INTEGRATED SYSTEM FOR DATA ACQUISITION AND NUMERICAL ANALYSIS OF THE SHIP RESISTANCE PERFORMANCE IN THE TOWING TANK OF GALAȚI UNIVERSITY*

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There are presented the towing tank facilities at the Galati University. We focus on the software BAZIN developed at the Naval Architecture Faculty, for the analysis of the ship resistance experimental data. There are also included the theoretical background and the significant results for a Panamax bulk carrier ship model.

Key words: ship resistance, experimental methods, software for data analysis.

1. INTRODUCTION

With all our modern computer facilities and many years of dedicated effort in developing and applying the theories concerning the hydrodynamics of marine vehicles we must still rely on experimental model test results [2].

The major curricula and the associated research interests justify the laboratory facilities at the Naval Architecture Faculty, presented in Fig. 1.

The main experimental naval architecture goal is to understand the significance and the limitation of scale model testing and the proper use of the model test results in ships performance prediction.

2. TOWING TANK EXPERIMENTAL FACILITIES

The Towing Tank of "Dunarea de Jos " University of Galati, presented in Fig. 2, is of $43 \times 4 \times 3$ meters in size [3]. Depending on the model scale, a maximum speed of 3.5 m/s can be realized on the basis of the gravity towing system. A hydraulic wave generating system is used in order to induce regular long-crested waves from 1 m to 15 m in length and a maximum height of 0.20 m. The wave height sensor is of resistance wire type.

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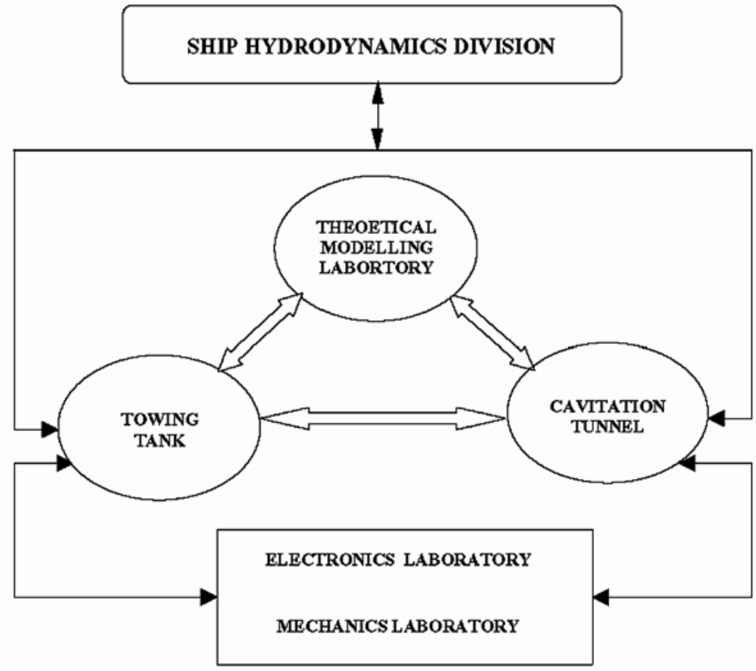

Fig. 1 – Ship Hydrodynamics Laboratories of the Naval Architecture Faculty.

Fig. 2 – The Towing Tank of the Naval Architecture Faculty.

The ship resistance force is measured by means of electronic dynamometers with an accuracy factor of about 0.2%. The velocity transducer is based on an impulse generating sensor with the accuracy factor of maximum 1%.

The towing tank is equipped with a digital computer data acquisition and analyzing system for 24 channels. The facilities of the towing tank are supplemented with digital photo and video camera, to have an additional visual record of the own wave train.

To permit the quick expansion of still water test data to ship scale results, a new computer program is used (chapter 4), based on the experimental methodology presented in chapter 3.

3. EXPERIMENTAL METHODOLOGY (FROUDE METHOD, ITTC-1957 [7])

In the resistance tests, the resistance force R_{T_m} and the speed of the model v_m are measured. In Froude's approach there are the following fundamental characteristics: in the case of Froude similarity, the residual resistance coefficient is of the same value, on model and full scale, at the same forward speed; the frictional resistance is equal to that of a flat plate of equal wetted surface area and length, at the same forward speed; the residual resistance and the frictional resistance are independent of each other.

The procedure ITTC-1957 to determine the total resistance for the ship, R_{Ts}, is as follows [1, 6, 7].

1. Determine the total resistance coefficient, c_{T_m}, in the model tests:

$$c_{T_m} = \frac{R_{T_m}}{\frac{1}{2} \cdot \rho_m \cdot v_m^2 \cdot S_m} \tag{1}$$

where R_{T_m} is the model total resistance, ρ_m is the fresh water density, v_m the model speed, while S_m represents the model wetted surface.

2. Calculate the frictional coefficient, c_{F_m}, for model by the ITTC-1957 formula:

$$c_{F_m} = \frac{0,075}{\left(\log Rn_m - 2\right)^2} \tag{2}$$

where Rn_m is the Reynolds number for the model defined as:

$$Rn_m = \frac{v_m \cdot L_{WL_m}}{\upsilon_m} \tag{3}$$

while, L_{WL_m} is the model length of waterline and υ_m represents the coefficient of kinematical viscosity of water, depending on the temperature.

3. The Froude number calculation (the same for ship and model):

$$Fn = \frac{v_m}{\sqrt{g \cdot L_{WL_m}}} = \frac{v_s}{\sqrt{g \cdot L_{WL_s}}} \tag{4}$$

where g is the acceleration due to gravity, v_s is the ship speed and L_{WL_s} is the ship length of waterline.

4. Calculate the residual resistance coefficient, c_R, same for model and ship:

$$c_R = c_{T_m} - c_{F_m} \tag{5}$$

5. Determine the total resistance coefficient, c_{T_s}, for the ship:

$$c_{T_s} = c_{F_s} + c_R + c_A \tag{6}$$

where c_{F_s} is the frictional coefficient for the ship and c_A is the correlation coefficient ([7]).

The frictional coefficient of the ship is calculated by the ITTC-1957 formula:

$$c_{F_s} = \frac{0,075}{\left(\log Rn_s - 2\right)^2} \tag{7}$$

where Rn_s is the Reynolds number for the ship:

$$Rn_s = v_s \cdot L_{WL_s} / \upsilon_s \tag{8}$$

(υ_s represents the coefficient of kinematical viscosity of salt water for the full scale case, at 15° C).

6. Determine the total resistance R_{T_s} and the effective power P_E for the ship:

$$R_{T_s} = c_{T_s} \cdot \frac{1}{2} \cdot \rho_s \cdot v_s^2 \cdot S_s\,; \quad P_E = R_{T_s} \cdot v_s \tag{9}$$

where ρ_s is the water density for the full scale case (15°C), c_{T_s} is calculated with (6) and S_s is the ship wetted surface.

4. COMPUTER PROGRAM FOR EXPERIMENTAL DATA ANALYSIS

For the post processing analysis of the experimental data obtained at the towering tank, for the ship resistance, we have developed our eigen program BAZIN, in the frame of the Naval Architecture Faculty, at the University „Dunărea de Jos” Galaţi, with Pascal code (www.freepascal.org version 1.0.10 compiler [8]).

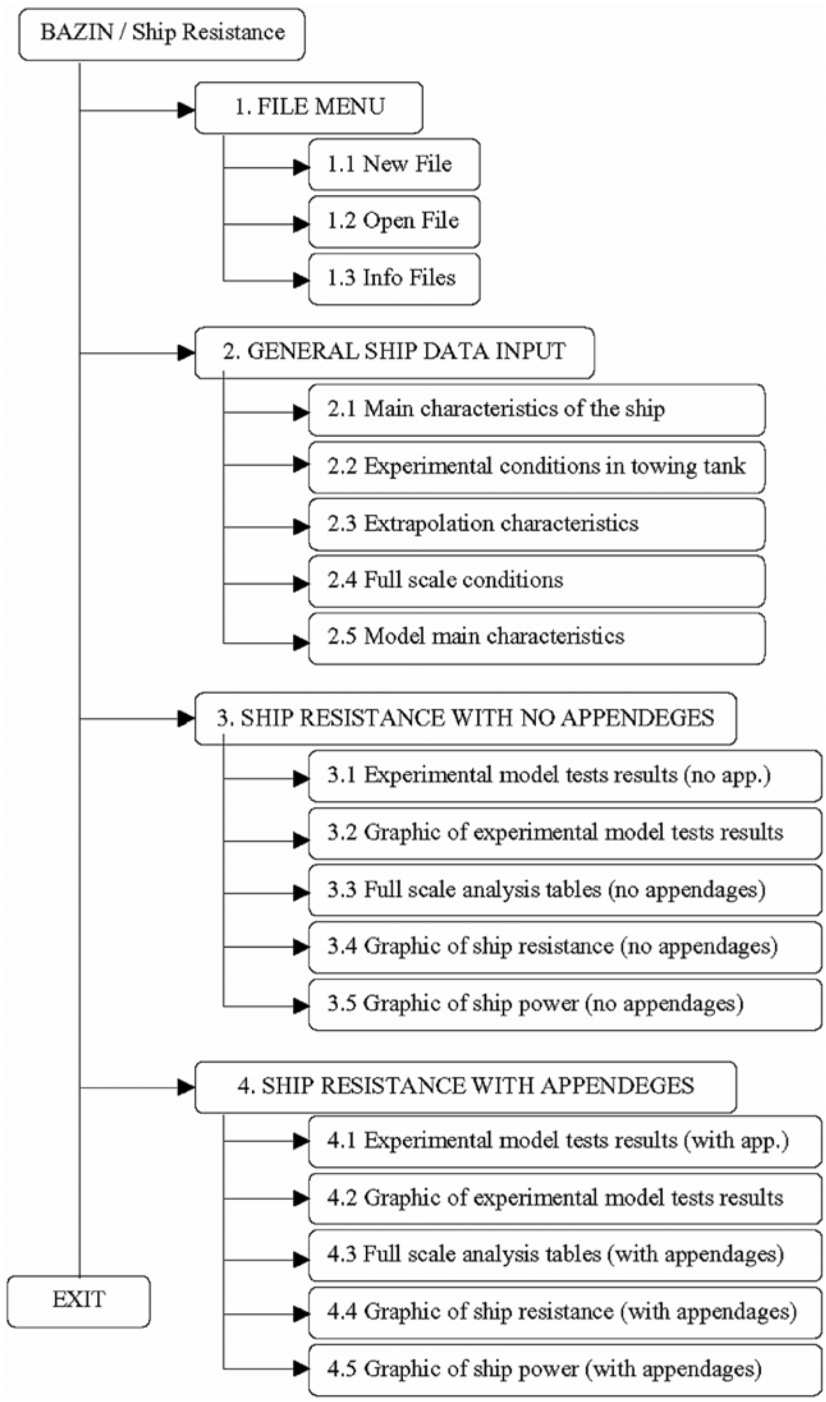

Fig. 3 – The main logical scheme of the BAZIN program.

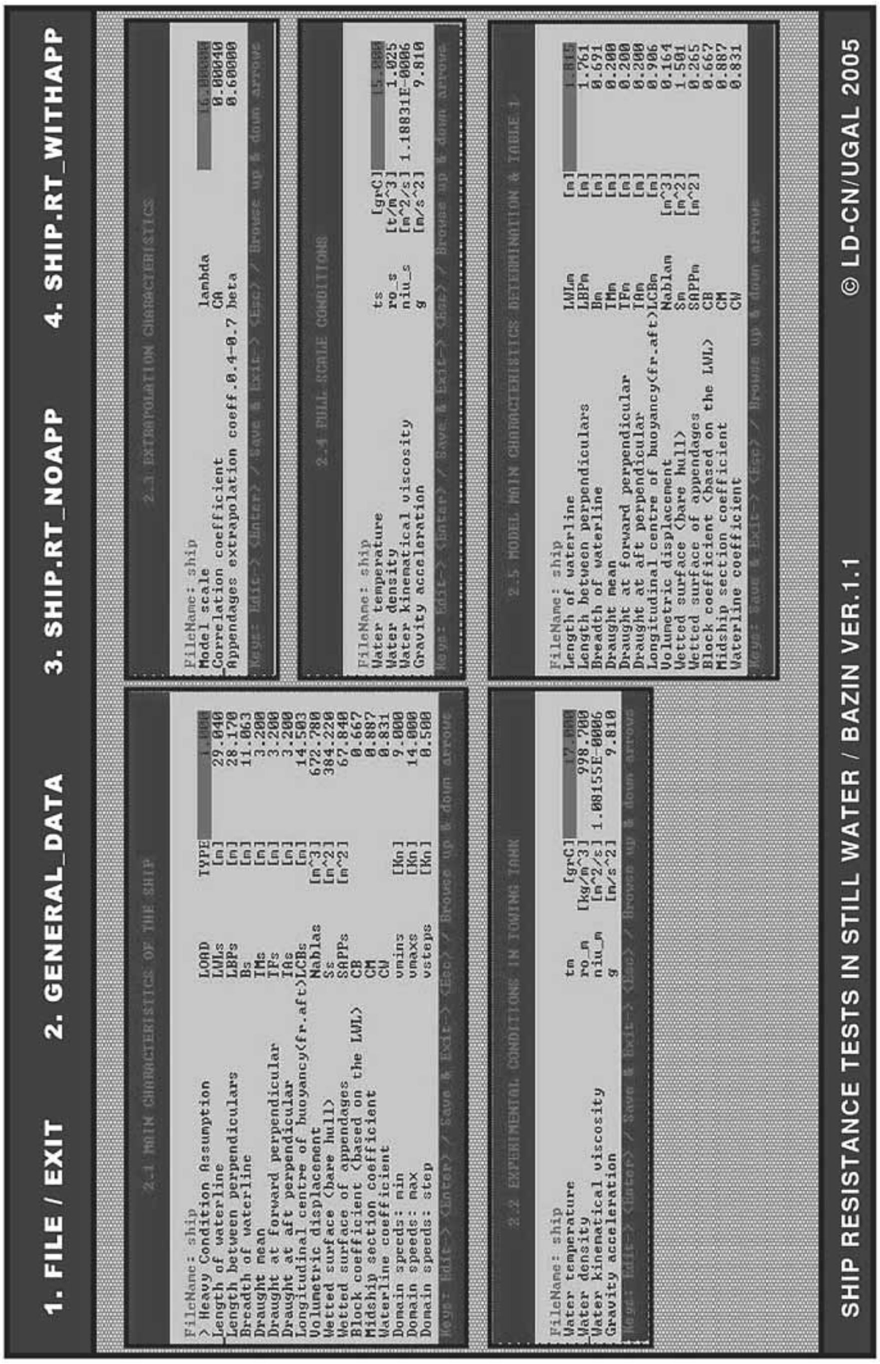

Fig. 4a – General Data Menu of the BAZIN program.

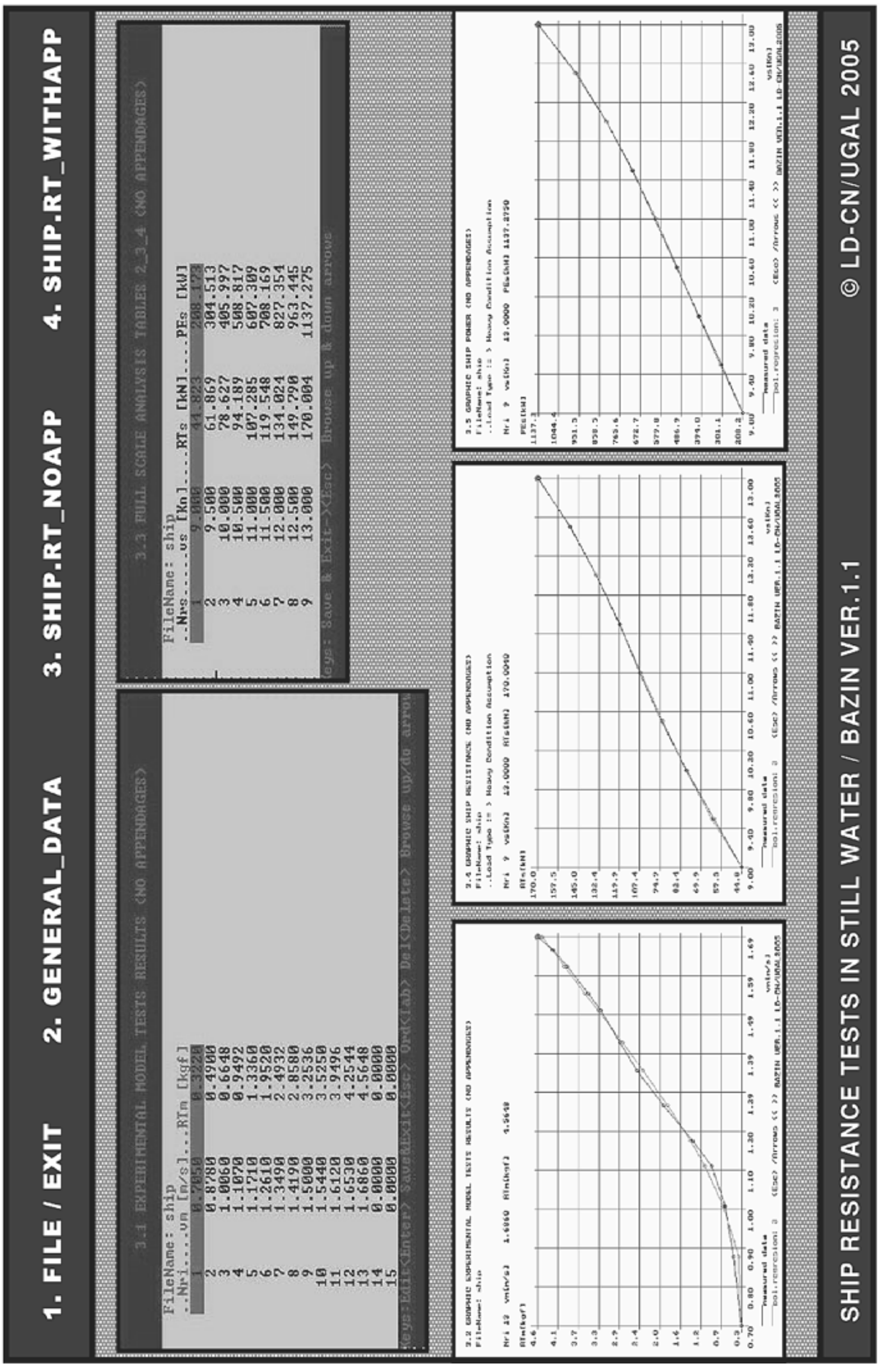

Fig. 4b – Ship Resistance Post processing Menu of the BAZIN program.

The logical scheme of program BAZIN is presented in Fig. 3.

The program has four main menus as following:

1. The File Menu

In this sections there are included the commands for creating a new data base files, opening an existing data base files, general information of the data base files. The data base for a ship application includes a total of 15 files. The first 8 files include the general input data and also the experimental data obtained at the towing tank test on ship models. The last 7 files will include the post processing results of the ship resistance experimental analysis.

2. The General Ship Data Input Menu (Table 1 and Fig. 4.a)

There are included the commands for the input of: the main characteristics of the ship, the experimental conditions in the towing tank, extrapolation characteristics from ship model to the ship scale condition. It results at this section the main characteristics of the ship model.

3. The Ship Resistance with no Appendages (see Tables 2–4 and Figs. 4.b, 6–8)

There are presented the commands for: the input of the experimental model tests results (Table 2) and associated diagram (Fig. 6), the expansion of still water test data to ship scale results (Tables 3 and 4, Figs. 7 and 8).

4. The Ship Resistance with Appendages

In this sections there are included the commands for the analysis of ship resistance experimental data in the case with appendages. This section has the same submenus structure as section 3.

5. RESISTANCE TESTS FOR A PANAMAX BULK CARRIER MODEL

The prediction of the resistance and power performance of a ship is based on the results of model experiments carried out in a towing tank. Also, the quality of the designed hull form is validated by means of model experiments.

In this chapter there are presented the post processing results with the BAZIN program, at experimental ship resistance analysis for a Panamax bulk carrier model.

The fore body lines plan with a high angle of water plane entrance, the wave pattern interference phenomena and the breaking waves are the main causes of ship resistance increasing.

The wave pattern at heavy condition (v = 16.57 Kn) is given in Fig. 5.

The characteristics of the ship and of the experimental model (1:80 scale) at heavy condition are presented in Table 1 ([4, 5]).

The tests results for the model at heavy condition are given in Table 2.

The full scale extrapolation at heavy condition is given in Table 3.

The model resistance diagram at heavy condition is given in Fig. 6.

Fig. 5 – Wave pattern at full load, v_s = 16.57 Kn.

Table 1

Full scale ship and model main characteristics for heavy condition

Main characteristics	Symbol	FULL SCALE SHIP		Model	
Length of waterline	L_{WL}	220.915	[m]	2.761	[m]
Length between perpendiculars	L_{BP}	217.30	[m]	2.716	[m]
Breadth of waterline	B	32.20	[m]	0.403	[m]
Draught mean	T_M	13.830	[m]	0.173	[m]
Draught at forward perpendicular	T_F	13.830	[m]	0.173	[m]
Draught at aft perpendicular	T_A	13.830	[m]	0.173	[m]
Longitudinal centre of buoyancy	LCB	114.081	[m]	1.426	[m]
Volumetric displacement	∇	82626.0	[m^3]	0.161	[m^3]
Wetted surface (bare hull)	S	11762.40	[m^2]	1.838	[m^2]
Water temperature	T	15.0	[^{o}C]	7.0	[°C]
Water density	ρ	1.025	[t/m^3]	998.70	[kg/m^3]
Water kinematical viscosity	υ	1.18831E-6	[m^2/s]	1.42667E-06	[m^2/s]
Gravity acceleration	g	9.810	[m/s^2]	9.810	[m/s^2]
Block coefficient (based on the waterline length)	C_B	0.837		0.837	
Midship section coefficient	C_M	0.995		0.995	
Waterline coefficient	C_W	0.923		0.923	

Table 2

Model tests analysis at heavy condition

Test No.	v_m [m/s]	Fn	Rn_m	R_{T_m} [kgf]	R_{T_m} [N]	c_{T_m}	c_{F_m}	c_R
1	0.4600	0.088	8.9037E+0	0.1650	1.619	0.0083352	0.0048080	0.0035272
2	0.5062	0.097	9.7979E+05	0.1770	1.736	0.0073837	0.0047083	0.0026754
3	0.5535	0.106	1.0713E+06	0.1900	1.864	0.0066293	0.0046181	0.0020111
4	0.5926	0.114	1.1470E+06	0.2058	2.019	0.0062643	0.0045509	0.0017133
5	0.6257	0.120	1.2111E+06	0.2214	2.172	0.0060450	0.0044985	0.0015465
6	0.6743	0.130	1.3052E+06	0.2422	2.376	0.0056940	0.0044277	0.0012662
7	0.7222	0.139	1.3979E+06	0.2695	2.644	0.0055232	0.0043643	0.0011589
8	0.7583	0.146	1.4678E+06	0.2938	2.882	0.0054616	0.0043200	0.0011415
9	0.7908	0.152	1.5307E+06	0.3210	3.149	0.0054868	0.0042825	0.0012043
10	0.8182	0.157	1.5837E+06	0.3506	3.439	0.0055981	0.0042524	0.0013457
11	0.8602	0.165	1.6650E+06	0.3872	3.798	0.0055935	0.0042087	0.0013848
12	0.9032	0.174	1.7482E+06	0.4177	4.098	0.0054732	0.0041668	0.0013065
13	0.9531	0.183	1.8448E+06	0.4498	4.413	0.0052929	0.0041213	0.0011716

Table 3

Full scale extrapolation at heavy condition

Test No.	v_s [Kn]	R_{n_s}	c_{F_s}	c_R	c_A	c_{T_s}	R_{T_s} [kN]	P_E [kW]
1	7.99	7.6489E+8	0.0015828	0.0035272	0.0001	0.0052100	531.664	2187.5
2	8.80	8.4171E+8	0.0015639	0.0026754	0.0001	0.0043393	536.218	2427.8
3	9.62	9.2036E+8	0.0015465	0.0020111	0.0001	0.0036576	540.401	2675.3
4	10.30	9.8538E+8	0.0015334	0.0017133	0.0001	0.0033467	566.795	3004.2
5	10.88	1.0404E+9	0.0015231	0.0015465	0.0001	0.0031696	598.435	3349.1
6	11.72	1.1212E+9	0.0015091	0.0012662	0.0001	0.0028754	630.489	3802.6
7	12.56	1.2009E+9	0.0014964	0.0011589	0.0001	0.0027553	693.061	4476.9
8	13.19	1.2609E+9	0.0014875	0.0011415	0.0001	0.0027291	756.789	5132.9
9	13.75	1.3149E+9	0.0014799	0.0012043	0.0001	0.0027842	839.689	5939.2
10	14.23	1.3605E+9	0.0014738	0.0013457	0.0001	0.0029195	942.561	6897.9
11	14.96	1.4303E+9	0.0014648	0.0013848	0.0001	0.0029497	1052.571	8098.3
12	15.70	1.5018E+9	0.0014562	0.0013065	0.0001	0.0028627	1126.215	9098.1
13	16.57	1.5848E+9	0.0014468	0.0011716	0.0001	0.0027184	1190.873	10151.9

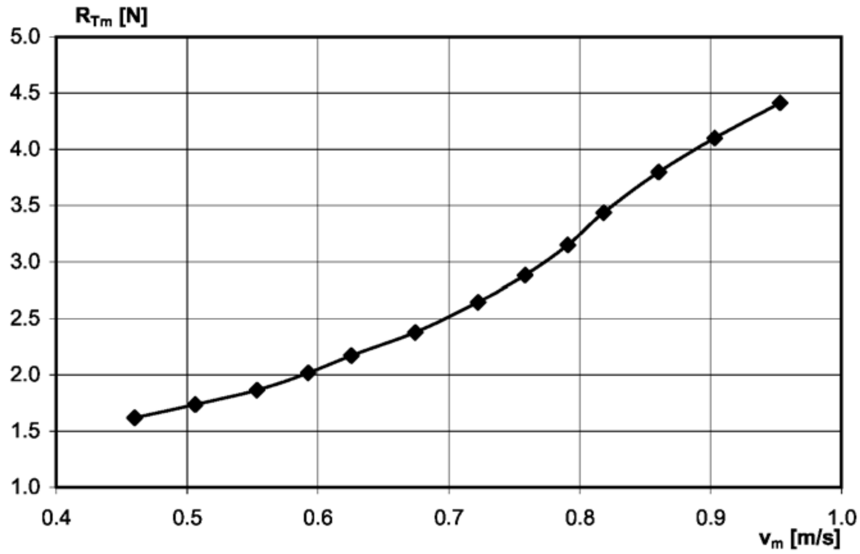

Fig. 6 – History of model resistance (heavy condition).

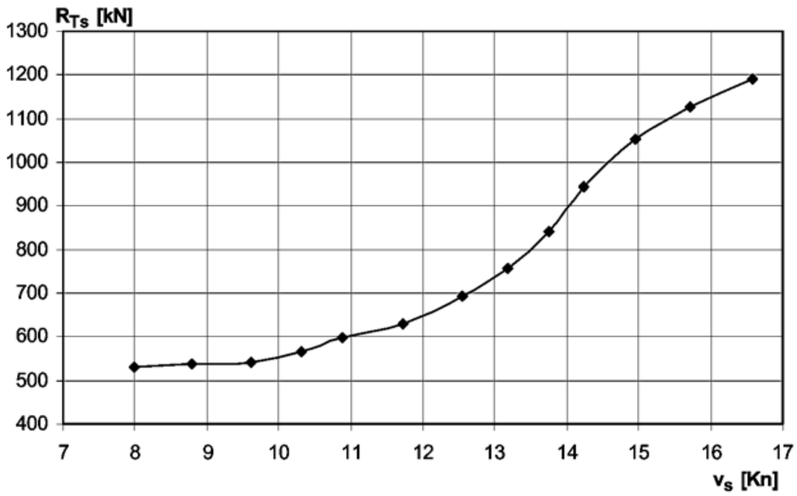

Fig. 7 – History of ship resistance (heavy condition).

The ship resistance diagram at heavy condition is given in Fig. 7.
The effective power diagram at heavy condition is given in Fig. 8.

6. CONCLUSIONS

From the analysis of the experimental data it results that the prognosis of ship resistance and effective power was performed with an overall accuracy of ±3%.

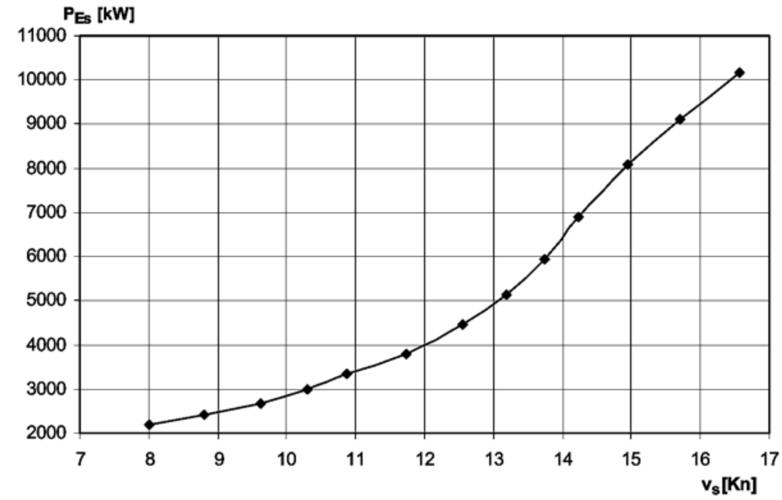

Fig. 8 – History of effective power (heavy condition).

The use of program BAZIN made possible to speed up the post processing of ship resistance experimental data, so that the researcher is able to analyse and to validate the results in the same time with the experiment.

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