NEAR EAST UNIVERSITY

FACULTY OF ENGINEERING

DEPERTMENT OF MECHANICAL ENGINEERING

RESISTANCE AND POWER CALCULATION FOR FISHING VESSELS

GRADUATION PROJECT

ME-400

STUDENT: Cengiz YAMAN (980171)

SUPERVISOR: Assist. Prof. Dr. Güner ÖZMEN

NICOSIA-2003

SUMMARY

In this study, resistance and power characteristics of three different fishing vessels are presented.

First chapter includes some definitions and basic expressions that are used throughout this research.

In second chapter the theoretical background and the mathematical formulations for the resistance and power calculation are given. In this chapter model testing procedure and experimental results for three fishing vessel are presented. Experimental results are compared for three different fishing vessels for two loading conditions.

In third chapter the resistance and power calculations by using 2-D methods are presented. The results are compared for three different fishing vessels for two loading conditions and presented in Tables and Figures.

In fourth chapter the resistance and power calculations by using 3-D methods are presented. The results are compared for three different fishing vessels for two loading conditions and presented in Tables and Figures.

ACKNOWLEDGEMENT

I wish to express my sincere thanks to Dr. Güner Özmen for her supervision, valuable advice and encouragement throughout this research. She will be always my respectful teacher.

I would like to thank the educational staff of Mechanical Engineering Department for their continued interest and encouragement. I would like to thank Prof. Kaşif Onaran and Dr. Ali Evcil for their support and valuable advices.

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CHAPTER 1

INTRODUCTION

This chapter includes basic equation for resistance and power calculation. The first section of this chapter explains the basic power definitions. Whereas, the second section is the definition of resistance on hull surface of vessel, and explain about the fundamental components of hull resistance. And major methods to predict hull resistance definitions are introduced in the third section. The third section also contains classifications of these methods and their general power overview determining methods are including in this section. So that by assuming those sections, calculation of resistance can be found on next chapters.

1.1 POWERING OVERVIEW

The power required to drive a ship through the water depends upon the resistance offered by the water and air.

To design a ship it is necessary to estimate the power to propel the ship at a particular speed. This allows estimating machinery masses/size and fuel consumption.

Power prediction problem can be split into the estimation of;

-Effective power, P_E

-Propulsive efficiency, η_D

Where;

Effective Power (P_E): Power required low the ship at the desired speed.

Propulsive efficiency (η_D): A measure of hydrodynamics losses in entire ship propulsion system.

Estimation of effective power requires the prediction of "Total hull resistance, R_T" effective power is calculated from;

$P_E = R_T . V_S$

where,

V_S: Ship speed.

1.2 SHIP HULL RESISTANCE

The resistance of a ship at a given speed is the fluid force acting on the ship in such a way as to oppose its motion. The resistance will be equal to the component of the fluid forces acting parallel to the axis of motion of the ship.

The fore and aft components of the tangential shear forces (τ) acting on each element of the hull surface can be summed over the hull to produce the total shear force or "FRICTIONAL RESISTANCE".

The fore and aft components of the pressure forces (P) acting on each element of the hull surface can be summed over the hull to produce a "PRESSURE RESISTANCE".

The pressure resistance is mainly caused by the hull's "wave making" effect. However the presence of turbulent region around the hull also effect the pressure resistance and additional pressure resistance due to viscous effect " VISCOUS PRESSURE RESISTANCE " or " FORM DRAG "

Alternatively, the hull resistance can be decomposed into two fundamental component "WAVE RESISTANCE", which is associated with the energy dissipated in the wave pattern and "VISCOUS DRAG" which is associated with the energy dissipated in "wake"

Depends of those resistance expressed as in Figure 1.1.

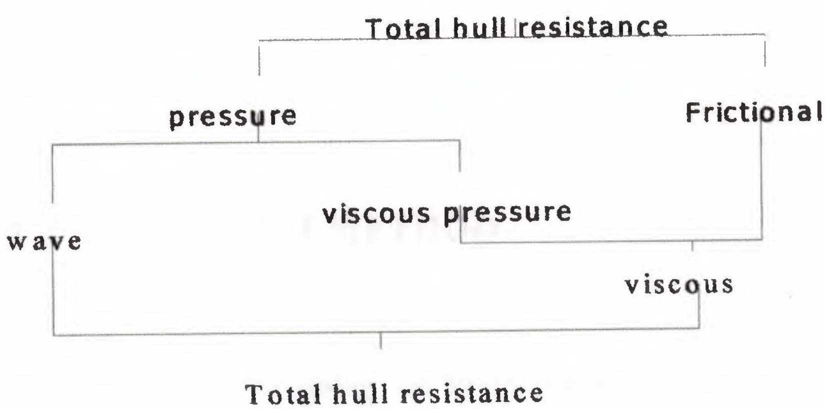

Figure 1.1

1.3 METHODS TO PREDICT HULL RESISTANCE

There are some methods for calculation the resistance on the hull surface of the ship. The aim here, choosing the best efficiency method.

-Direct model tests using

Froude's 2-D approach or

From factor (or 3D) approach

-Standard (Methodial) series methods

-Regression based methods

-Computational fluid dynamics (CFD) methods

The most expensive but the most reliable method amongst the above is the direct model test procedure. The reliability of the above methods generally decreases from top to bottom.

1.3.1 DIRECT MODEL TEST METHOD

The total resistance can be find by testing the model firstly and then these results can use on ship with depends its ratio. When model testing something is different like as density of water and wave resistance but this method can be apply for finding total resistance of ship.

Towing tank tests with geometrically similar model of a full-scale ship allow us to measure for the resistance of the full-scale vessel following certain similarity criteria.

By using "Dimensional Analysis" procedure one cam show that complete similarity between a model and full-scale ship (or between two ships) require to meet the following criteria

Shape parameters (Π_i) must be the same (Geometric similarity)

Reynolds number (R_n) must be the same (Kinematics flow similarity)

Froude number (F_n) must be the same (Dynamic flow similarity)

for the model and ship (or two similar ships).

Geometric similarity is achieved by linearly scaling down the underwater hull from of the ship by a constant factor (λ) known as "scale factor" is given as follow;

$$\lambda = \frac{L_S}{L_M} = \frac{B_S}{B_M} = \frac{T_S}{T_M} \qquad \lambda^2 = \frac{S_S}{S_M}$$

Where, L, B, T are underwater length, beam and draught of the ship or model, while S and indicate wetted surface area and displacement volume respectively subscripts s and m indicates "ship" and "model "

Reynolds number, R_n is defined as;

$$R_n = \frac{LV}{\nu}$$

Where L is the length of vessel at waterline, V is the vessel speed and υ is the kinematic viscosity.

Froude number, F_n is described as;

$$F_n = \frac{V}{\sqrt{g.L}}$$

where g is the gravitational acceleration.

Although the flow similarity condition (both kinematics & Dynamics) requires.

$$(R_n)_m = (R_n)_s \qquad \text{(Kinematics)}$$

$$(F_n)_m = (F_n)_s \qquad \text{(Dynamics)}$$

Fluid viscosity ratio is defined as;

$$\frac{v_m}{v_s} = \left(\frac{L_m}{L_s}\right)^{3/2}$$

Velocity of model can be calculated by using above similarity, as follows;

$$V_m = V_s\sqrt{\frac{L_m}{L_s}}$$

and by using scaling ratio of length factor;

$$V_s = V_m(\lambda)^{1/2}$$

Of course the violation of the kinematics condition brings about the problem of

$$(R_n)_m \leq (R_n)_s$$

Since R_n is the measure of viscous fluid forces, the flow regime around the hull, particularly in the boundary layer (friction belt) for the model will be in the laminar regime while for the ship it will be in turbulence. This problem can be overcome using "turbulence stimulators" in the form of studs, wires or roughness elements-placed at the bow sections of models to trip the flow.

Full-scale Power Prediction

The estimation of ship resistance and effective power for full-scale were carried out by two-dimensional and three-dimensional extrapolation procedure. The details of these calculations are given in following sections.

1.3.2 STANDARD SERIES METHOD

In the design process of a merchant ship, it is often the case that the prospective ship owner specifies the deadweight (ie. payload + fuel) at a particular displacement naval architect works out the probable displacement and dimensions. While the latter is usually subjected to restrictions, not associated with powering, the designer has to specific the proportions and shape of the hull for the particular speed to attain minimum resistance for lower power and fuel costs.

Therefore, $C_P = \left(\frac{C_B}{C_M}\right)$

together hull form parameters length to beam ratio, $\left(\frac{L}{B}\right)$

length to displacement ratio, $\left(\frac{L}{\nabla^{1/3}}\right)$

beam to drought ratio, $\left(\frac{B}{T}\right)$

Block-coefficient, $C_B = \frac{\nabla}{(L \times B \times T)}$

Mid-ship section coefficient, $C_M = \frac{mid - ship.area}{(B \times T)}$

Prismatic coefficient, $C_P = \left(\frac{C_B}{C_M}\right)$

Since Froude, naval architects have been studying effects of the above parameters upon resistance of a number of hull forms and proportions mainly performed resistance tests. Information of this kind is obtained by running a series of models in which some of the above parameters are changed in a systematic manner. The results of such "methodical" or "standard" series can be used to plot design charts which are of inestimable value to designer.

Such a series may be based upon a single parent from or upon a number of parents related to one another in some graphical or mathematical pattern.

The use of standard series data basically enables.

- To estimate rapid and cheaper power estimations at early design stage.

- Selections of suitable hull form parameters through merit comparisons.

- A standard for judging quality of hull form.

There are so many standard series available in open literature.

1.3.3 REGRESSION BASED METHOD

In additions to the published results for standard series, there exists a vast store of resistance data for the many models tested for specific designs. These are generally unrelated except in a generic way, but they contain the results of many changes made to hull forms to improve their performance. Such data might therefore be expects to yield valuable results if analyses statistically going powerful regression methods.

Within the above framework when sufficient data for a large number of independent designs exists in a standard form (e.g. from tests on models of similar size in one towing tank then statistical (regression) analysis gives an alternative to standard series. In addition, representative regression equations allow investigating the optimum choice of design parameters free from constraints.

Regression methods can only be applied in the long term to ship of closely similar types since more than 150 models may be required to provide an adequate analysis of non-linear combinations of parameters.

For example Doust et al (1959) fist applied regression analysis technique to the resistance data collected at the National Physical Laboratory with 150 models represents fishing trawlers.

Daust's regression equation for total resistance coefficient at particular values of Fn appears as;

$$C_T = f\left(\left(\frac{L}{B}\right), \left(\frac{B}{T}\right), C_M, C_P, LCB.position, i_E \right)$$

$$C_T = 0.00505 \times \left[a_0 + a_1 \times \left(\frac{B}{T}\right) + a_2 \times \left(\frac{B}{T}\right)^2 + ... + a_{28} \times \left(\frac{B}{T}\right) C_P + a_{29} \times \left(\frac{B}{T}\right)^2 C_P \right]$$

For four values of Fn, the values of regression equations coefficients a_0-a_{29} were evaluated on the computer from 150 trawler models.

Although the regression based methods are attractive and easy to use one should be careful with their limitation. Firstly analysis data should be for the correct ship type. Secondly one should check the statistical quality (e.g. stand error) of the data to be used. Finally great care must be taken that the prediction is confined to the limits of the data base.

1.3.4 COMPUTATIONAL FLUID DYNAMICS METHODS

Computational fluid dynamics (CFD) method is using from analysis of ship forms to predict the total resistance. This method is still in its infancy stage although considerable research effort is being devoted to the topic. CFD methods promise a significant predictive capability for the future when further development has taken place side by side with model testing techniques.

CHAPTER 2

CALM WATER RESISTANCE TESTS

Three different fishing vessel models was tested Test were carried out for a range of model speeds from 0.3 to 1.5 meters per second in the Froude number range of 0.07 to 0.4, which corresponds to full-scale speeds of between 3 and 16 knots. For each combination of the models tested value was taken. All those value given next parts.

2.1 TOWING TANK

A towing tank facility is essentially a long tank, of approximately rectangular cross-section, spanned with a carriage which towes the model along the tank. Improvements have been made over the years in terms of the carriage and its functioning, instrumentation and analysis of data. Digital recording and computers on carriages have reduced data acquisition time significantly.

Larger tanks in general amploy mechanically or electrically-driven towing carriages using models 4 to 10 or meters and conduct resistance as well as self-propulsion tests. Typical dimensions of these larger tanks are 250 m long, 10 m wide and 5 m deep. Depends upon the speed range, the model carriages may reach to 10 m/s and above.

In a typical run, the carriage is accelerated upto the required speed, resistance records is taken during a period of constant speed and then the carriage is decelerated.

2.2 PREPERATION OF MODELS;

Three different fishing vessels named as follows;

2-1F1A-3 type fishing vessel.

2-1F1A-4 type fishing vessel.

5-1F1A-4 type fishing vessel.

The models must be made to true to scale all points, at which they are in contact with water, for geometric similarity. Different type of material for construction of models can be used (e.g. wood, polystyrene foam, paraffin wax etc.). 2-1F1A-3 type models which using this project shown in Appendix-A

2.3 TEST RESULTS

In this case, prepared models enter the test from similarity condition of towing tank with particular speed. By this testing, the values can know on recorder of towing tank. These geometric properties give on (Table.2.1 and Table.2.2).

Table 2.1 Geometric Properties of Fishing Vessels

Lightship Draft												
Vessel	L	L_{WL}	B	T	L/B	B/T	CB	CP	CM	LCB	LCF	S_W
	(m)	(m)	(m)	(m)						(m)	(m)	(m2)
2-1F1A-3	41,40	43,20	11,50	5,735	3,600	2,005	0,736	0,793	0,928	-1,539	-3,593	943,100
2-1F1A-4	41,40	44,40	11,50	5,735	3,600	2,005	0,738	0,774	0,954	-1,435	-3,885	868,250
5-1F1A-4	41,40	46,80	11,50	5,735	3,600	2,005	0,742	0,778	0,954	-1,324	-3,567	875,190

Loaded Draft												
Vessel	L	L_{WL}	B	T	L/B	B/T	CB	CP	CM	LCB	LCF	S_W
	(m)	(m)	(m)	(m)						(m)	(m)	(m2)
2-1F1A-3	41,40	43,80	11,50	6,785	3,600	1,695	0,771	0,821	0,940	-1,907	-3,277	1041,080
2-1F1A-4	41,40	45,00	11,50	6,785	3,600	1,695	0,776	0,807	0,962	-1,913	-3,805	970,720
5-1F1A-4	41,40	45,90	11,50	6,785	3,600	1,695	0,781	0,812	0,962	-1,785	-3,677	977,680

Table 2.2 Geometric Properties of Models

Lightship Draft												
Model	L	L_{WL}	B	T	L/B	B/T	CB	CP	CM	LCB	LCF	S_W
	(m)	(m)	(m)	(m)						(m)	(m)	(m2)
2-1F1A-3	1,38	1,44	0,38	0,191	3,600	2,005	0,736	0,793	0,928	-0,051	-0,120	1,048
2-1F1A-4	1,38	1,48	0,38	0,191	3,600	2,005	0,738	0,774	0,954	-0,048	-0,130	0,965
5-1F1A-4	1,38	1,56	0,38	0,191	3,600	2,005	0,742	0,778	0,954	-0,044	-0,119	0,972

Loaded Draft												
Model	L	L_{WL}	B	T	L/B	B/T	CB	CP	CM	LCB	LCF	S_W
	(m)	(m)	(m)	(m)						(m)	(m)	(m2)
2-1F1A-3	1,38	1,46	0,38	0,226	3,600	1,695	0,771	0,821	0,940	-0,064	-0,109	1,157
2-1F1A-4	1,38	1,50	0,38	0,226	3,600	1,695	0,776	0,807	0,962	-0,064	-0,127	1,079
5-1F1A-4	1,38	1,53	0,38	0,226	3,600	1,695	0,781	0,812	0,962	-0,060	-0,123	1,086

Experiments results of resistance of models are given from Table 2.3, 2.4 and 2.5.

Table 2.3 Calm Water Resistance Data for 2-1F1A-3

Temperature 17.8 °C **Lightship Draft**			
Model speed (m/s)	Resistance (N)	Ship speed (knots)	Fn
0,2894	0,3148	3,0812	0,0770
0,3957	0,5737	4,2129	0,1053
0,4482	0,8138	4,7726	0,1193
0,5018	0,9540	5,3426	0,1335
0,5641	1,2031	6,0065	0,1501
0,6041	1,3262	6,4320	0,1607
0,7057	1,8422	7,5143	0,1878
0,8093	2,4984	8,6170	0,2153
0,9093	3,3910	9,6825	0,2419
1,0076	4,7834	10,7288	0,2681
1,1080	6,4801	11,7974	0,2948
1,2059	10,5240	12,8402	0,3208
1,3133	16,8036	13,9842	0,3494
1,4155	20,2439	15,0721	0,3766
1,5113	23,2813	16,0922	0,4021

Temperature 17.6 °C **Loaded Draft**			
Model speed (m/s)	Resistance (N)	Ship speed (knots)	Fn
0,2952	0,5239	3,1427	0,0779
0,3481	0,6465	3,7067	0,0919
0,4011	0,9151	4,2706	0,1059
0,4535	1,1744	4,8292	0,1197
0,5042	1,4007	5,3691	0,1331
0,6036	1,9177	6,4270	0,1593
0,7061	2,7398	7,5186	0,1864
0,8048	3,6152	8,5697	0,2124
0,9045	5,1295	9,6314	0,2388
1,0077	6,9049	10,7293	0,2660
1,1042	8,1489	11,7571	0,2915
1,2068	13,2278	12,8497	0,3185
1,3071	21,6552	13,9178	0,3450
1,4111	27,5063	15,0249	0,3725
1,5129	29,4284	16,1093	0,3994

Table 2.4 Calm Water Resistance Data for 2-1F1A-4

Temperature 17.6 °C	**Lightship Draft**		
Model speed (m/s)	Resistance (N)	Ship speed (knots)	Fn
0,5055	0,8747	5,3825	0,1327
0,6057	1,2640	6,4491	0,1590
0,7069	1,7513	7,5268	0,1855
0,8090	2,6526	8,6145	0,2123
0,9090	3,3126	9,6788	0,2386
1,0138	4,2142	10,7945	0,2661
1,1114	7,3827	11,8334	0,2917
1,2127	11,6537	12,9123	0,3183
1,3144	15,1490	13,9958	0,3450
1,4159	17,6368	15,0764	0,3716
1,5225	20,5235	16,2113	0,3996
Temperature 17.7 °C	**Loaded Draft**		
Model speed (m/s)	Resistance (N)	Ship speed (knots)	Fn
0,5033	1,0770	5,3588	0,1312
0,6054	1,6009	6,4462	0,1578
0,7094	2,1802	7,5535	0,1849
0,8080	3,1235	8,6035	0,2106
0,9112	4,2951	9,7025	0,2375
1,0110	5,4750	10,7646	0,2635
1,1108	8,3617	11,8279	0,2896
1,2140	13,0815	12,9268	0,3165
1,3136	18,6243	13,9867	0,3424
1,4179	23,0785	15,0970	0,3696
1,5195	24,3324	16,1792	0,3961

Table 2.5 Calm Water Resistance Data for 5-1F1A-4

Temperature 17.3 °C	Lightship Draft		
Model speed (m/s)	Resistance (N)	Ship speed (knots)	Fn
0,2931	0,3372	3,1205	0,0749
0,3466	0,4094	3,6910	0,0886
0,4022	0,5356	4,2822	0,1028
0,4515	0,6501	4,8079	0,1154
0,5063	0,8248	5,3914	0,1294
0,5557	1,0309	5,9169	0,1420
0,6086	1,2634	6,4802	0,1556
0,6566	1,5274	6,9909	0,1678
0,7090	1,7538	7,5493	0,1812
0,8099	2,7990	8,6237	0,2070
0,9127	3,7681	9,7186	0,2333
1,0122	4,6041	10,7775	0,2587
1,0628	5,5114	11,3164	0,2717
1,1138	7,1972	11,8596	0,2847
1,1623	9,2063	12,3761	0,2971
1,2132	11,0071	12,9181	0,3101
1,3152	14,1466	14,0040	0,3362
1,4179	16,7941	15,0973	0,3624
1,5191	19,8735	16,1748	0,3883
Temperature 17.2 °C	Loaded Draft		
Model speed (m/s)	Resistance (N)	Ship speed (knots)	Fn
0,2941	0,4052	3,1312	0,0762
0,3495	0,5336	3,7216	0,0905
0,4000	0,6581	4,2594	0,1036
0,4535	0,8774	4,8288	0,1174
0,5045	1,1450	5,3715	0,1306
0,5571	1,3964	5,9324	0,1443
0,6057	1,6394	6,4499	0,1569
0,6592	1,9534	7,0193	0,1707
0,7092	2,2675	7,5516	0,1837
0,8081	3,1214	8,6049	0,2093
0,9107	4,2776	9,6968	0,2358
1,0076	5,2771	10,7290	0,2609
1,0620	6,1277	11,3076	0,2750
1,1090	7,6657	11,8086	0,2872
1,1619	9,9719	12,3716	0,3009
1,2138	12,8857	12,9244	0,3143
1,3119	17,6516	13,9683	0,3397
1,4140	22,9810	15,0555	0,3662
1,5183	23,7475	16,1670	0,3932

2.4 DISCUSSION OF MODELS GRAFT

All these value putting on recorder. In here tables shown to us when velocity increasing, resistance on model also increases.

The difference between the lightship and loaded condition shown on Figure 2.2, 2.3, and 2.4

Major aim of these tests is finding the best efficiency type of ship. Resistance must be lower on same velocity and same weight of models. This different shown in Figure 2.5 and 2.6.

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To design a ship it is necessary to estimate the power to propel the ship at a particular speed. This allows estimating machinery masses/size and fuel consumption.

Power prediction problem can be split into the estimation of;

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Where;

Effective Power (P_E): Power required low the ship at the desired speed.

Propulsive efficiency (η_D): A measure of hydrodynamics losses in entire ship propulsion system.

Estimation of effective power requires the prediction of "Total hull resistance, R_T" effective power is calculated from;

$P_E = R_T . V_S$

where,

V_S: Ship speed.

1.2 SHIP HULL RESISTANCE

The resistance of a ship at a given speed is the fluid force acting on the ship in such a way as to oppose its motion. The resistance will be equal to the component of the fluid forces acting parallel to the axis of motion of the ship.

The fore and aft components of the tangential shear forces (τ) acting on each element of the hull surface can be summed over the hull to produce the total shear force or "FRICTIONAL RESISTANCE".

The fore and aft components of the pressure forces (P) acting on each element of the hull surface can be summed over the hull to produce a "PRESSURE RESISTANCE".

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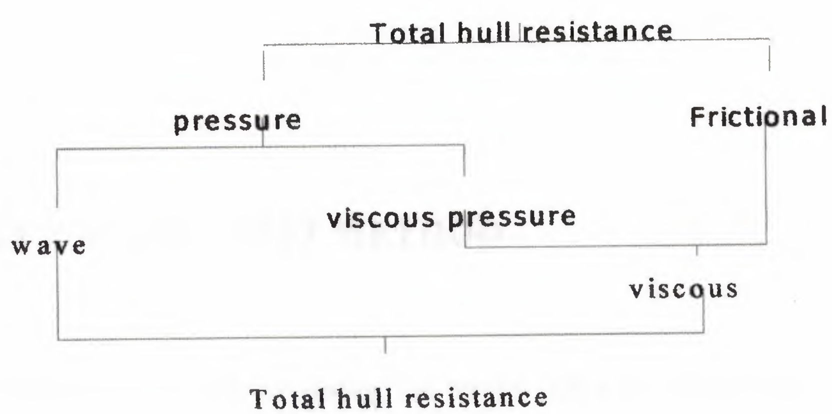


Figure 1.1

1.3 METHODS TO PREDICT HULL RESISTANCE

There are some methods for calculation the resistance on the hull surface of the ship. The aim here, choosing the best efficiency method.

-Direct model tests using

Froude's 2-D approach or

From factor (or 3D) approach

-Standard (Methodial) series methods

-Regression based methods

-Computational fluid dynamics (CFD) methods

The most expensive but the most reliable method amongst the above is the direct model test procedure. The reliability of the above methods generally decreases from top to bottom.

1.3.1 DIRECT MODEL TEST METHOD

The total resistance can be find by testing the model firstly and then these results can use on ship with depends its ratio. When model testing something is different like as density of water and wave resistance but this method can be apply for finding total resistance of ship.

Towing tank tests with geometrically similar model of a full-scale ship allow us to measure for the resistance of the full-scale vessel following certain similarity criteria.

By using "Dimensional Analysis" procedure one cam show that complete similarity between a model and full-scale ship (or between two ships) require to meet the following criteria

Shape parameters (Π_i) must be the same (Geometric similarity)

Reynolds number (R_n) must be the same (Kinematics flow similarity)

Froude number (F_n) must be the same (Dynamic flow similarity)

for the model and ship (or two similar ships).

Geometric similarity is achieved by linearly scaling down the underwater hull from of the ship by a constant factor (λ) known as "scale factor" is given as follow;

$$\lambda = \frac{L_S}{L_M} = \frac{B_S}{B_M} = \frac{T_S}{T_M} \qquad \lambda^2 = \frac{S_S}{S_M}$$

Where, L, B, T are underwater length, beam and draught of the ship or model, while S and indicate wetted surface area and displacement volume respectively subscripts s and m indicates "ship" and "model "

Reynolds number, R_n is defined as;

$$R_n = \frac{LV}{\nu}$$

Where L is the length of vessel at waterline, V is the vessel speed and υ is the kinematic viscosity.

Froude number, F_n is described as;

$$F_n = \frac{V}{\sqrt{g.L}}$$

where g is the gravitational acceleration.

Although the flow similarity condition (both kinematics & Dynamics) requires.

$$(R_n)_m = (R_n)_s \qquad \text{(Kinematics)}$$

$$(F_n)_m = (F_n)_s \qquad \text{(Dynamics)}$$

Fluid viscosity ratio is defined as;

$$\frac{v_m}{v_s} = \left(\frac{L_m}{L_s}\right)^{3/2}$$

Velocity of model can be calculated by using above similarity, as follows;

$$V_m = V_s \sqrt{\frac{L_m}{L_s}}$$

and by using scaling ratio of length factor;

$$V_s = V_m (\lambda)^{1/2}$$

Of course the violation of the kinematics condition brings about the problem of

$$(R_n)_m \leq (R_n)_s$$

Since R_n is the measure of viscous fluid forces, the flow regime around the hull, particularly in the boundary layer (friction belt) for the model will be in the laminar regime while for the ship it will be in turbulence. This problem can be overcome using "turbulence stimulators" in the form of studs, wires or roughness elements-placed at the bow sections of models to trip the flow.

Full-scale Power Prediction

The estimation of ship resistance and effective power for full-scale were carried out by two-dimensional and three-dimensional extrapolation procedure. The details of these calculations are given in following sections.

1.3.2 STANDARD SERIES METHOD

In the design process of a merchant ship, it is often the case that the prospective ship owner specifies the deadweight (ie. payload + fuel) at a particular displacement naval architect works out the probable displacement and dimensions. While the latter is usually subjected to restrictions, not associated with powering, the designer has to specific the proportions and shape of the hull for the particular speed to attain minimum resistance for lower power and fuel costs.

Therefore, $C_P = \left(\frac{C_B}{C_M}\right)$

together hull form parameters length to beam ratio, $\left(\frac{L}{B}\right)$

length to displacement ratio, $\left(\frac{L}{\nabla^{1/3}}\right)$

beam to drought ratio, $\left(\frac{B}{T}\right)$

Block-coefficient, $C_B = \frac{\nabla}{(L \times B \times T)}$

Mid-ship section coefficient, $C_M = \frac{mid - ship.area}{(B \times T)}$

Prismatic coefficient, $C_P = \left(\frac{C_B}{C_M}\right)$

Since Froude, naval architects have been studying effects of the above parameters upon resistance of a number of hull forms and proportions mainly performed resistance tests. Information of this kind is obtained by running a series of models in which some of the above parameters are changed in a systematic manner. The results of such "methodical" or "standard" series can be used to plot design charts which are of inestimable value to designer.

Such a series may be based upon a single parent from or upon a number of parents related to one another in some graphical or mathematical pattern.

The use of standard series data basically enables.

- To estimate rapid and cheaper power estimations at early design stage.

- Selections of suitable hull form parameters through merit comparisons.

- A standard for judging quality of hull form.

There are so many standard series available in open literature.

1.3.3 REGRESSION BASED METHOD

In additions to the published results for standard series, there exists a vast store of resistance data for the many models tested for specific designs. These are generally unrelated except in a generic way, but they contain the results of many changes made to hull forms to improve their performance. Such data might therefore be expects to yield valuable results if analyses statistically going powerful regression methods.

Within the above framework when sufficient data for a large number of independent designs exists in a standard form (e.g. from tests on models of similar size in one towing tank then statistical (regression) analysis gives an alternative to standard series. In addition, representative regression equations allow investigating the optimum choice of design parameters free from constraints.

Regression methods can only be applied in the long term to ship of closely similar types since more than 150 models may be required to provide an adequate analysis of non-linear combinations of parameters.

For example Doust et al (1959) fist applied regression analysis technique to the resistance data collected at the National Physical Laboratory with 150 models represents fishing trawlers.

Daust's regression equation for total resistance coefficient at particular values of Fn appears as;

$$C_T = f\left(\left(\frac{L}{B}\right), \left(\frac{B}{T}\right), C_M, C_P, LCB.position, i_E \right)$$

$$C_T = 0.00505 \times \left[a_0 + a_1 \times \left(\frac{B}{T}\right) + a_2 \times \left(\frac{B}{T}\right)^2 + \ldots\ldots + a_{28} \times \left(\frac{B}{T}\right) C_P + a_{29} \times \left(\frac{B}{T}\right)^2 C_P \right]$$

For four values of Fn, the values of regression equations coefficients a_0-a_{29} were evaluated on the computer from 150 trawler models.

Although the regression based methods are attractive and easy to use one should be careful with their limitation. Firstly analysis data should be for the correct ship type. Secondly one should check the statistical quality (e.g. stand error) of the data to be used. Finally great care must be taken that the prediction is confined to the limits of the data base.

1.3.4 COMPUTATIONAL FLUID DYNAMICS METHODS

Computational fluid dynamics (CFD) method is using from analysis of ship forms to predict the total resistance. This method is still in its infancy stage although considerable research effort is being devoted to the topic. CFD methods promise a significant predictive capability for the future when further development has taken place side by side with model testing techniques.

CHAPTER 2

CALM WATER RESISTANCE TESTS

Three different fishing vessel models was tested Test were carried out for a range of model speeds from 0.3 to 1.5 meters per second in the Froude number range of 0.07 to 0.4, which corresponds to full-scale speeds of between 3 and 16 knots. For each combination of the models tested value was taken. All those value given next parts.

2.1 TOWING TANK

A towing tank facility is essentially a long tank, of approximately rectangular cross-section, spanned with a carriage which towes the model along the tank. Improvements have been made over the years in terms of the carriage and its functioning, instrumentation and analysis of data. Digital recording and computers on carriages have reduced data acquisition time significantly.

Larger tanks in general amploy mechanically or electrically-driven towing carriages using models 4 to 10 or meters and conduct resistance as well as self-propulsion tests. Typical dimensions of these larger tanks are 250 m long, 10 m wide and 5 m deep. Depends upon the speed range, the model carriages may reach to 10 m/s and above.

In a typical run, the carriage is accelerated upto the required speed, resistance records is taken during a period of constant speed and then the carriage is decelerated.

2.2 PREPERATION OF MODELS;

Three different fishing vessels named as follows;

2-1F1A-3 type fishing vessel.

2-1F1A-4 type fishing vessel.

5-1F1A-4 type fishing vessel.

The models must be made to true to scale all points, at which they are in contact with water, for geometric similarity. Different type of material for construction of models can be used (e.g. wood, polystyrene foam, paraffin wax etc.). 2-1F1A-3 type models which using this project shown in Appendix-A

2.3 TEST RESULTS

In this case, prepared models enter the test from similarity condition of towing tank with particular speed. By this testing, the values can know on recorder of towing tank. These geometric properties give on (Table.2.1 and Table.2.2).

Table 2.1 Geometric Properties of Fishing Vessels

Lightship Draft												
Vessel	L (m)	L_{WL} (m)	B (m)	T (m)	L/B	B/T	CB	CP	CM	LCB (m)	LCF (m)	S_W (m2)
2-1F1A-3	41,40	43,20	11,50	5,735	3,600	2,005	0,736	0,793	0,928	-1,539	-3,593	943,100
2-1F1A-4	41,40	44,40	11,50	5,735	3,600	2,005	0,738	0,774	0,954	-1,435	-3,885	868,250
5-1F1A-4	41,40	46,80	11,50	5,735	3,600	2,005	0,742	0,778	0,954	-1,324	-3,567	875,190

Loaded Draft												
Vessel	L (m)	L_{WL} (m)	B (m)	T (m)	L/B	B/T	CB	CP	CM	LCB (m)	LCF (m)	S_W (m2)
2-1F1A-3	41,40	43,80	11,50	6,785	3,600	1,695	0,771	0,821	0,940	-1,907	-3,277	1041,080
2-1F1A-4	41,40	45,00	11,50	6,785	3,600	1,695	0,776	0,807	0,962	-1,913	-3,805	970,720
5-1F1A-4	41,40	45,90	11,50	6,785	3,600	1,695	0,781	0,812	0,962	-1,785	-3,677	977,680

Table 2.2 Geometric Properties of Models

Lightship Draft												
Model	L (m)	L_{WL} (m)	B (m)	T (m)	L/B	B/T	CB	CP	CM	LCB (m)	LCF (m)	S_W (m2)
2-1F1A-3	1,38	1,44	0,38	0,191	3,600	2,005	0,736	0,793	0,928	-0,051	-0,120	1,048
2-1F1A-4	1,38	1,48	0,38	0,191	3,600	2,005	0,738	0,774	0,954	-0,048	-0,130	0,965
5-1F1A-4	1,38	1,56	0,38	0,191	3,600	2,005	0,742	0,778	0,954	-0,044	-0,119	0,972

Loaded Draft												
Model	L (m)	L_{WL} (m)	B (m)	T (m)	L/B	B/T	CB	CP	CM	LCB (m)	LCF (m)	S_W (m2)
2-1F1A-3	1,38	1,46	0,38	0,226	3,600	1,695	0,771	0,821	0,940	-0,064	-0,109	1,157
2-1F1A-4	1,38	1,50	0,38	0,226	3,600	1,695	0,776	0,807	0,962	-0,064	-0,127	1,079
5-1F1A-4	1,38	1,53	0,38	0,226	3,600	1,695	0,781	0,812	0,962	-0,060	-0,123	1,086

Experiments results of resistance of models are given from Table 2.3, 2.4 and 2.5.

Table 2.3 Calm Water Resistance Data for 2-1F1A-3

Temperature 17.8 °C **Lightship Draft**			
Model speed (m/s)	Resistance (N)	Ship speed (knots)	Fn
0,2894	0,3148	3,0812	0,0770
0,3957	0,5737	4,2129	0,1053
0,4482	0,8138	4,7726	0,1193
0,5018	0,9540	5,3426	0,1335
0,5641	1,2031	6,0065	0,1501
0,6041	1,3262	6,4320	0,1607
0,7057	1,8422	7,5143	0,1878
0,8093	2,4984	8,6170	0,2153
0,9093	3,3910	9,6825	0,2419
1,0076	4,7834	10,7288	0,2681
1,1080	6,4801	11,7974	0,2948
1,2059	10,5240	12,8402	0,3208
1,3133	16,8036	13,9842	0,3494
1,4155	20,2439	15,0721	0,3766
1,5113	23,2813	16,0922	0,4021

Temperature 17.6 °C **Loaded Draft**			
Model speed (m/s)	Resistance (N)	Ship speed (knots)	Fn
0,2952	0,5239	3,1427	0,0779
0,3481	0,6465	3,7067	0,0919
0,4011	0,9151	4,2706	0,1059
0,4535	1,1744	4,8292	0,1197
0,5042	1,4007	5,3691	0,1331
0,6036	1,9177	6,4270	0,1593
0,7061	2,7398	7,5186	0,1864
0,8048	3,6152	8,5697	0,2124
0,9045	5,1295	9,6314	0,2388
1,0077	6,9049	10,7293	0,2660
1,1042	8,1489	11,7571	0,2915
1,2068	13,2278	12,8497	0,3185
1,3071	21,6552	13,9178	0,3450
1,4111	27,5063	15,0249	0,3725
1,5129	29,4284	16,1093	0,3994

Table 2.4 Calm Water Resistance Data for 2-1F1A-4

Temperature 17.6 °C **Lightship Draft**			
Model speed (m/s)	Resistance (N)	Ship speed (knots)	Fn
0,5055	0,8747	5,3825	0,1327
0,6057	1,2640	6,4491	0,1590
0,7069	1,7513	7,5268	0,1855
0,8090	2,6526	8,6145	0,2123
0,9090	3,3126	9,6788	0,2386
1,0138	4,2142	10,7945	0,2661
1,1114	7,3827	11,8334	0,2917
1,2127	11,6537	12,9123	0,3183
1,3144	15,1490	13,9958	0,3450
1,4159	17,6368	15,0764	0,3716
1,5225	20,5235	16,2113	0,3996
Temperature 17.7 °C **Loaded Draft**			
Model speed (m/s)	Resistance (N)	Ship speed (knots)	Fn
0,5033	1,0770	5,3588	0,1312
0,6054	1,6009	6,4462	0,1578
0,7094	2,1802	7,5535	0,1849
0,8080	3,1235	8,6035	0,2106
0,9112	4,2951	9,7025	0,2375
1,0110	5,4750	10,7646	0,2635
1,1108	8,3617	11,8279	0,2896
1,2140	13,0815	12,9268	0,3165
1,3136	18,6243	13,9867	0,3424
1,4179	23,0785	15,0970	0,3696
1,5195	24,3324	16,1792	0,3961

Table 2.5 Calm Water Resistance Data for 5-1F1A-4

Temperature 17.3 °C	**Lightship Draft**		
Model speed (m/s)	Resistance (N)	Ship speed (knots)	Fn
0,2931	0,3372	3,1205	0,0749
0,3466	0,4094	3,6910	0,0886
0,4022	0,5356	4,2822	0,1028
0,4515	0,6501	4,8079	0,1154
0,5063	0,8248	5,3914	0,1294
0,5557	1,0309	5,9169	0,1420
0,6086	1,2634	6,4802	0,1556
0,6566	1,5274	6,9909	0,1678
0,7090	1,7538	7,5493	0,1812
0,8099	2,7990	8,6237	0,2070
0,9127	3,7681	9,7186	0,2333
1,0122	4,6041	10,7775	0,2587
1,0628	5,5114	11,3164	0,2717
1,1138	7,1972	11,8596	0,2847
1,1623	9,2063	12,3761	0,2971
1,2132	11,0071	12,9181	0,3101
1,3152	14,1466	14,0040	0,3362
1,4179	16,7941	15,0973	0,3624
1,5191	19,8735	16,1748	0,3883

Temperature 17.2 °C	**Loaded Draft**		
Model speed (m/s)	Resistance (N)	Ship speed (knots)	Fn
0,2941	0,4052	3,1312	0,0762
0,3495	0,5336	3,7216	0,0905
0,4000	0,6581	4,2594	0,1036
0,4535	0,8774	4,8288	0,1174
0,5045	1,1450	5,3715	0,1306
0,5571	1,3964	5,9324	0,1443
0,6057	1,6394	6,4499	0,1569
0,6592	1,9534	7,0193	0,1707
0,7092	2,2675	7,5516	0,1837
0,8081	3,1214	8,6049	0,2093
0,9107	4,2776	9,6968	0,2358
1,0076	5,2771	10,7290	0,2609
1,0620	6,1277	11,3076	0,2750
1,1090	7,6657	11,8086	0,2872
1,1619	9,9719	12,3716	0,3009
1,2138	12,8857	12,9244	0,3143
1,3119	17,6516	13,9683	0,3397
1,4140	22,9810	15,0555	0,3662
1,5183	23,7475	16,1670	0,3932

2.4 DISCUSSION OF MODELS GRAFT

All these value putting on recorder. In here tables shown to us when velocity increasing, resistance on model also increases.

The difference between the lightship and loaded condition shown on Figure 2.2, 2.3, and 2.4

Major aim of these tests is finding the best efficiency type of ship. Resistance must be lower on same velocity and same weight of models. This different shown in Figure 2.5 and 2.6.

Figure 2.2 Calm Water Resistance for 2-1F1A-3

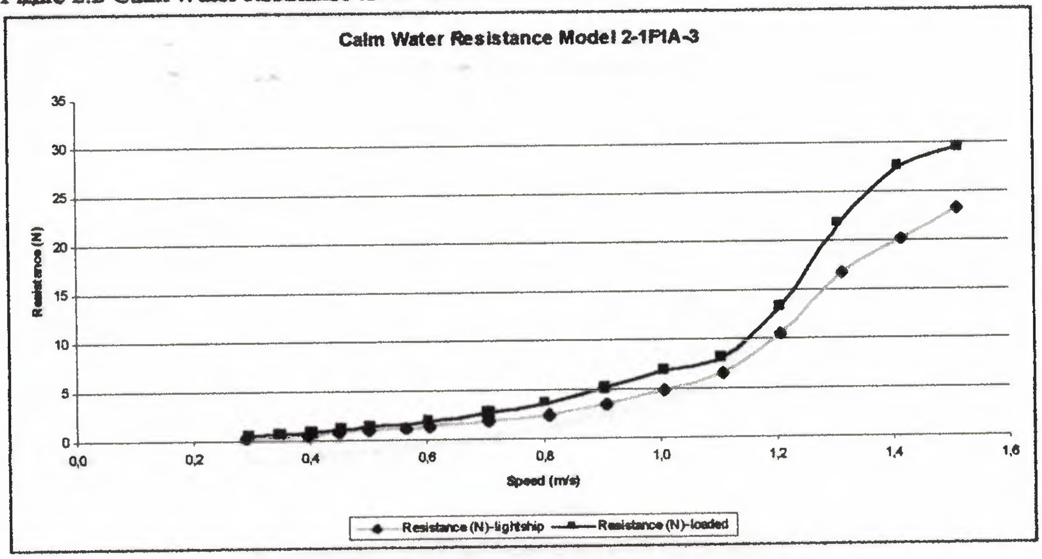


Figure 2.3 Calm Water Resistance for 2-1F1A-4

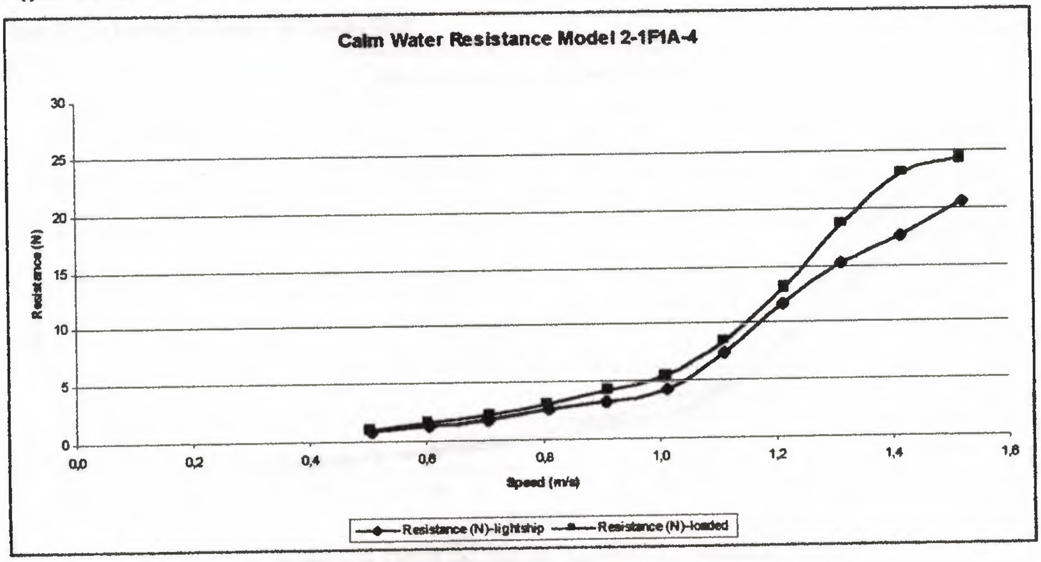


Figure 2.4 Calm Water Resistance for 5-1F1A-4

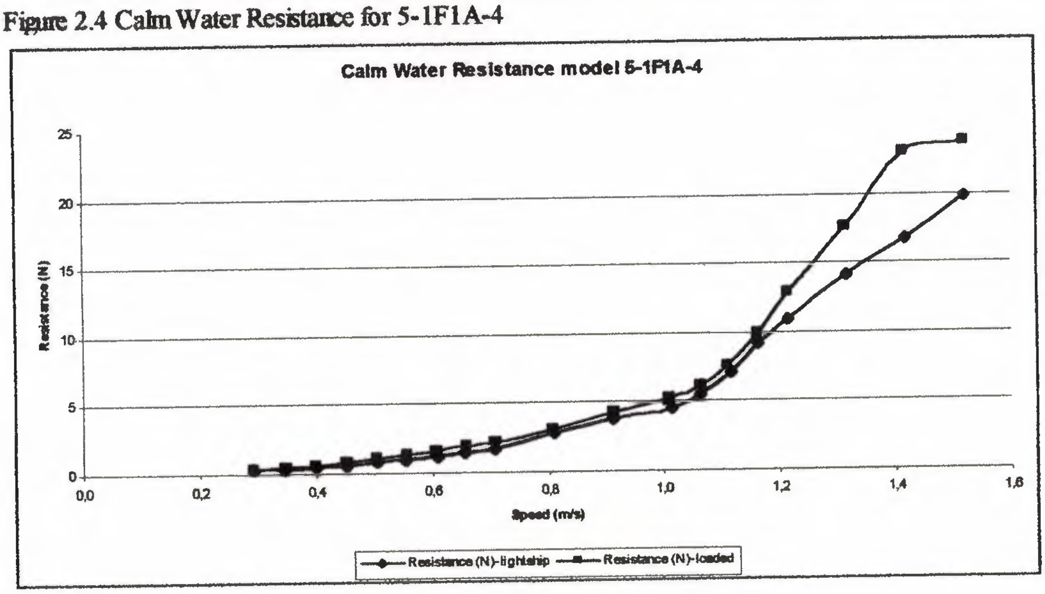


Figure 2.5 Calm water Resistance for Lightship Draft

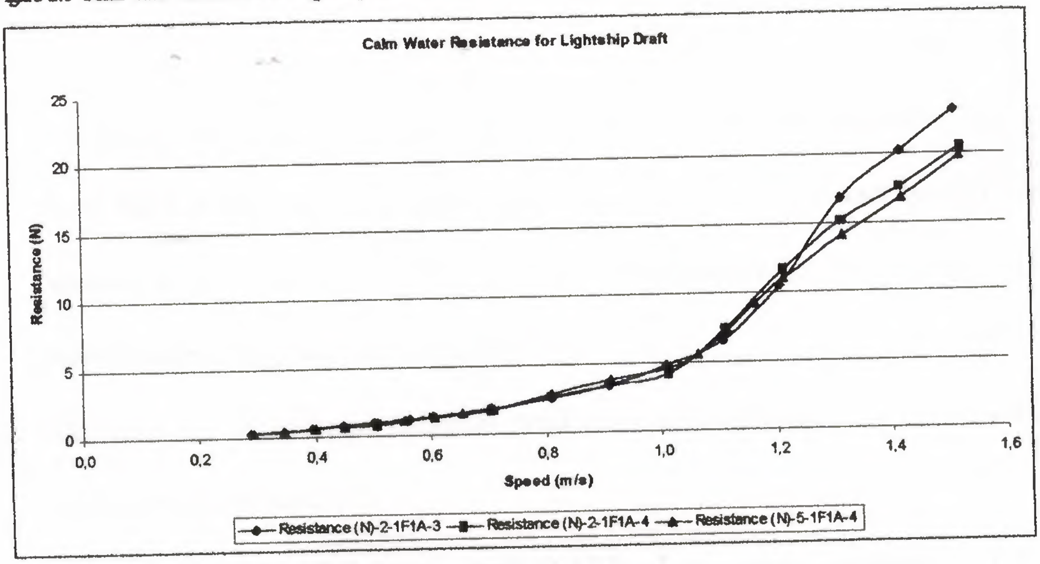
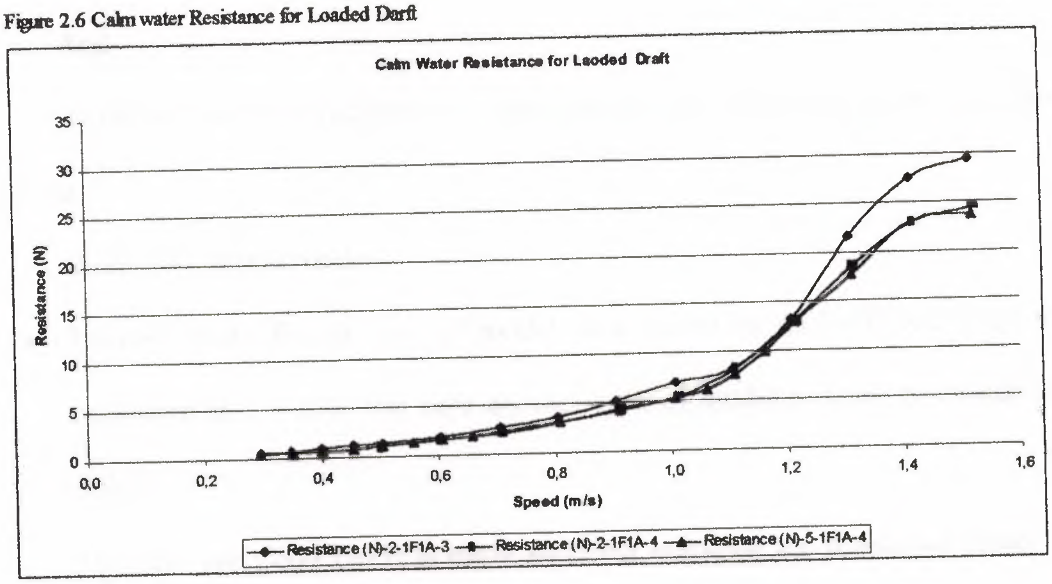


Figure 2.6 Calm water Resistance for Loaded Darft



2.5 REMARKS ON FINDINGS

- Difference between loaded and lightship draft of three type models are same until the 1.0 m/s. Then the third type of ship (5-1F1A-4) is start be different to another from 1,4 m/s suddenly stay the constant resistance. But between 1,0-1,4 m/s resistance increase more than another.
- Between the loaded and lightship draft resistance difference at 1,4 m/s for all kind of model around 5 N.
- When looking the all lightship draft, 2-1F1A-3 is a more resistance at 1.5 m/s. And

  5-1F1A-4 is lower resistance at same speed. Lightship draft for all type shown

to us

  5-1F1A-4 is best model.

- Loaded drafts for all kind of model also shown to us 2-1F1A-3 have more resistance at 1.5 m/s. But here another type of model is some resistance at all points.
- The first one (2-1F1A-3) is made suddenly changing the resistance value. This is not acceptable.

CHAPTER 3

Resistance and Power Calculation by using 2-D Method

Three different fishing vessel models were tested and by using this value, ship resistance and power is finding in this chapter.

3.1 Froude's 2-D Approach

Froude assumed the total ship hull resistance as;

Total ship hull resistance = Skin friction drag + the rest (i.e. residuary resistance)

$$R_T = R_F + R_R$$

In terms of coefficients expressed as;

$$C_T = C_F + C_R$$

where, C_T is the total resistance coefficient, C_F is the frictional resistance coefficient and

C_R is the residuary resistance coefficient.

$$C_T = \frac{R_T}{\frac{1}{2}\rho S V^2}, C_F = \frac{R_F}{\frac{1}{2}\rho S V^2} \; and \; C_R = \frac{R_R}{\frac{1}{2}\rho S V^2}$$

Froude found that;

$(C_R)_s = (C_R)_m$ at corresponding speed or at the same Froude number, $(Fn)_s = (Fn)_m$

Hence;

$$(C_T)_s = (C_T)_m - [(C_F)_m - (C_F)_s]$$

where subscript 'm' and 's' indicates 'model' and 'ship'.

In this equation $(C_T)_m$ can be obtained from model test whereas $(C_F)_m$ and $(C_F)_s$ can be calculated by using ITTC-57 model-ship correlation line as;

$$(C_F)_m = \frac{0.075}{(\log_{10}(Rn)_m - 2)^2}, \quad (C_F)_s = \frac{0.075}{(\log_{10}(Rn)_s - 2)^2}$$

The total resistance of the ship, $(R_T)_s$ is given. by;

$$(R_T)_s = (C_T)_s 1/2 \rho_s S_s V_s^2$$

Following this, the effective power, $(P_E)_s$ calculate as follows;

$$(P_E)_s = (R_T)_s V_s$$

Full-scale power predictions by using 2-D approach were carried out for both lightship and loaded draft for three different model.

In first section includes the calculations of tests results Table 3.1, 3.2 and 3.3.

And those calculation result given Figure 3.1, 3.2 and 3.3.

Table 3.1 Tabulated Data for Power Prediction by 2-D Approach, 2-IF1A-3

Lightship Draft													
$(V)_m$ (m/s)	$(RT)_m$ (N)	$(Rn)_{m10^6}$	$(CT)_m$	$(CF)_m$	$(CR)_m$	$(V)_s$ (m/s)	$(Fn)_s$	$(Rn)_{s10^6}$	$(CF)_s$	$(CR)_s$	$(CT)_s$	$(RT)_s$ (N)	PE (kW)
0,2894	0,3148	0,3894	0,0072	0,0058	0,0014	1,5849	0,0770	57,6198	0,0023	0,0014	0,0036	4,4076	6,9857
0,3957	0,5737	0,5325	0,0070	0,0054	0,0016	2,1671	0,1053	78,7848	0,0022	0,0016	0,0038	8,5437	18,5154
0,4482	0,8138	0,6032	0,0077	0,0052	0,0025	2,4550	0,1193	89,2517	0,0021	0,0025	0,0046	13,4490	33,0177
0,5018	0,9540	0,6753	0,0072	0,0051	0,0021	2,7482	0,1335	99,9096	0,0021	0,0021	0,0042	15,3900	42,2950
0,5641	1,2031	0,7592	0,0072	0,0050	0,0022	3,0897	0,1501	112,3257	0,0020	0,0022	0,0043	19,8285	61,2647
0,6041	1,3262	0,8129	0,0069	0,0049	0,0020	3,3086	0,1607	120,2828	0,0020	0,0020	0,0041	21,5517	71,3063
0,7057	1,8422	0,9497	0,0071	0,0047	0,0023	3,8654	0,1878	140,5232	0,0020	0,0023	0,0043	31,1790	120,5183
0,8093	2,4984	1,0891	0,0073	0,0046	0,0027	4,4326	0,2153	161,1443	0,0019	0,0027	0,0046	44,0639	195,3173
0,9093	3,3910	1,2238	0,0078	0,0045	0,0033	4,9807	0,2419	181,0698	0,0019	0,0033	0,0053	63,1781	314,6696
1,0076	4,7834	1,3560	0,0090	0,0044	0,0046	5,5189	0,2681	200,6357	0,0019	0,0046	0,0065	95,7858	528,6299
1,1080	6,4801	1,4911	0,0101	0,0043	0,0058	6,0686	0,2948	220,6203	0,0019	0,0058	0,0076	136,2351	826,7550
1,2059	10,5240	1,6229	0,0138	0,0042	0,0096	6,6050	0,3208	240,1211	0,0018	0,0096	0,0114	241,5033	1595,1284
1,3133	16,8036	1,7675	0,0186	0,0042	0,0145	7,1935	0,3494	261,5152	0,0018	0,0145	0,0163	407,6134	2932,1602
1,4155	20,2439	1,9050	0,0193	0,0041	0,0152	7,7531	0,3766	281,8587	0,0018	0,0152	0,0170	494,8845	3836,8748
1,5113	23,2813	2,0339	0,0195	0,0040	0,0154	8,2778	0,4021	300,9360	0,0018	0,0154	0,0172	571,0710	4727,2287
Loaded Draft													
$(V)_m$ (m/s)	$(RT)_m$ (N)	$(Rn)_{m10^6}$	$(CT)_m$	$(CF)_m$	$(CR)_m$	$(V)_s$ (m/s)	$(Fn)_s$	$(Rn)_{s10^6}$	$(CF)_s$	$(CR)_s$	$(CT)_s$	$(RT)_s$ (N)	PE (kW)
0,2952	0,5239	0,4027	0,0104	0,0058	0,0046	1,6166	0,0780	59,5874	0,0022	0,0046	0,0069	9,6133	15,5411
0,3481	0,6465	0,4750	0,0092	0,0055	0,0037	1,9067	0,0920	70,2816	0,0022	0,0037	0,0059	11,4188	21,7728
0,4011	0,9151	0,5473	0,0098	0,0054	0,0045	2,1968	0,1060	80,9725	0,0021	0,0045	0,0066	17,0843	37,5308
0,4535	1,1744	0,6188	0,0099	0,0052	0,0047	2,4841	0,1198	91,5633	0,0021	0,0047	0,0068	22,3343	55,4812
0,5042	1,4007	0,6880	0,0095	0,0051	0,0044	2,7619	0,1332	101,8008	0,0021	0,0044	0,0065	26,5688	73,3796
0,6036	1,9177	0,8236	0,0091	0,0049	0,0042	3,3060	0,1595	121,8589	0,0020	0,0042	0,0062	36,4553	120,5231
0,7061	2,7398	0,9635	0,0095	0,0047	0,0048	3,8675	0,1866	142,5553	0,0020	0,0048	0,0068	54,0601	209,0797
0,8048	3,6152	1,0982	0,0097	0,0046	0,0051	4,4083	0,2127	162,4858	0,0019	0,0051	0,0070	72,7757	320,8144
0,9045	5,1295	1,2342	0,0109	0,0045	0,0064	4,9544	0,2390	182,6166	0,0019	0,0064	0,0083	108,6116	538,1068
1,0077	6,9049	1,3749	0,0118	0,0044	0,0074	5,5192	0,2663	203,4332	0,0019	0,0074	0,0093	150,9242	832,9764
1,1042	8,1489	1,5066	0,0116	0,0043	0,0073	6,0479	0,2918	222,9203	0,0019	0,0073	0,0091	178,4390	1079,1737
1,2068	13,2278	1,6466	0,0157	0,0042	0,0115	6,6099	0,3189	243,6356	0,0018	0,0115	0,0133	311,3527	2058,0001
1,3071	21,6552	1,7835	0,0219	0,0041	0,0178	7,1593	0,3454	263,8879	0,0018	0,0178	0,0196	536,8084	3843,1799
1,4111	27,5063	1,9254	0,0239	0,0041	0,0198	7,7288	0,3729	284,8792	0,0018	0,0198	0,0216	689,9835	5332,7531
1,5129	29,4284	2,0644	0,0223	0,0040	0,0182	8,2866	0,3998	305,4398	0,0018	0,0182	0,0200	733,8692	6081,2973

Table 3.2 Tabulated Data for Power Prediction by 2-D Approach, 2-IF1A-4

Lightship Draft

$(V)_m$ (m/s)	$(RT)_m$ (N)	$(Rn)_m x10^6$	$(CT)_m$	$(CF)_m$	$(CR)_m$	$(V)_s$ (m/s)	$(Fn)_s$	$(Rn)_s x10^6$	$(CF)_s$	$(CR)_s$	$(CT)_s$	$(RT)_s$ (N)	PE (kW)
0,5055	0,8747	0,6992	0,0071	0,0051	0,0020	2,7687	0,1327	103,4519	0,0021	0,0020	0,0041	14,0121	38,7959
0,6057	1,2640	0,8378	0,0072	0,0049	0,0023	3,3174	0,1590	123,9526	0,0020	0,0023	0,0043	21,0716	69,9031
0,7069	1,7513	0,9777	0,0073	0,0047	0,0026	3,8718	0,1855	144,6659	0,0020	0,0026	0,0045	30,3146	117,3709
0,8090	2,6526	1,1190	0,0084	0,0046	0,0038	4,4313	0,2123	165,5722	0,0019	0,0038	0,0058	50,5122	223,8344
0,9090	3,3126	1,2573	0,0083	0,0045	0,0039	4,9788	0,2386	186,0289	0,0019	0,0039	0,0058	63,6628	316,9633
1,0138	4,2142	1,4022	0,0085	0,0044	0,0041	5,5527	0,2661	207,4730	0,0019	0,0041	0,0060	82,7910	459,7141
1,1114	7,3827	1,5372	0,0124	0,0043	0,0081	6,0871	0,2917	227,4412	0,0019	0,0081	0,0100	164,7642	1002,9404
1,2127	11,6537	1,6773	0,0164	0,0042	0,0122	6,6421	0,3183	248,1776	0,0018	0,0122	0,0141	276,6597	1837,6027
1,3144	15,1490	1,8181	0,0182	0,0041	0,0141	7,1994	0,3450	269,0019	0,0018	0,0141	0,0159	366,5857	2639,2098
1,4159	17,6368	1,9585	0,0183	0,0041	0,0142	7,7553	0,3716	289,7717	0,0018	0,0142	0,0160	428,1667	3320,5647
1,5225	20,5235	2,1059	0,0184	0,0040	0,0144	8,3391	0,3996	311,5851	0,0018	0,0144	0,0161	499,9952	4169,5166

Loaded Draft

$(V)_m$ (m/s)	$(RT)_m$ (N)	$(Rn)_m x10^6$	$(CT)_m$	$(CF)_m$	$(CR)_m$	$(V)_s$ (m/s)	$(Fn)_s$	$(Rn)_s x10^6$	$(CF)_s$	$(CR)_s$	$(CT)_s$	$(RT)_s$ (N)	PE (kW)
0,5033	1,0770	0,7055	0,0079	0,0051	0,0028	2,7566	0,1312	104,3886	0,0021	0,0028	0,0049	18,5396	51,1053
0,6054	1,6009	0,8487	0,0081	0,0049	0,0032	3,3159	0,1578	125,5710	0,0020	0,0032	0,0053	28,8294	95,5956
0,7094	2,1802	0,9945	0,0080	0,0047	0,0033	3,8855	0,1849	147,1417	0,0020	0,0033	0,0053	39,9969	155,4089
0,8080	3,1235	1,1327	0,0089	0,0046	0,0043	4,4256	0,2106	167,5956	0,0019	0,0043	0,0063	60,9909	269,9238
0,9112	4,2951	1,2774	0,0096	0,0044	0,0052	4,9910	0,2375	189,0041	0,0019	0,0052	0,0071	87,5491	436,9549
1,0110	5,4750	1,4172	0,0099	0,0044	0,0056	5,5373	0,2635	209,6935	0,0019	0,0056	0,0075	114,0343	631,4426
1,1108	8,3617	1,5572	0,0126	0,0043	0,0083	6,0843	0,2896	230,4075	0,0019	0,0083	0,0102	187,3653	1139,9858
1,2140	13,0815	1,7019	0,0165	0,0042	0,0123	6,6495	0,3165	251,8132	0,0018	0,0123	0,0141	310,8076	2066,7298
1,3136	18,6243	1,8415	0,0200	0,0041	0,0159	7,1948	0,3424	272,4601	0,0018	0,0159	0,0177	456,8667	3287,0473
1,4179	23,0785	1,9876	0,0213	0,0041	0,0173	7,7659	0,3696	294,0884	0,0018	0,0173	0,0190	571,8928	4441,2582
1,5195	24,3324	2,1301	0,0196	0,0040	0,0156	8,3226	0,3961	315,1700	0,0018	0,0156	0,0173	597,9230	4976,2678

Table 3.3 Tabulated Data for Power Prediction by 2-D Approach, 5-1F1A-4

Lightship Draft

$(V)_m$ (m/s)	$(RT)_m$ (N)	$(Rn)_m 10^6$	$(CT)_m$	$(CF)_m$	$(CR)_m$	$(V)_s$ (m/s)	$(Fn)_s$	$(Rn)_s 10^6$	$(CF)_s$	$(CR)_s$	$(CT)_s$	$(RT)_s$ (N)	PE (kW)
0,2931	0,3372	0,4273	0,0081	0,0057	0,0024	1,6052	0,0749	63,2177	0,0022	0,0024	0,0046	5,3549	8,5956
0,3466	0,4094	0,5054	0,0070	0,0055	0,0016	1,8986	0,0886	74,7755	0,0022	0,0016	0,0037	6,0309	11,4504
0,4022	0,5356	0,5863	0,0068	0,0053	0,0015	2,2028	0,1028	86,7545	0,0021	0,0015	0,0037	7,9923	17,6054
0,4515	0,6501	0,6583	0,0066	0,0051	0,0014	2,4732	0,1154	97,4046	0,0021	0,0014	0,0035	9,6598	23,8906
0,5063	0,8248	0,7382	0,0066	0,0050	0,0016	2,7733	0,1294	109,2247	0,0021	0,0016	0,0037	12,6861	35,1827
0,5557	1,0309	0,8102	0,0069	0,0049	0,0020	3,0436	0,1420	119,8707	0,0020	0,0020	0,0040	16,6344	50,6290
0,6086	1,2634	0,8873	0,0070	0,0048	0,0022	3,3334	0,1556	131,2827	0,0020	0,0022	0,0042	21,0556	70,1868
0,6566	1,5274	0,9572	0,0073	0,0047	0,0026	3,5961	0,1678	141,6305	0,0020	0,0026	0,0046	26,4253	95,0291
0,7090	1,7538	1,0337	0,0072	0,0047	0,0025	3,8834	0,1812	152,9426	0,0020	0,0025	0,0045	30,4408	118,2129
0,8099	2,7990	1,1808	0,0088	0,0045	0,0043	4,4360	0,2070	174,7087	0,0019	0,0043	0,0062	54,7294	242,7814
0,9127	3,7681	1,3307	0,0093	0,0044	0,0049	4,9993	0,2333	196,8909	0,0019	0,0049	0,0068	76,3419	381,6532
1,0122	4,6041	1,4757	0,0093	0,0043	0,0049	5,5439	0,2587	218,3426	0,0019	0,0049	0,0068	93,9912	521,0820
1,0628	5,5114	1,5495	0,0101	0,0043	0,0058	5,8212	0,2717	229,2606	0,0019	0,0058	0,0076	116,1809	676,3079
1,1138	7,1972	1,6239	0,0120	0,0042	0,0077	6,1006	0,2847	240,2647	0,0018	0,0077	0,0096	159,8423	975,1287
1,1623	9,2063	1,6946	0,0140	0,0042	0,0098	6,3663	0,2971	250,7286	0,0018	0,0098	0,0117	212,5308	1353,0257
1,2132	11,0071	1,7688	0,0154	0,0042	0,0113	6,6451	0,3101	261,7102	0,0018	0,0113	0,0131	259,1773	1722,2564
1,3152	14,1466	1,9175	0,0169	0,0041	0,0128	7,2037	0,3362	283,7088	0,0018	0,0128	0,0146	339,3174	2444,3262
1,4179	16,7941	2,0672	0,0172	0,0040	0,0132	7,7660	0,3624	305,8574	0,0018	0,0132	0,0150	405,3266	3147,7790
1,5191	19,8735	2,2147	0,0177	0,0040	0,0138	8,3203	0,3883	327,6881	0,0018	0,0138	0,0155	483,0171	4018,8649

Loaded Draft

$(V)_m$ (m/s)	$(RT)_m$ (N)	$(Rn)_m 10^6$	$(CT)_m$	$(CF)_m$	$(CR)_m$	$(V)_s$ (m/s)	$(Fn)_s$	$(Rn)_s 10^6$	$(CF)_s$	$(CR)_s$	$(CT)_s$	$(RT)_s$ (N)	PE (kW)
0,2941	0,4052	0,4177	0,0086	0,0057	0,0029	1,6107	0,0762	61,8092	0,0022	0,0029	0,0052	6,7102	10,8081
0,3495	0,5336	0,4965	0,0081	0,0055	0,0026	1,9144	0,0905	73,4622	0,0022	0,0026	0,0047	8,7225	16,6980
0,4000	0,6581	0,5683	0,0076	0,0053	0,0023	2,1910	0,1036	84,0790	0,0021	0,0023	0,0044	10,5978	23,2201
0,4535	0,8774	0,6442	0,0079	0,0052	0,0027	2,4839	0,1174	95,3182	0,0021	0,0027	0,0048	14,8429	36,8685
0,5045	1,1450	0,7166	0,0083	0,0050	0,0033	2,7631	0,1306	106,0308	0,0021	0,0033	0,0053	20,3621	56,2620
0,5571	1,3964	0,7915	0,0083	0,0049	0,0034	3,0516	0,1443	117,1029	0,0020	0,0034	0,0054	25,2124	76,9383
0,6057	1,6394	0,8605	0,0082	0,0048	0,0034	3,3178	0,1569	127,3185	0,0020	0,0034	0,0054	29,8582	99,0640
0,6592	1,9534	0,9365	0,0083	0,0048	0,0035	3,6107	0,1707	138,5580	0,0020	0,0035	0,0055	36,1142	130,3981
0,7092	2,2675	1,0075	0,0083	0,0047	0,0036	3,8845	0,1837	149,0653	0,0020	0,0036	0,0056	42,3986	164,6985
0,8081	3,1214	1,1480	0,0088	0,0046	0,0043	4,4264	0,2093	169,8586	0,0019	0,0043	0,0062	60,8942	269,5409
0,9107	4,2776	1,2937	0,0095	0,0044	0,0051	4,9880	0,2358	191,4113	0,0019	0,0051	0,0070	87,0613	434,2643
1,0076	5,2771	1,4314	0,0096	0,0043	0,0052	5,5190	0,2609	211,7861	0,0019	0,0052	0,0071	108,7261	600,0571
1,0620	6,1277	1,5086	0,0100	0,0043	0,0057	5,8166	0,2750	223,2073	0,0019	0,0057	0,0076	128,7280	748,7600
1,1090	7,6657	1,5754	0,0115	0,0043	0,0072	6,0743	0,2872	233,0973	0,0018	0,0072	0,0091	168,1700	1021,5204
1,1619	9,9719	1,6505	0,0136	0,0042	0,0094	6,3640	0,3009	244,2114	0,0018	0,0094	0,0112	228,4067	1453,5698
1,2138	12,8857	1,7243	0,0161	0,0042	0,0120	6,6483	0,3143	255,1237	0,0018	0,0120	0,0138	305,4437	2030,6881
1,3119	17,6516	1,8636	0,0189	0,0041	0,0148	7,1853	0,3397	275,7301	0,0018	0,0148	0,0166	430,1405	3090,6927
1,4140	22,9810	2,0086	0,0212	0,0041	0,0171	7,7446	0,3662	297,1914	0,0018	0,0171	0,0189	569,6925	4412,0244
1,5183	23,7475	2,1569	0,0190	0,0040	0,0150	8,3163	0,3932	319,1316	0,0018	0,0150	0,0168	581,9590	4839,7560

Figure 3.1 Effective Power by 2-D Approach for 2-1F1A-3

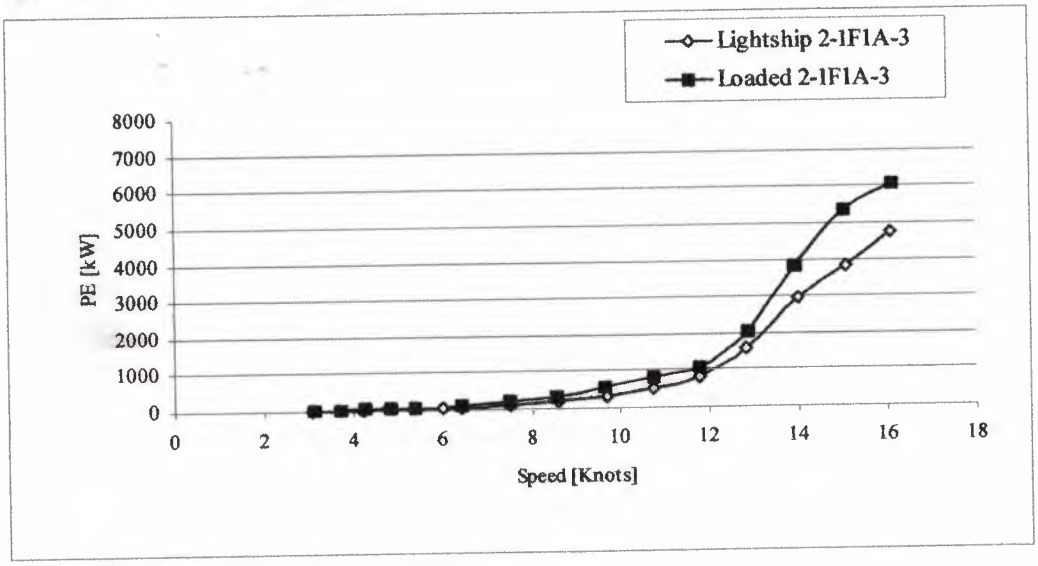


Figure 3.2 Effective Power by 2-D Approach for 2-1F1A-4

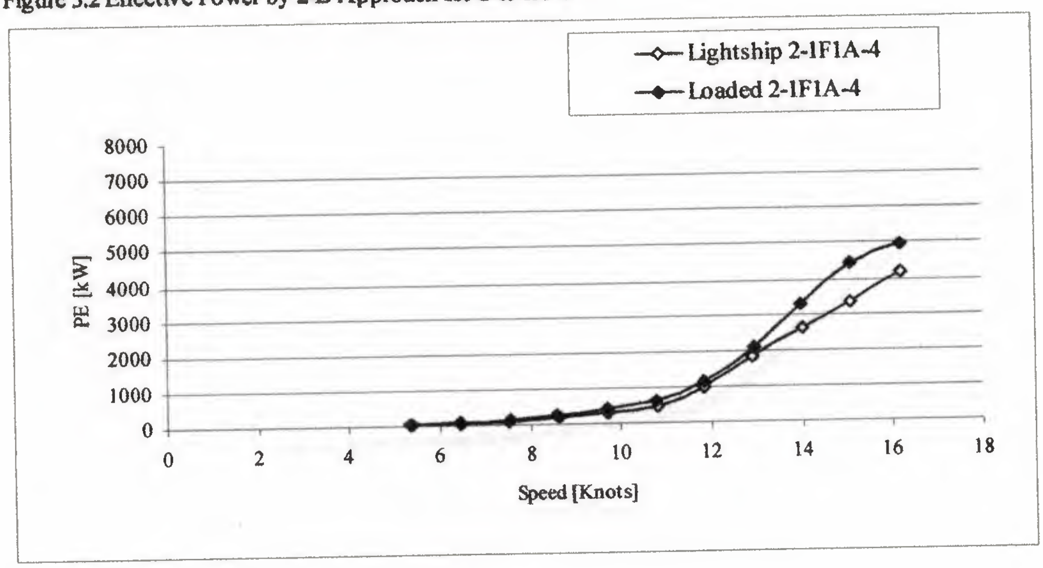


Figure 3.3 Effective Power by 2-D Approach for 5-1F1A-4

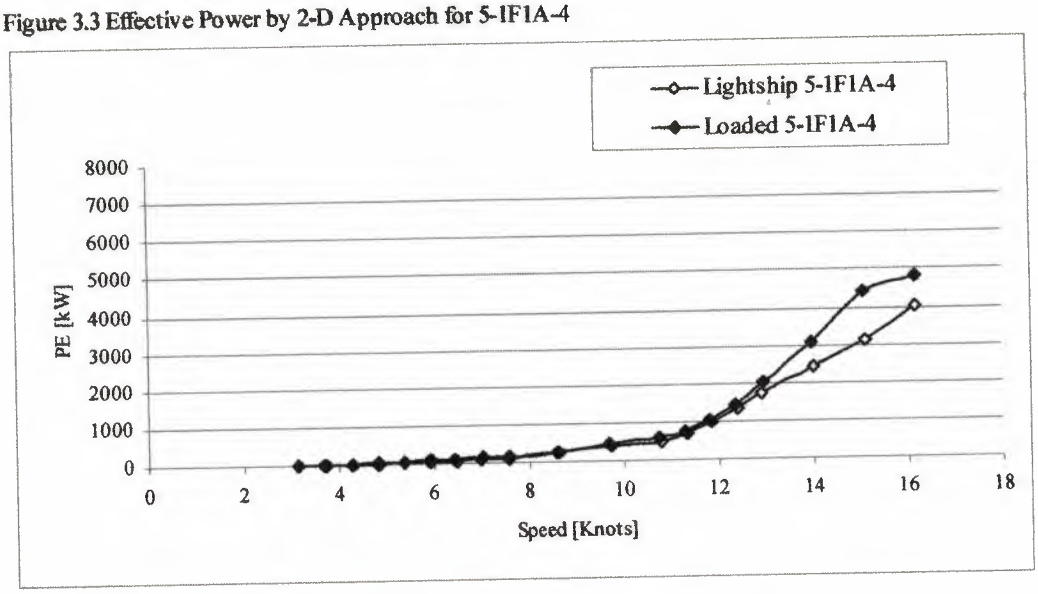


Figure 3.4 Effective Power for Short Hull Combinations at Lightship Draft

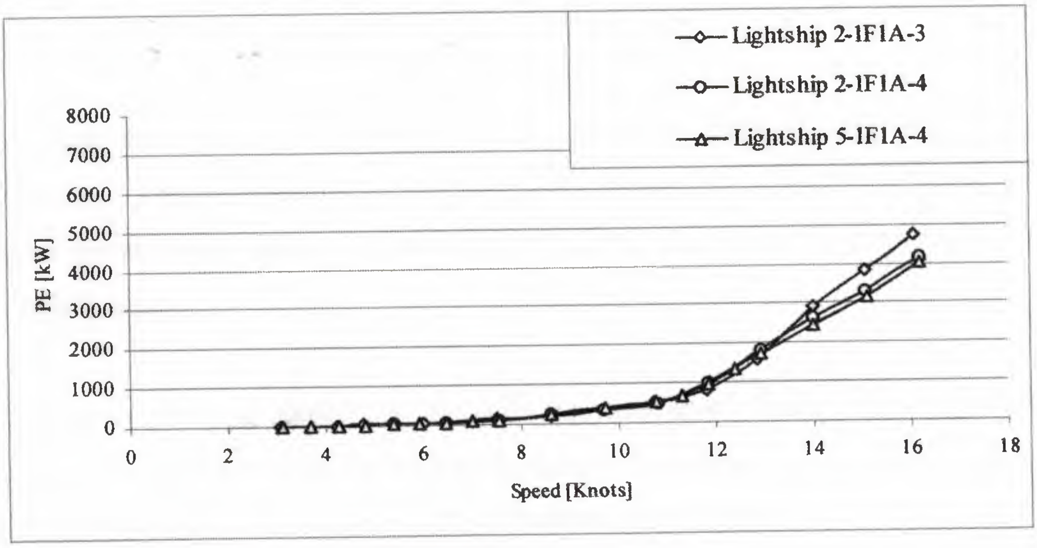
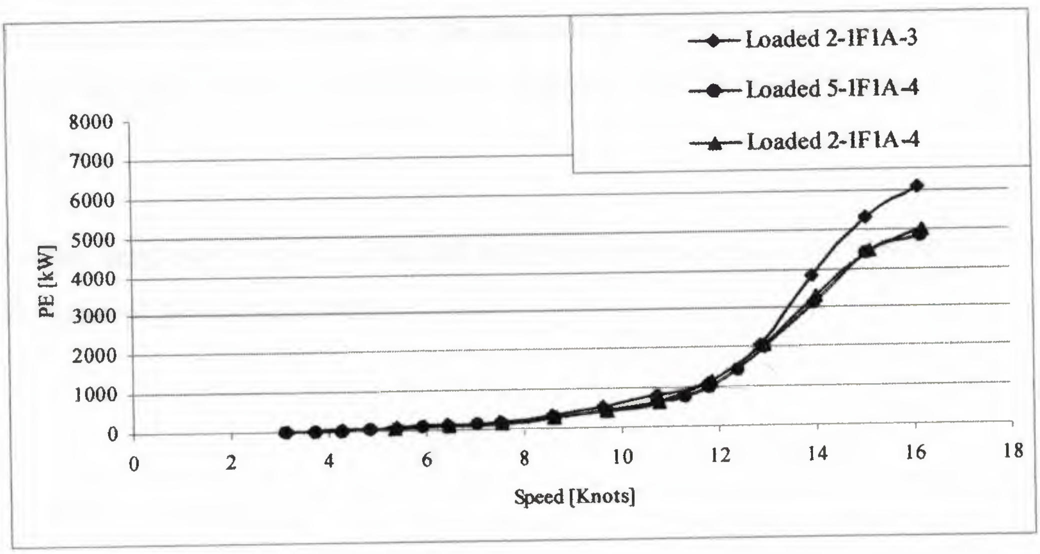


Figure 3.5 Effective Power for Short Hull Combinations at Loaded Draft



NEAR EAST UNIVERSITY

FACULTY OF ENGINEERING

DEPERTMENT OF MECHANICAL ENGINEERING

RESISTANCE AND POWER CALCULATION FOR FISHING VESSELS

GRADUATION PROJECT

ME-400

STUDENT: Cengiz YAMAN (980171)

SUPERVISOR: Assist. Prof. Dr. Güner ÖZMEN

NICOSIA-2003

SUMMARY

In this study, resistance and power characteristics of three different fishing vessels are presented.

First chapter includes some definitions and basic expressions that are used throughout this research.

In second chapter the theoretical background and the mathematical formulations for the resistance and power calculation are given. In this chapter model testing procedure and experimental results for three fishing vessel are presented. Experimental results are compared for three different fishing vessels for two loading conditions.

In third chapter the resistance and power calculations by using 2-D methods are presented. The results are compared for three different fishing vessels for two loading conditions and presented in Tables and Figures.

In fourth chapter the resistance and power calculations by using 3-D methods are presented. The results are compared for three different fishing vessels for two loading conditions and presented in Tables and Figures.

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RESISTANCE AND POWER CALCULATION BY USING 2-D METHOD

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RESISTANCE AND POWER CALCULATION BY USING 3-D METHOD

CHAPTER 1

INTRODUCTION

This chapter includes basic equation for resistance and power calculation. The first section of this chapter explains the basic power definitions. Whereas, the second section is the definition of resistance on hull surface of vessel, and explain about the fundamental components of hull resistance. And major methods to predict hull resistance definitions are introduced in the third section. The third section also contains classifications of these methods and their general power overview determining methods are including in this section. So that by assuming those sections, calculation of resistance can be found on next chapters.

1.1 POWERING OVERVIEW

The power required to drive a ship through the water depends upon the resistance offered by the water and air.

To design a ship it is necessary to estimate the power to propel the ship at a particular speed. This allows estimating machinery masses/size and fuel consumption.

Power prediction problem can be split into the estimation of;

-Effective power, P_E

-Propulsive efficiency, η_D

Where;

Effective Power (P_E): Power required low the ship at the desired speed.

Propulsive efficiency (η_D): A measure of hydrodynamics losses in entire ship propulsion system.

Estimation of effective power requires the prediction of "Total hull resistance, R_T" effective power is calculated from;

$P_E = R_T . V_S$

where,

V_S: Ship speed.

1.2 SHIP HULL RESISTANCE

The resistance of a ship at a given speed is the fluid force acting on the ship in such a way as to oppose its motion. The resistance will be equal to the component of the fluid forces acting parallel to the axis of motion of the ship.

The fore and aft components of the tangential shear forces (τ) acting on each element of the hull surface can be summed over the hull to produce the total shear force or "FRICTIONAL RESISTANCE".

The fore and aft components of the pressure forces (P) acting on each element of the hull surface can be summed over the hull to produce a "PRESSURE RESISTANCE".

The pressure resistance is mainly caused by the hull's "wave making" effect. However the presence of turbulent region around the hull also effect the pressure resistance and additional pressure resistance due to viscous effect " VISCOUS PRESSURE RESISTANCE " or " FORM DRAG "

Alternatively, the hull resistance can be decomposed into two fundamental component "WAVE RESISTANCE", which is associated with the energy dissipated in the wave pattern and "VISCOUS DRAG" which is associated with the energy dissipated in "wake"

Depends of those resistance expressed as in Figure 1.1.

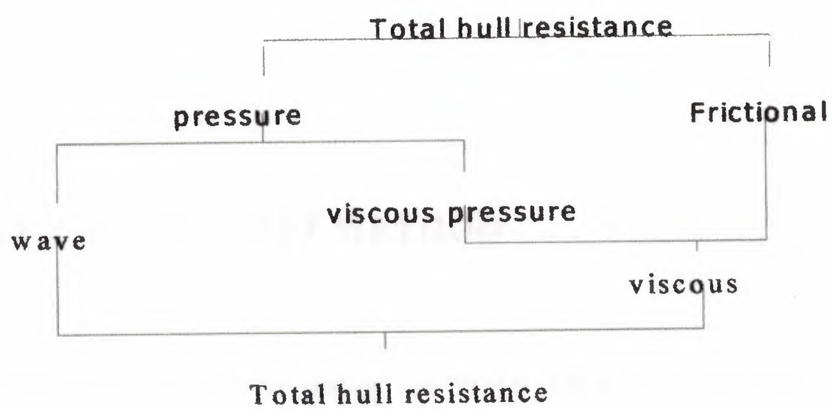


Figure 1.1

1.3 METHODS TO PREDICT HULL RESISTANCE

There are some methods for calculation the resistance on the hull surface of the ship. The aim here, choosing the best efficiency method.

-Direct model tests using

Froude's 2-D approach or

From factor (or 3D) approach

-Standard (Methodial) series methods

-Regression based methods

-Computational fluid dynamics (CFD) methods

The most expensive but the most reliable method amongst the above is the direct model test procedure. The reliability of the above methods generally decreases from top to bottom.

1.3.1 DIRECT MODEL TEST METHOD

The total resistance can be find by testing the model firstly and then these results can use on ship with depends its ratio. When model testing something is different like as density of water and wave resistance but this method can be apply for finding total resistance of ship.

Towing tank tests with geometrically similar model of a full-scale ship allow us to measure for the resistance of the full-scale vessel following certain similarity criteria.

By using "Dimensional Analysis" procedure one cam show that complete similarity between a model and full-scale ship (or between two ships) require to meet the following criteria

Shape parameters (Π_i) must be the same (Geometric similarity)

Reynolds number (R_n) must be the same (Kinematics flow similarity)

Froude number (F_n) must be the same (Dynamic flow similarity)

for the model and ship (or two similar ships).

Geometric similarity is achieved by linearly scaling down the underwater hull from of the ship by a constant factor (λ) known as "scale factor" is given as follow;

$$\lambda = \frac{L_S}{L_M} = \frac{B_S}{B_M} = \frac{T_S}{T_M} \qquad \lambda^2 = \frac{S_S}{S_M}$$

Where, L, B, T are underwater length, beam and draught of the ship or model, while S and indicate wetted surface area and displacement volume respectively subscripts s and m indicates "ship" and "model "

Reynolds number, R_n is defined as;

$$R_n = \frac{LV}{\nu}$$

Where L is the length of vessel at waterline, V is the vessel speed and υ is the kinematic viscosity.

Froude number, F_n is described as;

$$F_n = \frac{V}{\sqrt{g.L}}$$

where g is the gravitational acceleration.

Although the flow similarity condition (both kinematics & Dynamics) requires.

$$(R_n)_m = (R_n)_s \qquad \text{(Kinematics)}$$

$$(F_n)_m = (F_n)_s \qquad \text{(Dynamics)}$$

Fluid viscosity ratio is defined as;

$$\frac{v_m}{v_s} = \left(\frac{L_m}{L_s}\right)^{3/2}$$

Velocity of model can be calculated by using above similarity, as follows;

$$V_m = V_s \sqrt{\frac{L_m}{L_s}}$$

and by using scaling ratio of length factor;

$$V_s = V_m (\lambda)^{1/2}$$

Of course the violation of the kinematics condition brings about the problem of

$$(R_n)_m \leq (R_n)_s$$

Since R_n is the measure of viscous fluid forces, the flow regime around the hull, particularly in the boundary layer (friction belt) for the model will be in the laminar regime while for the ship it will be in turbulence. This problem can be overcome using "turbulence stimulators" in the form of studs, wires or roughness elements-placed at the bow sections of models to trip the flow.

Full-scale Power Prediction

The estimation of ship resistance and effective power for full-scale were carried out by two-dimensional and three-dimensional extrapolation procedure. The details of these calculations are given in following sections.

1.3.2 STANDARD SERIES METHOD

In the design process of a merchant ship, it is often the case that the prospective ship owner specifies the deadweight (ie. payload + fuel) at a particular displacement naval architect works out the probable displacement and dimensions. While the latter is usually subjected to restrictions, not associated with powering, the designer has to specific the proportions and shape of the hull for the particular speed to attain minimum resistance for lower power and fuel costs.

Therefore, $C_P = \left(\frac{C_B}{C_M} \right)$

together hull form parameters length to beam ratio, $\left(\frac{L}{B} \right)$

length to displacement ratio, $\left(\frac{L}{\nabla^{1/3}} \right)$

beam to drought ratio, $\left(\frac{B}{T} \right)$

Block-coefficient, $C_B = \frac{\nabla}{(L \times B \times T)}$

Mid-ship section coefficient, $C_M = \frac{mid - ship.area}{(B \times T)}$

Prismatic coefficient, $C_P = \left(\frac{C_B}{C_M} \right)$

Since Froude, naval architects have been studying effects of the above parameters upon resistance of a number of hull forms and proportions mainly performed resistance tests. Information of this kind is obtained by running a series of models in which some of the above parameters are changed in a systematic manner. The results of such "methodical" or "standard" series can be used to plot design charts which are of inestimable value to designer.

Such a series may be based upon a single parent from or upon a number of parents related to one another in some graphical or mathematical pattern.

The use of standard series data basically enables.

- To estimate rapid and cheaper power estimations at early design stage.

- Selections of suitable hull form parameters through merit comparisons.

- A standard for judging quality of hull form.

There are so many standard series available in open literature.

1.3.3 REGRESSION BASED METHOD

In additions to the published results for standard series, there exists a vast store of resistance data for the many models tested for specific designs. These are generally unrelated except in a generic way, but they contain the results of many changes made to hull forms to improve their performance. Such data might therefore be expects to yield valuable results if analyses statistically going powerful regression methods.

Within the above framework when sufficient data for a large number of independent designs exists in a standard form (e.g. from tests on models of similar size in one towing tank then statistical (regression) analysis gives an alternative to standard series. In addition, representative regression equations allow investigating the optimum choice of design parameters free from constraints.

Regression methods can only be applied in the long term to ship of closely similar types since more than 150 models may be required to provide an adequate analysis of non-linear combinations of parameters.

For example Doust et al (1959) fist applied regression analysis technique to the resistance data collected at the National Physical Laboratory with 150 models represents fishing trawlers.

Daust's regression equation for total resistance coefficient at particular values of Fn appears as;

$$C_T = f\left(\left(\frac{L}{B}\right), \left(\frac{B}{T}\right), C_M, C_P, LCB.position, i_E \right)$$

$$C_T = 0.00505 \times \left[a_0 + a_1 \times \left(\frac{B}{T}\right) + a_2 \times \left(\frac{B}{T}\right)^2 + \ldots\ldots. + a_{28} \times \left(\frac{B}{T}\right) C_P + a_{29} \times \left(\frac{B}{T}\right)^2 C_P \right]$$

For four values of Fn, the values of regression equations coefficients a_0-a_{29} were evaluated on the computer from 150 trawler models.

Although the regression based methods are attractive and easy to use one should be careful with their limitation. Firstly analysis data should be for the correct ship type. Secondly one should check the statistical quality (e.g. stand error) of the data to be used. Finally great care must be taken that the prediction is confined to the limits of the data base.

1.3.4 COMPUTATIONAL FLUID DYNAMICS METHODS

Computational fluid dynamics (CFD) method is using from analysis of ship forms to predict the total resistance. This method is still in its infancy stage although considerable research effort is being devoted to the topic. CFD methods promise a significant predictive capability for the future when further development has taken place side by side with model testing techniques.

CHAPTER 2

CALM WATER RESISTANCE TESTS

Three different fishing vessel models was tested Test were carried out for a range of model speeds from 0.3 to 1.5 meters per second in the Froude number range of 0.07 to 0.4, which corresponds to full-scale speeds of between 3 and 16 knots. For each combination of the models tested value was taken. All those value given next parts.

2.1 TOWING TANK

A towing tank facility is essentially a long tank, of approximately rectangular cross-section, spanned with a carriage which towes the model along the tank. Improvements have been made over the years in terms of the carriage and its functioning, instrumentation and analysis of data. Digital recording and computers on carriages have reduced data acquisition time significantly.

Larger tanks in general amploy mechanically or electrically-driven towing carriages using models 4 to 10 or meters and conduct resistance as well as self-propulsion tests. Typical dimensions of these larger tanks are 250 m long, 10 m wide and 5 m deep. Depends upon the speed range, the model carriages may reach to 10 m/s and above.

In a typical run, the carriage is accelerated upto the required speed, resistance records is taken during a period of constant speed and then the carriage is decelerated.

2.2 PREPERATION OF MODELS;

Three different fishing vessels named as follows;

2-1F1A-3 type fishing vessel.

2-1F1A-4 type fishing vessel.

5-1F1A-4 type fishing vessel.

The models must be made to true to scale all points, at which they are in contact with water, for geometric similarity. Different type of material for construction of models can be used (e.g. wood, polystyrene foam, paraffin wax etc.). 2-1F1A-3 type models which using this project shown in Appendix-A

2.3 TEST RESULTS

In this case, prepared models enter the test from similarity condition of towing tank with particular speed. By this testing, the values can know on recorder of towing tank. These geometric properties give on (Table.2.1 and Table.2.2).

Table 2.1 Geometric Properties of Fishing Vessels

Lightship Draft												
Vessel	L	L_{WL}	B	T	L/B	B/T	CB	CP	CM	LCB	LCF	S_W
	(m)	(m)	(m)	(m)						(m)	(m)	(m2)
2-1F1A-3	41,40	43,20	11,50	5,735	3,600	2,005	0,736	0,793	0,928	-1,539	-3,593	943,100
2-1F1A-4	41,40	44,40	11,50	5,735	3,600	2,005	0,738	0,774	0,954	-1,435	-3,885	868,250
5-1F1A-4	41,40	46,80	11,50	5,735	3,600	2,005	0,742	0,778	0,954	-1,324	-3,567	875,190

Loaded Draft												
Vessel	L	L_{WL}	B	T	L/B	B/T	CB	CP	CM	LCB	LCF	S_W
	(m)	(m)	(m)	(m)						(m)	(m)	(m2)
2-1F1A-3	41,40	43,80	11,50	6,785	3,600	1,695	0,771	0,821	0,940	-1,907	-3,277	1041,080
2-1F1A-4	41,40	45,00	11,50	6,785	3,600	1,695	0,776	0,807	0,962	-1,913	-3,805	970,720
5-1F1A-4	41,40	45,90	11,50	6,785	3,600	1,695	0,781	0,812	0,962	-1,785	-3,677	977,680

Table 2.2 Geometric Properties of Models

Lightship Draft												
Model	L	L_{WL}	B	T	L/B	B/T	CB	CP	CM	LCB	LCF	S_W
	(m)	(m)	(m)	(m)						(m)	(m)	(m2)
2-1F1A-3	1,38	1,44	0,38	0,191	3,600	2,005	0,736	0,793	0,928	-0,051	-0,120	1,048
2-1F1A-4	1,38	1,48	0,38	0,191	3,600	2,005	0,738	0,774	0,954	-0,048	-0,130	0,965
5-1F1A-4	1,38	1,56	0,38	0,191	3,600	2,005	0,742	0,778	0,954	-0,044	-0,119	0,972

Loaded Draft												
Model	L	L_{WL}	B	T	L/B	B/T	CB	CP	CM	LCB	LCF	S_W
	(m)	(m)	(m)	(m)						(m)	(m)	(m2)
2-1F1A-3	1,38	1,46	0,38	0,226	3,600	1,695	0,771	0,821	0,940	-0,064	-0,109	1,157
2-1F1A-4	1,38	1,50	0,38	0,226	3,600	1,695	0,776	0,807	0,962	-0,064	-0,127	1,079
5-1F1A-4	1,38	1,53	0,38	0,226	3,600	1,695	0,781	0,812	0,962	-0,060	-0,123	1,086

Experiments results of resistance of models are given from Table 2.3, 2.4 and 2.5.

Table 2.3 Calm Water Resistance Data for 2-1F1A-3

Temperature 17.8 °C **Lightship Draft**			
Model speed (m/s)	Resistance (N)	Ship speed (knots)	Fn
0,2894	0,3148	3,0812	0,0770
0,3957	0,5737	4,2129	0,1053
0,4482	0,8138	4,7726	0,1193
0,5018	0,9540	5,3426	0,1335
0,5641	1,2031	6,0065	0,1501
0,6041	1,3262	6,4320	0,1607
0,7057	1,8422	7,5143	0,1878
0,8093	2,4984	8,6170	0,2153
0,9093	3,3910	9,6825	0,2419
1,0076	4,7834	10,7288	0,2681
1,1080	6,4801	11,7974	0,2948
1,2059	10,5240	12,8402	0,3208
1,3133	16,8036	13,9842	0,3494
1,4155	20,2439	15,0721	0,3766
1,5113	23,2813	16,0922	0,4021

Temperature 17.6 °C **Loaded Draft**			
Model speed (m/s)	Resistance (N)	Ship speed (knots)	Fn
0,2952	0,5239	3,1427	0,0779
0,3481	0,6465	3,7067	0,0919
0,4011	0,9151	4,2706	0,1059
0,4535	1,1744	4,8292	0,1197
0,5042	1,4007	5,3691	0,1331
0,6036	1,9177	6,4270	0,1593
0,7061	2,7398	7,5186	0,1864
0,8048	3,6152	8,5697	0,2124
0,9045	5,1295	9,6314	0,2388
1,0077	6,9049	10,7293	0,2660
1,1042	8,1489	11,7571	0,2915
1,2068	13,2278	12,8497	0,3185
1,3071	21,6552	13,9178	0,3450
1,4111	27,5063	15,0249	0,3725
1,5129	29,4284	16,1093	0,3994

Table 2.4 Calm Water Resistance Data for 2-1F1A-4

Temperature 17.6 °C	**Lightship Draft**		
Model speed (m/s)	Resistance (N)	Ship speed (knots)	Fn
0,5055	0,8747	5,3825	0,1327
0,6057	1,2640	6,4491	0,1590
0,7069	1,7513	7,5268	0,1855
0,8090	2,6526	8,6145	0,2123
0,9090	3,3126	9,6788	0,2386
1,0138	4,2142	10,7945	0,2661
1,1114	7,3827	11,8334	0,2917
1,2127	11,6537	12,9123	0,3183
1,3144	15,1490	13,9958	0,3450
1,4159	17,6368	15,0764	0,3716
1,5225	20,5235	16,2113	0,3996
Temperature 17.7 °C	**Loaded Draft**		
Model speed (m/s)	Resistance (N)	Ship speed (knots)	Fn
0,5033	1,0770	5,3588	0,1312
0,6054	1,6009	6,4462	0,1578
0,7094	2,1802	7,5535	0,1849
0,8080	3,1235	8,6035	0,2106
0,9112	4,2951	9,7025	0,2375
1,0110	5,4750	10,7646	0,2635
1,1108	8,3617	11,8279	0,2896
1,2140	13,0815	12,9268	0,3165
1,3136	18,6243	13,9867	0,3424
1,4179	23,0785	15,0970	0,3696
1,5195	24,3324	16,1792	0,3961

Table 2.5 Calm Water Resistance Data for 5-1F1A-4

Temperature 17.3 °C	**Lightship Draft**		
Model speed (m/s)	Resistance (N)	Ship speed (knots)	Fn
0,2931	0,3372	3,1205	0,0749
0,3466	0,4094	3,6910	0,0886
0,4022	0,5356	4,2822	0,1028
0,4515	0,6501	4,8079	0,1154
0,5063	0,8248	5,3914	0,1294
0,5557	1,0309	5,9169	0,1420
0,6086	1,2634	6,4802	0,1556
0,6566	1,5274	6,9909	0,1678
0,7090	1,7538	7,5493	0,1812
0,8099	2,7990	8,6237	0,2070
0,9127	3,7681	9,7186	0,2333
1,0122	4,6041	10,7775	0,2587
1,0628	5,5114	11,3164	0,2717
1,1138	7,1972	11,8596	0,2847
1,1623	9,2063	12,3761	0,2971
1,2132	11,0071	12,9181	0,3101
1,3152	14,1466	14,0040	0,3362
1,4179	16,7941	15,0973	0,3624
1,5191	19,8735	16,1748	0,3883

Temperature 17.2 °C	**Loaded Draft**		
Model speed (m/s)	Resistance (N)	Ship speed (knots)	Fn
0,2941	0,4052	3,1312	0,0762
0,3495	0,5336	3,7216	0,0905
0,4000	0,6581	4,2594	0,1036
0,4535	0,8774	4,8288	0,1174
0,5045	1,1450	5,3715	0,1306
0,5571	1,3964	5,9324	0,1443
0,6057	1,6394	6,4499	0,1569
0,6592	1,9534	7,0193	0,1707
0,7092	2,2675	7,5516	0,1837
0,8081	3,1214	8,6049	0,2093
0,9107	4,2776	9,6968	0,2358
1,0076	5,2771	10,7290	0,2609
1,0620	6,1277	11,3076	0,2750
1,1090	7,6657	11,8086	0,2872
1,1619	9,9719	12,3716	0,3009
1,2138	12,8857	12,9244	0,3143
1,3119	17,6516	13,9683	0,3397
1,4140	22,9810	15,0555	0,3662
1,5183	23,7475	16,1670	0,3932

2.4 DISCUSSION OF MODELS GRAFT

All these value putting on recorder. In here tables shown to us when velocity increasing, resistance on model also increases.

The difference between the lightship and loaded condition shown on Figure 2.2, 2.3, and 2.4

Major aim of these tests is finding the best efficiency type of ship. Resistance must be lower on same velocity and same weight of models. This different shown in Figure 2.5 and 2.6.

Figure 2.2 Calm Water Resistance for 2-1F1A-3

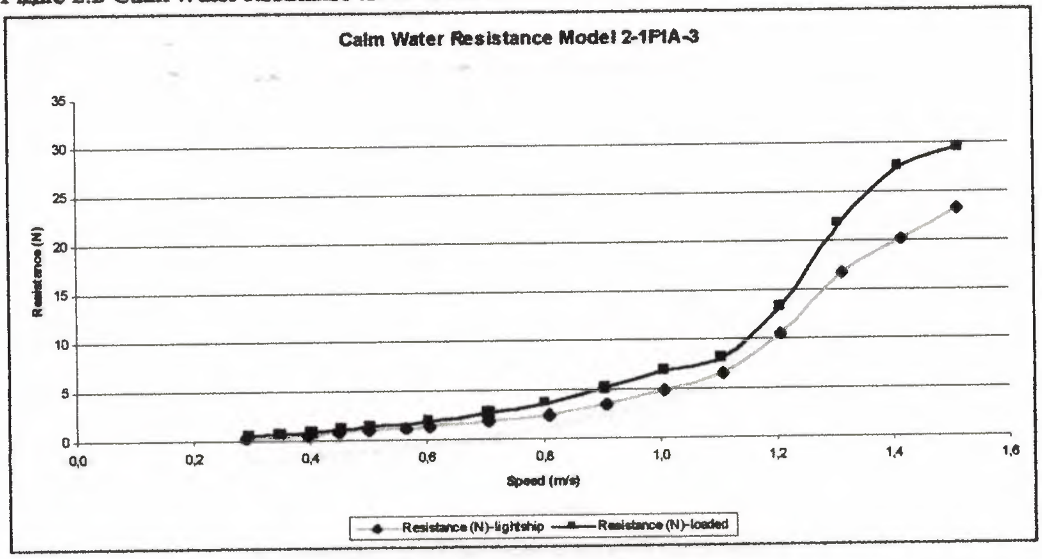


Figure 2.3 Calm Water Resistance for 2-1F1A-4

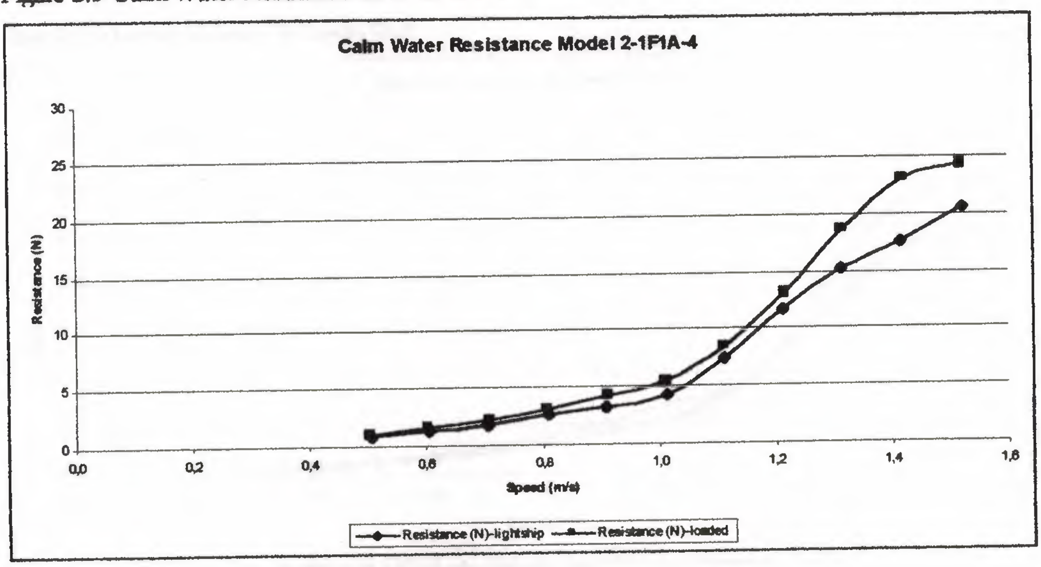


Figure 2.4 Calm Water Resistance for 5-1F1A-4

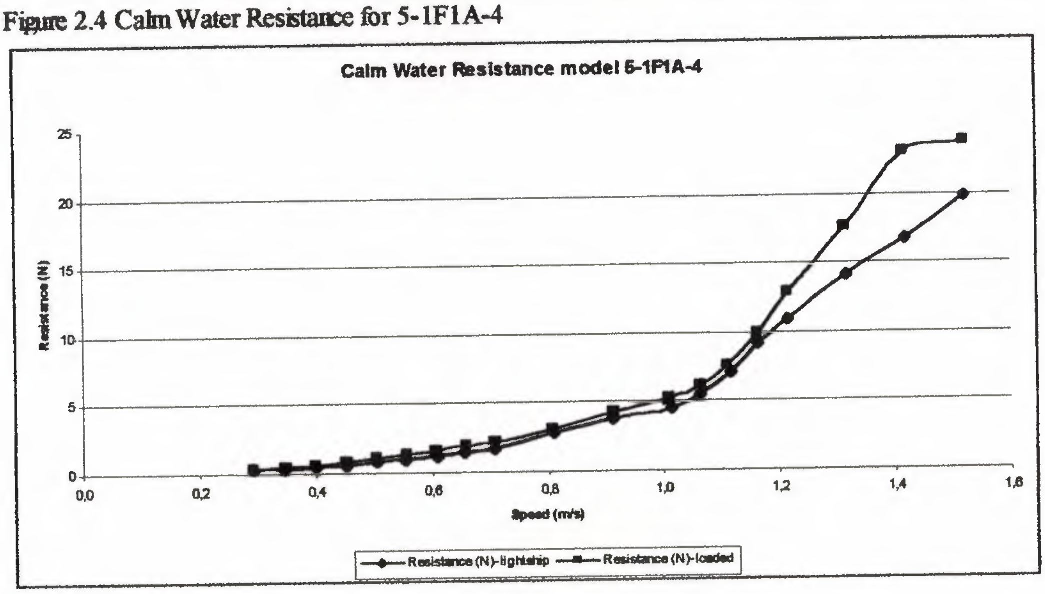


Figure 2.5 Calm water Resistance for Lightship Draft

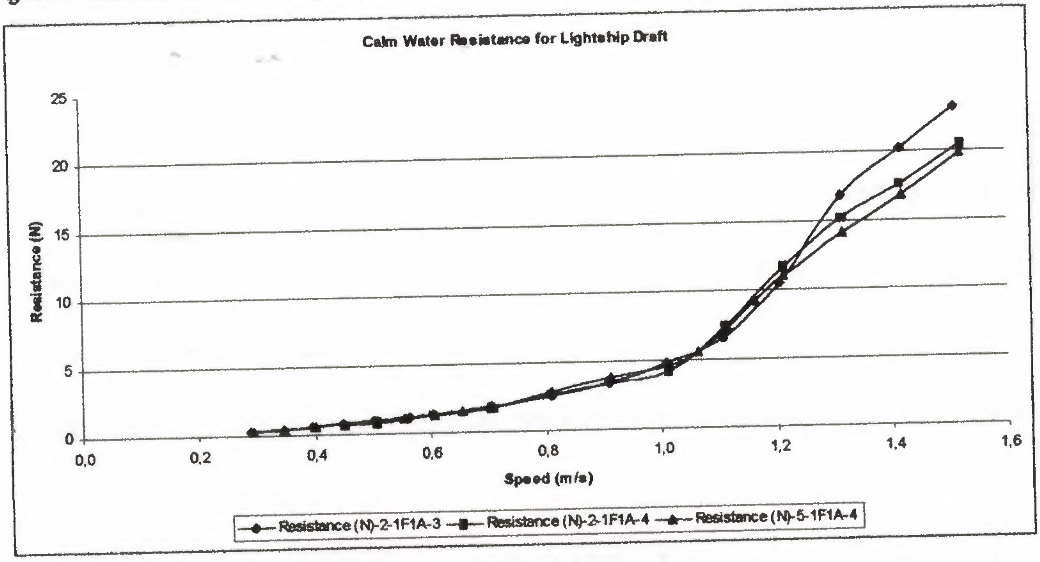
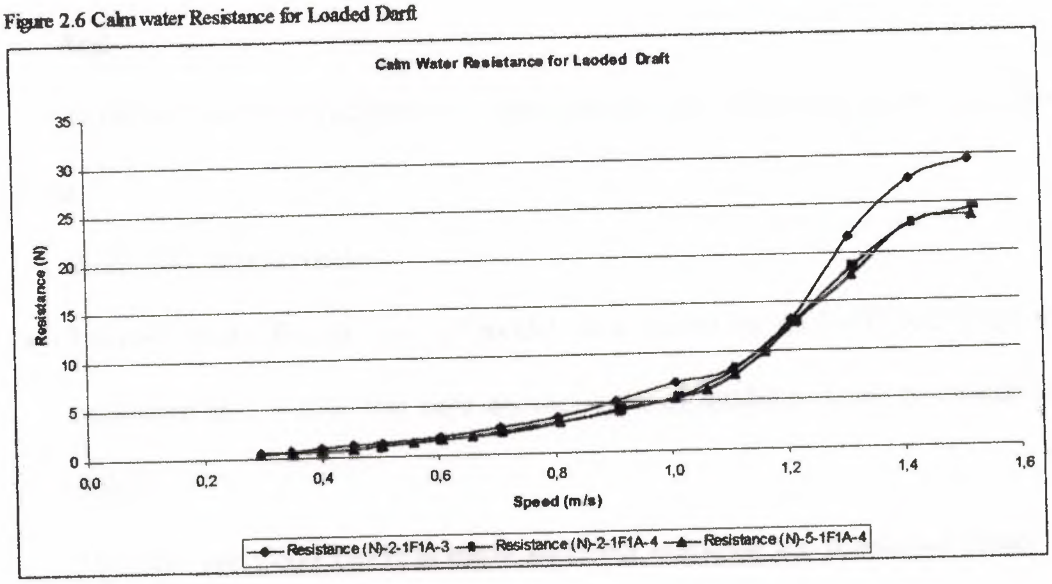


Figure 2.6 Calm water Resistance for Loaded Darft



2.5 REMARKS ON FINDINGS

- Difference between loaded and lightship draft of three type models are same until the 1.0 m/s. Then the third type of ship (5-1F1A-4) is start be different to another from 1,4 m/s suddenly stay the constant resistance. But between 1,0-1,4 m/s resistance increase more than another.
- Between the loaded and lightship draft resistance difference at 1,4 m/s for all kind of model around 5 N.
- When looking the all lightship draft, 2-1F1A-3 is a more resistance at 1.5 m/s. And

  5-1F1A-4 is lower resistance at same speed. Lightship draft for all type shown

to us

  5-1F1A-4 is best model.

- Loaded drafts for all kind of model also shown to us 2-1F1A-3 have more resistance at 1.5 m/s. But here another type of model is some resistance at all points.
- The first one (2-1F1A-3) is made suddenly changing the resistance value. This is not acceptable.

CHAPTER 3

Resistance and Power Calculation by using 2-D Method

Three different fishing vessel models were tested and by using this value, ship resistance and power is finding in this chapter.

3.1 Froude's 2-D Approach

Froude assumed the total ship hull resistance as;

Total ship hull resistance = Skin friction drag + the rest (i.e. residuary resistance)

$$R_T = R_F + R_R$$

In terms of coefficients expressed as;

$$C_T = C_F + C_R$$

where, C_T is the total resistance coefficient, C_F is the frictional resistance coefficient and

C_R is the residuary resistance coefficient.

$$C_T = \frac{R_T}{\frac{1}{2}\rho S V^2}, C_F = \frac{R_F}{\frac{1}{2}\rho S V^2} \; and \; C_R = \frac{R_R}{\frac{1}{2}\rho S V^2}$$

Froude found that;

$(C_R)_s = (C_R)_m$ at corresponding speed or at the same Froude number, $(Fn)_s = (Fn)_m$

Hence;

$$(C_T)_s = (C_T)_m - [(C_F)_m - (C_F)_s]$$

where subscript 'm' and 's' indicates 'model' and 'ship'.

In this equation $(C_T)_m$ can be obtained from model test whereas $(C_F)_m$ and $(C_F)_s$ can be calculated by using ITTC-57 model-ship correlation line as;

$$(C_F)_m = \frac{0.075}{(\log_{10}(Rn)_m - 2)^2}\ , \quad (C_F)_s = \frac{0.075}{(\log_{10}(Rn)_s - 2)^2}$$

The total resistance of the ship, $(R_T)_s$ is given. by;

$$(R_T)_s = (C_T)_s 1/2 \rho_s S_s V_s^2$$

Following this, the effective power, $(P_E)_s$ calculate as follows;

$$(P_E)_s = (R_T)_s V_s$$

Full-scale power predictions by using 2-D approach were carried out for both lightship and loaded draft for three different model.

In first section includes the calculations of tests results Table 3.1, 3.2 and 3.3.

And those calculation result given Figure 3.1, 3.2 and 3.3.

Table 3.1 Tabulated Data for Power Prediction by 2-D Approach, 2-IF1A-3

Lightship Draft													
$(V)_m$ (m/s)	$(RT)_m$ (N)	$(Rn)_{m}10^{6}$	$(CT)_m$	$(CF)_m$	$(CR)_m$	$(V)_s$ (m/s)	$(Fn)_s$	$(Rn)_{s}10^{6}$	$(CF)_s$	$(CR)_s$	$(CT)_s$	$(RT)_s$ (N)	PE (kW)
0,2894	0,3148	0,3894	0,0072	0,0058	0,0014	1,5849	0,0770	57,6198	0,0023	0,0014	0,0036	4,4076	6,9857
0,3957	0,5737	0,5325	0,0070	0,0054	0,0016	2,1671	0,1053	78,7848	0,0022	0,0016	0,0038	8,5437	18,5154
0,4482	0,8138	0,6032	0,0077	0,0052	0,0025	2,4550	0,1193	89,2517	0,0021	0,0025	0,0046	13,4490	33,0177
0,5018	0,9540	0,6753	0,0072	0,0051	0,0021	2,7482	0,1335	99,9096	0,0021	0,0021	0,0042	15,3900	42,2950
0,5641	1,2031	0,7592	0,0072	0,0050	0,0022	3,0897	0,1501	112,3257	0,0020	0,0022	0,0043	19,8285	61,2647
0,6041	1,3262	0,8129	0,0069	0,0049	0,0020	3,3086	0,1607	120,2828	0,0020	0,0020	0,0041	21,5517	71,3063
0,7057	1,8422	0,9497	0,0071	0,0047	0,0023	3,8654	0,1878	140,5232	0,0020	0,0023	0,0043	31,1790	120,5183
0,8093	2,4984	1,0891	0,0073	0,0046	0,0027	4,4326	0,2153	161,1443	0,0019	0,0027	0,0046	44,0639	195,3173
0,9093	3,3910	1,2238	0,0078	0,0045	0,0033	4,9807	0,2419	181,0698	0,0019	0,0033	0,0053	63,1781	314,6696
1,0076	4,7834	1,3560	0,0090	0,0044	0,0046	5,5189	0,2681	200,6357	0,0019	0,0046	0,0065	95,7858	528,6299
1,1080	6,4801	1,4911	0,0101	0,0043	0,0058	6,0686	0,2948	220,6203	0,0019	0,0058	0,0076	136,2351	826,7550
1,2059	10,5240	1,6229	0,0138	0,0042	0,0096	6,6050	0,3208	240,1211	0,0018	0,0096	0,0114	241,5033	1595,1284
1,3133	16,8036	1,7675	0,0186	0,0042	0,0145	7,1935	0,3494	261,5152	0,0018	0,0145	0,0163	407,6134	2932,1602
1,4155	20,2439	1,9050	0,0193	0,0041	0,0152	7,7531	0,3766	281,8587	0,0018	0,0152	0,0170	494,8845	3836,8748
1,5113	23,2813	2,0339	0,0195	0,0040	0,0154	8,2778	0,4021	300,9360	0,0018	0,0154	0,0172	571,0710	4727,2287
Loaded Draft													
$(V)_m$ (m/s)	$(RT)_m$ (N)	$(Rn)_{m}10^{6}$	$(CT)_m$	$(CF)_m$	$(CR)_m$	$(V)_s$ (m/s)	$(Fn)_s$	$(Rn)_{s}10^{6}$	$(CF)_s$	$(CR)_s$	$(CT)_s$	$(RT)_s$ (N)	PE (kW)
0,2952	0,5239	0,4027	0,0104	0,0058	0,0046	1,6166	0,0780	59,5874	0,0022	0,0046	0,0069	9,6133	15,5411
0,3481	0,6465	0,4750	0,0092	0,0055	0,0037	1,9067	0,0920	70,2816	0,0022	0,0037	0,0059	11,4188	21,7728
0,4011	0,9151	0,5473	0,0098	0,0054	0,0045	2,1968	0,1060	80,9725	0,0021	0,0045	0,0066	17,0843	37,5308
0,4535	1,1744	0,6188	0,0099	0,0052	0,0047	2,4841	0,1198	91,5633	0,0021	0,0047	0,0068	22,3343	55,4812
0,5042	1,4007	0,6880	0,0095	0,0051	0,0044	2,7619	0,1332	101,8008	0,0021	0,0044	0,0065	26,5688	73,3796
0,6036	1,9177	0,8236	0,0091	0,0049	0,0042	3,3060	0,1595	121,8589	0,0020	0,0042	0,0062	36,4553	120,5231
0,7061	2,7398	0,9635	0,0095	0,0047	0,0048	3,8675	0,1866	142,5553	0,0020	0,0048	0,0068	54,0601	209,0797
0,8048	3,6152	1,0982	0,0097	0,0046	0,0051	4,4083	0,2127	162,4858	0,0019	0,0051	0,0070	72,7757	320,8144
0,9045	5,1295	1,2342	0,0109	0,0045	0,0064	4,9544	0,2390	182,6166	0,0019	0,0064	0,0083	108,6116	538,1068
1,0077	6,9049	1,3749	0,0118	0,0044	0,0074	5,5192	0,2663	203,4332	0,0019	0,0074	0,0093	150,9242	832,9764
1,1042	8,1489	1,5066	0,0116	0,0043	0,0073	6,0479	0,2918	222,9203	0,0019	0,0073	0,0091	178,4390	1079,1737
1,2068	13,2278	1,6466	0,0157	0,0042	0,0115	6,6099	0,3189	243,6356	0,0018	0,0115	0,0133	311,3527	2058,0001
1,3071	21,6552	1,7835	0,0219	0,0041	0,0178	7,1593	0,3454	263,8879	0,0018	0,0178	0,0196	536,8084	3843,1799
1,4111	27,5063	1,9254	0,0239	0,0041	0,0198	7,7288	0,3729	284,8792	0,0018	0,0198	0,0216	689,9835	5332,7531
1,5129	29,4284	2,0644	0,0223	0,0040	0,0182	8,2866	0,3998	305,4398	0,0018	0,0182	0,0200	733,8692	6081,2973

Table 3.2 Tabulated Data for Power Prediction by 2-D Approach, 2-IF1A-4

						Lightship Draft							
$(V)_m$ (m/s)	$(RT)_m$ (N)	$(Rn)_m x10^6$	$(CT)_m$	$(CF)_m$	$(CR)_m$	$(V)_s$ (m/s)	$(Fn)_s$	$(Rn)_s x10^6$	$(CF)_s$	$(CR)_s$	$(CT)_s$	$(RT)_s$ (N)	PE (kW)
0,5055	0,8747	0,6992	0,0071	0,0051	0,0020	2,7687	0,1327	103,4519	0,0021	0,0020	0,0041	14,0121	38,7959
0,6057	1,2640	0,8378	0,0072	0,0049	0,0023	3,3174	0,1590	123,9526	0,0020	0,0023	0,0043	21,0716	69,9031
0,7069	1,7513	0,9777	0,0073	0,0047	0,0026	3,8718	0,1855	144,6659	0,0020	0,0026	0,0045	30,3146	117,3709
0,8090	2,6526	1,1190	0,0084	0,0046	0,0038	4,4313	0,2123	165,5722	0,0019	0,0038	0,0058	50,5122	223,8344
0,9090	3,3126	1,2573	0,0083	0,0045	0,0039	4,9788	0,2386	186,0289	0,0019	0,0039	0,0058	63,6628	316,9633
1,0138	4,2142	1,4022	0,0085	0,0044	0,0041	5,5527	0,2661	207,4730	0,0019	0,0041	0,0060	82,7910	459,7141
1,1114	7,3827	1,5372	0,0124	0,0043	0,0081	6,0871	0,2917	227,4412	0,0019	0,0081	0,0100	164,7642	1002,9404
1,2127	11,6537	1,6773	0,0164	0,0042	0,0122	6,6421	0,3183	248,1776	0,0018	0,0122	0,0141	276,6597	1837,6027
1,3144	15,1490	1,8181	0,0182	0,0041	0,0141	7,1994	0,3450	269,0019	0,0018	0,0141	0,0159	366,5857	2639,2098
1,4159	17,6368	1,9585	0,0183	0,0041	0,0142	7,7553	0,3716	289,7717	0,0018	0,0142	0,0160	428,1667	3320,5647
1,5225	20,5235	2,1059	0,0184	0,0040	0,0144	8,3391	0,3996	311,5851	0,0018	0,0144	0,0161	499,9952	4169,5166
						Loaded Draft							
$(V)_m$ (m/s)	$(RT)_m$ (N)	$(Rn)_m x10^6$	$(CT)_m$	$(CF)_m$	$(CR)_m$	$(V)_s$ (m/s)	$(Fn)_s$	$(Rn)_s x10^6$	$(CF)_s$	$(CR)_s$	$(CT)_s$	$(RT)_s$ (N)	PE (kW)
0,5033	1,0770	0,7055	0,0079	0,0051	0,0028	2,7566	0,1312	104,3886	0,0021	0,0028	0,0049	18,5396	51,1053
0,6054	1,6009	0,8487	0,0081	0,0049	0,0032	3,3159	0,1578	125,5710	0,0020	0,0032	0,0053	28,8294	95,5956
0,7094	2,1802	0,9945	0,0080	0,0047	0,0033	3,8855	0,1849	147,1417	0,0020	0,0033	0,0053	39,9969	155,4089
0,8080	3,1235	1,1327	0,0089	0,0046	0,0043	4,4256	0,2106	167,5956	0,0019	0,0043	0,0063	60,9909	269,9238
0,9112	4,2951	1,2774	0,0096	0,0044	0,0052	4,9910	0,2375	189,0041	0,0019	0,0052	0,0071	87,5491	436,9549
1,0110	5,4750	1,4172	0,0099	0,0044	0,0056	5,5373	0,2635	209,6935	0,0019	0,0056	0,0075	114,0343	631,4426
1,1108	8,3617	1,5572	0,0126	0,0043	0,0083	6,0843	0,2896	230,4075	0,0019	0,0083	0,0102	187,3653	1139,9858
1,2140	13,0815	1,7019	0,0165	0,0042	0,0123	6,6495	0,3165	251,8132	0,0018	0,0123	0,0141	310,8076	2066,7298
1,3136	18,6243	1,8415	0,0200	0,0041	0,0159	7,1948	0,3424	272,4601	0,0018	0,0159	0,0177	456,8667	3287,0473
1,4179	23,0785	1,9876	0,0213	0,0041	0,0173	7,7659	0,3696	294,0884	0,0018	0,0173	0,0190	571,8928	4441,2582
1,5195	24,3324	2,1301	0,0196	0,0040	0,0156	8,3226	0,3961	315,1700	0,0018	0,0156	0,0173	597,9230	4976,2678

Table 3.3 Tabulated Data for Power Prediction by 2-D Approach, 5-1F1A-4

Lightship Draft													
$(V)_m$(m/s)	$(RT)_m$ (N)	$(Rn)_{m}10^6$	$(CT)_m$	$(CF)_m$	$(CR)_m$	$(V)_s$ (m/s)	$(Fn)_s$	$(Rn)_{s}10^6$	$(CF)_s$	$(CR)_s$	$(CT)_s$	$(RT)_s$ (N)	PE (kW)
0,2931	0,3372	0,4273	0,0081	0,0057	0,0024	1,6052	0,0749	63,2177	0,0022	0,0024	0,0046	5,3549	8,5956
0,3466	0,4094	0,5054	0,0070	0,0055	0,0016	1,8986	0,0886	74,7755	0,0022	0,0016	0,0037	6,0309	11,4504
0,4022	0,5356	0,5863	0,0068	0,0053	0,0015	2,2028	0,1028	86,7545	0,0021	0,0015	0,0037	7,9923	17,6054
0,4515	0,6501	0,6583	0,0066	0,0051	0,0014	2,4732	0,1154	97,4046	0,0021	0,0014	0,0035	9,6598	23,8906
0,5063	0,8248	0,7382	0,0066	0,0050	0,0016	2,7733	0,1294	109,2247	0,0021	0,0016	0,0037	12,6861	35,1827
0,5557	1,0309	0,8102	0,0069	0,0049	0,0020	3,0436	0,1420	119,8707	0,0020	0,0020	0,0040	16,6344	50,6290
0,6086	1,2634	0,8873	0,0070	0,0048	0,0022	3,3334	0,1556	131,2827	0,0020	0,0022	0,0042	21,0556	70,1868
0,6566	1,5274	0,9572	0,0073	0,0047	0,0026	3,5961	0,1678	141,6305	0,0020	0,0026	0,0046	26,4253	95,0291
0,7090	1,7538	1,0337	0,0072	0,0047	0,0025	3,8834	0,1812	152,9426	0,0020	0,0025	0,0045	30,4408	118,2129
0,8099	2,7990	1,1808	0,0088	0,0045	0,0043	4,4360	0,2070	174,7087	0,0019	0,0043	0,0062	54,7294	242,7814
0,9127	3,7681	1,3307	0,0093	0,0044	0,0049	4,9993	0,2333	196,8909	0,0019	0,0049	0,0068	76,3419	381,6532
1,0122	4,6041	1,4757	0,0093	0,0043	0,0049	5,5439	0,2587	218,3426	0,0019	0,0049	0,0068	93,9912	521,0820
1,0628	5,5114	1,5495	0,0101	0,0043	0,0058	5,8212	0,2717	229,2606	0,0019	0,0058	0,0076	116,1809	676,3079
1,1138	7,1972	1,6239	0,0120	0,0042	0,0077	6,1006	0,2847	240,2647	0,0018	0,0077	0,0096	159,8423	975,1287
1,1623	9,2063	1,6946	0,0140	0,0042	0,0098	6,3663	0,2971	250,7286	0,0018	0,0098	0,0117	212,5308	1353,0257
1,2132	11,0071	1,7688	0,0154	0,0042	0,0113	6,6451	0,3101	261,7102	0,0018	0,0113	0,0131	259,1773	1722,2564
1,3152	14,1466	1,9175	0,0169	0,0041	0,0128	7,2037	0,3362	283,7088	0,0018	0,0128	0,0146	339,3174	2444,3262
1,4179	16,7941	2,0672	0,0172	0,0040	0,0132	7,7660	0,3624	305,8574	0,0018	0,0132	0,0150	405,3266	3147,7790
1,5191	19,8735	2,2147	0,0177	0,0040	0,0138	8,3203	0,3883	327,6881	0,0018	0,0138	0,0155	483,0171	4018,8649

Loaded Draft													
$(V)_m$(m/s)	$(RT)_m$ (N)	$(Rn)_{m}10^6$	$(CT)_m$	$(CF)_m$	$(CR)_m$	$(V)_s$ (m/s)	$(Fn)_s$	$(Rn)_{s}10^6$	$(CF)_s$	$(CR)_s$	$(CT)_s$	$(RT)_s$ (N)	PE (kW)
0,2941	0,4052	0,4177	0,0086	0,0057	0,0029	1,6107	0,0762	61,8092	0,0022	0,0029	0,0052	6,7102	10,8081
0,3495	0,5336	0,4965	0,0081	0,0055	0,0026	1,9144	0,0905	73,4622	0,0022	0,0026	0,0047	8,7225	16,6980
0,4000	0,6581	0,5683	0,0076	0,0053	0,0023	2,1910	0,1036	84,0790	0,0021	0,0023	0,0044	10,5978	23,2201
0,4535	0,8774	0,6442	0,0079	0,0052	0,0027	2,4839	0,1174	95,3182	0,0021	0,0027	0,0048	14,8429	36,8685
0,5045	1,1450	0,7166	0,0083	0,0050	0,0033	2,7631	0,1306	106,0308	0,0021	0,0033	0,0053	20,3621	56,2620
0,5571	1,3964	0,7915	0,0083	0,0049	0,0034	3,0516	0,1443	117,1029	0,0020	0,0034	0,0054	25,2124	76,9383
0,6057	1,6394	0,8605	0,0082	0,0048	0,0034	3,3178	0,1569	127,3185	0,0020	0,0034	0,0054	29,8582	99,0640
0,6592	1,9534	0,9365	0,0083	0,0048	0,0035	3,6107	0,1707	138,5580	0,0020	0,0035	0,0055	36,1142	130,3981
0,7092	2,2675	1,0075	0,0083	0,0047	0,0036	3,8845	0,1837	149,0653	0,0020	0,0036	0,0056	42,3986	164,6985
0,8081	3,1214	1,1480	0,0088	0,0046	0,0043	4,4264	0,2093	169,8586	0,0019	0,0043	0,0062	60,8942	269,5409
0,9107	4,2776	1,2937	0,0095	0,0044	0,0051	4,9880	0,2358	191,4113	0,0019	0,0051	0,0070	87,0613	434,2643
1,0076	5,2771	1,4314	0,0096	0,0043	0,0052	5,5190	0,2609	211,7861	0,0019	0,0052	0,0071	108,7261	600,0571
1,0620	6,1277	1,5086	0,0100	0,0043	0,0057	5,8166	0,2750	223,2073	0,0019	0,0057	0,0076	128,7280	748,7600
1,1090	7,6657	1,5754	0,0115	0,0043	0,0072	6,0743	0,2872	233,0973	0,0018	0,0072	0,0091	168,1700	1021,5204
1,1619	9,9719	1,6505	0,0136	0,0042	0,0094	6,3640	0,3009	244,2114	0,0018	0,0094	0,0112	228,4067	1453,5698
1,2138	12,8857	1,7243	0,0161	0,0042	0,0120	6,6483	0,3143	255,1237	0,0018	0,0120	0,0138	305,4437	2030,6881
1,3119	17,6516	1,8636	0,0189	0,0041	0,0148	7,1853	0,3397	275,7301	0,0018	0,0148	0,0166	430,1405	3090,6927
1,4140	22,9810	2,0086	0,0212	0,0041	0,0171	7,7446	0,3662	297,1914	0,0018	0,0171	0,0189	569,6925	4412,0244
1,5183	23,7475	2,1569	0,0190	0,0040	0,0150	8,3163	0,3932	319,1316	0,0018	0,0150	0,0168	581,9590	4839,7560

Figure 3.1 Effective Power by 2-D Approach for 2-1F1A-3

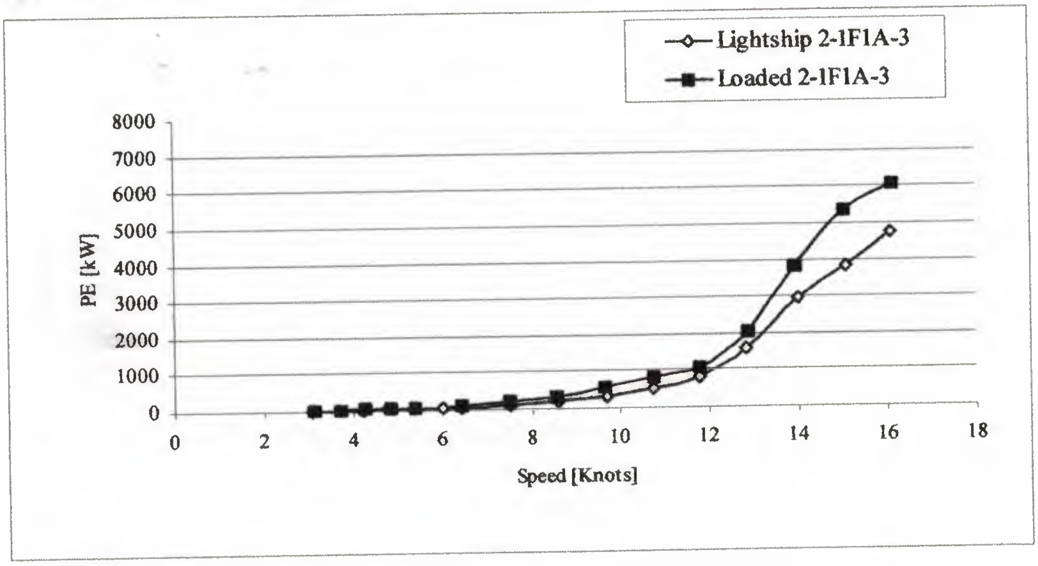


Figure 3.2 Effective Power by 2-D Approach for 2-1F1A-4

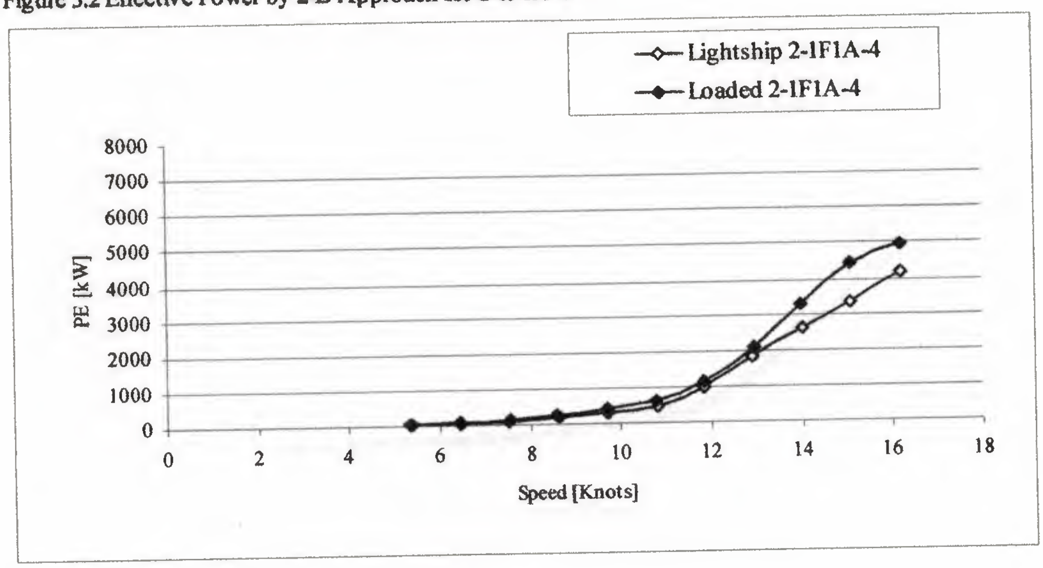


Figure 3.3 Effective Power by 2-D Approach for 5-1F1A-4

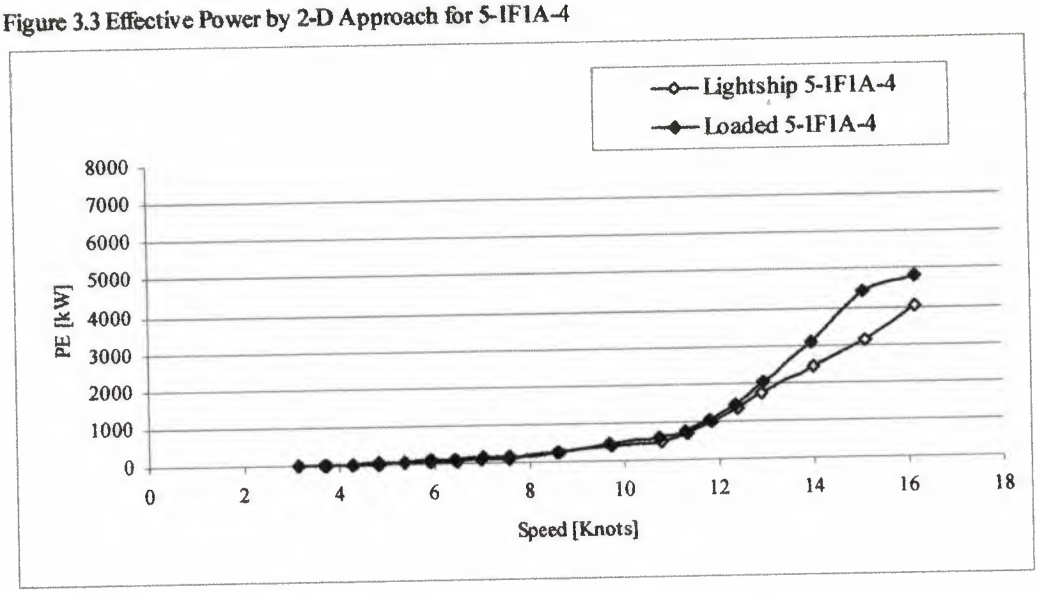


Figure 3.4 Effective Power for Short Hull Combinations at Lightship Draft

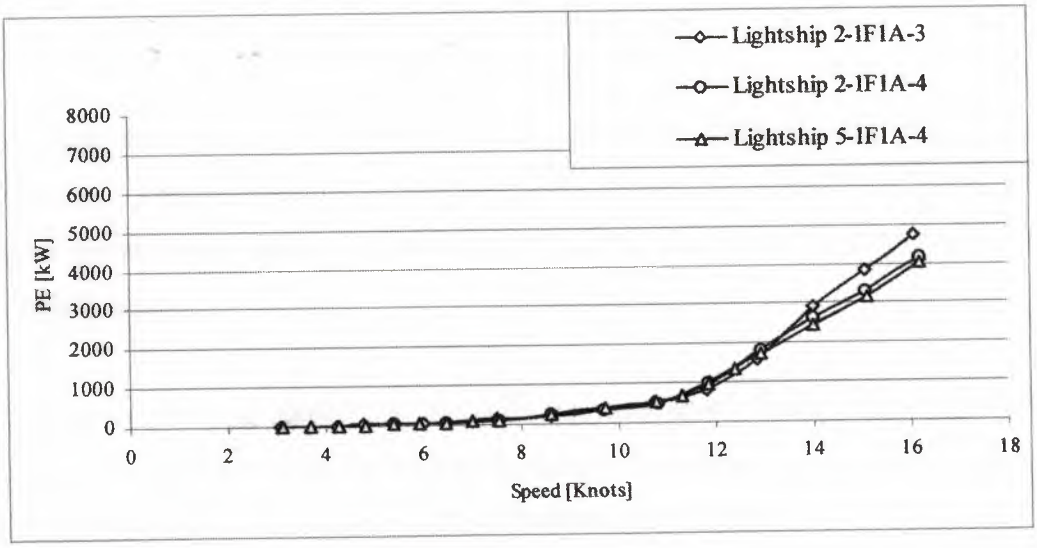
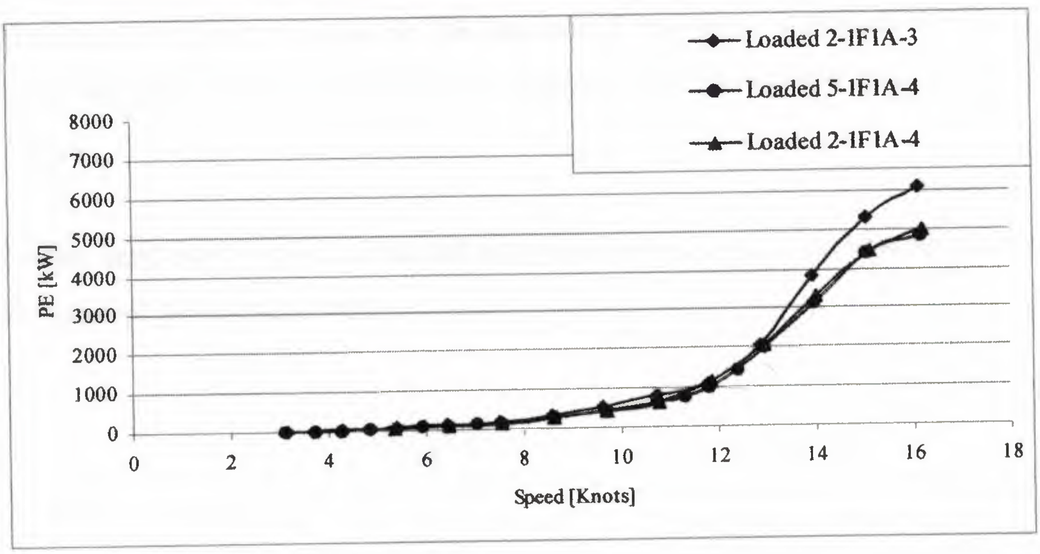


Figure 3.5 Effective Power for Short Hull Combinations at Loaded Draft



3.2 PRESENTATION OF RESULTS

- The first ship type (2-1F1A-3) is the worst resistance characteristics for the loaded condition. The introduction of the new stern displays a reduction in resistance at most speeds, particularly after the13 knots region. The new bow also shows some useful benefits.

- The above trend is similar for the lightship condition although the original hull displays marginally better resistance characteristics around 11-13 knots. However the effectiveness of the new stern after 13 about knots is clear.

- The same trend can be seen for the lengthened hull form combinations. The new stern displays a reduction in resistance at most speeds, particularly after the13 knots region.

- Similar trend can be seen for the full scale resistance curves. The new stern reduces the required power significantly.

CHAPTER 4

Resistance and Power Calculation by using 2-D Method

The 3-D methods give to us best results for finding the power efficiency. Difference between 2-D and 3-D is added here form factor (1+k). The results are compared for three different fishing vessels for two loading conditions and presented.

4.1 Form Factor (3-D) Approach

Hughes proposed that

Total ship hull resistance = Viscous resistance + the rest (i.e. residuary resistance)

$$R_T = R_v + R_R (\cong R_w)$$

In terms of coefficients;

$$\begin{aligned} C_T &= C_v + C_W \\ &= C_F + C_{FD} + C_W \end{aligned}$$

He further assumed that

$$\begin{aligned} C_T &= C_F + kC_F + C_W \\ &= (1+k)C_F + C_W \end{aligned}$$

where R_w is the wave resistance, C_v is the viscous resistance coefficient, C_W is the wave resistance coefficient, C_{FD} is the form drag coefficient and $(1+k)$ is the form factor.

At corresponding speed or at the same Froude number, $(Fn)_s = (Fn)_m$

$(C_w)_s = (C_w)_m$

Assuming that $(1+k)_s \cong (1+k)_m = (1+k)$

Hence

$$(C_T)_s = (C_T)_m - (1+k)[(C_F)_m - (C_F)_s]$$

This equation is similar to the expression derived in Froude's 2-D approach, except the additional (1+k), the form factor term. The form factor can be obtained by performing model tests at slow speed.

Since $(C_w)_m \cong 0$ and $(C_T)_m \cong (1+k)(C_F)_m$

Form factor (1+k) was found for both lightship and loaded draft by Prohaska method based on low-speed resistance tests. The results are given on (Table.1.3)

Table 1.3 Form Factor of all Model Combinations		
	1+k	1+k
Model	Lightship Draft	Loaded Draft
2-1F1A-3	1,32	1,77
2-1F1A-4	1,32	1,77
5-1F1A-4	1,29	1,48

Full-scale power predictions by using form factor (3-D) approach were carried out for both lightship and loaded draft for all model combinations.

In these calculation, Froude number and Reynolds number for model and ship,

$$(Fn)_m = (Fn)_s = \frac{V_m}{\sqrt{gL_m}}$$

$$(Rn)_m = \frac{L_m V_m}{\gamma_m}, (Rn)_s = \frac{L_s V_s}{\gamma_s}$$

Total resistance for model and ship

$$(C_T)_m = \frac{(R_T)_m}{\frac{1}{2}\rho_m S_m V_m^2}, (C_T)_s = \frac{(R_T)_s}{\frac{1}{2}\rho_s S_s V_s^2}$$

where

L_m, L_s: model and ship length at waterline, (m)

V_m, V_s: model and ship speed, (m/s)

$(S)_m$, $(S)_s$: wetted surface area of model and ship, (m^2)

ρ_m, ρ_s: density of towing tank water at test temperature and seawater temperature (15 C° is assumed as standard temperature), (kg/m^3)

γ_m, γ_s: kinematic viscosity of towing tank water at test temperature and seawater temperature, (m^2/s)

Table 4.2, 4.3, and 4.4 are shown the results of power calculation.

Figure 4.1, 4.2, and 4.3 are compared of those result between loaded and lightship draft.

Figure 4.4, and 4.5. are shown the all type of ship on lightship condition and loaded condition respectively.

Table 4.2 Tabulated Data for Power Prediction by 2-D Approach, 2-1F1A-3

Lightship Draft

$(V)_m$(m/s)	$(RT)_m$ (N)	$(Rn)_m 10^6$	$(CT)_m$	$(CF)_m$	$(V)_s$ (m/s)	$(Fn)_s$	$(Rn)_s 10^6$	$(CF)_s$	$(CT)_s$	$(RT)_s$ (N)	PE (kW)
0,2894	0,3148	0,3894	0,0072	0,0058	1,5849	0,0770	57,6198	0,0023	0,0025	3,0240	4,7929
0,3957	0,5737	0,5325	0,0070	0,0054	2,1671	0,1053	78,7848	0,0022	0,0027	6,1851	13,4039
0,4482	0,8138	0,6032	0,0077	0,0052	2,4550	0,1193	89,2517	0,0021	0,0036	10,5289	25,8488
0,5018	0,9540	0,6753	0,0072	0,0051	2,7482	0,1335	99,9096	0,0021	0,0032	11,8466	32,5569
0,5641	1,2031	0,7592	0,0072	0,0050	3,0897	0,1501	112,3257	0,0020	0,0034	15,4949	47,8753
0,6041	1,3262	0,8129	0,0069	0,0049	3,3086	0,1607	120,2828	0,0020	0,0031	16,6765	55,1760
0,7057	1,8422	0,9497	0,0071	0,0047	3,8654	0,1878	140,5232	0,0020	0,0034	24,8045	95,8785
0,8093	2,4984	1,0891	0,0073	0,0046	4,4326	0,2153	161,1443	0,0019	0,0038	35,9879	159,5193
0,9093	3,3910	1,2238	0,0078	0,0045	4,9807	0,2419	181,0698	0,0019	0,0044	53,2959	265,4496
1,0076	4,7834	1,3560	0,0090	0,0044	5,5189	0,2681	200,6357	0,0019	0,0057	83,9793	463,4713
1,1080	6,4801	1,4911	0,0101	0,0043	6,0686	0,2948	220,6203	0,0019	0,0069	122,3123	742,2634
1,2059	10,5240	1,6229	0,0138	0,0042	6,6050	0,3208	240,1211	0,0018	0,0107	225,3716	1488,5790
1,3133	16,8036	1,7675	0,0186	0,0042	7,1935	0,3494	261,5152	0,0018	0,0155	388,8981	2797,5322
1,4155	20,2439	1,9050	0,0193	0,0041	7,7531	0,3766	281,8587	0,0018	0,0163	473,5596	3671,5415
1,5113	23,2813	2,0339	0,0195	0,0040	8,2778	0,4021	300,9360	0,0018	0,0165	547,1658	4529,3451

Loaded Draft

$(V)_m$(m/s)	$(RT)_m$ (N)	$(Rn)_m 10^6$	$(CT)_m$	$(CF)_m$	$(V)_s$ (m/s)	$(Fn)_s$	$(Rn)_s 10^6$	$(CF)_s$	$(CT)_s$	$(RT)_s$ (N)	PE (kW)
0,2952	0,5239	0,4027	0,0104	0,0058	1,6166	0,0780	59,5874	0,0022	0,0042	5,8282	9,4220
0,3481	0,6465	0,4750	0,0092	0,0055	1,9067	0,0920	70,2816	0,0022	0,0033	6,4043	12,2115
0,4011	0,9151	0,5473	0,0098	0,0054	2,1968	0,1060	80,9725	0,0021	0,0042	10,6974	23,5000
0,4535	1,1744	0,6188	0,0099	0,0052	2,4841	0,1198	91,5633	0,0021	0,0044	14,4509	35,8979
0,5042	1,4007	0,6880	0,0095	0,0051	2,7619	0,1332	101,8008	0,0021	0,0042	17,1132	47,2644
0,6036	1,9177	0,8236	0,0091	0,0049	3,3060	0,1595	121,8589	0,0020	0,0040	23,5723	77,9311
0,7061	2,7398	0,9635	0,0095	0,0047	3,8675	0,1866	142,5553	0,0020	0,0047	37,1752	143,7768
0,8048	3,6152	1,0982	0,0097	0,0046	4,4083	0,2127	162,4858	0,0019	0,0050	51,6060	227,4926
0,9045	5,1295	1,2342	0,0109	0,0045	4,9544	0,2390	182,6166	0,0019	0,0063	82,6972	409,7163
1,0077	6,9049	1,3749	0,0118	0,0044	5,5192	0,2663	203,4332	0,0019	0,0074	119,6746	660,5047
1,1042	8,1489	1,5066	0,0116	0,0043	6,0479	0,2918	222,9203	0,0019	0,0073	141,8088	857,6397
1,2068	13,2278	1,6466	0,0157	0,0042	6,6099	0,3189	243,6356	0,0018	0,0115	268,6020	1775,4236
1,3071	21,6552	1,7835	0,0219	0,0041	7,1593	0,3454	263,8879	0,0018	0,0178	487,6820	3491,4689
1,4111	27,5063	1,9254	0,0239	0,0041	7,7288	0,3729	284,8792	0,0018	0,0199	633,8471	4898,8858
1,5129	29,4284	2,0644	0,0223	0,0040	8,2866	0,3998	305,4398	0,0018	0,0183	670,4768	5555,9880

Table 4.3 Tabulated Data for Power Prediction by 2-D Approach, 2-IF1A-4

Lightship Draft											
$(V)_m$(m/s)	$(RT)_m$ (N)	$(Rn)_m 10^6$	$(CT)_m$	$(CF)_m$	$(V)_s$ (m/s)	$(Fn)_s$	$(Rn)_s 10^6$	$(CF)_s$	$(CT)_s$	$(RT)_s$ (N)	PE (kW)
0,5055	0,8747	0,6992	0,0071	0,0051	2,7687	0,1327	103,4519	0,0021	0,0031	10,7335	29,7182
0,6057	1,2640	0,8378	0,0072	0,0049	3,3174	0,1590	123,9526	0,0020	0,0034	16,5969	55,0587
0,7069	1,7513	0,9777	0,0073	0,0047	3,8718	0,1855	144,6659	0,0020	0,0037	24,4731	94,7542
0,8090	2,6526	1,1190	0,0084	0,0046	4,4313	0,2123	165,5722	0,0019	0,0049	43,1356	191,1465
0,9090	3,3126	1,2573	0,0083	0,0045	4,9788	0,2386	186,0289	0,0019	0,0049	54,6371	272,0266
1,0138	4,2142	1,4022	0,0085	0,0044	5,5527	0,2661	207,4730	0,0019	0,0052	71,8849	399,1557
1,1114	7,3827	1,5372	0,0124	0,0043	6,0871	0,2917	227,4412	0,0019	0,0092	151,9705	925,0636
1,2127	11,6537	1,6773	0,0164	0,0042	6,6421	0,3183	248,1776	0,0018	0,0133	261,7693	1738,6994
1,3144	15,1490	1,8181	0,0182	0,0041	7,1994	0,3450	269,0019	0,0018	0,0151	349,4525	2515,8606
1,4159	17,6368	1,9585	0,0183	0,0041	7,7553	0,3716	289,7717	0,0018	0,0153	408,6619	3169,2989
1,5225	20,5235	2,1059	0,0184	0,0040	8,3391	0,3996	311,5851	0,0018	0,0154	477,8572	3984,9048
Loaded Draft											
$(V)_m$(m/s)	$(RT)_m$ (N)	$(Rn)_m 10^6$	$(CT)_m$	$(CF)_m$	$(V)_s$ (m/s)	$(Fn)_s$	$(Rn)_s 10^6$	$(CF)_s$	$(CT)_s$	$(RT)_s$ (N)	PE (kW)
0,5033	1,0770	0,7055	0,0079	0,0051	2,7566	0,1312	104,3886	0,0021	0,0026	8,7824	24,2091
0,6054	1,6009	0,8487	0,0081	0,0049	3,3159	0,1578	125,5710	0,0020	0,0031	15,0671	49,9612
0,7094	2,1802	0,9945	0,0080	0,0047	3,8855	0,1849	147,1417	0,0020	0,0032	21,6842	84,2544
0,8080	3,1235	1,1327	0,0089	0,0046	4,4256	0,2106	167,5956	0,0019	0,0042	36,9058	163,3318
0,9112	4,2951	1,2774	0,0096	0,0044	4,9910	0,2375	189,0041	0,0019	0,0051	56,5751	282,3646
1,0110	5,4750	1,4172	0,0099	0,0044	5,5373	0,2635	209,6935	0,0019	0,0056	75,9725	420,6828
1,1108	8,3617	1,5572	0,0126	0,0043	6,0843	0,2896	230,4075	0,0019	0,0083	136,9348	833,1515
1,2140	13,0815	1,7019	0,0165	0,0042	6,6495	0,3165	251,8132	0,0018	0,0123	242,2235	1610,6767
1,3136	18,6243	1,8415	0,0200	0,0041	7,1948	0,3424	272,4601	0,0018	0,0159	367,6015	2644,8054
1,4179	23,0785	1,9876	0,0213	0,0041	7,7659	0,3696	294,0884	0,0018	0,0173	464,6393	3608,3396
1,5195	24,3324	2,1301	0,0196	0,0040	8,3226	0,3961	315,1700	0,0018	0,0156	481,9010	4010,6645

Table 4.4 Tabulated Data for Power Prediction by 2-D Approach, 5-IF1A-4

Lightship Draft

$(V)_m$ (m/s)	$(RT)_m$ (N)	$(Rn)_m 10^6$	$(CT)_m$	$(CF)_m$	$(V)_s$ (m/s)	$(Fn)_s$	$(Rn)_s 10^6$	$(CF)_s$	$(CT)_s$	$(RT)_s$ (N)	PE (kW)
0,2931	0,3372	0,4273	0,0081	0,0057	1,6052	0,0749	63,2177	0,0022	0,0036	4,1941	6,7322
0,3466	0,4094	0,5054	0,0070	0,0055	1,8986	0,0886	74,7755	0,0022	0,0028	4,4850	8,5154
0,4022	0,5356	0,5863	0,0068	0,0053	2,2028	0,1028	86,7545	0,0021	0,0028	5,9991	13,2148
0,4515	0,6501	0,6583	0,0066	0,0051	2,4732	0,1154	97,4046	0,0021	0,0026	7,2289	17,8785
0,5063	0,8248	0,7382	0,0066	0,0050	2,7733	0,1294	109,2247	0,0021	0,0028	9,7267	26,9754
0,5557	1,0309	0,8102	0,0069	0,0049	3,0436	0,1420	119,8707	0,0020	0,0032	13,1614	40,0586
0,6086	1,2634	0,8873	0,0070	0,0048	3,3334	0,1556	131,2827	0,0020	0,0034	16,9935	56,6462
0,6566	1,5274	0,9572	0,0073	0,0047	3,5961	0,1678	141,6305	0,0020	0,0038	21,7951	78,3782
0,7090	1,7538	1,0337	0,0072	0,0047	3,8834	0,1812	152,9426	0,0020	0,0037	25,1534	97,6799
0,8099	2,7990	1,1808	0,0088	0,0045	4,4360	0,2070	174,7087	0,0019	0,0054	48,0733	213,2549
0,9127	3,7681	1,3307	0,0093	0,0044	4,9993	0,2333	196,8909	0,0019	0,0061	68,1536	340,7178
1,0122	4,6041	1,4757	0,0093	0,0043	5,5439	0,2587	218,3426	0,0019	0,0061	84,1926	466,7591
1,0628	5,5114	1,5495	0,0101	0,0043	5,8212	0,2717	229,2606	0,0019	0,0069	105,5152	614,2209
1,1138	7,1972	1,6239	0,0120	0,0042	6,1006	0,2847	240,2647	0,0018	0,0089	148,2706	904,5345
1,1623	9,2063	1,6946	0,0140	0,0042	6,3663	0,2971	250,7286	0,0018	0,0110	200,0681	1273,6845
1,2132	11,0071	1,7688	0,0154	0,0042	6,6451	0,3101	261,7102	0,0018	0,0124	245,7487	1633,0226
1,3152	14,1466	1,9175	0,0169	0,0041	7,2037	0,3362	283,7088	0,0018	0,0139	323,8609	2332,9834
1,4179	16,7941	2,0672	0,0172	0,0040	7,7660	0,3624	305,8574	0,0018	0,0143	387,7046	3010,9260
1,5191	19,8735	2,2147	0,0177	0,0040	8,3203	0,3883	327,6881	0,0018	0,0149	463,1409	3853,4883

Loaded Draft

$(V)_m$ (m/s)	$(RT)_m$ (N)	$(Rn)_m 10^6$	$(CT)_m$	$(CF)_m$	$(V)_s$ (m/s)	$(Fn)_s$	$(Rn)_s 10^6$	$(CF)_s$	$(CT)_s$	$(RT)_s$ (N)	PE (kW)
0,2941	0,4052	0,4177	0,0086	0,0057	1,6107	0,0762	61,8092	0,0022	0,0035	4,0591	6,5379
0,3495	0,5336	0,4965	0,0081	0,0055	1,9144	0,0905	73,4622	0,0022	0,0032	5,1934	9,9420
0,4000	0,6581	0,5683	0,0076	0,0053	2,1910	0,1036	84,0790	0,0021	0,0029	6,1933	13,5697
0,4535	0,8774	0,6442	0,0079	0,0052	2,4839	0,1174	95,3182	0,0021	0,0033	9,2034	22,8605
0,5045	1,1450	0,7166	0,0083	0,0050	2,7631	0,1306	106,0308	0,0021	0,0039	13,3246	36,8170
0,5571	1,3964	0,7915	0,0083	0,0049	3,0516	0,1443	117,1029	0,0020	0,0040	16,7532	51,1241
0,6057	1,6394	0,8605	0,0082	0,0048	3,3178	0,1569	127,3185	0,0020	0,0040	20,0108	66,3921
0,6592	1,9534	0,9365	0,0083	0,0048	3,6107	0,1707	138,5580	0,0020	0,0042	24,5558	88,6640
0,7092	2,2675	1,0075	0,0083	0,0047	3,8845	0,1837	149,0653	0,0020	0,0043	29,1358	113,1787
0,8081	3,1214	1,1480	0,0088	0,0046	4,4264	0,2093	169,8586	0,0019	0,0049	43,4584	192,3632
0,9107	4,2776	1,2937	0,0095	0,0044	4,9880	0,2358	191,4113	0,0019	0,0058	64,3410	320,9347
1,0076	5,2771	1,4314	0,0096	0,0043	5,5190	0,2609	211,7861	0,0019	0,0059	81,1263	447,7345
1,0620	6,1277	1,5086	0,0100	0,0043	5,8166	0,2750	223,2073	0,0019	0,0064	97,4835	567,0232
1,1090	7,6657	1,5754	0,0115	0,0043	6,0743	0,2872	233,0973	0,0018	0,0079	131,4014	798,1756
1,1619	9,9719	1,6505	0,0136	0,0042	6,3640	0,3009	244,2114	0,0018	0,0101	183,7082	1169,1110
1,2138	12,8857	1,7243	0,0161	0,0042	6,6483	0,3143	255,1237	0,0018	0,0127	251,0288	1668,9201
1,3119	17,6516	1,8636	0,0189	0,0041	7,1853	0,3397	275,7301	0,0018	0,0155	359,4089	2582,4644
1,4140	22,9810	2,0086	0,0212	0,0041	7,7446	0,3662	297,1914	0,0018	0,0179	480,7518	3723,2168
1,5183	23,7475	2,1569	0,0190	0,0040	8,3163	0,3932	319,1316	0,0018	0,0157	487,8644	4057,2353

Figure 4.1 Effective Power by 2-D Approach for 2-1F1A-3

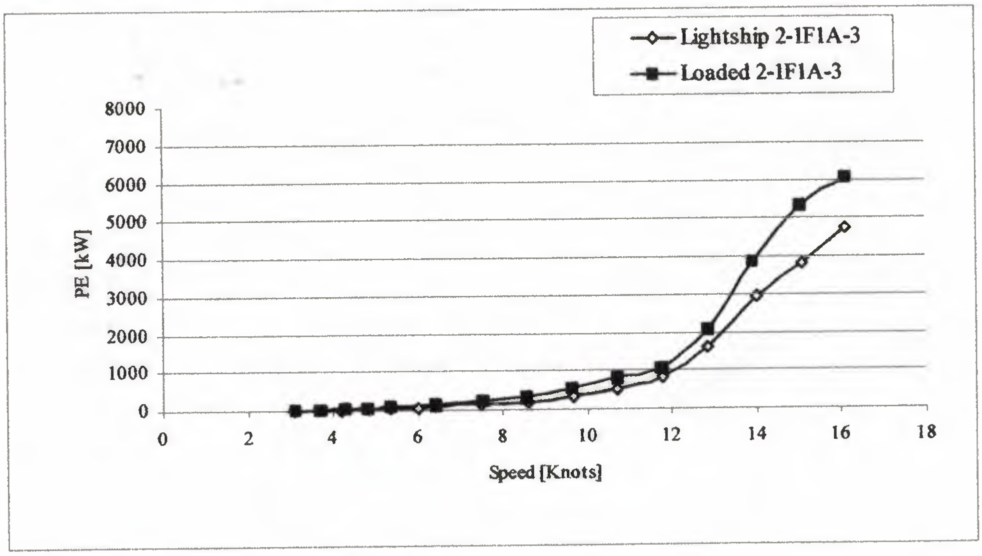


Figure 4.2 Effective Power by 2-D Approach for 2-1F1A-4

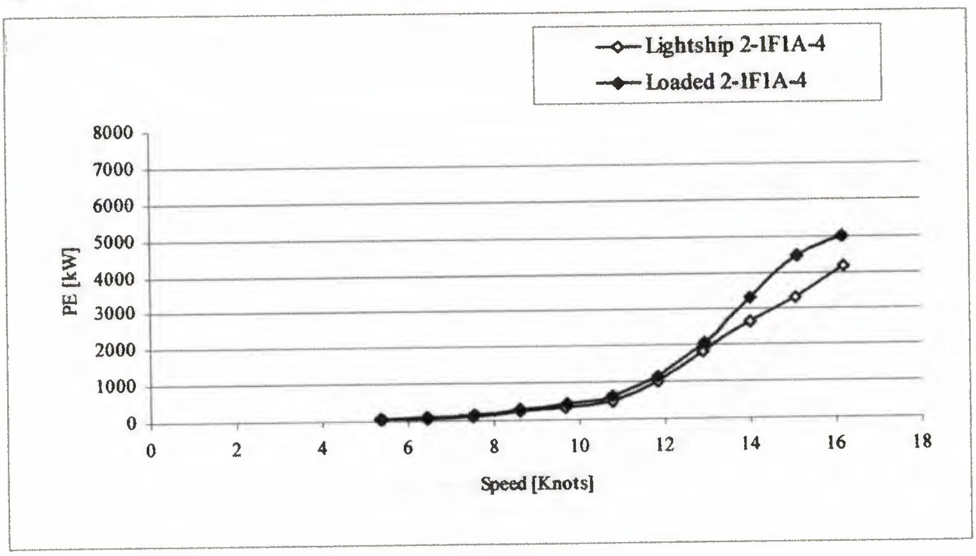


Figure 4.3 Effective Power by 2-D Approach for 5-1F1A-4

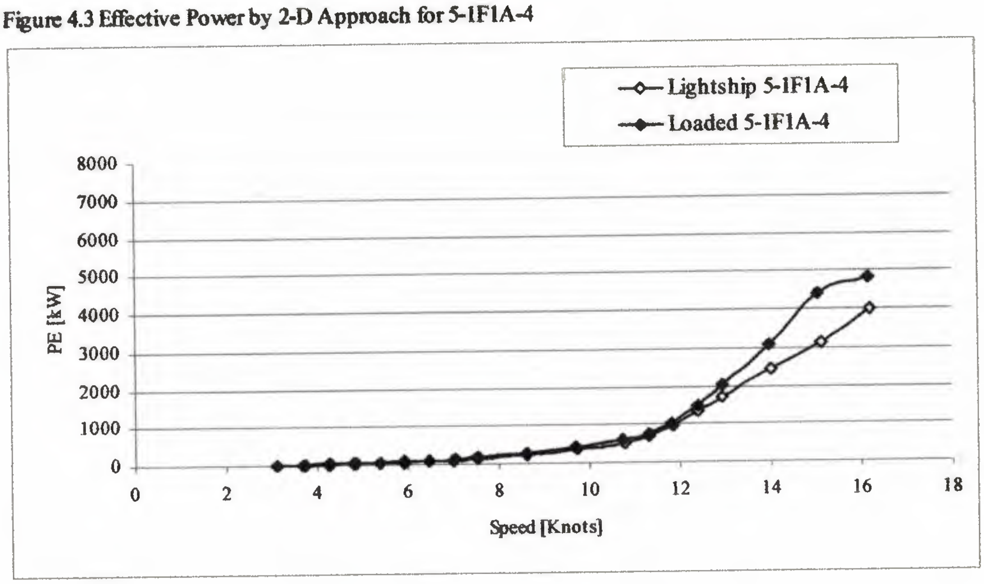


Figure 4.4 Effective Power for Short Hull Combinations at Lightship Draft

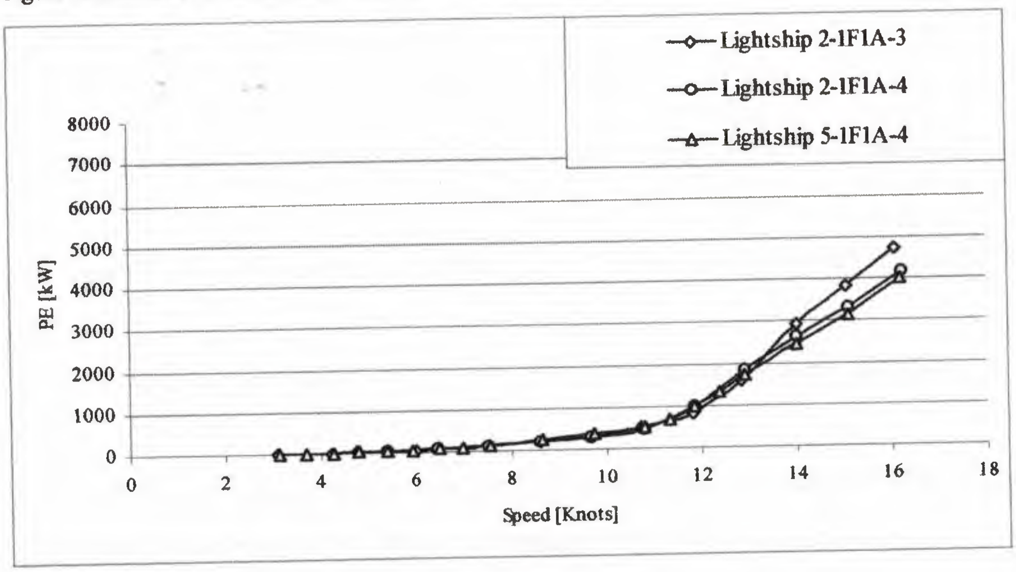
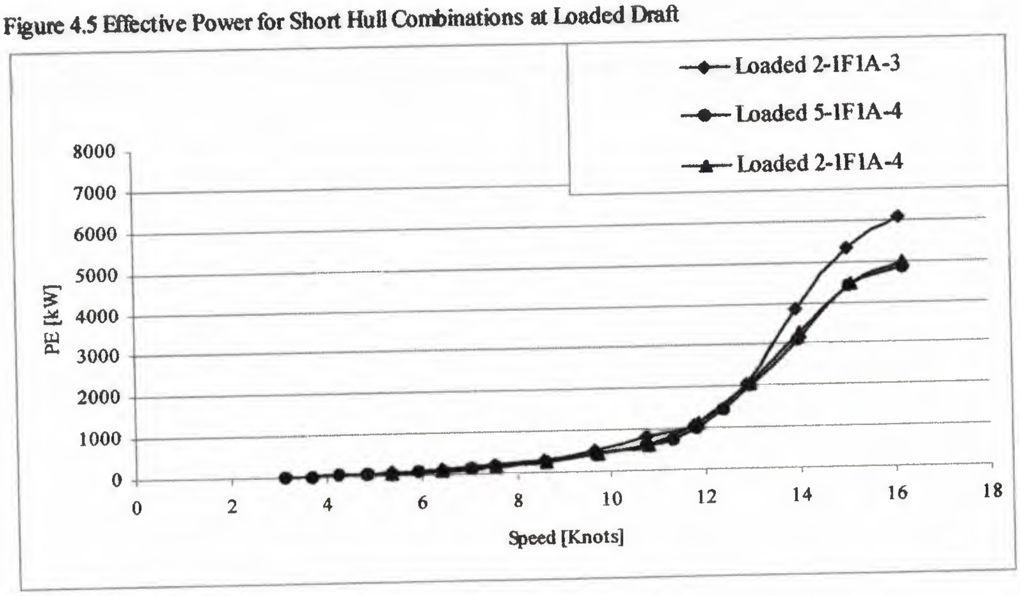


Figure 4.5 Effective Power for Short Hull Combinations at Loaded Draft



4.2 PRESENTATION OF RESULTS

- In Figure 4.4 and 4.5 are shown to us first type of ship (2-1F1A-3) has best power

- All type of ship has same trend until the 12 knots and generally Then (2-1F1A-4 and
  5-1F1A-4) has similar trend but another has more power at same speed.

- When compared the lightship and loaded draft, they have same different, so here can understanding when weight is increasing the power also increasing.

- Speed is the same for all kind of but those three different ships behave different conditions. This different conditions are depends the shape of they.

CONCLUSION

This project's aim is the choosing best ship. Same factor is depends of the effective ship design. These are choosing the ship, material factor, types of fuel etc. But another important thing for ship is the shape of hull surface and lower resistance on the surface and best power efficiency.

Throughout this project the resistance and effective power were analyzed by introducing classification of resistance in the first chapter. This classification is important to find the total hull resistance. In the second chapter model of ship prepared and tested by a constant speed. End of the test, the resistance value of the ship shown on the recorder. Model test is important for making the ship analyses. In the third chapter, calculated the resistance and power of ship by using 2-D method, and choosing best ship type. It depends of the resistance and power values. In fourth chapter is also calculated resistance and power of ship. But here used the 3-D method for finding exact value.

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2) Basic Ship Theory Volume-2 K J RAWSON & E C TUPPER

3) Design of Fishing Vessels JOHN FYSON

4) Vector Mechanics for Engineering FERDINAND P. BEER & E. RUSSELL JOHNSTON

APPENDIX-A

PHOTOGRAPHS OF MODEL COMBINATIONS

From Bow

From Stern

Original Hull form (2-1F1A-3)

APPENDIX-B

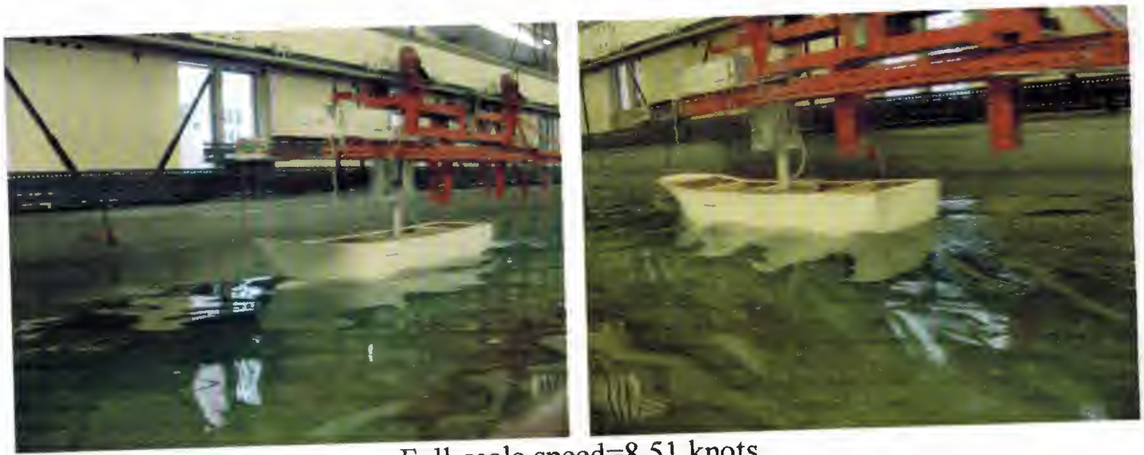
PHOTOGRAPHS OF MODEL DURING EXPERIMENTS

Full-scale speed=8.51 knots

Full-scale speed=12.77 knots

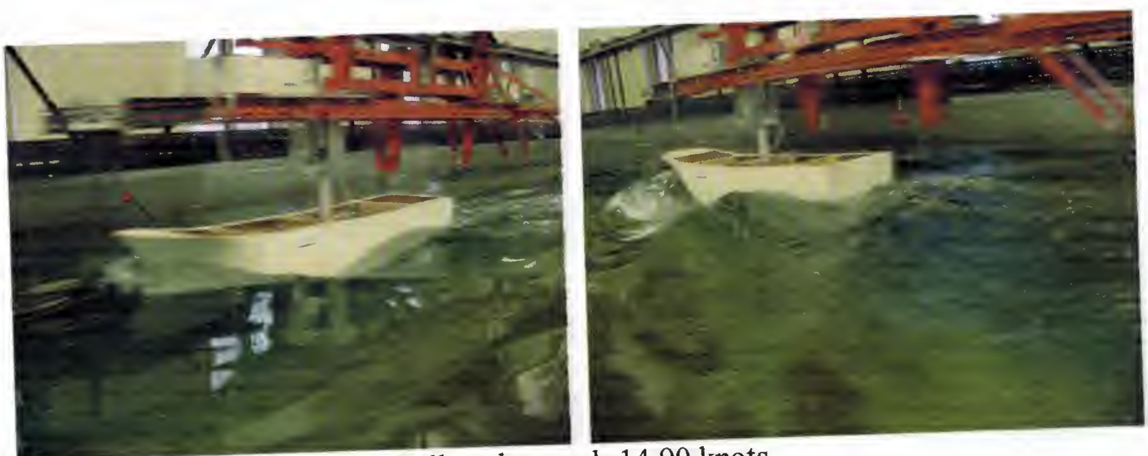
Full-scale speed=14.90 knots

Model Tests with Original Hull Form (2-1F1A-3)



Full-scale speed=8.51 knots

Full-scale speed=12.77 knots



Full-scale speed=14.90 knots

Model Tests with Original Hull Form with new Stern (2-1F1A-4)

Full-scale speed=8.51 knots

Full-scale speed=12.77 knots

Full-scale speed=14.90 knots

Model Tests with Modified Hull Form
with new Bow and new Stern (5-1F1A-4)