Estimation of Wave Making Resistance by Wave Analysis Ship Wave at Sea

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Abstract

This paper presented some estimation result of three-scale a model ship's wave making resistance based on ordinary wave analysis. In this study, in order to estimate the actual ship wave making resistance, actual ship experiment were carried out. Actual ship's wave measurement is difficult in actual sea because other wave exist. We studied a method of estimation actual ship's wave making resistance applied the Fourier transfer. Using the proposed method, estimated value of wave making resistance was very close between actual ship result and model ship result. From this result, the ordinary wave analysis can be estimated the actual ship wave resistance excepting other wave value from the recorded actual sea data

Introduction

Ship (navigation) wave is a characteristics physical phenomenon and this wave is included some information related ship's forms. Therefore, many investigation and study were performed for ship wave already. Qualitative ship wave was used for wave resistance analyze. Nowadays, there are many study and investigation about the wave making resistance. However, it was not performed that the systematical study of wave making resistance with using different model scale a ship. Especially, the experiment of actual ships navigation waves measurement and analysis is so rare [5], [6]. In this reason, the recorded data at the real sea was included some non-linear factor. And it is so difficult to analyze recorded data. However, if utilize of actual ship's navigation waves data for wave making resistance, it will be make the advance for the study of wave making resistance.

In this study, the purpose is the estimation of ship wave resistance using different scale model ship's data included the actual ship data recorded in real sea. For the purpose, we studied a method of separation ship wave and sea wave from actual ship wave data. In this paper, we used and applied to Newman [1] – Sharma [2] method that is so popular and ordinary method at analyzing wave resistance from a ship wave. In order to the verification of this method, tank test data were carried out used model ship. And we compared result actual test data result and tank tests data result.

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Method of Wave analyze

We indicate the coordinate system in Fig.1. The velocity potential ϕ is shown follow equation in the coordinate system.

$$\phi = \frac{K_0}{\pi}\iint_S m(x',y',z')dS$$

$$= \int_{-\frac{\pi}{2}}^{\frac{\pi}{2}+\Theta} \sec^2\theta e^{K_0\sec^2\theta(z+z')} \sin[K_0\sec^2\theta\{(x-x')\cos\theta+(y-y')\sin\theta\}]d\theta \quad (1)$$

Here, K_0 is wave number, and Θ is the angle of wave analysis area.

For the estimation of wave making resistance, we used the method of wave analyze Newman [1] – Sharma [2] method. This method is very popular method (ordinary method) and some papers used this method [4], [5].

In the Newman-Sharma method, equation (1) is transformed by Fourier transform following equation.

$$\phi = -\frac{K_0}{\pi}\int_{-\frac{\pi}{2}}^{\frac{\pi}{2}} \{P(\theta_0)\sin(K_0 p\sec^2\theta_0) - Q(\theta_0)\cos(K_0 p\sec^2\theta_0)\} e^{K_0 z\sec^2\theta_0}\sec^2\theta_0 d\theta_0 \quad (2)$$

However, this formula was expanded by IKEHATA and NOZAWA [3] considering for realistic calculation. Here, p was indicated the following formula.

$$p = (x-x')\cos\theta_0 + (y-y')\sin\theta_0$$

Functions $P(\theta_0)$ and $Q(\theta_0)$ are amplitude function, which fund the Fourier Transfer using measured ship navigation wave. Wave making resistance is indicated the following formula

$$R = \frac{1}{2}\rho\int_{-\infty}^{\infty}\int_{-\infty}^{0}\left\{\left(\frac{\partial\phi}{\partial x}\right)^2+\left(\frac{\partial\phi}{\partial y}\right)^2+\left(\frac{\partial\phi}{\partial z}\right)^2\right\}dydz + \frac{1}{2}\rho\frac{U^2}{g}\int_{-\infty}^{\infty}\left(\frac{\partial\phi}{\partial x}\right)_{z=0}^2 dy \quad (4)$$

Using (3) formulas, we carried out the ship wave making resistance using the follow

formula.

$$R = \frac{\rho K_0^2}{\pi}\int_0^{\frac{\pi}{2}} \left\{P^2(\theta_0)+Q^2(\theta_0)\right\}\sec^3\theta_0 d\theta_0 \quad (5)$$

From this formula, wave-making resistance is obtained amplitude function. Amplitude function is obtained from that analyzing by Fourier Transfer to the measured ship navigation wave.

In the present method, it is so difficult to the actual ship's navigation wave because measurement actual ship' s data included sea wave. In this paper, we consider the technique that remove from the recorded data except ship navigation wave. Following formula is defined amplitude spectrum used by amplitude function $P(\theta)$ and $Q(\theta)$.

$$A(\theta) = \frac{1}{2\pi}\left\{P^2(\theta)+Q^2(\theta)\right\}\sec^3\theta \qquad (6)$$

In this amplitude spectrum, we define a function $A_1(\theta)$, which is amplitude spectrum calculated from the data including ship navigation wave and sea wave. On the other hand, we defined function $A_2(\theta)$ that is amplitude spectrum carried out using sea wave data. Here, following formula was defined.

$$A_0(\theta) = A_1(\theta) - A_2(\theta) \qquad (7)$$

Namely, we perform a subtracted $A_2(\theta)$ from $A_1(\theta)$, we obtained the value of the ship navigation wave's amplitude spectrum $A_0(\theta)$. We appraised the result of value for the technique.

Experiment

Towing tank test

In order to examine the reliability of the proposed method, we carried out towing tank test and actual ship test. Towing tank test was performed in Tokyo University of Mercantile Marine. On this experiment, model ship " SHIOJI MARU" that is the training ship of Tokyo University of Mercantile Marine was used. This ship's principal dimensions were shown Table 1 and we indicate the lines in Fig 2.

Experiment at Tokyo University of Mercantile Marine, outline figure of

experiment installment and arrangement are shown in Fig.3. We measured total ship Resistance and ship navigation wave in Tokyo University of Mercantile Marine's towing tank. In order to measure SHIOJI MARU total resistance, we set a load cell, which have 5kg capacity. As the motion of model, heave and pitch were free. However, other motions were fixed. Wave height meatier was set 2 point in towing tank. One of them, it was set on 2-meter point from ship navigation line. And other one, we set on 3.0-merter from ship navigation line. When we measure wave height, we used the 2-type wave height meter. One of then, it is servo type and other one is capacitance type. And we used two lengths SHIOJI MARU model ship that are 1.5m models and 2.7m models. In experience, model speed is set from 0.345m/sec to 1.2m/sec at 1.5m models. And as used 2.7m models, model ship speed is from 0.643m/sec to 1.2m/sec.

Actual ship experiment

We performed actual ship test. The experiment was done a dolphin near the Tokyo west traffic route in KEIHIN harbor TOKYO part. We showed an experiment outline in Fig. 4. We set a wave height mater on this dolphin and recorded SHIOJI- MARU ship wave. In this experiment, ship speed was recorded from E.M. log on SHIOJI-MARU. And the distance that is between wave measuring point and ship was analyzed from ship's course line used by GPS. We are shown ship speed and distance from ship and measuring point in actual ship test in the Table 2. Regarding Weather condition in actual test day (July 23rd. 1998), wind velocity was 4m/sec. On the other days, wind velocity was 6 or 7 m/sec. There was not big swell in the experiment area

Result

Towing tank experiment (used model ship)

On the Fig.5, we indicated the result of experiment that is compare with estimated wave resistance by the propose method. In this figure, abscissa is indicated wave resistance coefficient. Resistance coefficient r_w estimated by resistance measurements experiment. Resistance coefficient C_w is obtained from wave analyzes. In this paper, wave resistance coefficients are defined follow formula.

$$Cw, r_w = \frac{R}{\rho \nabla^{2/3} V^2} \qquad (9)$$

And horizontal axis is FROUDE number (Fn). In this formula, R means a resistance and ρ represent density of fluid and delta represent displacement. In the figure, the marks of black circle and circle represent the non-dimension position of wave height meter (Y) that is the divided the value of distance that is between ship navigation line and wave height mater position by ship length. The marks of black circle indicated the result of Y equal 0.5 and the mark of the circle indicated result of the Y equal 2.0. And the mark of diamond shaped was represented the estimated wave resistance coefficient which is a value from wave making resistance experiment by resistance experiment. The form effect value coefficient that is K was 0.279. This value recorded from an experiment in IHI towing tank. And solid line is the coefficient of wave resistance that recorded from IHI towing tank.

In the Fig.6, we indicated some result of resistance experiment used by 2.7m models. In this figure, the mark of square was represented the result from Yokohama National University towing tank. Other marks are same definition in Fig.5. From Fig.5 and Fig.6, it is qualitative same that wave resistance wave analyze and resistance experiment. Regarding to resistance coefficient, wave analyze value is lower than resistance experiment. In this result, the past paper and experiment were recorded same value and result [3], [4], [5]. About these results, we consider that different of present method result and result from resistance result show a different of definition above some value. The results of free running conditions were higher than the towing conditions one. About this result, we consider that wave resistance affected some experiment condition. But the results are nearly same value to resistance experiment.

Compare with model scale effect, we were shown a result of wave analyze from every scale model in the Fig.7. In the figure, the mark of black circle is shown the result of 1.5m models and the circle is shown 2.7m models result. And the diamond shaped is shown 2.7m model results at free running condition. These results were recorded from Y equal 0.5 positions.

The result of wave resistance analyze in the wave was indicated in the Fig.8. In the figure, abscissa is the wave resistance coefficient (Cw) and horizontal axis is the Froude number (Fn). From the figure, the mark of black circle indicated the result of wave analyze from the data of irregular wave conditions and the mark of square indicated the result of free running condition and the mark of circle indicated the result of slight wave conditions. And we were shown the result of IHI tank experiment result to compare other result. The experiment of measuring ship wave in the wave, we were done five times. We used 2.7m models at this experiment. In the result, we could recognize same result compared with wave conditions result and slight condition.

However, Fn is 0.242 results are different from same condition data. In this result, we investigated the amplitude spectrum value. We showed an amplitude spectrum in the Fig.9. In this figure, abscissa is shown amplitude spectrum A(θ) and horizontal axis is shown angle which show a propagation ship wave. In this figure, solid lines represent a result at slight surface experiment and dot line and one point chain line represent the result in irregular wave condition result. From these results, one point chain line is shown sharp fluctuations. Wave resistance which is the result from wave analyze is able to know integration amplitude spectrum. We consider that if aptitude spectrums suffer sharp fluctuation, integration value (wave resistance) increase. In all result, we could know a wave resistance used present method from the data included irregular wave condition.

Actual ship experiment

We indicate the wave resistance that is a result from actual ship wave data used present method in the Fig. 10. In this figure, we compared with actual ship result and model ship (towing tank experiment) it. This figures definitions are same Fig.5. The mark of double circle represents actual ship result. The result of experiment gave agreement with the value that had been obtained by model ship experiment. From this result, our present method was able to get wave resistance from the data included irregular wave condition.

Conclusion

We performed a systematic study of wave making resistance estimation using three different scale ship model. As one of these models, actual ship was used. In order to analyze to wave making resistance from these models ship experimental data, ordinal wave analyzing method (Newman – Sharma method) was adopted. The results may be summarized as follows:

(1) We compared these results (experiment result of model and actual ship) as coefficient of wave making resistance Cw. At the result, in qualitative, there values were good agreement. However, when Cw compared with rw, it was lower than about 50 or 60%.

(2) In the towing tank test, we measured ship navigation wave using two different scale model ships. And we were obtained some good result used the present method. In this result, sea wave and ship wave were separated by presented method.

(3) From actual ship experiments that were carried out verify the proposed method, actual ship navigation waves that was included sea wave were measured. And we were obtained some good result form proposed method. From the result, actual ship wave making resistance was estimated from a data that removed the sea waves.

As problem for further investigating, additional experiment should be more to other situation and condition using the present method.

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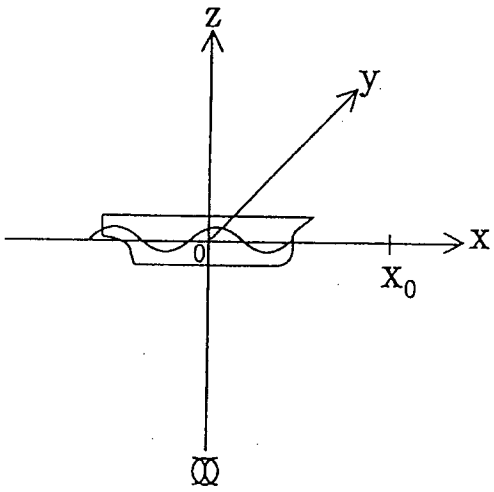
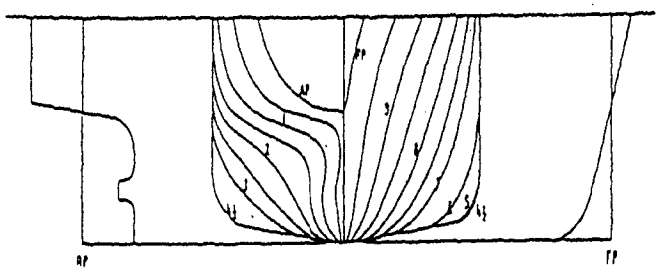
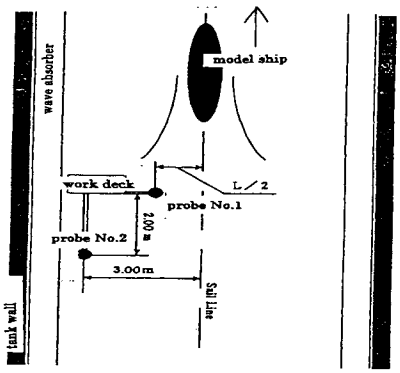
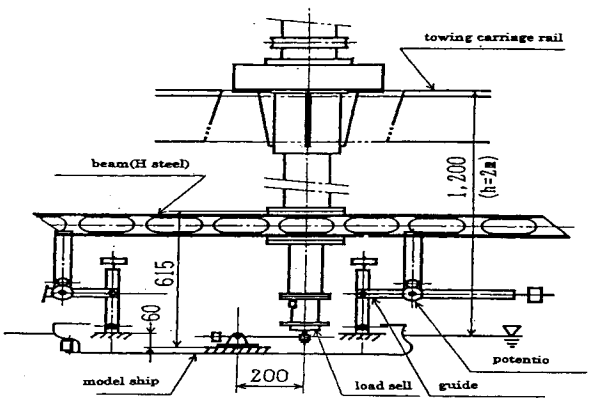
	SHIP	MODEL(2.7m)	MODEL(1.5m)
Lpp(m)	46.0	2.7	1.5
Berth(m)	10.0	0.587	0.328
Depth(m)	3.8	0.358	0.124
Draft(m)	3.0	0.176	0.098
Displacement(t)	785.0	0.1549	0.0265
Water Plane Area(m^2)	530.1	1.8262	0.534
Cb	0.555	0.555	0.555
Scale ratio	−	1/17.04	1/30.67

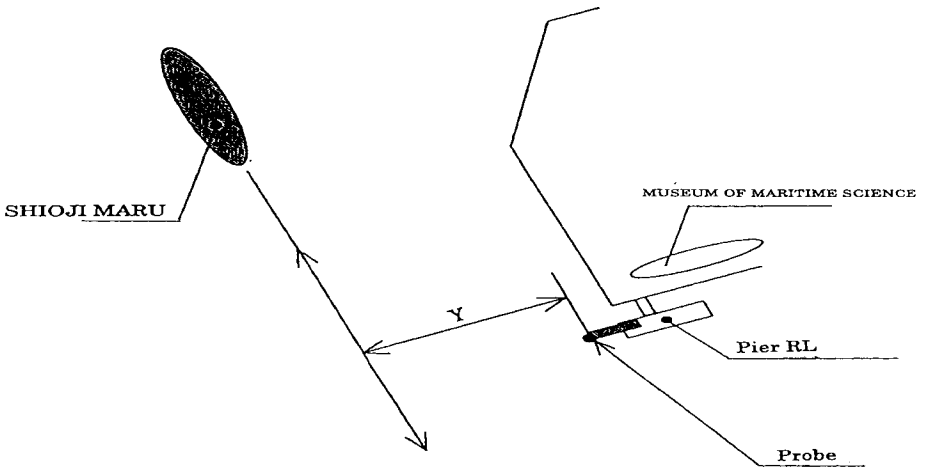
Experiment day	Ship Speed(m/sec)	Y(m)
July,23ed1996	5.556	211
July,26th,1996	6.070	282
July,30th,1996	5.402	370
Augast,1st,1996	6.636	271

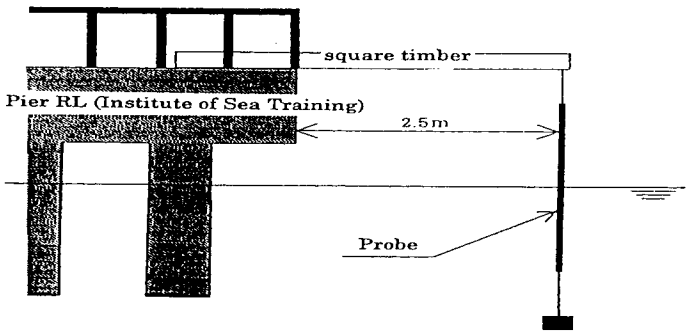


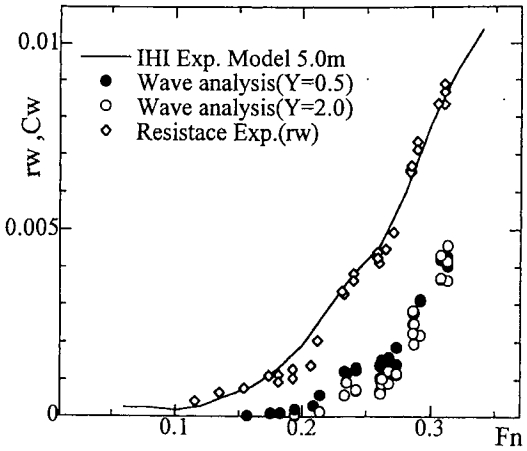


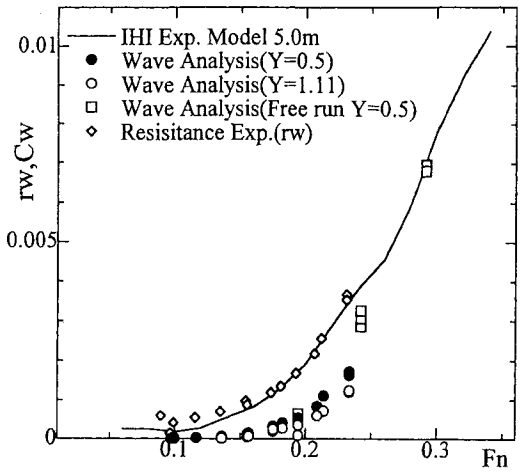

model ship
wave absorber
work deck
L/2
probe No.1
probe No.2
1.00m
3.00m
tank wall
Sail line

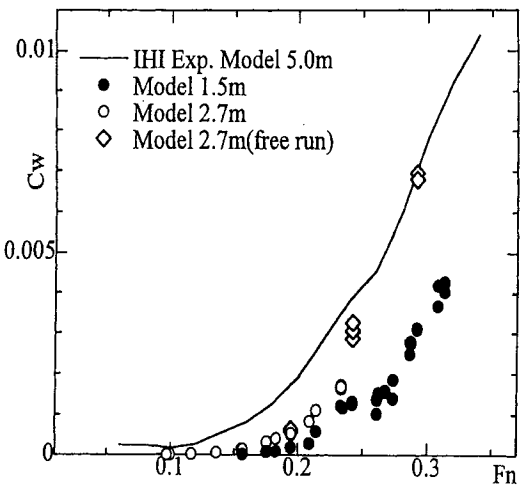

towing carriage rail
beam(H steel)
1,200
(h=2m)
615
60
model ship
200
load sell
guide
potentio

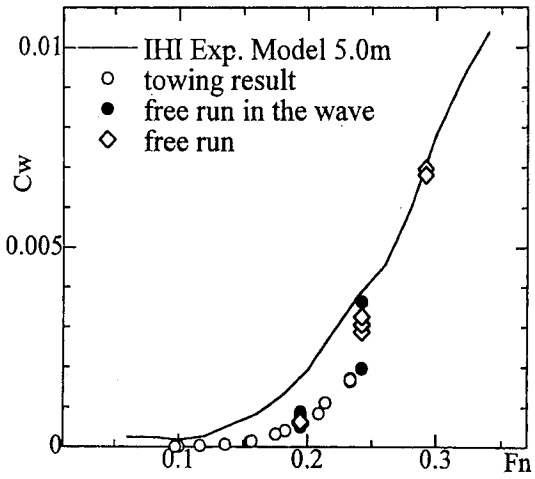

SHIOJI MARU
MUSEUM OF MARITIME SCIENCE
Y
Pier RL
Probe

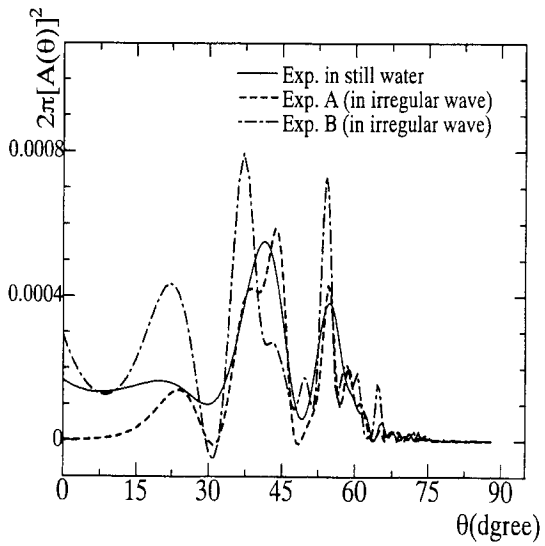

square timber
Pier RL (Institute of Sea Training)
2.5m
Probe

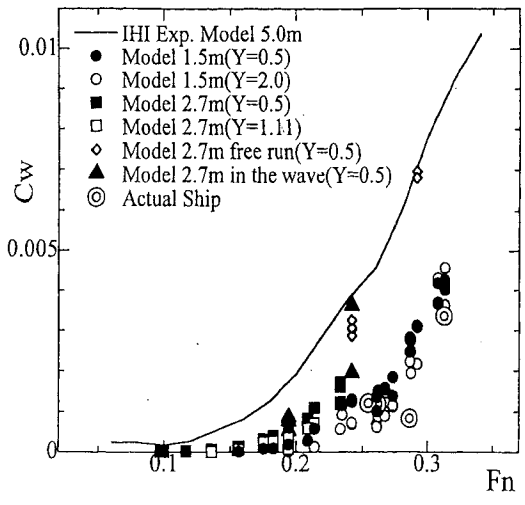

IHI Exp. Model 5.0m
Wave analysis(Y=0.5)
Wave analysis(Y=2.0)
Resistace Exp.(rw)
rw ,Cw
0.01
0.005
0
0.1
0.2
0.3
Fn


IHI Exp. Model 5.0m
Wave Analysis(Y=0.5)
Wave Analysis(Y=1.11)
Wave Analysis(Free run Y=0.5)
Resisitance Exp.(rw)
rw, Cw
0.01
0.005
0
0.1
0.2
0.3
Fn


IHI Exp. Model 5.0m
Model 1.5m
Model 2.7m
Model 2.7m(free run)
Cw
0.01
0.005
0
0.1
0.2
0.3
Fn


IHI Exp. Model 5.0m
towing result
free run in the wave
free run
Cw
0.01
0.005
0
0.1
0.2
0.3
Fn


Exp. in still water
Exp. A (in irregular wave)
Exp. B (in irregular wave)
2π[A(θ)]²
0.0008
0.0004
0
0
15
30
45
60
75
90
θ(dgree)


IHI Exp. Model 5.0m
Model 1.5m(Y=0.5)
Model 1.5m(Y=2.0)
Model 2.7m(Y=0.5)
Model 2.7m(Y=1.11)
Model 2.7m free run(Y=0.5)
Model 2.7m in the wave(Y=0.5)
Actual Ship
Cw
0.01
0.005
0
0.1
0.2
0.3
Fn