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The Prediction of Resistance of a 23m Class Planing Hull

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Abstract

The present report describes the results of the cooperative experimental study organized by the High-Speed Marine Vehicle Committee of the Korea Towing Tank Conference. The study aims to improve model test technique and accuracy and to self-evaluate their own capabilities.

The resistance tests of a 23m class planing hull were performed at the towing tanks of the Korea Research Institute of Ships and Ocean Engineering (KRISO), Hyundai Maritime Research Institute (HMRI), Seoul National University (SNU), Inha University (IU) and Pusan National University (PNU). In addition, the longitudinal wave cut was measured and analyzed at the KRISO.

All the results of total resistance, trim and mean sinkage are presented in this report and the results show fairly good agreements comparing with the ITTC HSMV committee's report.

1 Introduction

The High-Speed Marine Vehicle Committee of the Korea Towing Tank Conference organized a program for the cooperative experimental study at the General Meeting on January 1993.

All the member organizations in Korea spontaneously joined the program to motivate cooperations between them, to improve model test technique and accuracy and to self-evaluate their own capabilities.

*Member, Korea Research Institute of Ships & Ocean Engineering
†Member, Hyundai Maritime Research Institute
‡Member, Seoul National University
§Member, Inha University
¶Member, Pusan National University

A 23m class planing hull model was selected for the cooperative program in line with the international cooperative experimental program organized by the High-Speed Marine Vehicle Committee of the ITTC and reported at the 20th ITTC meeting in 1993.

The organizations prepared a model based on the lines drawing from Setouchi Craft Co. in Japan. The model was carefully checked by the measuring device at KRISO and it was confirmed that deviations were within $\pm 0.2\%$ of given offsets.

Towing tank tests were conducted in accordance with the test scope of Japanese cooperative experimental study program which was basically identical with the ITTC cooperative study.

The test results obtained by KRISO, HMRI, SNU, IU and PNU are summarized in the present paper. The wave pattern analysis results by KRISO are available to analyze the cooperative test results.

2 Test Descriptions

All experimental works for the present program were carried out at the towing tanks of KRISO, HMRI, SUN, IU and PNU. Dimensions of each towing tank are described in Table 1.

Table 1 Principal Dimensions of Towing Tanks

KTTC Organization	Towing Tank $L \times W \times D(m)$
KRISO	223 × 16 × 7
HMRI	232 × 14 × 6
SNU	117 × 8 × 3.5
IU	79 × 5 × 3
PNU	87 × 5 × 3

An 1/11.6 scale ship model made by FRP is light enough to install the resistance dynamometer and trim gauges.

The model ship was towed along the thrust line of the propeller shaft positively inclined eight degrees with respect to the still water level. The resistance was measured by a resistance dynamometer which was connected to the towing points by a bar at the location of L.C.B. on the thrust line. The sketch of resistance dynamometer is shown in Fig. 1.

The body plan of the 23m class planing hull is shown in Fig. 2 and the test item and condition of the planing hull model are shown in Table 2.

The principal dimensions of the 23m class planing hull are tabulated in Table 3.

Table 2 Test Item and Load Condition of Planing Hull

Hull Form	Test Item	Load Cond.	Disp.(m^3)	Drafts(m)	
				DF	DA
23m Class Planing Hull	Resistance	Half L.	0.02455	0.058	0.076
	Resistance & Wave Pattern Analysis	Full L.	0.02987	0.078	0.072

3 Test Results

3.1 Resistance

The photographs of the model ship are shown in Fig. 3 and the resistance test results are summarized in Tables 4 ~12. The frictional resistance coefficients and the residual resistance coefficients are calculated by "ITTC 1957 Model-Ship Correlation Line" and all the results are brought to a standard temperature of 15°C.

Curves of the total resistance and the residual resistance coefficients are shown in Figs. 4 and 5 at half load and full load conditions, respectively. For the comparison, the resistance test results of SRI (Ship Research Institute of Japan) are also plotted. Although the model ship is rather smaller than SRI model (the model length of SRI is 4m), the results shows fairly good agreements.

Photographs of the running ship model are shown in Fig. 12.

3.2 Trim and Mean Sinkage

The relative displacements at bow and stern were measured by pentagraph type trim guiders. From these displacements, trim and mean sinkage are derived as follows:

$$\text{Trim}(\%) = \frac{(DA - DF)}{L_{PP}} \times 100,$$

$$\text{Mean Sinkage}(\%) = \frac{(DA + DF)}{2 \cdot L_{PP}} \times 100,$$

where DF and DA denote the variation of drafts at FP and AP, respectively.

The results of the organizations were tabulated in Tables 4 ~ 12 and plotted in Figs. 6 ~ 9. The trim increases according to the increase of speeds at whole measured ranges. But, the peak value of mean sinkage is shown at Fn=0.4 for half load and Fn=0.5 for full load condition, respectively. It is interesting that this trend is also shown from resistance curves (Figs. 4 and 5). Generally, trim and mean sinkage curves show good agreements with SRI's results.

3.3 Wave Pattern Resistance

KRISO measured wave patterns at two longitudinal cuts (y/L=0.325 and 0.5) in the full load condition. The mean values of wave pattern resistance coefficients (C_{WP}) analyzed by KRISO in the range of $F_n = 0.307 \sim 1.023$ were tabulated in Table 13 and the coefficient curves are shown in Fig. 10. The analyzed wave pattern resistance coefficients agree well with the SRI's results (y/L=0.5). Around Fn=0.5, a hump is shown and this trend is exactly the same as in the resistance test results.

Typical wave pattern analysis results at Fn=0.784 are shown in Fig. 11. The peak of the wave spectrum is shown at around 65 degrees, so that the resistance by divergence wave is dominant for this hull form.

4 Conclusions

The resistance tests of a 23m class planing hull were carried out at the towing tanks of KRISO, HMRI, SNU, IU and PNU.

All the results of total resistance, trim, mean sinkage and wave pattern analysis are presented and compared in this paper. Comparisons of the measured results between organizations including SRI show fairly good agreement.

It can be mentioned that the cooperative experimental study program has been finished successfully. The authors wish to thank all the member organizations of the KTTC for their significant contributions to the present cooperative experimental study program. The present report has been published under the financial support from the Korea Towing Tank Conference.

References

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[5] "Report of the High Speed Marine Vehicle Committee," Proc. of 20th ITTC, 1993.

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Table 3 Principal Dimensions of the Planing Hull

DESIGNATION	SYMBOL(UNIT)	ACTUAL	MODEL	ACTUAL	MODEL
Scale ratio	SCALE	11.6000		11.6000	
Length between per.	LPP (m)	23.200	2.0000	23.200	2.0000
Breadth, moulded	B (m)	5.200	0.4483	5.200	0.4483
Depth , moulded	D (m)	2.400	0.2069	2.400	0.2069
Load condition		HALF L.		FULL L.	
Draft, moulded F.P.	DF (m)	0.670	0.0578	0.898	0.0774
A.P.	DA (m)	0.878	0.0757	0.840	0.0724
Mean	TMEAN(m)	0.774	0.0667	0.869	0.0749
Length of waterline	LWL (m)	23.200	2.0000	23.200	2.0000
Wetted surface area	S (m2)	103.5	0.7694	111.5	0.8286
Displacement volume	DISV(m3)	47.	0.0299	38.	0.0244
Block coefficient	CB	0.4845		0.4640	
Load waterline c.	CW	0.8879		0.8700	
Midship section c.	CM	0.5637		0.5756	
Prismatic c.	CP	0.8595		0.8061	
LPP / B		4.4615		4.4615	
LPP / T		29.9742		26.6974	
B / T		6.7183		5.9839	

Table 4 Resistance Test Results: KRISO, Half Load

MODEL CONDITION

TOWING TANK : KRISO
LOAD CONDITION : HALF LOAD
MODEL LENGTH LPP = 2.0 M
DISPLACEMENT VOLUME DISP = 0.02445 M3
WETTED SURFACE AREA = 0.7453 M2
DRAFT MOULDED ON F.P = 0.0578 M
ON A.P = 0.0756 M
MEAN = 0.0667 M

SYMBOLS

LS WETTED LENGTH FOR SHIP
SS WETTED SURFACE AREA FOR SHIP
CA INCREMENTAL RESISTANCE COEF. FOR MODEL-SHIP CORRELATION
CF SPECIFIC FRICTIONAL MODEL RESISTANCE COEF.
CR SPECIFIC RESIDUARY RESISTANCE COEF.
CT SPECIFIC TOTAL MODEL RESISTANCE COEF.
FN FROUDE NUMBER
RN REYNOLDS NUMBER
RT TOTAL MODEL RESISTANCE
V MODEL SPEED
DF VARIATION OF DRAFT AT FP (+, DOWN)
DA VARIATION OF DRAFT AT AP (+, DOWN)

INTRODUCED VALUES AND FORMULAS

TEMPERATURE TANK WATER = 8.4 C
COEF. OF KINEMATIC VISCOSITY FOR 8.4 C NU = 1.3636 E-06 M2/SEC
MASS DENSITY FOR 8.4 C RHO = 101.95 KG*SEC2/M4
TRIM = (DA-DF)/LPP x 100 (%)
MEAN SINK. = (DA+DF)/2/LPP x 100 (%)
CA = 0.000000
RN = V*LPP/NU
CT =CF + CR + CA
G = 9.80665 M/SEC2
CF = 0.075/(ALOG10(RN)-2)**2
FN = V/SQRT(G*LPP)

FN	VS KNOTS	V M/SEC	RTM KGF	CT *E+03	RN *E+06	CF *E+03	CR *E+03	DF MM	DA MM	TRIM (%)	MEAN SINK
0.307	9.00	1.359	0.666	9.488	1.994	4.057	5.431	-0.5	4.5	0.250	0.100
0.375	11.00	1.661	1.029	9.812	2.437	3.897	5.915	-2.4	8.5	0.545	0.153
0.443	13.00	1.964	1.333	9.098	2.880	3.771	5.326	-7.6	13.8	1.070	0.155
0.512	15.00	2.266	1.662	8.513	3.323	3.668	4.845	-17.0	19.3	1.815	0.057
0.580	17.00	2.568	1.933	7.704	3.766	3.582	4.122	-22.0	21.8	2.190	-0.005
0.648	19.00	2.870	2.219	7.076	4.209	3.507	3.569	-28.0	22.0	2.500	-0.150
0.716	21.00	3.172	2.488	6.493	4.652	3.442	3.051	-32.0	20.3	2.615	-0.293
0.784	23.00	3.474	2.767	6.020	5.095	3.385	2.636	-34.0	17.8	2.590	-0.405
0.853	25.00	3.776	3.066	5.648	5.539	3.333	2.314	-35.0	14.1	2.455	-0.523
0.921	27.00	4.078	3.377	5.334	5.982	3.287	2.047	-35.0	11.8	2.340	-0.580
0.955	28.00	4.229	3.557	5.223	6.203	3.265	1.958	-40.0	9.4	2.470	-0.765
0.989	29.00	4.380	3.707	5.075	6.425	3.245	1.831	-40.0	8.3	2.415	-0.793
1.023	30.00	4.531	3.888	4.973	6.646	3.225	1.748	-42.0	7.8	2.490	-0.855

Table 5 Resistance Test Results: KRISO, Full Load

MODEL CONDITION

TOWING TANK	:	KRISO	
LOAD CONDITION	:	FULL LOAD	
MODEL LENGTH	LPP =	2.0	M
DISPLACEMENT VOLUME	DISP =	0.02897	M3
WETTED SURFACE AREA	=	0.8043	M2
DRAFT MOULDED	ON F.P =	0.0774	M
	ON A.P =	0.0724	M
	MEAN =	0.0749	M

SYMBOLS

LS	WETTED LENGTH FOR SHIP
SS	WETTED SURFACE AREA FOR SHIP
CA	INCREMENTAL RESISTANCE COEF. FOR MODEL-SHIP CORRELATION
CF	SPECIFIC FRICTIONAL MODEL RESISTANCE COEF.
CR	SPECIFIC RESIDUARY RESISTANCE COEF.
CT	SPECIFIC TOTAL MODEL RESISTANCE COEF.
FN	FROUDE NUMBER
RN	REYNOLDS NUMBER
RT	TOTAL MODEL RESISTANCE
V	MODEL SPEED
DF	VARIATION OF DRAFT AT FP (+, DOWN)
DA	VARIATION OF DRAFT AT AP (+, DOWN)

INTRODUCED VALUES AND FORMULAS

TEMPERATURE TANK WATER		= 14.1	C
COEF. OF KINEMATIC VISCOSITY FOR 8.4 C	NU	= 1.1670 E-06	M2/SEC
MASS DENSITY FOR 8.4 C	RHO	= 101.88	KG*SEC2/M4

TRIM = (DA-DF)/LPP x 100 (%)
MEAN SINK. = (DA+DF)/2/LPP x 100 (%)
CA = 0.000000
RN = V*LPP/NU
CT =CF + CR + CA
G = 9.80665 M/SEC2
CF = 0.075/(ALOG10(RN)-2)**2
FN = V/SQRT(G*LPP)

FN	VS KNOTS	V M/SEC	RTM KGF	CT *E+03	RN *E+06	CF *E+03	CR *E+03	DF MM	DA MM	TRIM (%)	MEAN SINK
0.307	9.00	1.359	0.651	8.593	1.994	4.057	4.536	3.0	4.3	0.065	0.183
0.375	11.00	1.661	1.040	9.189	2.437	3.897	5.292	2.4	6.8	0.220	0.230
0.443	13.00	1.964	1.486	9.399	2.880	3.771	5.627	-1.5	12.8	0.715	0.283
0.512	15.00	2.266	1.905	9.044	3.323	3.668	5.375	-10.0	20.8	1.540	0.270
0.580	17.00	2.568	2.278	8.411	3.766	3.582	4.829	-20.3	25.5	2.290	0.130
0.648	19.00	2.870	2.645	7.813	4.209	3.507	4.305	-26.5	26.3	2.640	-0.005
0.716	21.00	3.172	3.033	7.333	4.652	3.442	3.890	-30.8	23.3	2.705	-0.188
0.784	23.00	3.474	3.288	6.626	5.095	3.385	3.241	-33.0	22.5	2.775	-0.263
0.853	25.00	3.776	3.597	6.136	5.539	3.333	2.802	-38.0	16.5	2.725	-0.538
0.921	27.00	4.078	4.009	5.863	5.982	3.287	2.576	-39.0	15.8	2.740	-0.580
0.955	28.00	4.229	4.200	5.711	6.203	3.265	2.446	-40.8	14.0	2.740	-0.670
0.989	29.00	4.380	4.377	5.547	6.425	3.245	2.303	-42.5	14.3	2.840	-0.705
1.023	30.00	4.531	4.530	5.365	6.646	3.225	2.140	-43.5	13.9	2.870	-0.740

Table 6 Resistance Test Results: HMRI, Full Load

MODEL CONDITION

TOWING TANK	:	HMRI	
LOAD CONDITION	:	FULL LOAD	
MODEL LENGTH	LPP =	2.0	M
DISPLACEMENT VOLUME	DISP =	0.02897	M3
WETTED SURFACE AREA	=	0.8043	M2
DRAFT MOULDED	ON F.P =	0.0774	M
	ON A.P =	0.0724	M
	MEAN =	0.0749	M

FN	VS KNOTS	V M/SEC	RTM KGF	CT *E+03	RN *E+06	CF *E+03	CR *E+03	DF MM	DA MM	TRIM (%)	MEAN SINK
0.300	8.79	1.328	0.676	9.360	2.275	3.951	5.409	0.0	0.0	0.000	0.000
0.350	10.26	1.550	0.950	9.655	2.656	3.832	5.823	0.0	2.0	0.100	0.050
0.400	11.72	1.770	1.298	10.109	3.034	3.734	6.376	-1.0	6.0	0.350	0.125
0.450	13.19	1.992	1.658	10.193	3.414	3.649	6.544	-3.0	13.0	0.800	0.250
0.500	14.66	2.214	1.962	9.759	3.795	3.577	6.182	-9.0	20.0	1.450	0.275
0.550	16.12	2.435	2.278	9.362	4.173	3.513	5.848	-20.0	24.0	2.200	0.100
0.600	17.58	2.655	2.530	8.736	4.551	3.457	5.280	-26.0	25.0	2.550	-0.025
0.649	19.04	2.876	2.757	8.113	4.929	3.406	4.707	-30.0	25.0	2.750	-0.125
0.700	20.52	3.099	3.019	7.649	5.312	3.359	4.290	-30.0	25.0	2.750	-0.125
0.750	21.98	3.320	3.263	7.202	5.690	3.317	3.885	-34.0	25.0	2.950	-0.225
0.800	23.45	3.542	3.546	6.873	6.070	3.278	3.595	-38.0	25.0	3.150	-0.325
0.850	24.91	3.763	3.787	6.505	6.448	3.242	3.262	-42.0	21.0	3.150	-0.525
0.900	26.38	3.985	4.085	6.253	6.829	3.209	3.044	-45.0	22.0	3.350	-0.575
0.950	27.85	4.207	4.361	5.987	7.209	3.178	2.809	-49.0	22.0	3.550	-0.675
1.000	29.31	4.427	4.580	5.676	7.587	3.149	2.527	-52.0	20.0	3.600	-0.800
1.149	33.70	5.090	5.420	5.081	8.724	3.072	2.008	-58.0	14.0	3.600	-1.100
1.366	40.06	6.051	6.462	4.281	10.370	2.981	1.299	-69.0	13.0	4.100	-1.400
1.535	45.02	6.800	7.228	3.785	11.654	2.922	0.863	-72.0	20.0	4.600	-1.300
1.705	49.98	7.549	7.979	3.394	12.938	2.870	0.524	-75.0	10.0	4.250	-1.625
1.877	55.02	8.310	9.009	3.159	14.242	2.824	0.335	-81.0	10.0	4.550	-1.775

Table 7 Resistance Test Results: SNU, Half Load

MODEL CONDITION

TOWING TANK : SNU
LOAD CONDITION : HALF LOAD
MODEL LENGTH LPP = 2.0 M
DISPLACEMENT VOLUME DISP = 0.02445 M3
WETTED SURFACE AREA = 0.7453 M2
DRAFT MOULDED ON F.P = 0.0578 M
ON A.P = 0.0756 M
MEAN = 0.0667 M

SYMBOLS

LS WETTED LENGTH FOR SHIP
SS WETTED SURFACE AREA FOR SHIP
CA INCREMENTAL RESISTANCE COEF. FOR MODEL-SHIP CORRELATION
CF SPECIFIC FRICTIONAL MODEL RESISTANCE COEF.
CR SPECIFIC RESIDUARY RESISTANCE COEF.
CT SPECIFIC TOTAL MODEL RESISTANCE COEF.
FN FROUDE NUMBER
RN REYNOLDS NUMBER
RT TOTAL MODEL RESISTANCE
V MODEL SPEED
DF VARIATION OF DRAFT AT FP (+, DOWN)
DA VARIATION OF DRAFT AT AP (+, DOWN)

INTRODUCED VALUES AND FORMULAS

TEMPERATURE TANK WATER = 4.3 C
COEF. OF KINEMATIC VISCOSITY FOR 8.4 C NU = 1.5285 E-06 M2/SEC
MASS DENSITY FOR 8.4 C RHO = 101.96 KG*SEC2/M4
TRIM = (DA-DF)/LPP x 100 (%)
MEAN SINK. = (DA+DF)/2/LPP x 100 (%)
CA = 0.000000
RN = V*LPP/NU
CT =CF + CR + CA
G = 9.80665 M/SEC2
CF = 0.075/(ALOG10(RN)-2)**2
FN = V/SQRT(G*LPP)

FN	VS KNOTS	V M/SEC	RTM KGF	CT *E+03	RN *E+06	CF *E+03	CR *E+03	DF MM	DA MM	TRIM (%)	MEAN SINK
0.308	9.04	1.365	0.708	9.994	1.772	4.155	5.839	-	-	0.255	0.137
0.377	11.05	1.669	1.117	10.557	2.166	3.990	6.568	-	-	0.574	0.176
0.446	13.08	1.976	1.483	10.002	2.564	3.858	6.144	-	-	1.245	0.176
0.481	14.09	2.128	1.673	9.726	2.762	3.803	5.923	-	-	1.628	0.157
0.516	15.12	2.284	1.869	9.432	2.963	3.751	5.682	-	-	1.978	0.118
0.549	16.10	2.432	2.045	9.104	3.156	3.705	5.399	-	-	2.329	0.039
0.583	17.10	2.583	2.213	8.731	3.351	3.663	5.069	-	-	2.681	-0.078
0.618	18.12	2.737	2.348	8.250	3.551	3.622	4.628	-	-	2.936	-0.216
0.652	19.12	2.888	2.480	7.825	3.747	3.585	4.240	-	-	3.095	-0.333

Table 8 Resistance Test Results: SNU, Full Load

MODEL CONDITION

TOWING TANK : SNU
LOAD CONDITION : FULL LOAD
MODEL LENGTH LPP = 2.0 M
DISPLACEMENT VOLUME DISP = 0.02897 M3
WETTED SURFACE AREA = 0.8043 M2
DRAFT MOULDED ON F.P = 0.0774 M
ON A.P = 0.0724 M
MEAN = 0.0749 M

FN	VS KNOTS	V M/SEC	RTM KGF	CT *E+03	RN *E+06	CF *E+03	CR *E+03	DF MM	DA MM	TRIM (%)	MEAN SINK
0.308	9.02	1.362	0.713	9.369	1.783	4.150	5.219	-	-	0.064	0.196
0.376	11.02	1.665	1.193	10.503	2.178	3.985	6.518	-	-	0.223	0.275
0.445	13.06	1.973	1.681	10.537	2.581	3.853	6.683	-	-	0.894	0.314
0.480	14.06	2.124	1.928	10.428	2.779	3.798	6.630	-	-	1.277	0.333
0.514	15.08	2.278	2.189	10.289	2.980	3.746	6.542	-	-	1.787	0.294
0.549	16.10	2.432	2.433	10.035	3.182	3.699	6.336	-	-	2.362	0.216
0.583	17.10	2.583	2.646	9.673	3.380	3.657	6.016	-	-	2.809	0.118
0.617	18.10	2.734	2.825	9.218	3.577	3.617	5.601	-	-	3.064	0.000
0.651	19.09	2.883	3.015	8.845	3.773	3.581	5.264	-	-	3.287	-0.176

Table 9 Resistance Test Results: IU, Half Load

MODEL CONDITION

TOWING TANK : INHA U.
LOAD CONDITION : HALF LOAD
MODEL LENGTH LPP = 2.0 M
DISPLACEMENT VOLUME DISP = 0.02445 M3
WETTED SURFACE AREA = 0.7453 M2
DRAFT MOULDED ON F.P = 0.0578 M
ON A.P = 0.0756 M
MEAN = 0.0667 M

SYMBOLS

LS WETTED LENGTH FOR SHIP
SS WETTED SURFACE AREA FOR SHIP
CA INCREMENTAL RESISTANCE COEF. FOR MODEL-SHIP CORRELATION
CF SPECIFIC FRICTIONAL MODEL RESISTANCE COEF.
CR SPECIFIC RESIDUARY RESISTANCE COEF.
CT SPECIFIC TOTAL MODEL RESISTANCE COEF.
FN FROUDE NUMBER
RN REYNOLDS NUMBER
RT TOTAL MODEL RESISTANCE
V MODEL SPEED
DF VARIATION OF DRAFT AT FP (+, DOWN)
DA VARIATION OF DRAFT AT AP (+, DOWN)

INTRODUCED VALUES AND FORMULAS

TEMPERATURE TANK WATER = 20.0 C
COEF. OF KINEMATIC VISCOSITY FOR 8.4 C NU = 1.0036 E-06 M2/SEC
MASS DENSITY FOR 8.4 C RHO = 101.78 KG*SEC2/M4
TRIM = (DA-DF)/LPP x 100 (%)
MEAN SINK. = (DA+DF)/2/LPP x 100 (%)
CA = 0.000000
RN = V*LPP/NU
CT =CF + CR + CA
G = 9.80665 M/SEC2
CF = 0.075/(ALOG10(RN)-2)**2
FN = V/SQRT(G*LPP)

FN	VS KNOTS	V M/SEC	RTM KGF	CT *E+03	RN *E+06	CF *E+03	CR *E+03	DF MM	DA MM	TRIM (%)	MEAN SINK
0.302	8.86	1.338	0.668	9.835	2.667	3.829	6.007	2.1	7.5	0.271	0.242
0.395	11.58	1.749	1.077	9.281	3.486	3.635	5.646	-0.8	12.2	0.646	0.285
0.441	12.93	1.953	1.368	9.452	3.892	3.560	5.893	-5.3	18.4	1.187	0.329
0.505	14.81	2.237	1.670	8.788	4.458	3.470	5.318	-12.6	25.1	1.886	0.314
0.672	19.70	2.976	2.298	6.828	5.931	3.292	3.536	-18.9	27.8	2.339	0.222
0.717	21.03	3.176	2.503	6.526	6.330	3.253	3.272	-27.1	26.0	2.656	-0.029

Table 10 Resistance Test Results: IU, Full Load

MODEL CONDITION

TOWING TANK : INHA U.
LOAD CONDITION : FULL LOAD
MODEL LENGTH LPP = 2.0 M
DISPLACEMENT VOLUME DISP = 0.02897 M3
WETTED SURFACE AREA = 0.8043 M2
DRAFT MOULDED ON F.P = 0.0774 M
ON A.P = 0.0724 M
MEAN = 0.0749 M

FN	VS KNOTS	V M/SEC	RTM KGF	CT *E+03	RN *E+06	CF *E+03	CR *E+03	DF MM	DA MM	TRIM (%)	MEAN SINK
0.312	9.16	1.383	0.667	8.519	2.756	3.804	4.715	5.3	-4.6	-0.496	0.017
0.386	11.31	1.709	1.098	9.184	3.406	3.651	5.532	4.2	10.1	0.295	0.356
0.434	12.73	1.923	1.522	10.054	3.832	3.570	6.484	0.6	16.8	0.808	0.434
0.503	14.75	2.228	1.908	9.382	4.440	3.473	5.910	-6.8	25.1	1.598	0.458
0.674	19.76	2.985	2.730	7.465	5.949	3.290	4.174	-24.6	30.2	2.740	0.139

Table 11 Resistance Test Results: PNU, Half Load

MODEL CONDITION

TOWING TANK	:	PUSAN U.	
LOAD CONDITION	:	HALF LOAD	
MODEL LENGTH	LPP =	2.0	M
DISPLACEMENT VOLUME	DISP =	0.02445	M3
WETTED SURFACE AREA	=	0.7453	M2
DRAFT MOULDED	ON F.P =	0.0578	M
	ON A.P =	0.0756	M
	MEAN =	0.0667	M

SYMBOLS

LS	WETTED LENGTH FOR SHIP
SS	WETTED SURFACE AREA FOR SHIP
CA	INCREMENTAL RESISTANCE COEF. FOR MODEL-SHIP CORRELATION
CF	SPECIFIC FRICTIONAL MODEL RESISTANCE COEF.
CR	SPECIFIC RESIDUARY RESISTANCE COEF.
CT	SPECIFIC TOTAL MODEL RESISTANCE COEF.
FN	FROUDE NUMBER
RN	REYNOLDS NUMBER
RT	TOTAL MODEL RESISTANCE
V	MODEL SPEED
DF	VARIATION OF DRAFT AT FP (+, DOWN)
DA	VARIATION OF DRAFT AT AP (+, DOWN)

INTRODUCED VALUES AND FORMULAS

```
TEMPERATURE TANK WATER        = 14.0  C
COEF. OF KINEMATIC     NU  = 1.1701 E-06  M2/SEC
VISCOSITY FOR  8.4 C
MASS DENSITY           RHO = 101.88   KG*SEC2/M4
        FOR  8.4 C
TRIM       = (DA-DF)/LPP   x 100 (%)
MEAN SINK. = (DA+DF)/2/LPP x 100 (%)
CA = 0.000000
RN = V*LPP/NU
CT =CF + CR  +  CA
G = 9.80665 M/SEC2
CF = 0.075/(ALOG10(RN)-2)**2
FN = V/SQRT(G*LPP)
```

FN	VS KNOTS	V M/SEC	RTM KGF	CT *E+03	RN *E+06	CF *E+03	CR *E+03	DF MM	DA MM	TRIM (%)	MEAN SINK
0.294	8.61	1.300	0.595	9.275	2.282	3.948	5.326	0.0	4.0	0.200	0.100
0.361	10.59	1.600	0.913	9.393	2.809	3.790	5.603	-3.0	9.0	0.600	0.150
0.429	12.58	1.900	1.208	8.811	3.335	3.666	5.145	-5.0	15.0	1.000	0.250
0.497	14.57	2.200	1.608	8.741	3.862	3.565	5.176	-13.0	23.0	1.800	0.250
0.565	16.55	2.500	1.926	8.099	4.389	3.480	4.619	-25.0	24.0	2.450	-0.025
0.632	18.54	2.800	2.191	7.338	4.915	3.407	3.931	-33.0	25.0	2.900	-0.200
0.700	20.52	3.100	2.453	6.697	5.442	3.344	3.353	-41.0	24.0	3.250	-0.425
0.768	22.51	3.400	2.673	6.066	5.968	3.288	2.778	-43.0	23.0	3.300	-0.500
0.831	24.37	3.680	2.972	5.757	6.460	3.241	2.516	-45.0	21.0	3.300	-0.600
0.906	26.55	4.010	3.373	5.502	7.039	3.192	2.311	-48.0	19.0	3.350	-0.725
0.977	28.64	4.325	3.595	5.040	7.592	3.149	1.891	-52.0	17.0	3.450	-0.875

Table 12 Resistance Test Results: PNU, Full Load

MODEL CONDITION

TOWING TANK	:	PUSAN U.	
LOAD CONDITION	:	FULL LOAD	
MODEL LENGTH	LPP =	2.0	M
DISPLACEMENT VOLUME	DISP =	0.02897	M3
WETTED SURFACE AREA	=	0.8043	M2
DRAFT MOULDED	ON F.P =	0.0774	M
	ON A.P =	0.0724	M
	MEAN =	0.0749	M

FN	VS KNOTS	V M/SEC	RTM KGF	CT *E+03	RN *E+06	CF *E+03	CR *E+03	DF MM	DA MM	TRIM (%)	MEAN SINK
0.291	8.54	1.290	0.600	8.799	2.205	3.976	4.824	3.0	5.0	0.100	0.200
0.361	10.59	1.600	1.021	9.731	2.735	3.810	5.922	-2.0	8.0	0.500	0.150
0.431	12.65	1.910	1.460	9.765	3.265	3.681	6.084	-1.0	12.0	0.650	0.275
0.503	14.74	2.227	2.005	9.854	3.807	3.575	6.279	-12.0	24.0	1.800	0.300
0.565	16.55	2.500	2.344	9.118	4.273	3.497	5.620	-32.0	31.0	3.150	-0.025
0.632	18.54	2.800	2.703	8.382	4.786	3.424	4.958	-31.0	32.0	3.150	0.025
0.700	20.52	3.100	3.028	7.660	5.299	3.361	4.299	-32.0	32.0	3.200	0.000
0.768	22.51	3.400	3.386	7.116	5.812	3.304	3.812	-40.0	29.0	3.450	-0.275
0.831	24.37	3.680	3.840	6.894	6.291	3.257	3.637	-38.0	24.0	3.100	-0.350
0.908	26.62	4.020	4.036	6.071	6.872	3.206	2.866	-43.0	21.0	3.200	-0.550
0.978	28.67	4.330	4.415	5.722	7.401	3.163	2.559	-43.0	24.0	3.350	-0.475
1.005	29.46	4.450	4.622	5.671	7.607	3.148	2.523	-45.0	23.0	3.400	-0.550

Table 13 Wave Pattern Resistance Coefficients

Fn	Speed (knots)	$C_{WP} \times 10^{-3}$ (y/L = 0.325)	$C_{WP} \times 10^{-3}$ (y/L = 0.5)
0.307	9.0	1.1299	0.8692
0.375	11.0	2.5273	2.1656
0.443	13.0	2.7425	2.7595
0.512	15.0	3.2237	3.2103
0.580	17.0	2.7172	2.6258
0.648	19.0	2.0911	2.2352
0.716	21.0	1.9826	1.8849
0.784	23.0	1.8723	1.5464
0.853	25.0	1.4889	1.2328
0.921	27.0	1.1479	0.9573
0.955	28.0	1.4316	0.8658
0.989	29.0	0.9052	0.7279
1.023	30.0	0.8198	0.6692

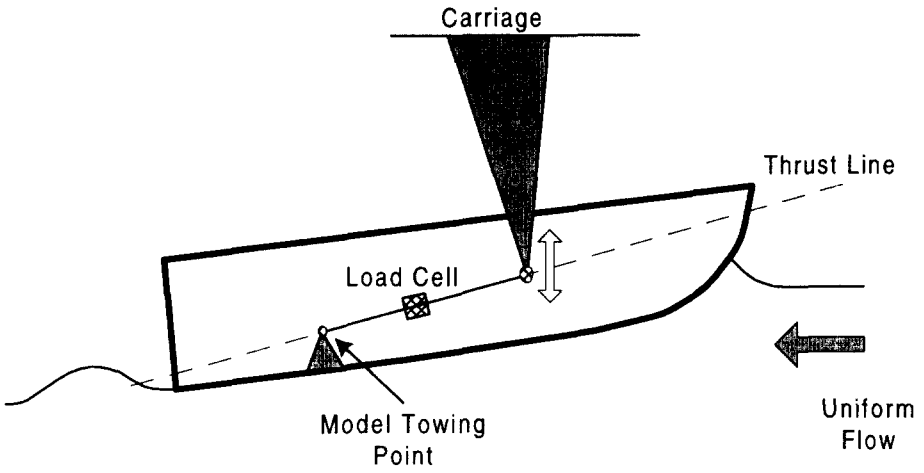

Fig. 1 Sketch of Resistance Dynamometer

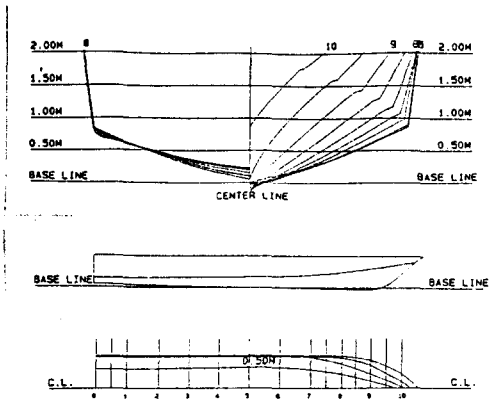

Fig. 2 Body Plan, Bow and Stern Contours of the Hull Form

Fig. 3 Photographs of Model Ship

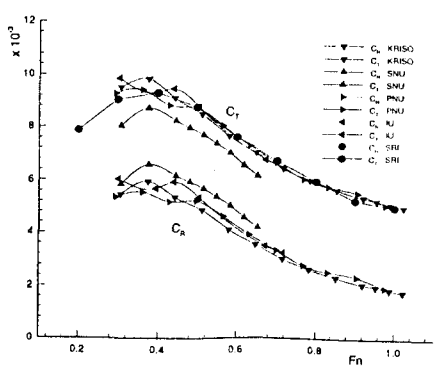

Fig. 4 Curves of Resistance Coefficients (Half Load)

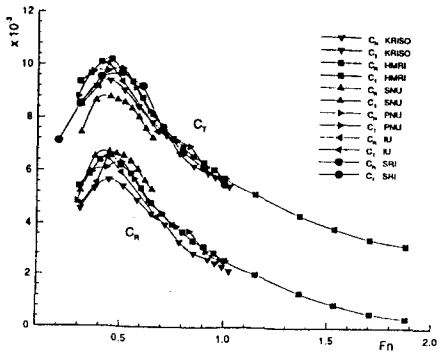

Fig. 5 Curves of Resistance Coefficients (Full Load)

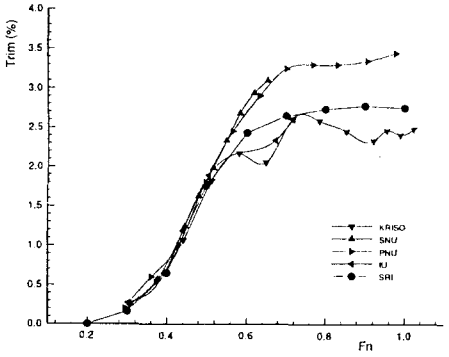

Fig. 6 Curves of Mean Trim (Half Load)

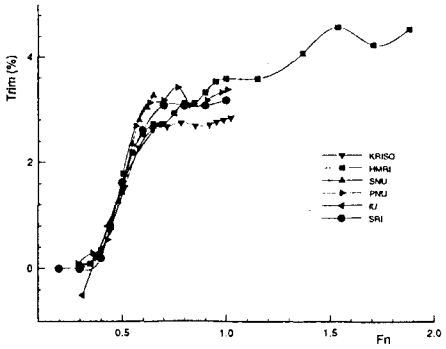

Fig. 7 Curves of Mean Trim (Full Load)

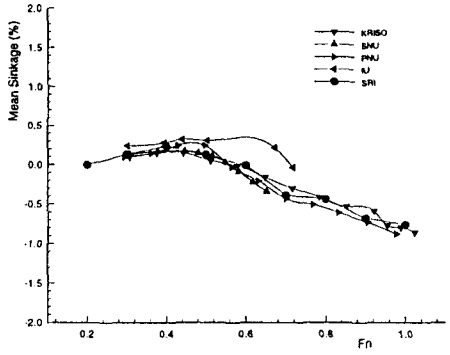

Fig. 8 Curves of Mean Sinkage (Half Load)

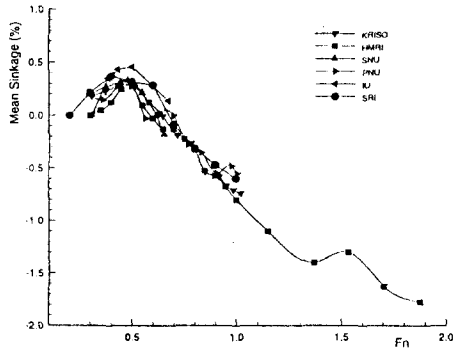

Fig. 9 Curves of Mean Sinkage (Full Load)

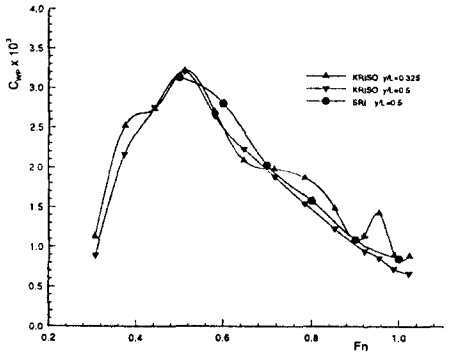

Fig. 10 Curves of Wave Pattern Analysis Results (Full Load)

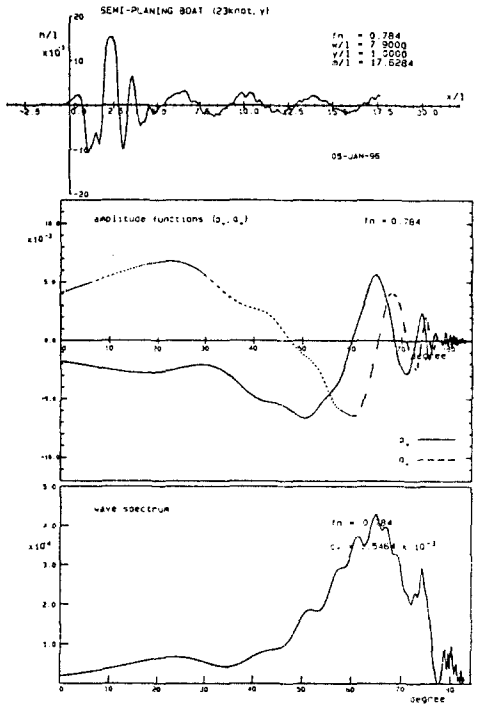

Fig. 11 Wave Pattern Analysis Results (Full Load, y/L=0.5, Fn=0.784)

Fig. 12 Photographs of Running Ship Model (Half Load, From Above: Fn=0.853 and 1.023)