k(t_r)\}$$

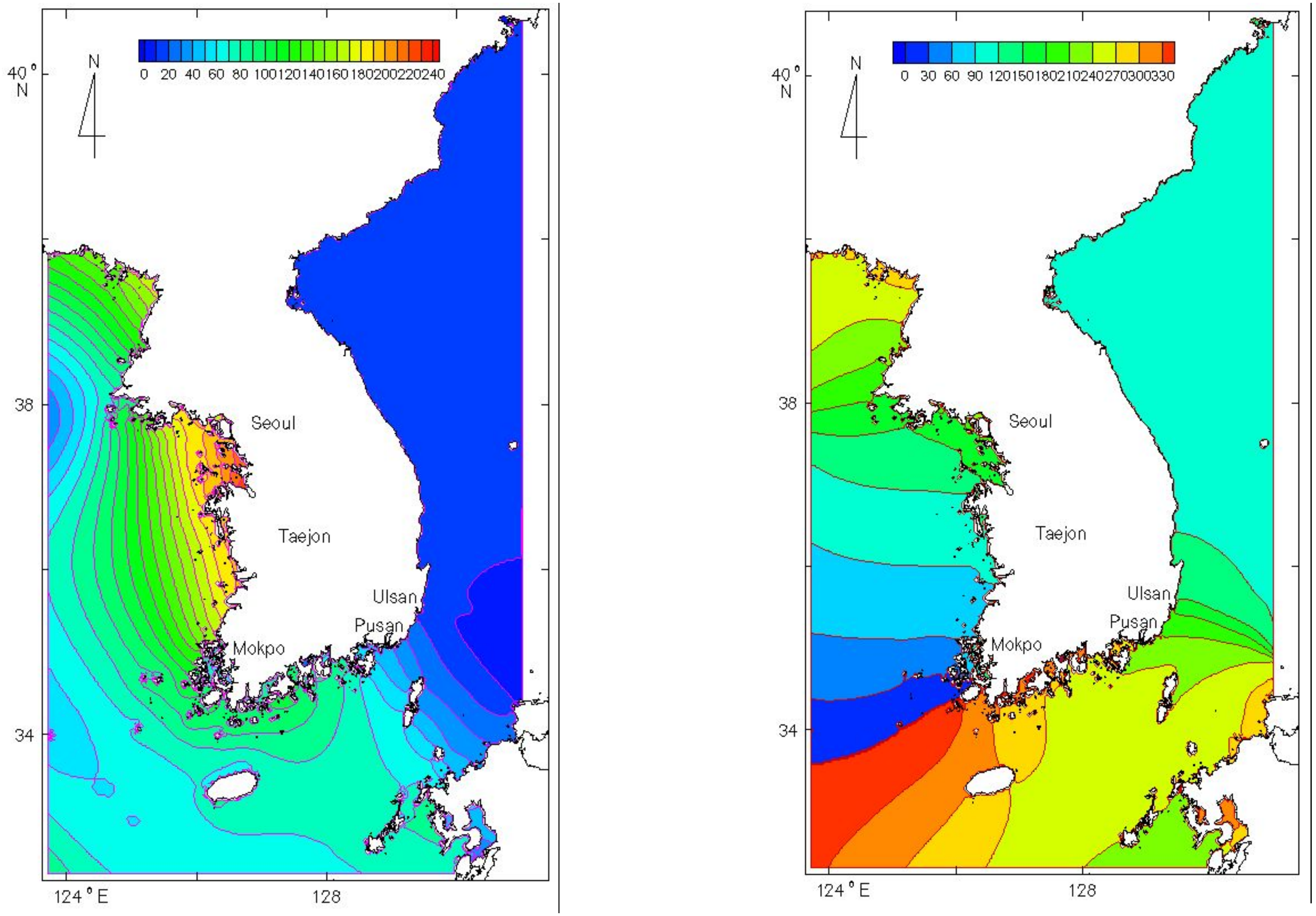
- Problem of Previous Technology
  - Consideration of 4-6 major constituents because of difficulty in specifying open boundary condition
  - Inaccuracy of predicted currents

Current Simulation : Tidal Currents

- Prediction by Harmonic Response
  - Using data from tidal station
  - Compute harmonic constants of modulated tide for each group (diurnal, semi-diurnal, quarter-diurnal, etc.) by using observed elevation of tidal station
  - Compute relationship between harmonic constants of modulated tide and of computed tide from numerical model at the tidal station
  - Adjust harmonic constants of computed tide for the whole model domain by using the relationship



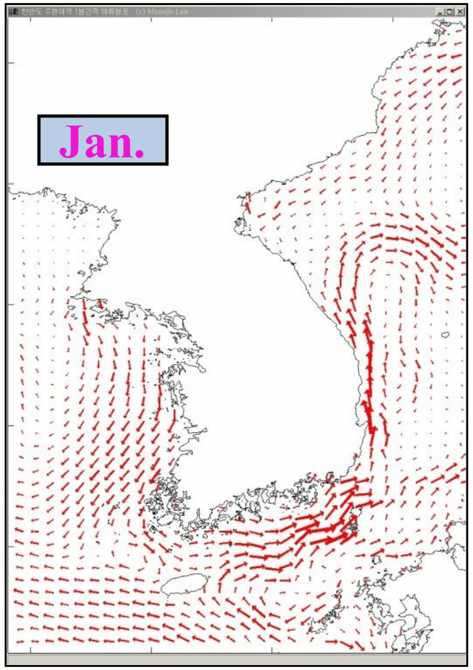
Current Simulation : Tidal Currents

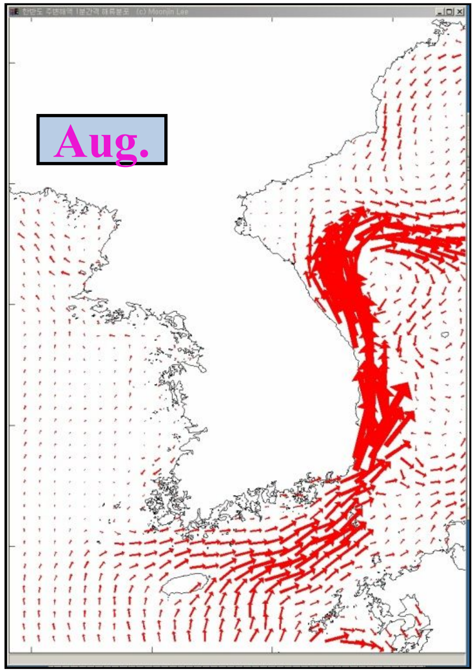


Computed Harmonic Constant of M2 tide by Numerical Modeling

Current Simulation : Oceanic Currents

- Real time connection to US Navy HYCOM server using FTP
- Download HYCOM oceanic current prediction data once in a day
- Interpolate HYCOM data to fit our grid system





Oceanic Currents of the sea off the coast of Korea Peninsula

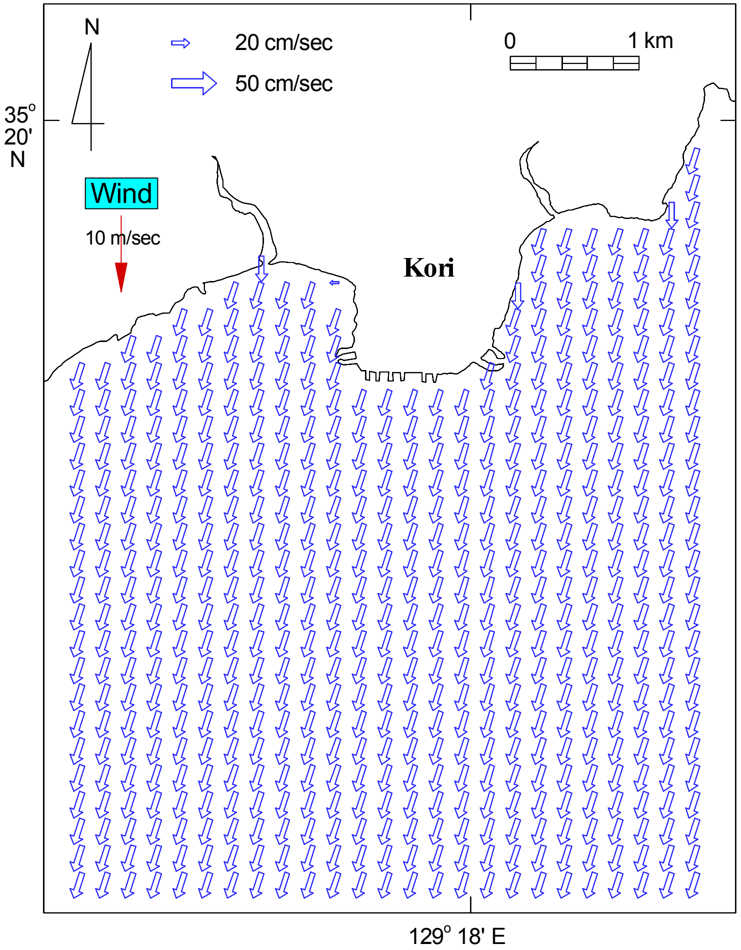
Current Simulation : Wind Driven Currents

- Relationship Between Surface Wind Driven Currents (Skin Drifts) and Wind (Lee and Kang, 1999)
  - Skin Drifts Speed = 0.029 * Wind Speed
  - Skin Drifts Dir. = 18.6 Deg. + Wind Dir.
- Simulation of Skin Drifts
  - Specify uniform distribution by using the relationship
  - Specify non-normal condition and non-slip condition at coastline
- Prediction of Skin Drifts
  - Consider time leg between skin drift and wind
  - Predict skin drifts as response function of wind

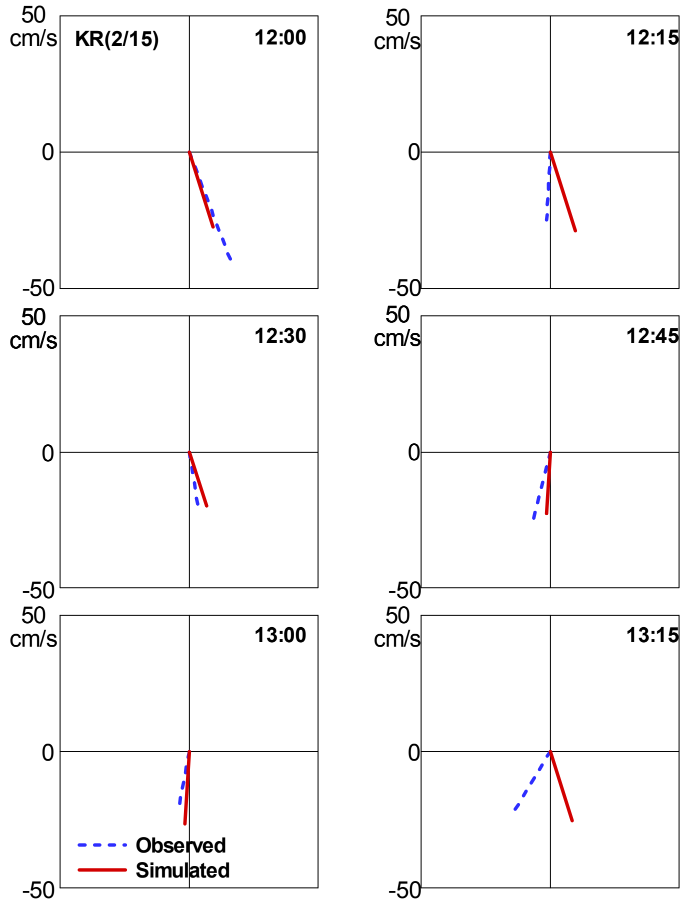
$$WDC(t) = \int_{-\infty}^{\infty} h(u) W(t-u)\, du$$

Current Simulation : Wind Driven Currents

Simulated Skin Drifts



Comparison between Observed and Simulated Skin Drifts

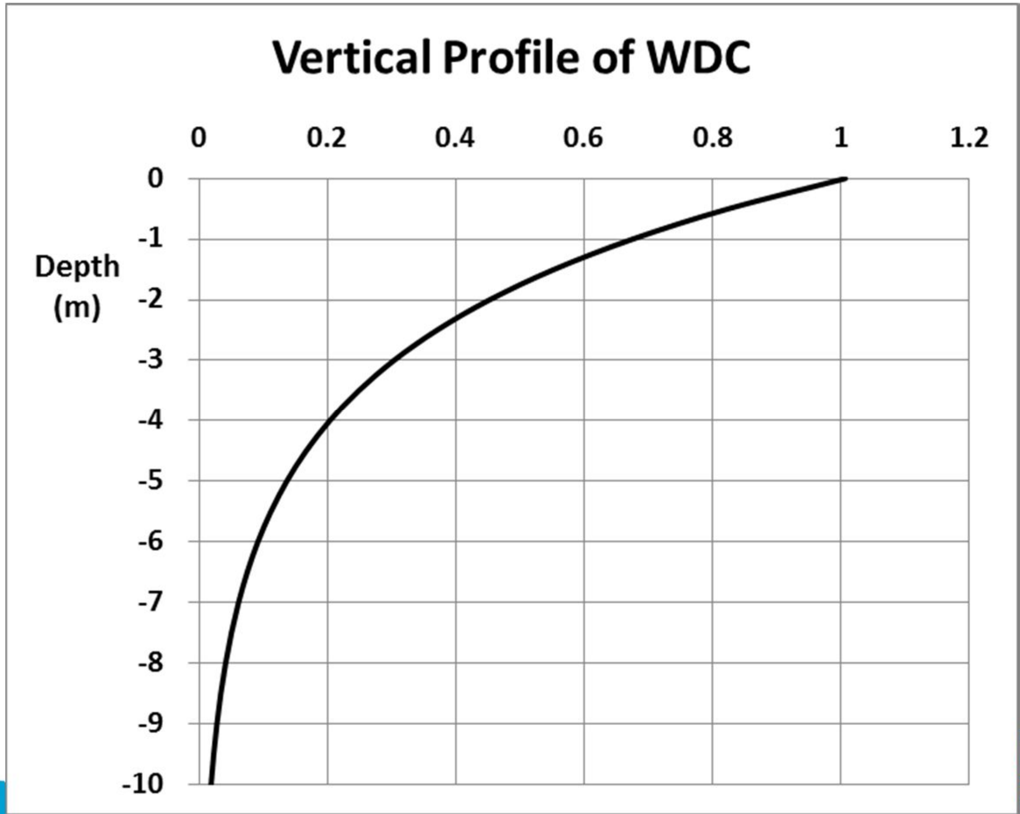


Current Simulation : Wind Driven Currents

- Vertical profile of wind driven current due to wind (Collar and Vassie, 1978)

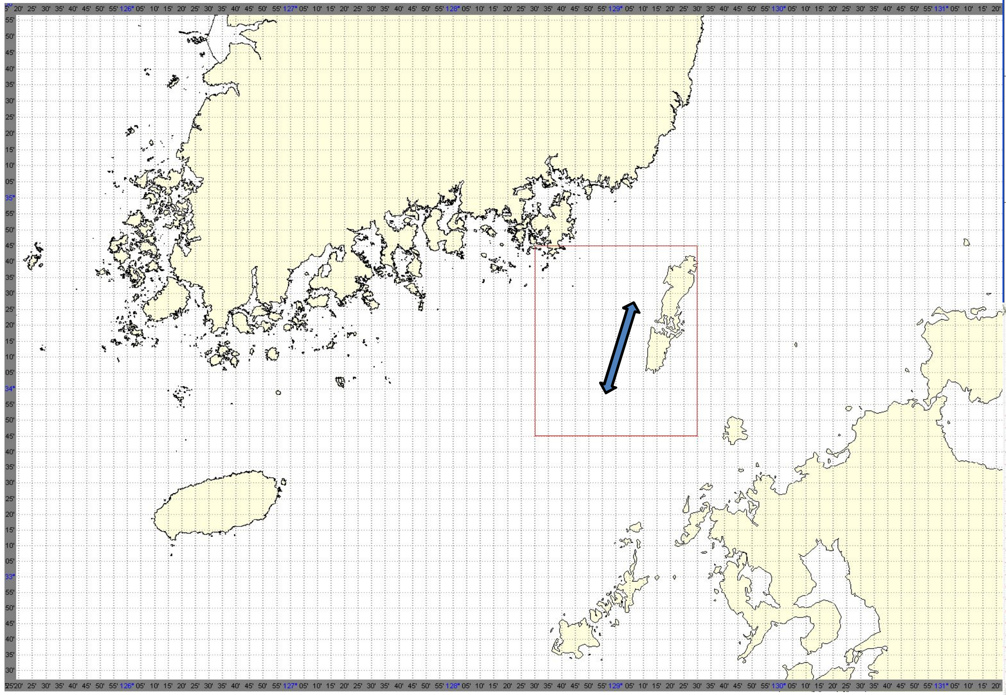
  $$U(Z) = e^{-(0.4z+3.5)}$$

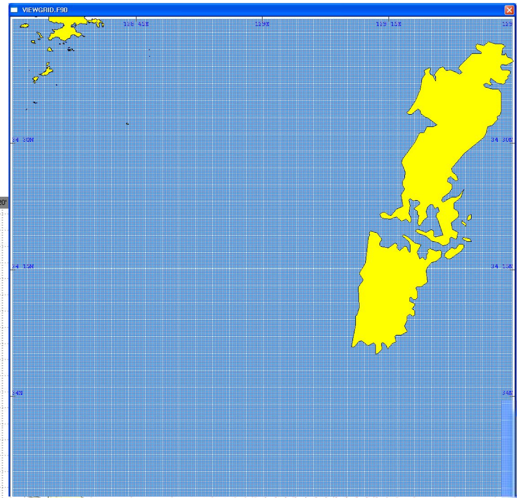
- Wind 1m/s ∝ 0.03m/s of WDC
- Considering the draft in sea trial, WDC effect seems small.



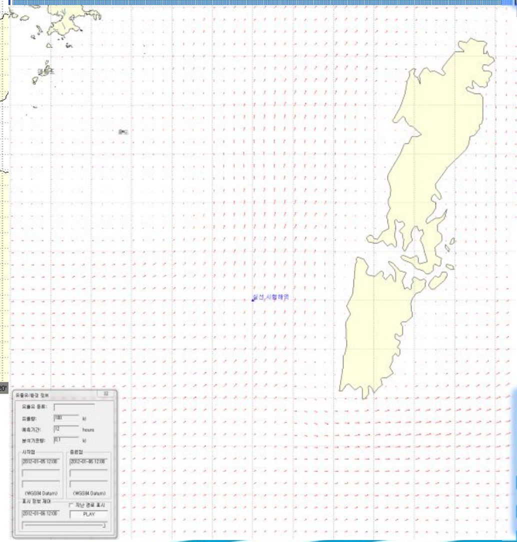
Currents Simulation of Sea-Trial Test Area

- South-east area of South sea of Korea, near Tsushima of Japan
- Simulated results are compared with sea trial test results





Grid System



Simulated Result

Input Data
Speed Trial Analysis Results by ISO15016:2002

- Speed trial analysis results by ISO15016:2002 without Currents is used as an input data for the comparison between Iterative method and simulation.
  - Speed-Power correction :Taniguchi-Tamura method
  - Waves : Maruo & Fujii-Takahashi
  - Wind : Wind test results

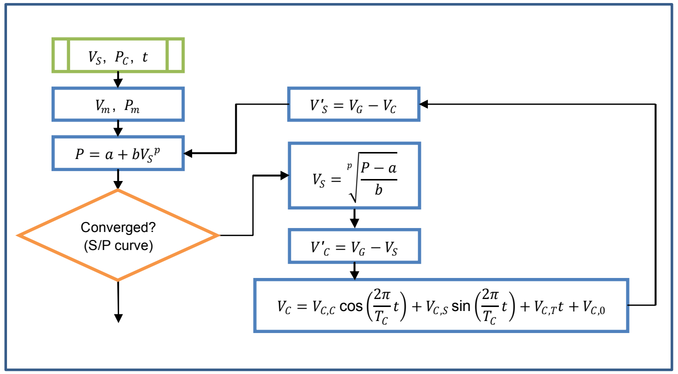
Speed loss from added resistance	Taniguchi-Tamura
Added resistance due to wind	Wind Test Results
	JTTC Chart
Resistance Increase due to waves	Maruo
Diffraction of incident waves in short waves	Faltinsen
	Kwon
	Fujii-Takahashi
Effect of steering for course keeping	SR208
Effect of drifting	SR208
Effect of water temperature and salt content	Simple Formula
Effect of displacement	Simple Formula
Effect of shallow water	Lackenby

Iterative Method on ISO15016 WD

- As current speed is assumed to vary periodically with the semidiurnal period considering the nature of current, a current curve is defined as a periodic function as follows:

$$V_C = V_{C,C}\cos\left(\frac{2\pi}{T_C}t\right) + V_{C,S}\sin\left(\frac{2\pi}{T_C}t\right) + V_{C,T}t + V_{C,0}$$

V_C: current speed, T_C: Period of variation of current speed,



- ***Stage 1: First approximation of ship speed through the water***

$$P = a + bV_S^{\,p}$$

$$V_S = \sqrt[p]{\frac{P-a}{b}}$$

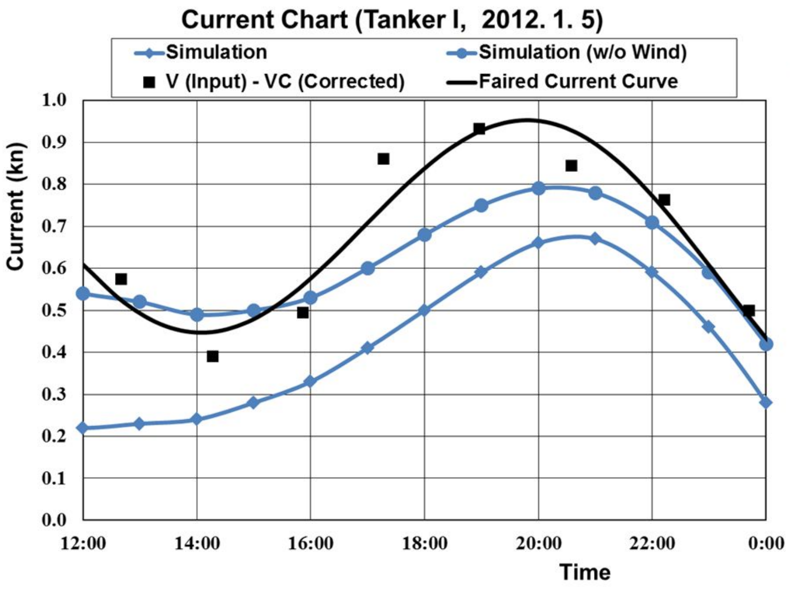
V_S : ship speed through the water, P : power, unknown factors a, b and p.

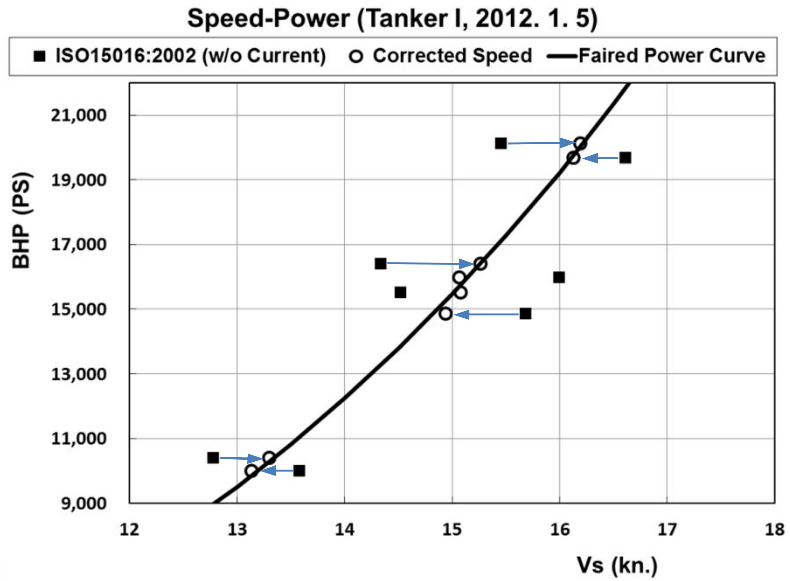
- ***Stage 2 : Calculation of current velocity***
  - Current speed at the time for each run V'_C is calculated by subtracting the updated ship speed through the water V_S from the measured ship speed over the ground V_G.

$$V_C' = V_G - V_S$$

- ***Stage 3: calculation of ship speed though the water***
  - The ship speed corrected for current V'_S is calculated subtracting the updated current speed V_C from the measured ship speed over the ground V_G.

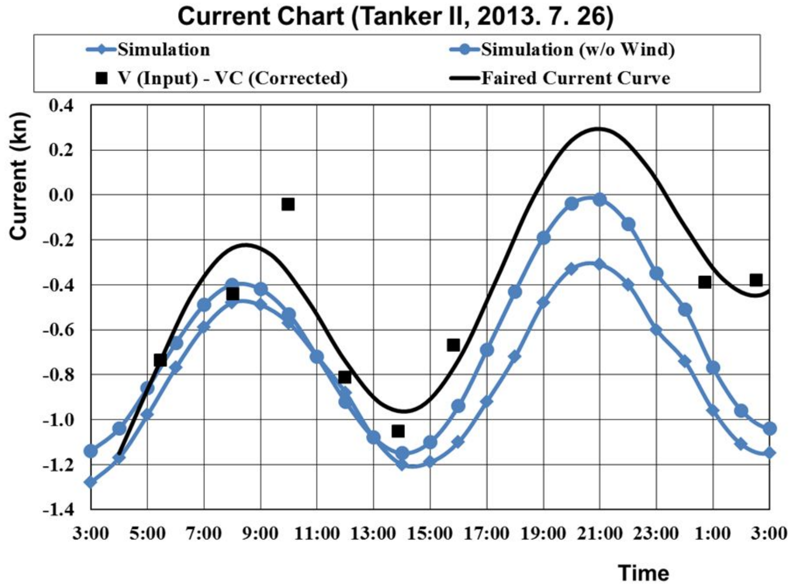
$$V_S' = V_G - V_C$$

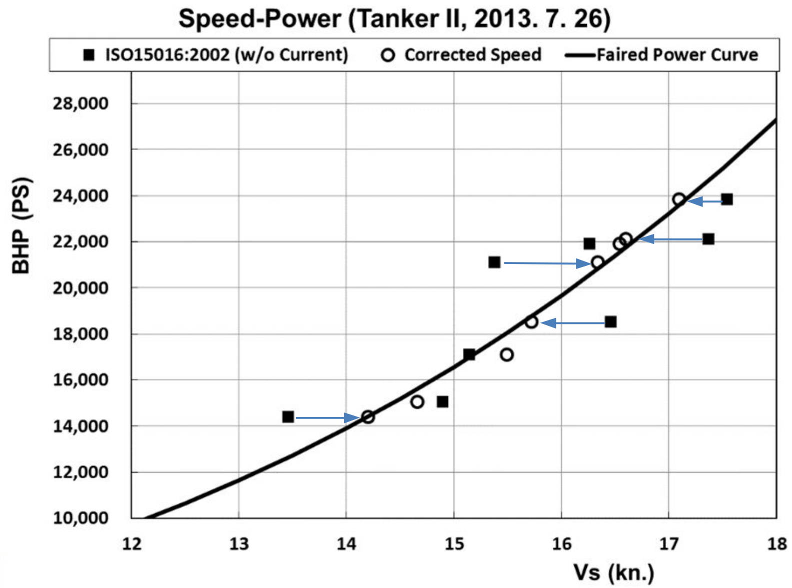




- Date : Jan. 5, 2012
- Waves : 1.5 m
- Wind : abt. 10 m/s

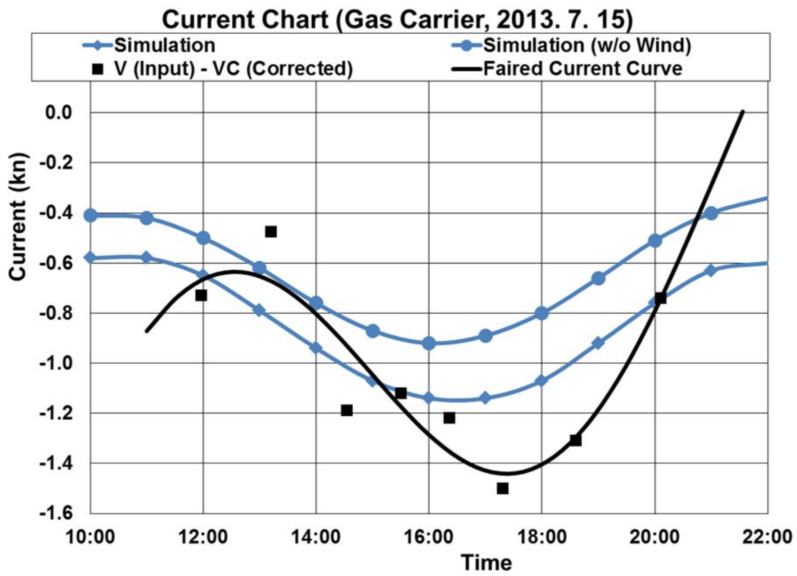
- Input data
  - By ISO15016:2002 without current correction
  - Maruo, Fujii-Takahashi (waves)
  - Wind Tunnel Test

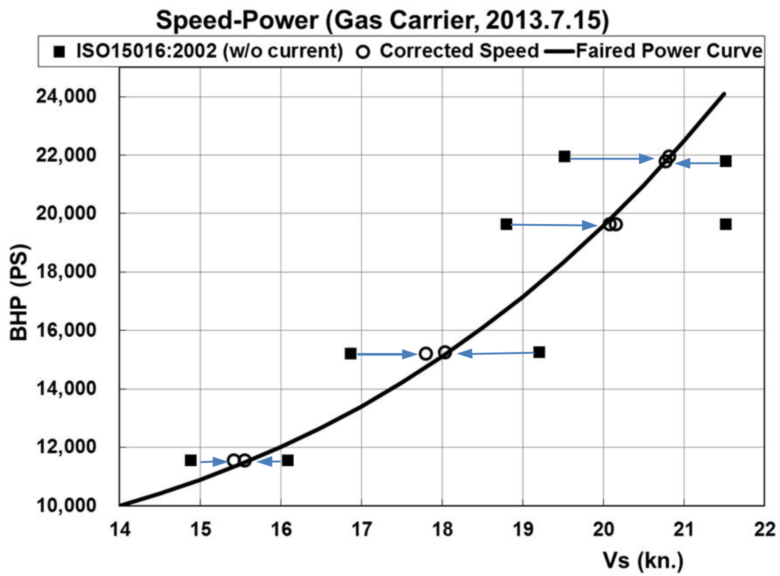




- Date : July 26, 2013
- Waves : 0.5 m
- Wind : abt. 4.5 m/s

- Input data
  - By ISO15016:2002 without current correction
  - Maruo, Fujii-Takahashi (waves)
  - Wind Tunnel Test





- Date : July 15, 2013
- Waves : 1.5 m
- Wind : abt. 7.0 m/s

- Input data
  - By ISO15016:2002 without current correction
  - Maruo, Fujii-Takahashi (waves)
  - Wind Tunnel Test

Conclusion

- Validation of Iterative method on ISO WD
  - Input data : Sea trial analysis data by ISO15016:2002 without current correction.
  - Comparisons between the Iterative method and real time current simulation show good agreements. The discrepancy between them seems within allowable range of error.
  - The faired curve of Speed-Power by Iterative method seems quite reasonable.

- Iterative method based on BSRA Standard in ISO15016 Working Draft provides **enough accuracy** for the EEDI speed verification.

Thanks for Your Attention!

by Myung-Soo Shin, Maritime & Ocean Engineering Research Institute (MOERI), KIOST.
Tel : +82-42-866-3414, Fax : +82-42-866-3429, E-mail: msshin@kiost.ac