2015년도 추계학술대회 논문집 pp. 100~103

Desingularized indirect boundary integral method를 이용한 2 차원 단면의 동유체력 계산

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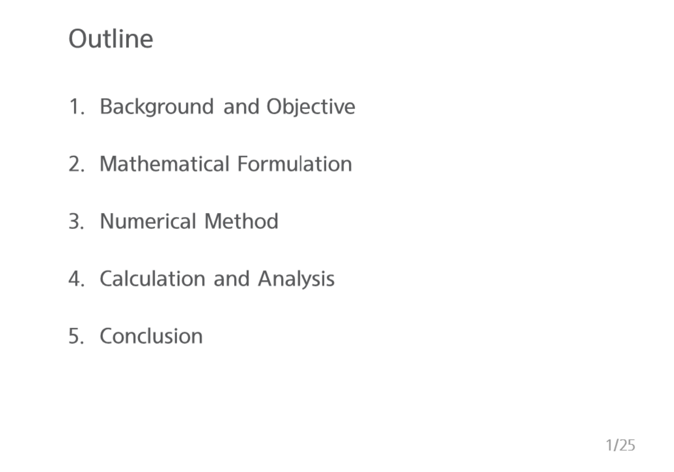
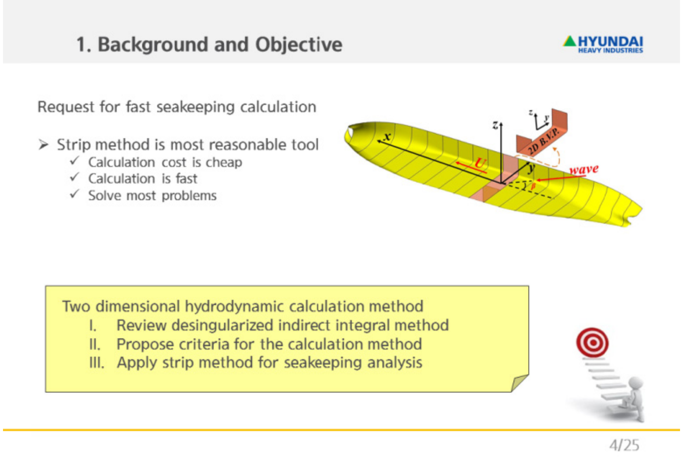
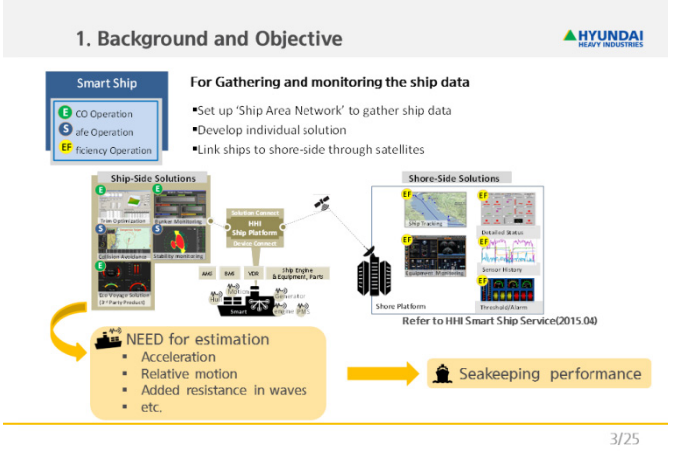
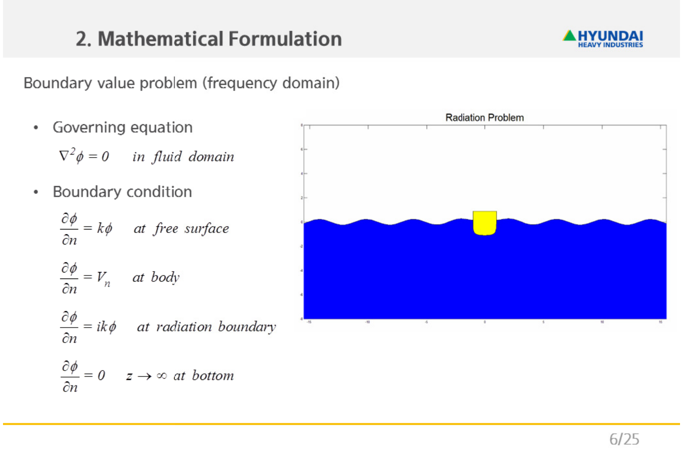
요약 :본연구에서는선박의내항및조종성능평가를위해사용되는 2차원부가질량계수와파랑감쇠계수를desingularized indirect boundary integral method를이용하여주파수영역에서계산하였다. 본방법은 Rankine source를유체경계면전체에분포하는방법으로수학적으로간단하고경계조건의변경및적용이용이하다는장점이있다. 하지만물체표면, 자유수면그리고방사경계면의계산영역및요소의배치에따라계산정확도에차이가발생한다. 따라서본연구에서는수치시험을통해, 자유수면과방사경계면의적절한계산영역과요소의개수를결정하였다. 계산의정도와효율성을확보하기위하여, 자유수면과방사경계면의계산영역과요소의분포를파의주파수에따라달리적용하였다. 본연구에서제안된수치방법을활용하여계산된동유체력과실험에서계측된동유체력을비교하여본방법의정도를확인하였다.

핵심용어 :부가질량계수, 파랑감쇠계수, desingularized indirect boundary integral method, Rankine Source









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2. Mathematical Formulation

Indirect boundary integral equation

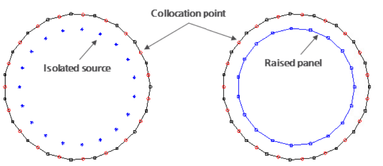
$$\phi\left(\vec{x}\right) = \int_{\Gamma} \sigma\left(\vec{\xi}\right) \cdot G\left(\vec{x},\vec{\xi}\right) d\Gamma\left(\vec{\xi}\right)$$

$$G\left(\vec{x},\vec{\xi}\right) = \frac{1}{2\pi} ln\left(r\right) \qquad \textit{two dimensional case}$$

$$G\left(\vec{x},\vec{\xi}\right) = \frac{1}{r} \qquad \textit{three dimensional case}$$

3. Numerical Method

Desingularized indirect boundary integral method (Cao et. al, 1991, Raven, 1996)



Desingularized isolated sources(Cao) Desingularized raised panel(Raven)

This method is a kind of boundary integral method. Rankine sources are distributed outside of fluid domain, so that the difficulty associated with the singular behavior of the green function is avoided

Refer to Yan-Lin Shao(2010)

3. Numerical Method

Desingularized indirect boundary integral method (Cao et. al, 1991, Raven, 1996)

Advantage

- Mathematically simple
- Easy to modify boundary condition
- Generally shorter and easier to make the code (Betram, 2000)

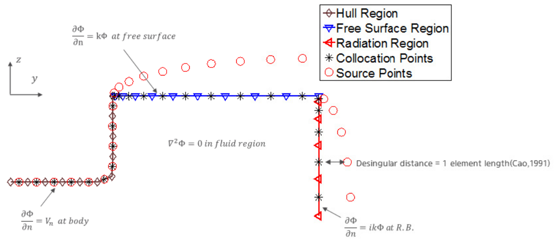
Disadvantage

- Computation cost is more expansive than free surface green function method
- Proper distribution of source is requested

3. Numerical Method

Desingularized indirect boundary integral method for radiation problem

- Discretization for domain



3. Numerical Method

Desingularized indirect boundary integral method for radiation problem

- Discretized equations

$$-0.5 \cdot \sigma_i + \sum_{j=1, j\neq 1}^{N_B} \sigma_j \int_{\Delta l_j} \frac{1}{2\pi} \frac{(x_i - \xi_j) \cdot N_i}{\left|x_i - \xi_j\right|^2} dl + \sum_{N_B + j}^{N_F + N_R} \sigma_j \cdot \frac{1}{2\pi} \frac{(x_i - \xi_j) \cdot N_i}{\left|x_i - \xi_j\right|^2} \cdot \Delta l_j = V_i \cdot N_i,\ x_i \in C_B$$

$$\sum_{j=1}^{N_B} \sigma_j \left[ik \int_{\Delta l_j} \frac{1}{\pi} ln\left(\left|x_i - \xi_j\right|\right) dl - \int_{\Delta l} \frac{1}{2\pi} \frac{(x_i - \xi_j) \cdot N_i}{\left|x_i + \xi_j\right|^2} dl \right] + \sum_{N_B + j}^{N_F + N_R} \sigma_j \left[ik \frac{1}{\pi} ln\left(\left|x_i - \xi_j\right|\right) \cdot \Delta l_j - \frac{1}{2\pi} \frac{(x_i - \xi_j) \cdot N_i}{\left|x_i - \xi_j\right|^2} \cdot \Delta l \right] = 0,\ x_i \in C_R$$

$$\sum_{j=1}^{N_B} \sigma_j \left[k \int_{\Delta l_j} \frac{1}{\pi} ln\left(\left|x_i - \xi_j\right|\right) dl - \int_{\Delta l} \frac{1}{2\pi} \frac{(x_i - \xi_j) \cdot N_i}{\left|x_i - \xi_j\right|^2} dl \right] + \sum_{N_B + j}^{N_F + N_R} \sigma_j \left[k \frac{1}{\pi} ln\left(\left|x_i - \xi_j\right|\right) \cdot \Delta l_j - \frac{1}{2\pi} \frac{(x_i - \xi_j) \cdot N_i}{\left|x_i - \xi_j\right|^2} \cdot \Delta l \right] = 0,\ x_i \in C_F$$

3. Numerical Method

Some techniques for fast and accurate calculation

1. Mirror technique
   - Symmetric source & anti-symmetric source
2. Far field solution at desingularized source panel
   - $\int ln\left(r\right) dl \Rightarrow ln\left(r\right) \Delta l$
3. Specific computation domain is generated each calculation condition

3. Numerical Method

Criteria for making boundary element

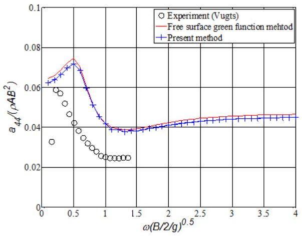
- Criteria were chosen after extensive test computation

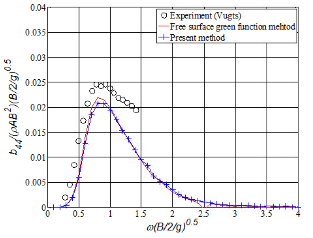
	Number of element	Length for boundary	Element distribution
Body	20	-	-
Free surface	70	$L_F = \lambda \quad (\omega\sqrt{\frac{B}{2g}} < 1)$ $L_F = \pi B \quad (\omega\sqrt{\frac{B}{2g}} \geq 1)$	$x_i = L \cdot \left(1 - \cos\left(\frac{\pi}{2} \cdot \frac{i}{N_F}\right)\right)$ $z_i = 0$
Radiation	20	$L_F = \lambda \quad (\omega\sqrt{\frac{B}{2g}} < 1)$ $L_F = \pi B \quad (\omega\sqrt{\frac{B}{2g}} \geq 1)$	$x_i = \lambda$ $z_i = L \cdot \left(1 - \cos\left(\frac{\pi}{2} \cdot \frac{i}{N_R}\right)\right)$

4. Calculation and Analysis

Rectangular cylinder

- Roll mode

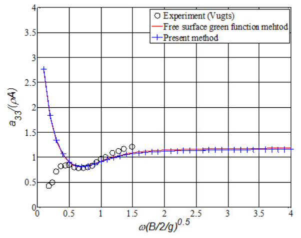


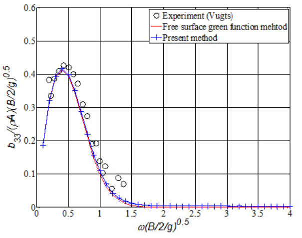


4. Calculation and Analysis

Rectangular cylinder

- Heave mode

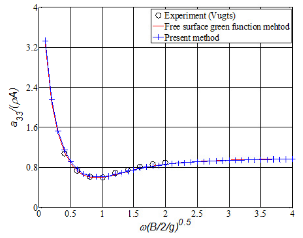


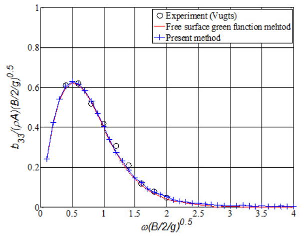


4. Calculation and Analysis

Circular cylinder

- Heave mode

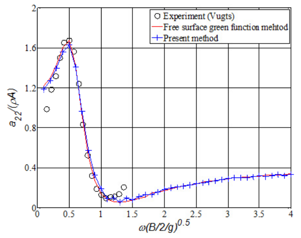


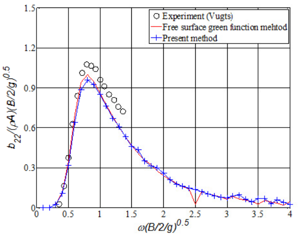


4. Calculation and Analysis

Rectangular cylinder

- Sway mode

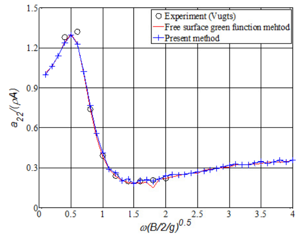


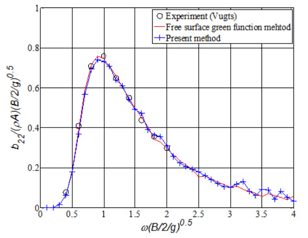


4. Calculation and Analysis

Circular cylinder

- Sway mode

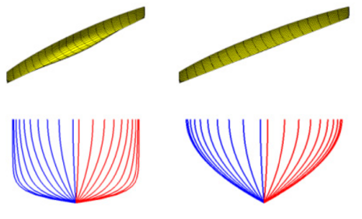




4. Calculation and Analysis

Application

	Wigley I	Wigely III
Fn	0.2	0.2
L(m)	10.0	10.0
B(m)	1.0	1.0
T(m)	0.625	0.625
Cb	0.5606	0.4622



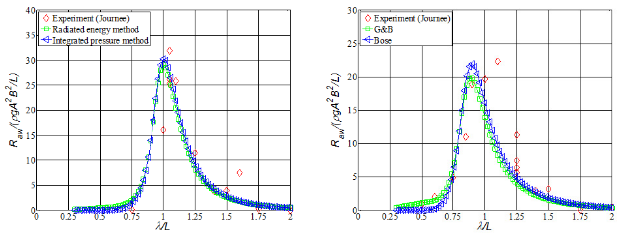
Wigley I *Wigley III*

4. Calculation and Analysis

Application - Added resistance in waves

- Radiated energy method(Gerritsma & Beukelman, 1972) & Integrated pressure method(Bose,1970)

Wigley I *Wigley III*



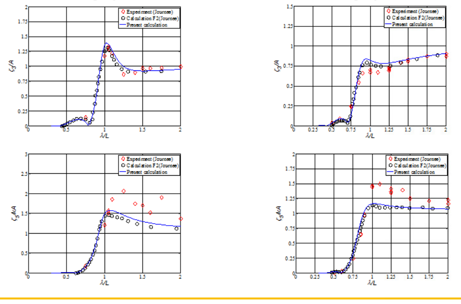
Refer to Journee (1992)

4. Calculation and Analysis

Application - Ship motion calculation

- Salvesen-Tuck-Faltinsen Method(Salvesen et. al, 1970)

Wigley I *Wigley III*



Refer to Journee (1992)

5. Conclusion

I. Two dimensional hydrodynamic coefficients were calculated by using desingularized indirect boundary integral method.

II. For a fast and accurate calculation, we propose criteria for making boundary element after extensive test computation.

III. Desingularized indirect boundary integral method was applied in the strip calculation for ship motion and added resistance.