Comparative Study of Ship Resistance between Model Test and Empirical Calculation of 60 GT Fishing Vessel

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Abstract: ***The main objective of this paper is to study and research on the ship resistance for 21.98 m single screw fishing vessel. The ship resistance is normally determined by using model test in a towing tank . However it can also be predicted by using, empirical formula or statistical data. Prediction in the preliminary design stage is one of the important practice and research in ship design. Several methods can be used in the ship resistance prediction depends on the type of the ship and the limitation of the methods. Consequently using existing method, the resistance of 21.98 m fishing vessel will be investigated. A prediction for fishing vessel resistance, van Oortmersen method shows the same result with model test result. The rest method compromises with model test can be used for calculating resistance of fishing vessel. Naval architecture task is to ensure that, within the bounds of the other design requirement, the hull form design of propulsion and the procedure will be the most efficient in terms of hydrodynamics. The final test of the ship will perform at the required speed with minimum of shaft power, and the problem is to achieve the best combination of low resistance and high efficiency propulsive. In general, this can only be achieved by matching precisely the hull and propeller***

Keywords: comparitive, resistance, empirical, model-test

1. Introduction

In general, the basic contractual obligations are placed on the dock that ship must reach or achieved a certain speed with particular strength in the good weather on trial and for this reason smooth water performance or calm water is very important.

Predicting the resistance of vessel is very fundamental topics of interest to naval architects. Hydrodynamic's been interested in determining the laws of physics related to the ship resistance and speed characteristic. Due to the complicated nature of flow around the ship hull, a satisfactory analytical method relating speed and powering requirement to hull form has not yet been developed.

Generally, there are many methods can be used to determine the ship's resistance.

According to Harvald (1983), these methods can be divided into four groups which namely:
1) Model experiments
2) Standard series of experiments
3) Statistical methods
4) Diagrams

Model testing is still the most accurate and reliable method but the others may only be used to predict ship resistance between certain limits or only for a ship that comparative data on these groups to forecast. Have similar particulars to such Group.

For the purpose of this study, only three methods of ship resistance prediction will be discussed in connection with the four groups are shown above. These methods are:

1) Van Oortmersen's method
2) Holtrop's and Mennen method
3) DESP
3) Model Test

Van Oortmersen's method [1]

This method is useful for estimating the resistance of small ships such as trawlers and tugs. In this method, the derivation of formula by G. Van Ootmerssen (1971) is based on the resistance and propulsion of a ship as a function of the Froude number and Reynolds number. The constraint of this formula is also based on other general parameters for small ships such as trawlers and tugs that are collected from random tank data. The method was developed through a regression analysis of data from 93 models of tugs and trawlers obtained by the Mariteme Research Institute, Netherlands (MARIN). Besides, few assumptions were made for predicting resistance and powering of small craft such as follows:

1. According to the Figure 1 there are positive and negative pressure peak distributions for the hull surface. For the ship hull scope, there are high pressure at the bow and stern, while in the middle it becomes a low pressure.

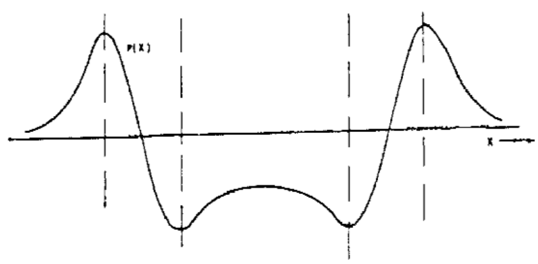

Figure 1: Pressure distribution around a ship hull [1]

2. Small ship can be said to have a certain characteristics such as the absence of a parallel middle body, so the regions of low pressure and the wave system of fore and after shoulder coincide and consequently the pressure distribution is illustrated as in figure 2.

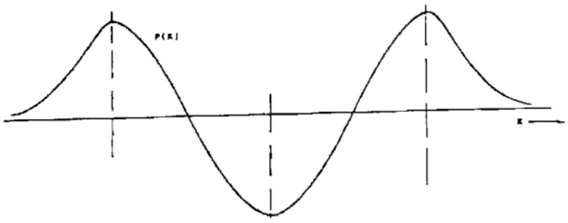

Figure 2: Wave system at fore and aft shoulder [1]

3. The summation of viscous resistance and wave-making resistance representing the components of the total resistance.

Table 1: Limitations for Van Oortmerssen's Method [2]

Parameter	Limitations
Length of water line, LWL	8 to 80 m
Volume, Ñ	5 to 3000 m³
Length/Breadth, L/B	3 to 6.2
Breadth/Draft, B/T	1.9 to 4.0
Prismatic coefficient, CP	0.50 to 0.73
Midship coefficient, Cm	0.70 to 0.97
Longitudinal center of buoyancy, LCB	-7% L to 2.8% L
½ entrance angle, ½ ie	10° to 46°
Speed/length, V/√L	0 to 1.79
Froude number, Fn	0 to 0.50

Van Oortmerssen's suggested that the final form of the resistance equation is represented by the summation of viscous resistance and wave-making resistance as follow:

$$R_T = (c_1 f_1 + c_2 f_2 + c_3 f_3 + c_4 f_4)\Delta + \text{..............(1)}$$
$$(c_f + \Sigma \Delta c_f)0{,}5 \rho V^2 S$$

Usually, the Van Oortmerssen's methods are useful for estimating the resistance of small ships such as trawlers and tugs.

Holtrop's & Mennen's Method [2]

This method is one of the techniques widely used in prediction of resistance of displacement and semi-displacement vessels. Like all methods, however, this technique is limited to a suitable range of hull form parameters. This algorithm is designed for predicting the resistance of tankers, general cargo ships, fishing vessels, tugs, container ships and frigates. The algorithms implements are based upon hydrodynamic theory with coefficients obtained from the regression analysis of the results of 334 ship model tests.

In their approach to establishing their formulas, Holtrop and Mennen [2,3] assumed that the non-dimensional coefficient represents the components of resistance for a hull form. It might be represented by appropriate geometrical parameters, thus enabling each component to be expressed as a non-dimensional function of the sealing and the hull form. The range of parameters of fishing vessel for which the coefficients of the basic expressions are valid is shown as following: max Fn = 0.38, 0.38< Cp < 0.55 , 0.39 < L/B < 6.3 , 2.1< B/T <3.0. This method is only limited to the Froude number below 0.5, (Fn < 0.5) and also valid for TF / LWL > 0.04. There is correlation allowance factor in model ship that will affect some 15% difference in the total resistance and the effective power. This method is also limited to hull form resembling the average ship described by the main dimension and form coefficients used in the method.

DESP [3]

DESP (1992) applies a simple hydrodynamic model for the resistance components according to the form factor method. As to the propellerhull interaction statistical formulas were derived for the wake fraction, the thrust deduction factor and the relative-rotative efficiency. A propeller is preliminary designed by using the Wageningen B-series or Ka-series polynomials. The propeller can be designed either for a fixed speed or for a fixed power. In addition, either the diameter or the rotation rate can be optimised within given constrains. Effects of cavitation on the propulsion, if any, are approximated. Applying DESP for optimising hull forms or hull form details is advised against since the performance effects of various parameters are modelled with limited accuracy.

Model Test

Based on the "Modern MARIN" extrapolation procedure, the friction resistance coefficient formulated by ITTC-1957 must be combined with an allowance (CA) correlation between the model and the ship with the form factor (1 + k) whose magnitude is derived from the results of "PRETEST". The magnitude of the coefficients and form factors are:
CA to extrapolate on ideal trial conditions: 0.00073
Form Factor (1 + k): 1,343
The form factor is derived from the ratio between the total resistance coefficient and the friction resistance coefficient obtained from the results of testing the resistance at a low velocity area. The allowance correlation value reflects the effect of vessel surface roughness and wind resistance arising from ship movements.

2. Methods

The main dimensions and Lines Plan of the 60 GT fishing vessel are presented in table 1 and Figure 1 respectively.

Table 1: Main ship dimension of 60 GT Fishing vessel

Parameter	Value
Length on waterline **Lwl**	21.980 m
Breadth moulded **B**	5.200 m
Depth moulded D	2.300 m
Draught moulded on FP T_F	1.600 m
Draught moulded on AP T_A	1.600 m
Displacement volume moulded Δ	101.756 m³
Mass density of seawater	1025 t/m³
Wetted surface area bare hull S	128.235m²
Wetted surface with appendages **S'**	--
LCB position from AP	9.266 m
Block coefficient C_B	0.455
Midship section coefficient $\mathbf{C_M}$	0.854
Prismatic coefficient $\mathbf{C_P}$	0.621
Length-Breadth ratio **L/B**	4.227
Breadth-Draught ratio **B/T**	3.25

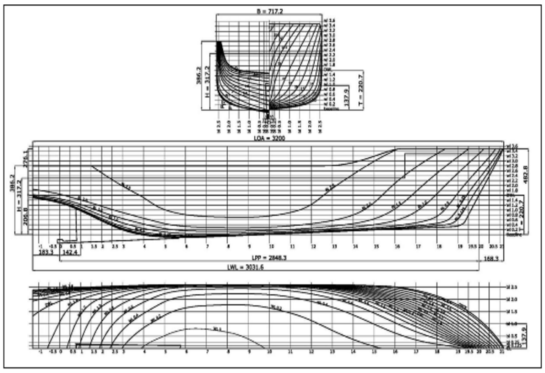

Figure 1: Lines Plan 60 GT Fishing vessel

For model test, a ship model was made with scale 7.25 : 1 and made of wood as presented in figure 2.

The model was tested at the Towing Tank of BTH-BPPT. The resistance test was carried out at full draft condition 1.6 m and towed at various speed of carriage..

The main dimensions of the ship as presented at Table 1, are used as the input parameter for running the DESP program. Based on [1,2], a simple program by Excell was made for predicting the total ship resistance

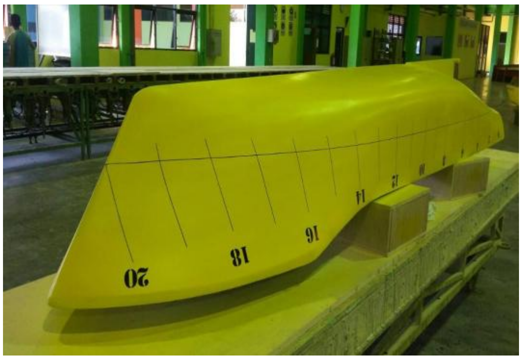

Figure 2: Ship Model 60 GT Fishing vessel

3. Results

As stated above for model test at Towing tank, the results for model testing are presented in Table 2 and Figure 3. Resistance coefficient of the ship can be shown in Figure 4.

Table 2: Resistance model test results

RESULTS OF RESISTANCE EXTRAPOLATION

RESISTANCE TEST KAPAL IKAN 60 GT — DRAUGHT FWD 1.600 M
SHIP MODEL NO. — DRAUGHT AFT 1.600 M

VS KNOTS	VM M/S	RM N	CTM *10^5	CFM *10^5	CRES *10^5	CFS *10^5	CTS *10^5	FD N	RS KN	PE KW	CE
5.0	0.955	5.75	516	364	28	221	398	1.32	1.7	4.5	458
5.5	1.051	7.04	523	357	43	218	409	1.53	2.2	6.1	446
6.0	1.146	8.53	532	351	60	215	423	1.76	2.6	8.2	431
6.5	1.242	10.34	550	346	85	213	443	2.00	3.3	10.9	411
7.0	1.337	12.49	572	341	114	211	470	2.24	4.0	14.4	388
7.5	1.433	15.26	609	337	156	208	509	2.50	5.0	19.2	358
8.0	1.528	19.29	677	333	229	206	580	2.77	6.5	26.6	314
8.5	1.624	24.25	754	329	311	205	659	3.04	8.3	36.2	276
9.0	1.720	29.40	815	326	377	203	723	3.33	10.2	47.2	252
9.5	1.815	35.26	877	323	444	201	787	3.62	12.4	60.4	231
10.0	1.911	42.38	952	320	522	200	864	3.92	15.0	77.3	211
10.5	2.006	50.78	1034	317	608	199	948	4.23	18.2	98.2	192
11.0	2.102	60.65	1126	315	703	197	1041	4.55	21.9	124.0	175

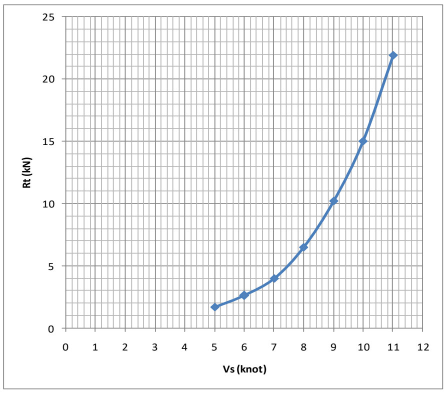

Figure 3: Total resistance of 60 GT Fishing vessel (Model Test method)

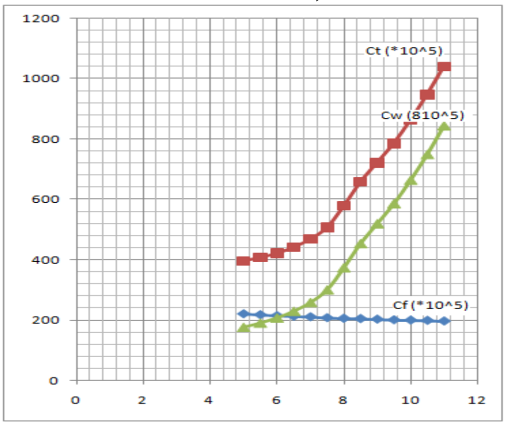

Figure 4: Resistance Coefficient of 60 GT Fishing vessel

The wave profiles at each speed are shown at figure 5. It's very clear that the highest bow wave profile occurs at 9 knot. It means that R-wave significantly increase starting from 8 knot.

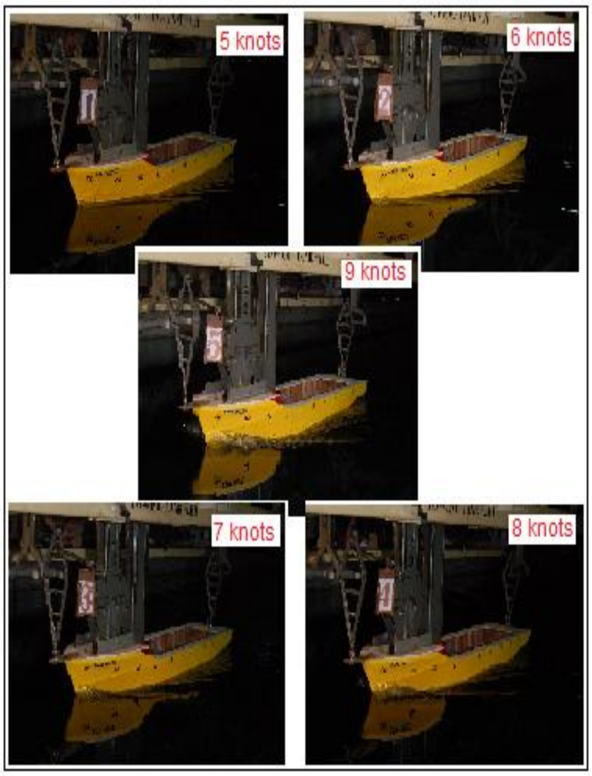

Figure 5: Model testing of 60 GT Fishing vessel at *full load* condition

The resistance results from software (DESP) are presented at Table 3.

Table 3: Running program DESPPC

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Resistance deep water (calm water)
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   VS   R-FRIC  R-WAV  R-BULB  R-TRANS  R-APP  R-ALL   R-TOT
[knots]  [kN]   [kN]    [kN]     [kN]    [kN]   [kN]    [kN]

  5.00   1.0     0.0    0.0      0.1     0.1    0.3     1.8
  5.50   1.1     0.1    0.0      0.0     0.1    0.4     2.2
  6.00   1.3     0.2    0.0      0.0     0.2    0.5     2.6
  6.50   1.6     0.4    0.0      0.0     0.2    0.6     3.2
  7.00   1.8     0.7    0.0      0.0     0.2    0.6     3.9

  7.50   2.0     1.3    0.0      0.0     0.2    0.7     4.9
  8.00   2.3     2.1    0.0      0.0     0.3    0.8     6.2
  8.50   2.6     3.4    0.0      0.0     0.3    1.0     8.1
  9.00   2.9     4.9    0.0      0.0     0.3    1.1    10.0
  9.50   3.2     5.9    0.0      0.0     0.4    1.2    11.6

 10.00   3.5     7.3    0.0      0.0     0.4    1.3    13.6
 10.50   3.8     9.6    0.0      0.0     0.4    1.5    16.5
 11.00   4.2    12.7    0.0      0.0     0.5    1.6    20.2
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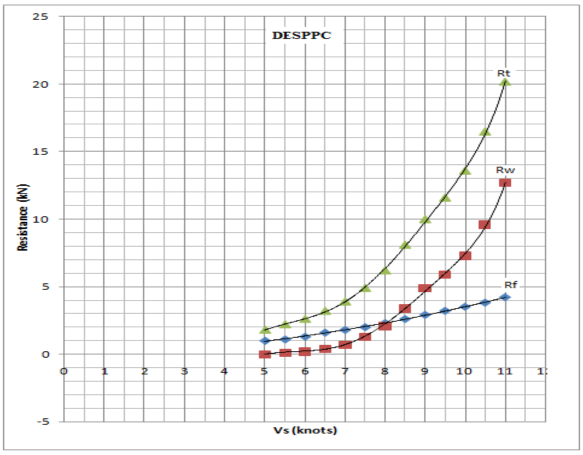

Table 4: Running program Hotrop Mennen method

	v(knots)	5	6	7	8	9	10	11	12
	V(m/s)	2,57385	3,08862	3,60339	4,11816	4,63293	5,1477	5,66247	6,17724
Raynold No.	Rn	4,8253E+07	5,7904E+07	6,7554E+07	7,7205E+07	8,6856E+07	9,6506E+07	1,0616E+08	1,1581E+08
Friction Coeff.	C_F	0,0023	0,0023	0,0022	0,0022	0,0021	0,0021	0,0021	0,0020
Frouda No.	Fn	0,1741	0,2090	0,2438	0,2786	0,3134	0,3483	0,3831	0,4179
	Fnt	5,5273	6,6327	7,7382	8,8436	9,9491	11,0545	12,1600	13,2654
	C_6	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000
	Fni	0,6300	0,7463	0,8579	0,9643	1,0652	1,1607	1,2505	1,3347
Appendage Resistance	Rapp(N)	0,1427	0,1998	0,2658	0,3403	0,4234	0,5147	0,6143	0,7219
Frictional Resistance	Rf(N)	1,1174	1,5651	2,0816	2,6655	3,3157	4,0311	4,8108	5,6541
Wave Making resistance	Rw(N)	0,0138	0,1066	0,3849	1,5467	3,0240	5,0071	9,5867	17,7424
Addition Press. Resistanceof Immersed transom stern	Rtr(N)	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000
Modelship correlation Resistance	Ra(N)	0,3517	0,5065	0,6894	0,9004	1,1396	1,4069	1,7023	2,0259
Press. Resistance due to bulbous bow	Rb(N)	0,0787	0,0706	0,0633	0,0569	0,0514	0,0467	0,0427	0,0393
Total Resistance	Rt(kN)	1,9409	2,7801	3,9258	6,0744	8,6562	11,8601	17,7757	27,3812

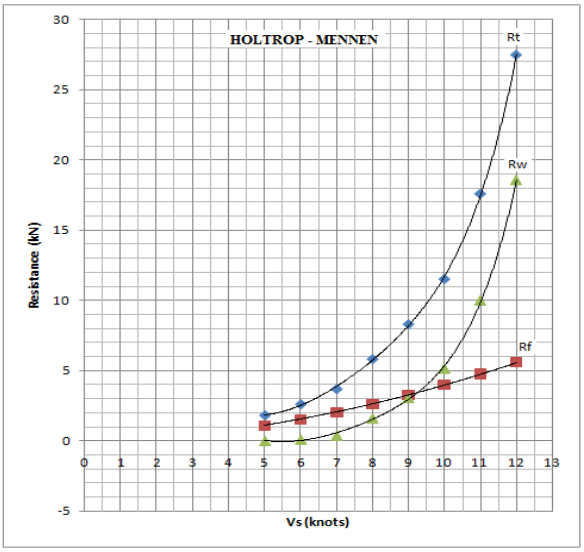

Table 5: Running program van Oortmersen method

V(knot)	Rw (kN)	Rf (kN)	Rt (kN)
5	0,744591	1,23215	1,976741
6	1,092067	1,734744	2,826811
7	1,449471	2,316726	3,766197
8	3,118869	2,978614	6,097483
9	4,760238	3,728594	8,488333
10	8,69784	4,532339	13,23018
11	18,7213	5,424165	24,14547

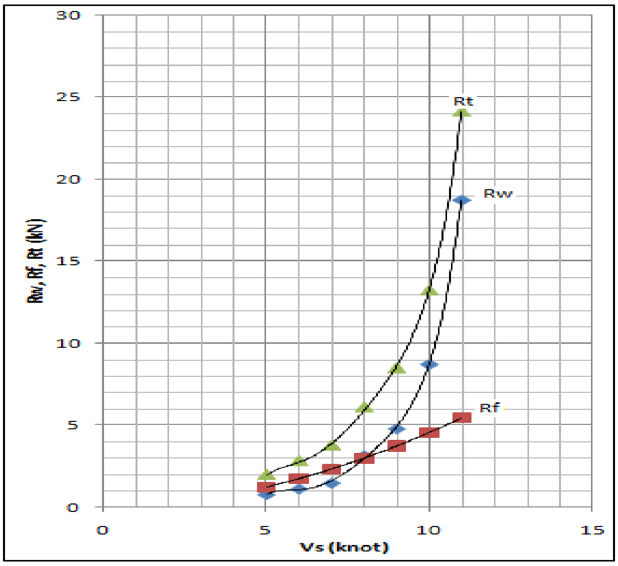

Figure 6: Componen of Resistance prediction by van Oortmersen method

4. Discussion

From the chosen methods, there are parameter on limitation need to be consider before resistance prediction can start. It is because ensure the parameter of the vessel are not out of the range or less than range that will affected accuracy of values and results.

To predict the resistance of a 60 GT fishing vessel by 4 methods to achieve result is still have differences. The results are been plotted to the graph as presented in Figure 7 and Table 6.

The differences of percentage and the accuracy of the method can be shown through the bar graph as below (Figure 8). From this figure shows that all the methods gainned the same result only at the **Froude number (Fn) <0.3** (the ship speed is under 8 knots).

So, limitations of the empirical methods need to be considered, at Froude number (Fn) > 0.3. The all empirical method is clearly different result compared with model test. As shown in figure 8, at the high speed (more than 8 knots), all the empirical results are higher than model test, except from Holtrop-Mennen method.

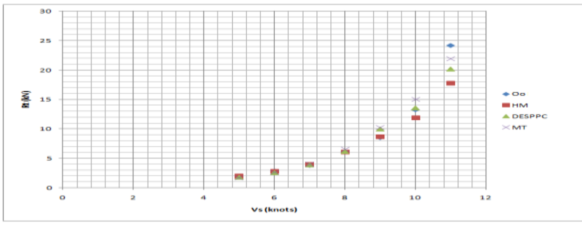

Figure 7: Curves of total resistance according to Model Test, DESP, Holtrop–Mannen, Oortmersen

Table 6: Ship resistance prediction by 4 methods

Vs (knot)	Oo	HM	DESPPC	MT
	Rt (kN)	Rt (kN)	Rt (kN)	Rt (kN)
5	1,976741	1,9409	1,8	1,7
6	2,826811	2,7801	2,6	2,6
7	3,766197	3,9258	3,9	4
8	6,097483	6,0744	6,2	6,5
9	8,488833	8,6562	10	10,2
10	13,23018	11,8601	13,6	15
11	24,14547	17,7757	20,2	21,9

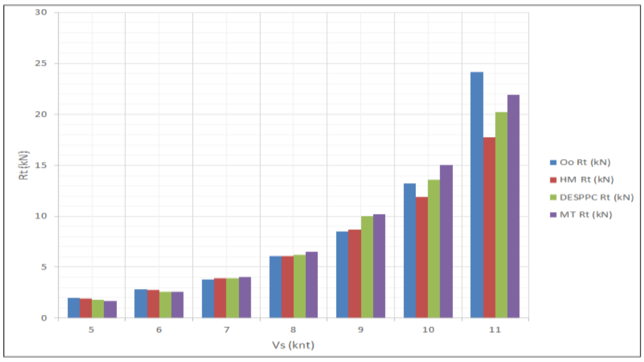

Figure 8: Bar graph, resistance prediction of 60 GRT fishing vessel.

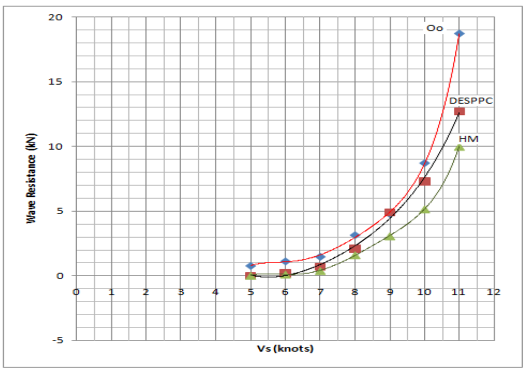

Figure 9: Wave making resistance prediction by three emperical methods.

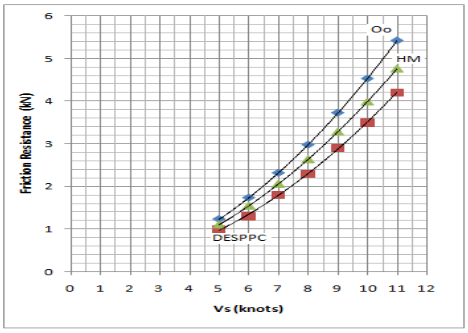

Figure 10: Friction resistance prediction by three emperical methods

Only one method that can be used to calculate the fishing trawler's resistance and that is Van Oortmersen's method. In this case for 28.3 m fishing vessel is not reliable to use calculate the resistance using Holtrop and Mannen method because the vessel parameter are less the range within the limitation. To estimating resistance for the fishing vessel, the Van Oortmesen method is useful for predict the resistance.

Only one method that can be used to calculate the fishing trawler's resistance and that is Van Oortmersen's method. The Holtrop-Manen are not reliable enough due to their formula limitations but it can be used to calculate the resistance of other type of vessels such as frigate and tanker.

This program can be used widely to calculate and predict of ship's resistance and help to calculate the powering requirement of their vessel. Even though there is many reliable software or programs that exist nowadays to calculate and predict the vessel's resistance and powering, this program is also reliable and can be used like other existing and well-known program such as Hullspeed.

This program can calculate the resistance without having the user have to draw or design the shape of the vessel. This program just need main particulars to calculate the resistance and can give the result that almost similar to well-known software.

Therefore, all the factors below are considered to determine the degree of uncertain parameter:

1) Increasing in Froude number which will create a greater residuary resistance (wave making resistance, eddy resistance, breaking waves and shoulder wave) is a common phenomenon in small ships. As a result, errors in total resistance increase, as shown in Fig. 9,
2) Small vessels are easily influenced by environmental condition such as wind and current during operational.
3) For smaller ship, the form size and ship type have a great difference.

5. Conclusion

During prelimanary stages of ship design, the prediction of ship resistance is the main role for predicting powering of the ship. For estimating resistance of the fishing vessel and Froude number of the ship is less than 0.3, the Van Oortmesen method is useful for predicting the resistance. The advantages of this method are simple, easy and very cheap. A simple program by Excell might be made to make a faster process for calculating ship resistance. However, with this method, there are still errors exist for high speed (Fn> 0,3).

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Author Profile

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