On the Current Correction Method of Sea Trial Tests

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

\[
\text{Currents} = \text{OC} + \text{TC} + \text{WDC}
\]
Current Simulation: Tidal Currents

- Momentum and Continuity Equations

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

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

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

- Previous Tidal Currents Prediction

\[
U(t_r) = \sum_{k=1}^{6} f_k(t_r) A_{U_k} \cos \left( \omega_k \cdot t + \varphi_{U_k} + v_{U_k}(t_r) + u_{U_k}(t_r) \right)
\]

\[
V(t_r) = \sum_{k=1}^{6} f_k(t_r) A_{V_k} \cos \left( \omega_k \cdot t + \varphi_{V_k} + v_{V_k}(t_r) + u_{V_k}(t_r) \right)
\]

- 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

![Diagram of Tidal Currents Prediction]

- **Real Time Tide Prediction**

Comparison of harmonic const.
at tidal station

Adjustment of harmonic const.
for the whole model domain

Numerical model

Tidal station

Harmonic const. of major tides

Harmonic const. of modulated wave
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

Jan.

Aug.
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

\[ WDC(t) = \int_{-\infty}^{\infty} k(u) W(t-u) \, du \]
Current Simulation: Wind Driven Currents

Simulated Skin Drifts

Comparison between Observed and Simulated Skin Drifts

Wind: 10 m/sec

Kori

129° 18’ E

35° 20’ N

20 cm/sec
50 cm/sec

Simulated Skin Drifts

2013-11-7/8
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 \( \propto \) 0.03m/s of WDC
- Considering the draft in sea trial, WDC effect seems small.

![Vertical Profile of WDC Graph](attachment:vertical_profile.png)
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
### 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

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Method/Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed loss from added resistance</td>
<td>Taniguchi-Tamura</td>
</tr>
<tr>
<td>Added resistance due to wind</td>
<td>Wind Test Results</td>
</tr>
<tr>
<td>Resistance Increase due to waves</td>
<td>JTTC Chart</td>
</tr>
<tr>
<td>Diffraction of incident waves in short waves</td>
<td>Maruo</td>
</tr>
<tr>
<td></td>
<td>Faltinsen</td>
</tr>
<tr>
<td></td>
<td>Kwon</td>
</tr>
<tr>
<td></td>
<td>Fujii-Takahashi</td>
</tr>
<tr>
<td>Effect of steering for course keeping</td>
<td>SR208</td>
</tr>
<tr>
<td>Effect of drifting</td>
<td>SR208</td>
</tr>
<tr>
<td>Effect of water temperature and salt content</td>
<td>Simple Formula</td>
</tr>
<tr>
<td>Effect of displacement</td>
<td>Simple Formula</td>
</tr>
<tr>
<td>Effect of shallow water</td>
<td>Lackenby</td>
</tr>
</tbody>
</table>
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:

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

\[ V_C: \text{ current speed,} \quad T_C: \text{ Period of variation of current speed,} \]

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

\[ P = a + bV_S^p \]

\[ V_S = \sqrt[3]{\frac{P-a}{b}} \]

\[ V_S: \text{ ship speed through the water,} \quad P: \text{ power, unknown factors} \ a, \ b \ \text{and} \ p. \]

- **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 through 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!

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