Rankine Source Method Using Rectangular Panels on Water Surface

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Introduction

We previously developed a Rankine source method which used the panel-shifting method instead of finite difference operator in order to satisfy the radiation condition. Our Rankine source method [1] gives reasonable results if we apply it to narrow ships. However it becomes unstsble in case of wide ships as discussed by Eguchi [2].

In this paper, we adopt the rectangular panel division on the still water surface in order to obtain stable results even if the breadth of ship is wide. In the new method, rectangular panels are also located on the water surface inside the ship. However, we force the source strengths of them to be zero in the computation.

We calculate the wave fields around some numerical ships and confirm the usefulness of the present method by comparing analytical results with experimental ones.

Formulation

Following Dawson [3], we denote the total, the double body flow and the wave flow velocity potentials by ϕ, ϕ_0 and ϕ_1, respectively. They are expressed as

$$\phi = \phi_0 + \phi_1 \qquad \text{where} \qquad \phi_0 = V \cdot x + \phi_H, \qquad \phi_1 = \Delta\phi_H + \phi_F. \tag{1}$$

ϕ_H,Δ,ϕ_H and ϕ_F express the double body source ($\bar{m}$) term, the wave effect soure (Δm) term and the free surface source (σ_F) term, respectively as shown in Fig.1. The unknowns $m(=\bar{m}+\Delta m)$ and σ_F are determined from the following boundary conditions.

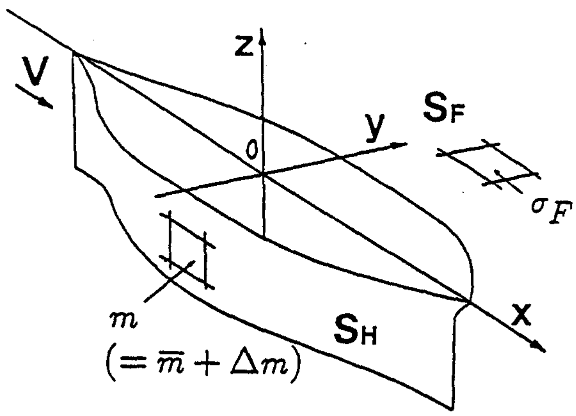

Fig. 1 Coordinate system

Hull surface boundary condition :

$$\frac{\partial \phi}{\partial n} = 0 \tag{2}$$

where $\mathbf{n}(n_x, n_y, n_z)$ expresses the unit outward normal vector on the hull surface

Double body linearized free surface condition [3]

$$\phi_{0s}^2 \phi_{1ss} + 2\phi_{0s}\phi_{0ss} + g\phi_{1z} = -\phi_{0s}^2 \phi_{0ss} \tag{3}$$

where s is the coordinate along the streamline on S_F,

Radiation Condition is satisfied by the panel shifting method.

The previous method used the water surface panels along the hull surface. But, with increase of B/L, the source distribution on the water surface begins to oscillates violently. Since this seemed to be due to the inclined panels, we simply adopt the rectangular paneling which in very stable as two-dimenaional case.

Therefore, S_H and S_F are divided into small rectangular panels and m, σ_F are assumed to be constant on each panel.

As to the strength of source σ_I inside the hull surface, we force σ_I to be zero since there exists no wave. Then the simultaneuos equation of the free surface condition has the following form.

$$\left[\begin{array}{c|cccc} \multicolumn{5}{c}{\text{Non}-0} \\ \hline & 1 & 0 & 0 & 0 \\ & 0 & 1 & 0 & 0 \\ 0 & 1 & 0 & \ddots & 0 \\ & 0 & 0 & 0 & 1 \end{array}\right] \left[\begin{array}{c} \sigma_F \\ \hline \sigma_I \end{array}\right] = \left[\begin{array}{c} c_1 \\ c_2 \\ \vdots \\ c_1 \\ \hline 0 \end{array}\right]$$

Simultaneous equations for m and σ_F are solved iteratively. Then the wave elevation ζ, the wave resistance R_W and their coefficients $\bar{\zeta}$, C_W are expressed as follows.

$$\zeta = \frac{1}{2g}(V^2 - \phi_{0x}^2 - \phi_{0y}^2 - 2\phi_{0x}\phi_{1x} - 2\phi_{0y}\phi_{1y}), \qquad \bar{\zeta} = \frac{2g}{V^2}\zeta$$

$$R_W = -\int\int_{SH} (p - p_0) n_x ds, \qquad C_W = \frac{R_W}{\frac{1}{2}\rho S V^2}, \tag{4}$$

where

$$p - p_0 = \rho(V^2 - \phi_x^2 - \phi_y^2 - 2\phi_z^2)/2$$

Results and Discussion

As numerical examples, we computed flow fields around Wigley hulls with B/L = 0.10, 0.20, 0.30, 0.40 and Series-60 (C_b = 0.60) hull. The hull surface S_H and the water surface S_F are divided into 400(40 × 10) and 2000(80 × 25) panels, respectively.

At first, we show the results of Wigley hulls at Froude number (F_n) 0.289. Fig.2 shows two kinds of panel arrangements and the values of ϕ_{0s} and ϕ_{0ss} along lengthwise direction. Fig.3 compares wave patterns obtained by two methods. Almost the same wave patterns are obtained. Fig.4 shows a comparison of ship-side wave profiles of Wigley hull (B/L=0.10). The difference between two methods is very small. Fig.5 compares the wavemaking resistance coefficients obtained by two methods. Almost the same values are obtained. Fig.6 shows wave patterns computed for wider Wigley hulls (B/L=0.20, 0.30, 0.40) at F_n = 0.289. Then the present method can be applicable to these very wide hulls. Fig.7 shows a comparison of wave patterns of Series-60 hull at F_n = 0.316. We confirm nearly the same wave patterns between two methods.

Conclusion and Future Scope

We developed a new Rankine Source method using rectangular panels on still water surface and confirmed nearly the same results between the present method and the previous method. Though this method is applicable to any hull forms, we wish to improve it further so as to consider the empty source panels near the bow and the stern.

References

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[2] Eguchi, T. : Namerical Analysis of Rankine Source Collocation Method for the Steady Wave Making Resistance Problem, J. of the S. N. A. of Japan, Vol. 177 (1995)

[3] Dawson, C. W. : A Practical Computer Method for Solving Ship-Wave Problems. Proc. 2nd Int. Conf. on Numerical Ship Hydrodynamics. Univ. California, Berkeley (1977)

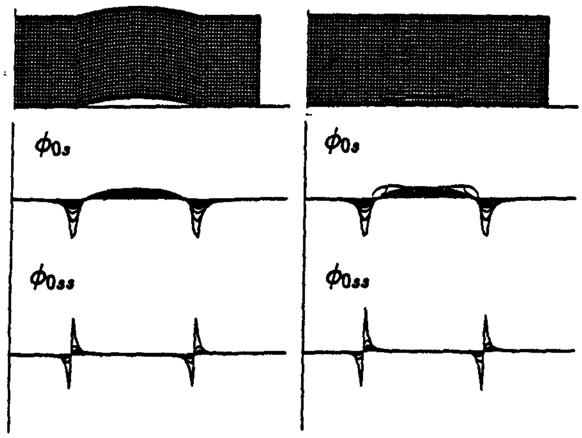

Fig. 2 Panel arrangement on the free surface, ϕ_{0s} and ϕ_{0ss}(F_n=0.289)

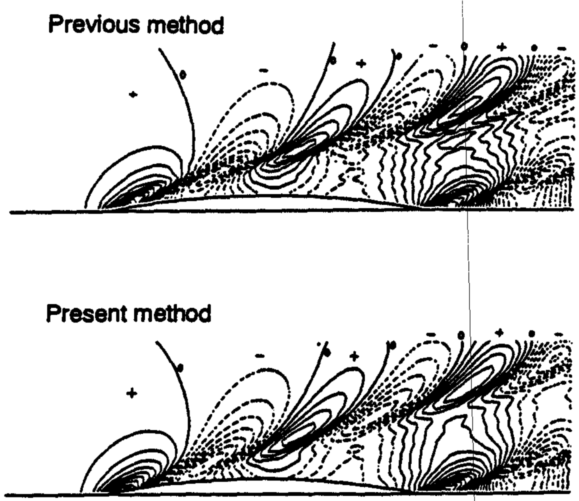

Fig. 3 Comparison of wave patterns (F_n=0.289)

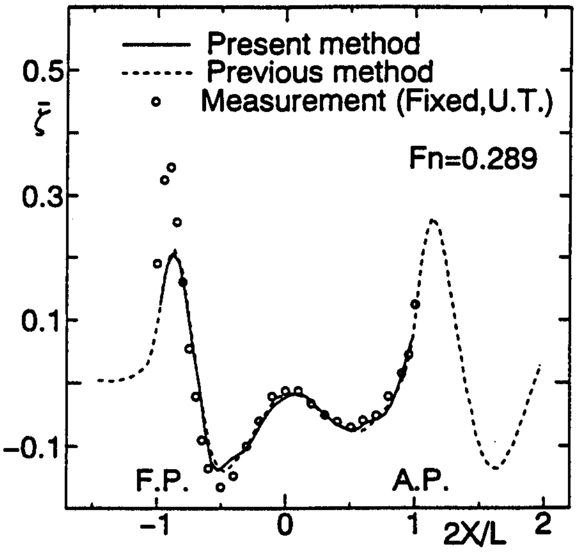

Fig. 4 Comparison of ship-side wave profiles of Wigley hull (F_n=0.289)

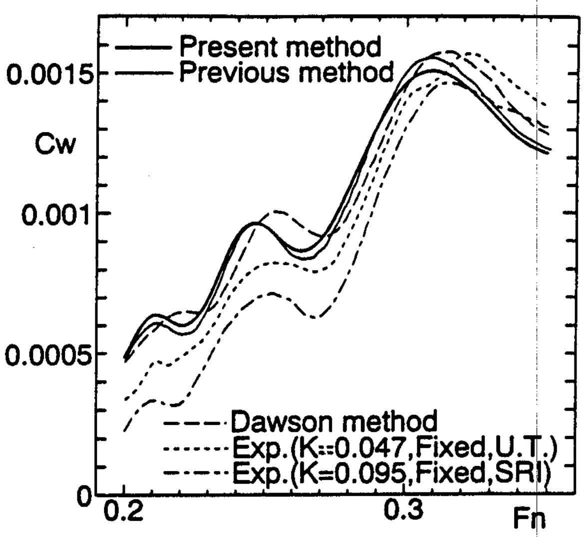

Fig. 5 Comparison of wavemaking resistance coefficients of Wigley hull

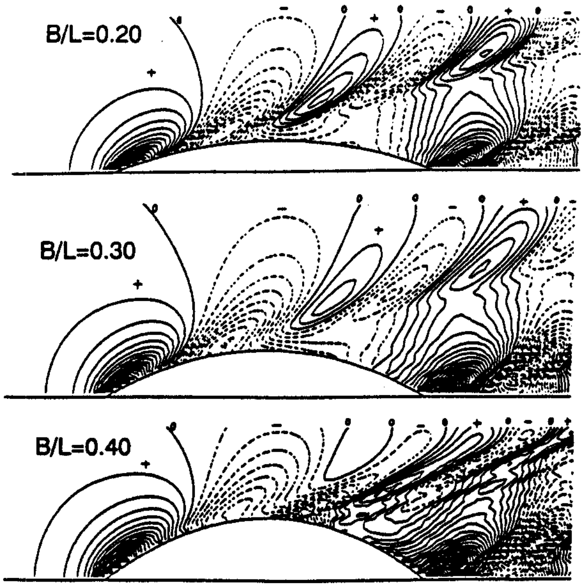

Fig. 6 Wave patterns of Wigley hull with wide breadth (F_n=0.289)

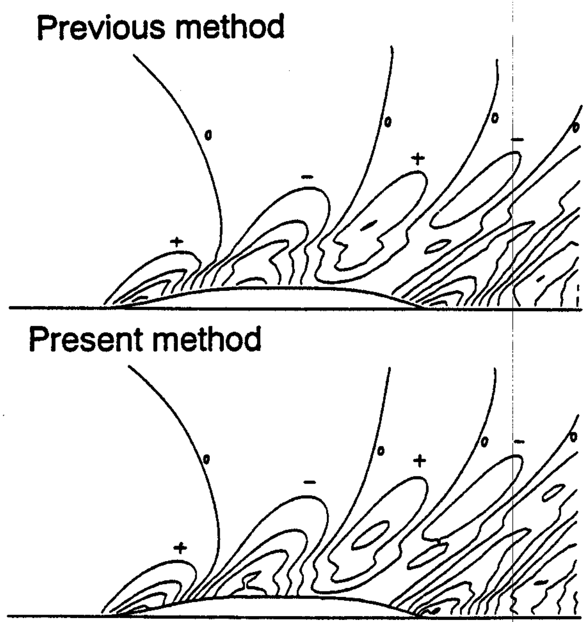

Fig. 7 Comparison of wave patterns of Series-60 (F_n=0.316)