A New Ridgely-Nevitt Regression-Based Computational Tool for Resistance and Power Predictions for Trawlers

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This paper aims to present the architecture and the prediction accuracy of a new computational procedure of the “Ship Power V 1.0” software based on the Ridgely–Nevitt regression, applied to hull resistance predictions for Ridgely-Nevitt series trawlers. The Ridgely-Nevitt series is an important series of trawlers developed by and tested at the Webb Institute. Experimental resistance data have also been presented in the form of a regression model used to develop a new procedure of the “Ship Power V 1.0” software. Furthermore, this new procedure was completely harmonized with other software procedures based on the Holtrop and Van Oortmerssen evaluation methods. Although the mathematical formulation of the Ridgely-Nevitt regression model allows the assessment of the residual resistance coefficient of only nine values from the speed-length ratio, the implementation of an interpolation procedure made possible resistance predictions for any speeds from the acceptable speed-length ratio range. Resistance prediction accuracy improvement introduced by the new procedure was proven by the validation of calculation results not only against experimental data but also against the prediction results of other software procedures for three hulls from the Ridgely-Nevitt fishing vessel series. MAPE (mean absolute percentage error) values calculated against experimental data for the analyzed models were 3.26, 1.71, and 3.36, respectively. Prediction result comparisons of the Ridgely-Nevitt regression-based “Ship Power V 1.0” computational procedure and the experimental data and predictions of other computational procedures performed on three hulls from the Ridgely-Nevitt series have shown a substantial improvement in prediction accuracy.

KEYWORDS

~ Ridgely-Nevitt regression
~ Computational procedure
~ Fishing vessel series
~ Resistance
~ Hull model

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1. INTRODUCTION

In the ship design practice, the use of systematic series is traditionally considered one of the fundamental methods of ship resistance prediction (Molland, 2008; Trincas, 2010; Xhareraj 2022). Although resistance measurement conducted on models in towing tanks is considered the most accurate resistance evaluation method, over the last decade, the more intensive use of CFD applications for resistance prediction has shown them to be an alternative to towing tank measurements. Some examples of CFD application to resistance prediction can be found in Chirosca and Rusu (2021); Deshpande et al. (2020); Polyzos and Tzabiras (2020); Elkafas et al. (2019); Jeong (2020); Niklas and Pruszko (2019). Despite the increasing use of CFD for resistance prediction, the use of systematic series resistance data is still considered highly helpful in ship design practices. The method can produce reliable results since the systematic series resistance data are obtained through towing tank tests. Experimental test data have been presented in the form of charts or tables for appropriate use in the design process. In addition, regression analysis can be applied to original experimental data.

In general, regression models, which are algebraic expressions of experimental data, have given us highly effective design tools used in complex engineering system design and analysis. (Venkateshan, 2015). In engineering practice, there are many areas of regression model application (Pavlenko, et al., 2022; Unigovsky, 2000; Achebo, 2015; QIU and Bo 2012; Bhatt and Parappagoudar 2015). In ship design practice, regression analysis has been used in several aspects of the design process (Kim, et al., 2022; Hou, et al., 2011; Cho, 2011; Liu and Papanikolaou 2020; Fung, 1992; Jeong, et al., 2021; Yilmaz and Kükner 1999). One of the main areas of application in ship design practice are resistance and power predictions. Holtrop, Holtrop-Mennen, and Van Oortmerssen are traditional regression models used in the ship design practice to predict the resistance and power of a wide range of ship types (Holtrop and Mennen, 1982; Holtrop, 1984; Oortmerssen, 1971). In addition to these fundamental and popular regression models, there is also literature dealing with other specific regression models for resistance and power predictions for specific hulls (Koznowski and Lebkowski, 2022). A regression model for resistance and power predictions for fishing vessels designed based on the well-known Ridgely-Nevitt series of trawlers was presented in literature (Helmore and Swain, 2006). This specific regression was used to develop a new computational procedure in Ship Power V 1.0 - a computer tool developed by the author (Xhaferaj and Dukaj, 2012; Xhaferaj and Dukaj, 2017a; Xhaferaj, 2022). The architecture and the validation of this newly developed procedure are presented in the following sections of the paper.

As previously highlighted, the Ridgely-Nevitt series is an important series of high displacement length ratio of trawlers developed at the Webb Institute. (Nevitt, 1956; Nevitt, 1963; Nevitt, 1967). This series has been the subject of several studies by different authors. Boccadamo and Cassella (1990); Boccadamo et al. (1992); Boccadamo et al. (1993); and Boccadamo et al., (1999) have presented polynomial expressions to evaluate and verify, from the preliminary design stage, the stability characteristics and IMO stability criteria for Ridgely-Nevitt series hulls. Some equations for the analytical evaluations of offsets of the Ridgely-Nevitt series were shown in Boccadamo et al. (1987). A regression model of resistance data for the Ridgely-Nevitt trawler series was presented in Helmore and Swain (2006). This regression model, which is presented in the next section, was used to develop a new computational procedure in “Ship Power V 1.0” software.

Currently, the program uses two procedures based on Holtrop and Van Oortmerssen methods (Xhaferaj, 2022; Xhaferaj and Dukaj, 2012; Xhaferaj and Dukaj, 2017a). As reported in Xhaferaj (2022) and Xhaferaj and Dukaj (2017b), the predicting accuracy of the current program procedures was shown to be satisfactory compared to experimental resistance results and outputs of predictions made by other commercial software. Despite this, research on some Ridgely-Nevitt series hulls, as presented in Xhaferaj (2022), has shown high level of prediction result deviation of the current computational procedures compared to resistance test data. Since Holtrop and Van Oortmerssen regressions have been applied to different vessel types to accurately predict resistance and power, which is a crucial aspect of the ship design process, attempts to improve the prediction accuracy of the software for specific hulls and expand its range of computational procedures have raised some issues. First, can other computational procedures based on specific regression models for resistance prediction be added to current software procedures? Second, can the predictive accuracy of the software be improved through the implementation of other procedures based on specific regression models of the resistance data for specific hulls?

Bearing in mind the above considerations, a new computational procedure was developed in "Ship Power V 1.0". This newly developed procedure was based on the Ridgely-Nevitt regression, as presented in Helmore and Swain (2006). Although the Ridgely-Nevitt regression model allows resistance predictions for only for nine speed-length ratio values, the implementation of an interpolation procedure made possible predictions for any value of speeds within the limits of the acceptable speed-length ratio range. Results of validation of this computational procedure against resistance data of three hulls from the series (W-10; W-11, W-12) have shown a substantial improvement in the prediction accuracy compared to the current computational procedures of the software.

2. METHODS

2.1. Regression equations of resistance data of the Ridgely-Nevitt series

Experimental resistance data of the Ridgely-Nevitt fishing vessel series were first presented by C. Nevitt in 1967 (Nevitt, 1967). Originally, the resistance data were organized in the form of graphs of residual resistance coefficients based on the prismatic coefficient C_P, displacement-length ratio $\Delta/(0.01L)^3$ for nine values of the speed-length ratio $V/\sqrt{L}$, from 0.7 to 1.5 in 0.1 $kn/\sqrt{ft}$ increments (Nevitt, 1967; Helmore and Swain, 2006). The regression of experimental resistance data for the Ridgely-Nevitt fishing vessel series was presented in Helmore and Swain (2006) as follows:

$$1000\ C_R = \sum_{i=0}^{20} a_i C_P^j \left[\frac{\Delta}{(0.01\ L)^3}\right]^k \qquad (1)$$

- C_R – is the coefficient of residual resistance
- C_P – is the prismatic coefficient
- $\Delta/(0.01L)^3$ – is the displacement-length ratio, based on waterline length.
- The values of coefficients a_i, j, and k have been given in *Appendix 1* of Helmore and Swain (2006).

More details on this regression model can be found in Helmore and Swain (2006).

2.2. Architecture of the computational procedure of "Ship Power V 1.0" based on the Ridgely-Nevitt regression

The architecture of the computational procedure of "Ship Power V 1.0" based on the Ridgely-Neviit regression was developed taking into account the previous computational procedures of the software, which are based on Holtrop and Van Oortmerssen computational methods (Xhaferaj, 2022; Xhaferaj and Dukaj, 2012; Xhaferaj and Dukaj, 2017a). The main issue during the development of this new procedure was the difference between the Ridgely-Nevitt regression model and Holtrop, Holtrop-Mennen, and Van Oortmerssen models which allow predictions for any speeds, while the Ridgely-Nevit regression model allows predictions only for some speeds, i.e. speeds corresponding to the speed-length ratios $V/\sqrt{L}$ equal to 0.7, 0.8, 0.9, 1.0, 1.1, 1.2, 1.3, 1.4, and 1.5 ($kn/\sqrt{ft}$). An interpolating procedure was developed to solve this problem. The development of this interpolating procedure, as described in the following sections of the paper, enabled the software to make resistance predictions based on the Ridgely-Nevitt regression without any restriction on the number of speeds. In other terms, this means that the developed interpolation procedure enabled the software to evaluate resistance and power for any speeds within the eligible speed length ratio range, starting from the discrete evaluations of residual resistance based on the Ridgely-Nevitt resistance regression model.

Given that the Ridgely-Nevitt regression equation evaluates residual resistance coefficient in a manner similar to the procedure based on the Van Oortmerssen method (Xhaferaj and Dukaj, 2017a; Xhaferaj, 2022), as well as the procedure based on the Ridgely-Nevitt regression, total resistance R_T is calculated as follows.

$$R_T = R_F + R_R + R_{APP} + R_A + R_{AIR} + R_{MARGIN} \quad (2)$$

where frictional resistance is *(R_F),* residual resistance *(R_R)*, appendage resistance (R_{APP}), model ship correlation resistance (R_A), air resistance (R_{AIR}), and additional resistance for the meteorological conditions (R_{MARGIN}). In the computational procedure based on the Ridgely-Nevitt regression model, the terms R_F, R_{APP}, R_A, R_{AIR}, *and* R_{Margin} are calculated as in the previous procedures implemented in the “Ship Power V 1.0” software, as reported in Xhaferaj and Dukaj (2012) and Xhaferaj and Dukaj (2017a). Residual resistance R_R is calculated based on the regression model presented in Helmore and Swain (2006) while interpolation procedure was implemented as described in sections 2.1 and 2.3. The value of the R_{MARGIN}, even in the computational procedure based on Ridgely-Nevitt regression, is calculated as percentage addition of resistance in calm seas (Xhaferaj, 2022).

Residual resistance for speeds corresponding to the values of the $V/\sqrt{L}$ ratio equal to 0.7, 0.8, 0.9, 1.0, 1.1, 1.2, 1.3, 1.4, and 1.5 is calculated using residual resistance coefficients as defined in the mathematical formulations of the Ridgely-Nevitt regression presented in Helmore and Swain (2006). Residual resistance is calculated every time software runs an analysis. Based on the geometric input data of the ship, the nine speeds corresponding to speed length ratios from 0.7 to 1.5, in 0.1 $kn/\sqrt{ft}$ increments, are calculated as follows:

$$V_i = 0.5144 \left(\frac{V}{\sqrt{L}}\right)_i \sqrt{L/0.3048} \quad (3)$$

- V_i – Values of speeds for each point, in m/s (i = 1,2, …, 9).
- $\left(\frac{V}{\sqrt{L}}\right)_i$ - Values of speed-length ratios for each point (i = 1, 2,.., 9), from 0.7 to 1.5, in 0.1 $kn/\sqrt{ft}$ increments.
- L – Waterline length of the ship, in m, taken as input data from the graphic user interface (GUI) of the software.

Based on these speed values and residual resistance coefficients C_R, calculated as in equation (1), the nine values of residual resistance R_R have been calculated as follows:

$$R_R = 0.5\, C_{R_i}\, \rho\, S\, V_i^2 \quad (4)$$

- C_{Ri} – Values of residual resistance coefficients, calculated for each point as in equation (1).
- S – Hull surface in m^2, taken as input data, or calculated approximately as in Xhaferaj and Dukaj (2012) and also in Xhaferaj and Dukaj (2017a).
- ρ – water density, kg/m^3
- V_i – Values of speed for each point, in m/s (i = 1,2,…..9)

Interpolation procedure was used to predict the residual resistance for other speeds, as described in the following section. Range and step of speeds for resistance predictions were taken as input data from the software's GUI (Xhaferaj and Dukaj, 2012); (Xhaferaj and Dukaj, 2017a). The calculated value of residual resistance R_R, and the values of components R_F, R_{APP}, R_A, R_{AIR}, and R_{Margin}, were used to calculate the value of total resistance R_T using equation 2. In computational procedure based on the Ridgely-Nevitt regression model, form factor, power and propulsive coefficients were calculated as in Xhaferaj and Dukaj (2012) and Xhaferaj and Dukaj (2017a).

2.3. Interpolation procedure

The following general requirements apply to every interpolation function of a set of discrete points (Hanelli and Osmani, 2004):

- the interpolation function must pass through the given data points (in our case, data obtained from the Ridgley-Nevitt regression model),
- the interpolation function must satisfactorily approximate the function of discrete data points to be interpolated at intermediate values between the given data points,
- the interpolation function must be as simple as possible.

The interpolation subroutine used in the computational procedure of the "Ship Power V 1.0" software, based on the Ridgely-Nevitt method, was based on the second-order interpolating function. The accuracy of approximations was improved by not performing interpolation as a single function, but as zonal interpolation. Each range (zone) of three consecutive knot points has a particular interpolation function. Since the Ridgely-Nevitt regression model is defined for nine values of the $V/\sqrt{L}$ ratio, there are nine available speeds (knot interpolation points) for a given ship (L defined) to perform Ridgley-Nevitt regression calculations and four interpolation intervals.

At each interpolation interval, the interpolating function was expressed as follows:

$$Y = A_i \cdot X^2 + B_i \cdot X + C_i \tag{5}$$

Where:

- i – Number of the interpolation interval
- A_i, B_i, C_i –interpolation function coefficients in the "i" range (interval)

The interpolation procedure consists of the following main stages:

- knot point data calculations
- point grouping and indexing
- determining *A, B, and C* coefficients of interpolating functions.

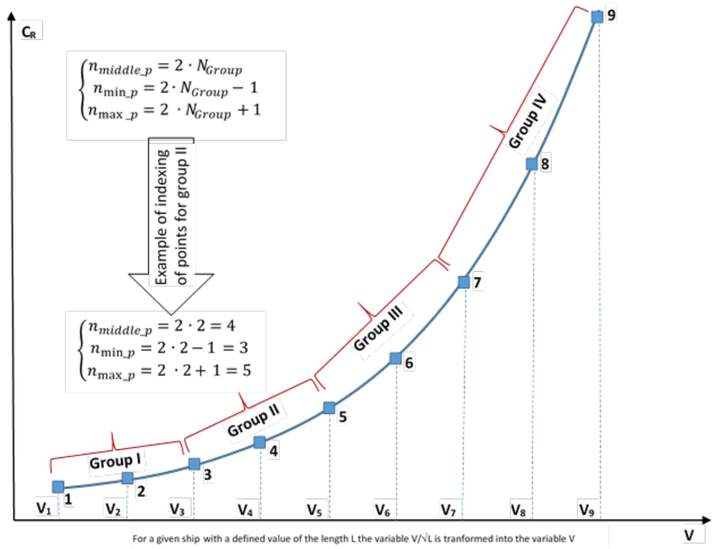

Figure 1. Grouping and indexing of points.

Figure 1 shows the principle of point grouping and indexing, while Figure 2 shows the flow diagram for determining *A, B,* and *C* coefficients of second-order interpolation functions. The numbers of groups are used to identify values of *A, B,* and *C* coefficients and use them to formulate the expression for the calculation of the residual resistance coefficient for the given velocity. The value of the residual resistance coefficient C_R is used to calculate the value of residual resistance R_R for a given velocity.

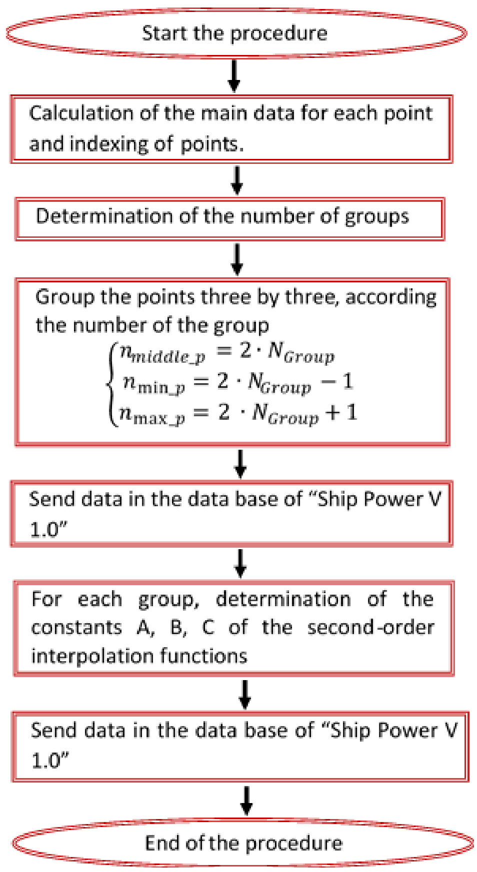

Figure 2. Flow chart for determining coefficients of second-order interpolating functions.

The general algorithm of the procedure based on the Ridgely-Nevitt regression is presented in Figure 3.

2.4. Validation of the developed procedure

The validation of the developed procedure was performed against experimental resistance data and outputs of calculations of other procedures of the "Ship Power V 1.0" software. The hulls were W-10, W-11, and W-12 hulls from the Ridgely-Nevitt trawlers series. The hulls had the length between perpendiculars L_{PP} = 30.48 m and the prismatic coefficient C_P = 0.65. The respective values of displacement length ratios were 200, 400, and 500. Detailed characteristics of these hulls can be found in Nevitt (1963) and Xhaferaj (2022). Resistance test data of the hulls were used to validate the newly developed procedure. The data used for procedure validation were resistance experimental resistance data for hulls W-10, W-11, and W-12, as presented in Claytor, et al. (1956). In addition, to evaluate the improvement in the predicting accuracy of this newly developed procedure for hulls based on the data for the Ridgely-Nevitt series, comparisons were also performed against the predictions of the current computational procedures of the software based on Holtrop and Van Oortmerssen methods.

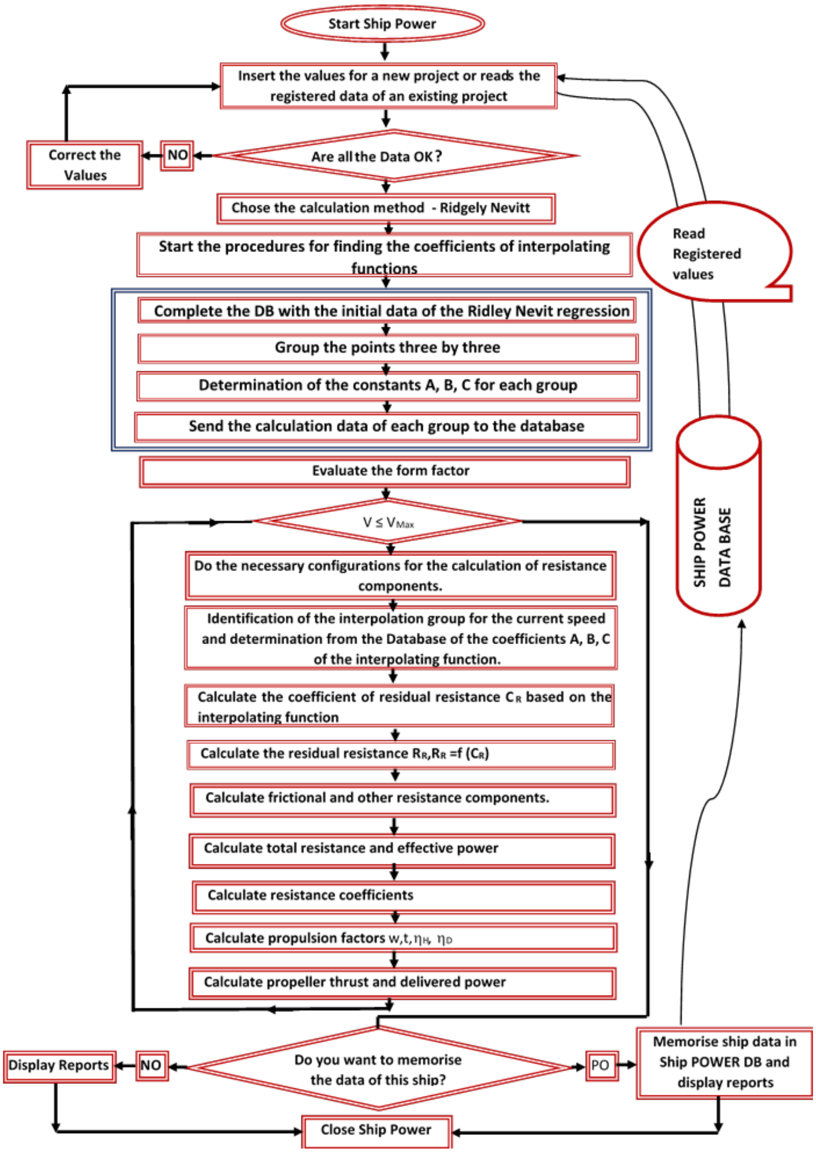

Figure 3. Algorithm of the procedure of "Ship Power V 1.0" based on the Ridgely-Nevitt regression.

3. RESULTS

The coding of algorithms presented in Figures 1, 2, and 3 has resulted in the development of a new operational procedure for the "Ship Power V 1.0" software, called the Ridgely-Nevitt procedure. The new procedure was developed using the same calculation report structure as in the current procedures of the software. The procedure can be activated through the graphical user interfaces in the software and enables resistance predictions based on the Ridgely-Nevitt regression.

As previously highlighted, the newly developed procedure was tested on three hulls from the Ridgely-Nevitt series. To compare the performance of this new procedure not only compared to experimental data but also compared to predictions outputs of other software procedures, resistance towing tank data, and predictions outputs of other software procedures (procedures based on Holtrop and Van Oortmerssen methods) as presented in Xhaferaj (2022) were used. All the three hulls from the Ridgely-Nevitt series were analyzed using the procedure based on the Ridgely-Nevitt regression for the same speeds as in Xhaferaj (2022), corresponding to speed-length ratios $V/\sqrt{L}$ of 0.60, 0.67, 0.74, 0.81, 0.87, 0.94, 1.01, 1.07, 1.14, 1.21, 1.28, 1.34, 1.41, 1.48, and 1.51. Results of procedure predictions based on the Ridgely-Nevitt regression obtained from the analysis of the three hulls are given in Table 1. Table 1 also gives calculation deviations in percentages, obtained by the procedure based on the Ridgely-Nevitt regression compared to experimental data on resistance, as presented in Claytor et al. (1956).

Speed-Length ratio $V/\sqrt{L}$	Froude Number FN	Hull W-10		Hull W-11		Hull W-12	
		R_T (N)	Dif %	R_T (N)	Dif %	R_T (N)	Dif %
0.60	0.18	4186	13.8	5918	0.8	-	-
0.67	0.20	5048	8.3	7376	-0.2	8770	3.8
0.74	0.22	6080	5.4	9173	-1.0	10624	-2.5
0.81	0.24	7358	3.7	11437	2.0	13052	-0.9
0.87	0.25	8963	3.9	14296	3.5	16259	-1.2
0.94	0.27	12143	6.8	19319	3.2	21485	-4.1
1.01	0.29	16443	-0.1	26392	-2.2	28679	-4.7
1.07	0.31	20909	2.2	34667	-2.9	37332	-3.9
1.14	0.33	24190	1.3	42236	-2.4	47022	-1.9
1.21	0.35	28487	1.0	52269	-0.9	60464	-0.9
1.28	0.37	35454	-0.5	67314	-2.6	80007	-3.7
1.34	0.39	47260	0.1	94864	-0.3	114217	-3.7
1.41	0.41	64019	1.0	135930	-0.3	164341	-5.4
1.48	0.43	85716	0.7	189466	-1.6	229134	-7.0
1.51	0.44	98468	-0.1	-	-	-	-

Table 1. Calculation deviations obtained by procedure based on the Ridgeley-Nevitt regression compared to resistance data.

Evaluations obtained from the procedure based on the Ridgely-Nevitt regression, presented in Table 1, and resistance test data as presented in Claytor et al. (1956), were used to graphically represent and compare prediction results, as a function of the Froude Number, as presented in figure 4. Figure 5 gives relative calculation deviations between the procedure based on the Ridgely-Nevitt regression and resistance data for all hulls of the Ridgely-Nevitt series concerned. All graphs presented in Figure 5 are constructed for speeds, and Froude Numbers that correspond to the values of the speed-length ratios within the eligible interval of the applicability of the Ridgely-Nevitt regression.

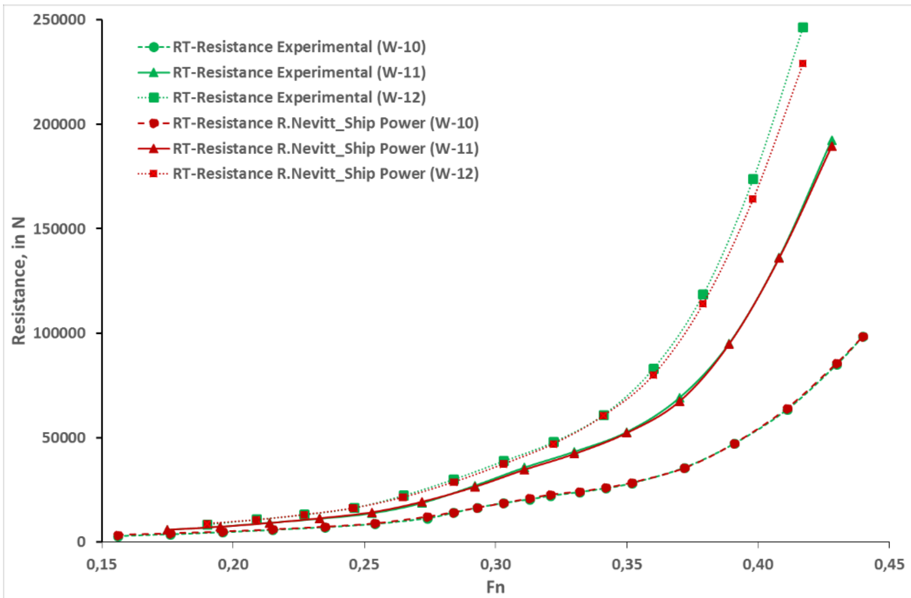

Figure 4. Predictions obtained through procedure based on the Ridgely-Nevitt regression for the hulls concerned.

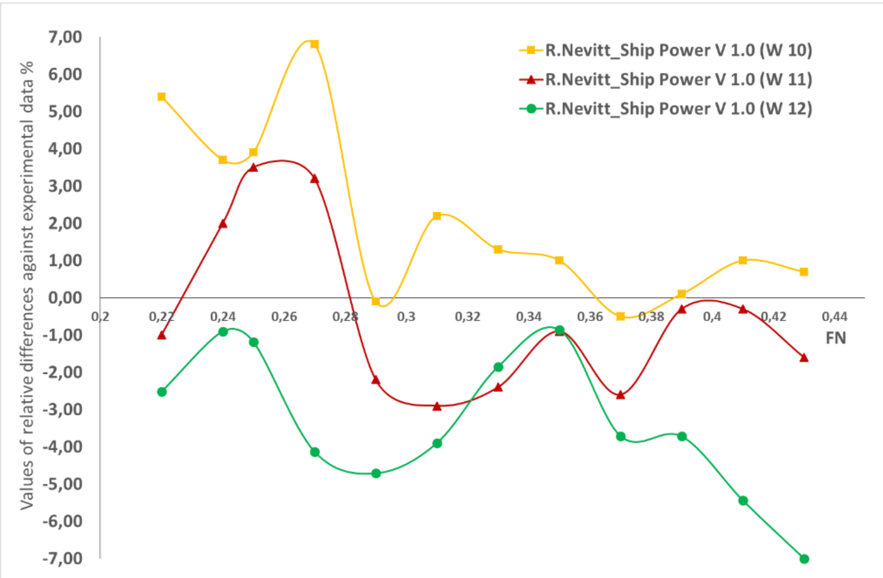

Figure 5. Relative deviations of the procedure based on the Ridgely-Nevitt regression from resistance towing tank data, for the hulls concerned.

A comparative analysis of calculation results was also carried out to evaluate and compare the predicting accuracy of the newly developed procedure with other procedures of the software. Predictions procedure results, based on Holtrop and Van Oortmerssen methods, for all hulls from the Ridgely-Nevitt series, as presented in Xhaferaj (2022), were taken into consideration. Table 2 shows absolute percentage deviation values relating to experimental values and the mean absolute percentage error (MAPE) of computational procedures based on the Ridgely-Nevitt regression for the hulls concerned. The mean absolute percentage error (MAPE) is usually used to evaluate the predicting accuracy of regression models (Moreno et al., 2013; Myttenaere et al., 2016). MAPE values below 10 indicate highly accurate predictions, MAPE values between 10 and 20 indicate good predicting accuracy, while MAPE values between 20 and 50 indicate reasonable predicting accuracy, and MAPE values greater than 50 indicate inaccurate predictions (Moreno et al., 2013).

The MAPE values are calculated as follows: (Khair et al., 2017)

$$MAPE = \frac{\sum \frac{|y_1 - y_t'|}{y_1}}{n} 100 \quad (\%) \tag{6}$$

where:

- y_1 – experimental resistance data
- y_t' – predicted resistance obtained using computational procedures of the software
- n – number of predictions.

MAPE value presented in Table 2 is calculated for the entire interval of the speed-length ratios in Table 1, for all three hulls concerned. As stated previously, there are some speed values whose corresponding speed-length ratio values fall outside the eligible range of the applicability of the Ridgely-Nevitt regression. The calculated MAPE values, excluding the values of absolute deviations for velocities that correspond to speed-length ratios outside the interval [0.7 - 1.5], for hulls W-10, W-11, and W-12 were found to be, respectively, 2.22, 1.91, and 3.33. MAPE value was also calculated for predictions results obtained from other procedures of the "Ship Power V 1.0" software, as presented in Xhaferaj (2022). The calculated MAPE values of the procedure based on the Holtrop method calculated in the same field of speeds for the hulls considered were 3.68, 7.77, and 7.43, respectively. MAPE values of the procedure based on the Van Oortmerssen method calculated in the same field of speeds for the hulls concerned were 5.51, 9.88, and 11.60, respectively.

Relative deviation values given in Table 1 are grouped as in Table 3. Table 3 results highlight the intervals of Froude Numbers and speed-length ratios for which predictions based on the Ridgely-Nevitt procedure overestimated or underestimated experimental data. Froude Number intervals and speed-length ratios given in Table 3 have been selected to represent ranges for which two or more consecutive predictions based on the Ridgely-Nevitt regression overestimated or underestimated experimental data. Positive values presented in columns "range of relative differences" and "average value of relative differences" mean that in the corresponding Froude Number intervals and speed-length ratios, the predictions based on the Ridgely-Nevitt regression overestimated experimental resistance data. Negative values mean that in the corresponding Froude Number intervals and speed-length ratios, the predictions based on the Ridgely-Nevitt regression underestimated experimental resistance data.

Speed-Length ratio $V/\sqrt{L}$	Absolute deviation (%) "Hull W-10"	Absolute deviation (%) "Hull W-11"	Absolute deviation (%) "Hull W-12"	Froude Number FN
0.60	13.8	0.8	-	0.18
0.67	8.3	0.2	3.8	0.20
0.74	5.4	1.0	2.5	0.22
0.81	3.7	2.0	0.9	0.24
0.87	3.9	3.5	1.2	0.25
0.94	6.8	3.2	4.1	0.27
1.01	0.1	2.2	4.7	0.29
1.07	2.2	2.9	3.9	0.31
1.14	1.3	2.4	1.9	0.33
1.21	1.0	0.9	0.9	0.35
1.28	0.5	2.6	3.7	0.37
1.34	0.1	0.3	3.7	0.39
1.41	1.0	0.3	5.4	0.41
1.48	0.7	1.6	7	0.43
1.51	0.1	-	-	0.44
MAPE Value	3.26	1.71	3.36	-

Table 2. Absolute percentage errors (deviations) of the computational procedures based on the Ridgely-Nevit regression and MAPE values for the hulls concerned.

	Intervals of Froude Numbers	Intervals of speed length ratios, $V/\sqrt{L}$	Range of relative differences	The average value of relative differences
Hull W-10	[0.22 - 0.28]	[0.74 - 0.97]	[+1.7% - +6.8%]	+ 4.3%
	[0.30 - 0.35]	[1.04 - 1.21]	[+1.0% - +2.2%]	+1.7%
	[0.39 - 0.43]	[1.34 - 1.48]	[+0.1% - +1.0%]	+0.6%
Hull W-11	[0.24 - 0.27]	[0.806 - 0.94]	[+2.0% - +3.5%]	+2.9%
	[0.29 - 0.41]	[1.007 - 1.41]	[-0.3% - -2.9%]	-1.6%
Hull W-12	[0.22 - 0.43]	[0.74 - 1.48]	[-0.9% - -7%]	-3.3%

Table 3. Froude Number intervals and speed-length ratios for which the predictions based on the Ridgely-Nevitt regression overestimated or underestimated experimental data.

4. DISCUSSION

The first impression from the graphical representations of prediction results of the "Ship Power V 1.0" procedure based on the Ridgely-Nevitt regression presented in Figure 4, and the respective comparisons with resistance test data for hulls from the Ridgely-Nevitt series, is that the correspondence between prediction results and experimental data is very high.

Based on the results presented in Table 2 for W-10 hull, the mean absolute percentage error (MAPE) calculated for the entire interval of Froude Numbers 0.18 ≤Fn≤ 0.44, corresponding to speed-length ratio values 0.6 $\leq V/\sqrt{L} \leq$ 1.51, is 3.26. MAPE value calculated within the eligible values of applicability of the Ridgely-Nevitt regression, corresponding to speed-length ratio values 0.74 $\leq V/\sqrt{L} \leq$ 1.48 and Froude numbers $0.22 \leq F_n \leq 0.43$, is 2.23. MAPE values of 3.26 and 2.23, calculated respectively within the entire interval of Froude numbers, and within the eligible values for the applicability of the Ridgely-Nevitt regression, are a clear indicator that the "Ship Power V 1.0" software procedure based on the Ridgely-Nevitt regression has performed extremely well compared to experimental resistance data. The maximum deviation from experimental data in the speed-length ratio interval $V/\sqrt{L} = 0.7 - 1.5$, which is the eligible range of applicability of the Ridgely-Nevitt regression, is 6.8 %, and was registered for the 0.94 speed-length ratio. The highest values of deviations from experimental data were registered for velocities corresponding to speed-length ratio values of 0.60, and 0.67, which are both outside the eligible range of applicability of the Ridgely-Nevitt regression. Results in Tables 1 and 3 show that the procedure generally overestimates experimental data. Minor and irrelevant underestimations (-0.1 %, -0.5 %, -0.1 %) were registered in only three cases. Results in Table 3 also prove that the Ridgely-Nevitt procedure of the "Ship Power V 1.0" software has high prediction accuracy across the entire Froude Number range. For this hull form, the results of the study also showed that the Ridgely-Nevitt procedure has higher prediction accuracy than the "Ship Power V 1.0" procedures based on the Holtrop and Van Ortmerssen methods.

Based on Table 2 results for the W-11 hull, the mean absolute percentage error (MAPE) calculated in the Froude number interval 0.18 ≤Fn≤ 0.43, corresponding to the speed-length ratio of 0.6 $\leq V/\sqrt{L} \leq$ 1.48, is 1.71. MAPE value calculated within the eligible values of applicability of the Ridgely-Nevitt regression, corresponding to the speed-length ratio 0.74 $\leq V/\sqrt{L} \leq$ 1.48 and Froude numbers $0.22 \leq F_n \leq 0.43$, is 1.91. MAPE values of 1.71 and 1.91, calculated respectively across the entire Froude number interval, and within the eligible values of the applicability of the Ridgely-Nevitt regression, are a clear indicator that the computational procedure of the "Ship Power V 1.0" software based on Ridgely-Nevitt regression has shown excellent performances compared to experimental resistance data. The maximum deviation from experimental data in the speed-length ratio interval $V/\sqrt{L} = 0.7 - 1.5$, which is the eligible range of applicability of the Ridgely-Nevitt regression, is 3.5 %, and was registered for the speed-length ratio of 0.87. Results given in Tables 1, and 3 show that, across the range of applicability of the Ridgely-Nevitt regression, calculations gave overestimated predictions for speed-length ratios under 0.94, underestimated predictions for speed length ratios of 0.94-1.48. Also in the case of this hull form, the results of the study showed that the procedure based on the Ridgely-Nevitt regression has higher prediction accuracy than "Ship Power V 1.0" procedures based on the Holtrop and Van Ortmerssen methods.

Based on the results of Table 2 for the W-12 hull, the mean absolute percentage error (MAPE) calculated in the Froude number interval 0.20 ≤Fn≤ 0.43, corresponding to the speed-length ratio of 0.67 $\leq V/\sqrt{L} \leq$ 1.48, is 3.36. MAPE value calculated within the eligible values of applicability of the Ridgely-Nevitt regression, corresponding to the speed-length ratio 0.74 $\leq V/\sqrt{L} \leq$ 1.48 and Froude numbers $0.22 \leq F_n \leq 0.43$, is 3.33. MAPE values of 3.36 and 3.33, calculated respectively across the entire Froude number interval, and within the eligible values of the applicability of the Ridgely-Nevitt regression, are a clear indicator that the computational procedure of the "Ship Power V 1.0" software based on Ridgely-Nevitt regression has shown excellent performances compared to experimental resistance data. The maximum deviation from experimental data in the speed-length ratio interval $V/\sqrt{L} = 0.7 - 1.5$, which is the eligible range of applicability of the Ridgely-Nevitt regression, is -7 %, and was registered for the speed-length ratio of 1.48. Results given in Tables 1, and 3 show that the procedure underestimates experimental data, within the entire range of speed-length ratios considered eligible for the applicability of the Ridgely-Nevitt regression. Even in the case of this model, the results showed that the "Ship

Power V 1.0" procedure based on the Ridgely-Nevitt regression has better prediction accuracy than procedures based on the Holtrop and Van Ortmerssen methods.

In quantitative terms, the findings and discussion in this section have highlighted that for all three analyzed hulls from the Ridgely-Nevitt fishing vessel series, prediction results obtained through this procedure had MAPE under 4%, indicative of very high predicting accuracy. Compared to the calculation results of other computational procedures of the software, based on MAPE values calculated across the entire Froude number range and relative differences calculated for different sub-ranges of Froude numbers, the "Ship Power V 1.0" procedure based on the Ridgely-Nevitt regression showed substantial improvements in predictive accuracy compared to the procedures based on the Holtrop and Van Oortmerssen methods performed on the same hulls from the Ridgely-Nevitt series.

In contrast to other computational procedures of the software, which apply to a wide range of ship types, the newly developed procedure applies only to trawlers from the Ridgely-Nevitt series. The results of this study show that the developed design tool can be used with the same reliability as the resistance data and regression model of the Ridgely-Nevitt series, avoiding tedious and long manual procedures without compromising the prediction accuracy. In addition, the tool can be used not only for speeds corresponding to the speed-length ratios reported in the resistance charts for the series and their regression model but for any speed determined by the user and design requirements. Although software outputs have not shown high resistance prediction overestimations or underestimations, study results may be used as a reference point to correct the results of software outputs in some Froude Number intervals. These results can be used for any software output corrections, providing the hull analyzed by “Ship Power V 1.0” has the same or similar characteristics to W-10, W-11, and W-12 hulls from the Ridgely-Nevitt trawler series. The procedure can be used as an effective tool and an alternative to the systematic series method for resistance and power prediction. In conclusion, this procedure is a powerful tool for predicting resistance and power if used for resistance and power predictions of hulls derived from models from the Ridgely-Nevitt fishing vessels series.

5. CONCLUSIONS

The study presented the conceptualization of a new computational procedure developed in the "Ship Power V 1.0" software. The newly developed procedure was based on the Ridgely-Nevitt resistance regression and allows the evaluation of resistance and power at different speeds, without any limitation on the number of speeds within the limits of the acceptable speed-length ratio values. The predicting accuracy of this newly developed procedure was analyzed not only against resistance towing tank data but also against the predictions results of other procedures of the software for three hulls from the Ridgely-Nevitt series. Study results have shown this procedure to give highly accurate predictions against the experimental resistance data for all analyzed models from the Ridgely-Nevitt series. In addition, based on MAPE values (mean absolute percentage error), the comparative analysis with the results of other computational procedures of “Ship Power V 1.0” (Holtrop and Van Oortmerssen) has shown a substantial improvement in the predictions for all hulls of the Ridgely-Nevitt series concerned. Detailed conclusions based on the results of this study are presented below:

- The results of the comparative analysis of the predictions of the computational procedure based on the Ridgely-Nevitt regression and experimental data for the W-10, W-11, and W-12 hulls have shown mean absolute percentage error (MAPE) values of 3.26, 1.71, and 3.36, respectively, calculated across the entire Froude number range. In case of Froude numbers corresponding to the allowed speed-length ratio range ($V/\sqrt{L} = 0.7 - 1.5$), the respective MAPE values for the W-10, W-11, and W-12 hulls were 2.23, 1.91, and 3.33. For all the analyzed hulls, the value of (MAPE) under 4% indicates highly accurate predictions.

- Results of this study have also shown that the newly developed procedure performed very well across the entire range of speeds, for all hulls analyzed, i.e. that its predictive accuracy is sustainable.
- MAPE value calculation results for the computational procedure based on the Holtrop method, for the W-10, W-11, and W-12 hulls, have shown that the procedure based on the Ridgely-Nevitt regression improved resistance predictions, reducing MAPE values by 0.42%, 6.06%, and 4.07%, respectively.
- MAPE value calculation results for the computational procedure based on the Van Oortmerssen method, for the W-10, W-11, and W-12 hulls, have shown that the procedure based on the Ridgely-Nevitt regression improved resistance predictions, reducing MAPE values by 1.95%, 8.17%, and 8.24%.

The results of this study have proved that the “Ship Power V 1.0” procedure based on the Ridgely-Nevitt regression can be used with high reliability for resistance predictions for hulls designed based on models belonging to the Ridgely-Nevitt series.

Future Work: Additional research and future studies are required to determine the accuracy of predictions for hulls differing from those of the Ridgely-Nevitt trawlers series by form and characteristics.

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