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New Optimal Fishing Vessels Design Approach for Power - Speed Prediction

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ABSTRACT

Numerous regression formulae centered on computation of main power and speed are derived from 197 modern existing fishing vessels of length up to 150*m* and presented here under. Optimal methods for the application of these formulae are exemplified using a projected fishing vessel of 100 tonnes deadweight. A power prediction criterion is formulated and used to select the best set out of the three projected main dimensions of this projected vessel, basing on optimum power and speed computation. These formulae can be used for more advanced mathematical, computerized optimization procedure.

1. Introduction

The regression analysis was done using Microsoft Excel program basing on main power and vessel speed and presented in figure 1 to figure 20. The vessels data for the regression taken from Lloyds register of Ships, (Soviet- Trawlers 2016), and (marintimesales 2016) are presented in Table 1 in a short form, while the regression formulas derived from them are collected in Table 3. Regression coefficients range from 0.8 to 0.99 for all the formulae presented. A total of 32 formulae are presented.

The new method of how to utilize these formulae to find the best required power for a comparative design process is presented. This is within the premises of preliminary design before the preliminary machinery weight or Light weight estimation of the vessel. The detailed power estimation based on more advanced hydrodynamics methods (Sugalski, 2014; Kleppestø, 2015; Holtrop, 1984) amongst others is used in the latter stage of vessel design. The result from this method serves to set or select the desired limits for power and speed to be achieved by the latter stage vessel design process.

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Similar works exist (Duru, 1997; Brett Wilson, 1985; Watson, 1989) and (M.F.C. Santerelli, 1982) amongst others, in different perspectives. This work serves as an update as well as a new approach to solve this problem.

2. Methodolgy

The method follows the following exemplified steps:

- In the process for preliminary design presented by the author (Duru, 2016) three optimal main dimensions of projected 1000 *tonnes* deadweight fishing vessel was predicted. These three best comparative designs named A1, A2, A3 options respectively, are shown in row 1 to 6 and column 1 of Table 5, 6, 7, respectively.

- Calculate the power P_1, P_2 , to P_{21} using the 21 respective formulae 1 to 21 give in Table 3, see column 2 of Table 5,6,7 for the three respective designs A1, A2, A3. Then select the average power P_{avg} predicted for each design option

- Calculate v_1 and v_2 using the respective P_{avg} in formula 22 and 23. See v_1 and v_2 of column 3 of Table 5, 6, and 7 respectively.

- Do similarly to above step for v_3 to v_{11} using $P_{(L)}$, $P_{(B)}$, $P_{(D)}$, and $P_{(T)}$ being the average power with respect to the main dimensions, to the corresponding speeds v_3 to v_5, v_6 to v_7, v_8 to v_9, and v_{10} to v_{11} respectively shown in Table 5,6,and 7 for each design option.

- Finally calculate the criterion power P_{crit} requirement based on the power and speed criteria formula V_{crit} which are derived for fishing vessel which has a regression coefficient $R^2 = 0.94185$, equation 33 and 34 respectively presented below as:

$$P_{crit} = 21.093L - 252.624B + 114.128D + 346.970T + 99.622V + 0.0389LBT - 179.014\frac{L}{T} - 891.651\frac{D}{T} - 89.627\frac{B}{T} + 0.1567LBD + 199.031\frac{B}{D} - 533.571\frac{L}{B} + 373.240\frac{L}{D} + 4589.493\frac{F}{D} \tag{33}$$

and,

$$Vcrit = \frac{X}{(-2E-06X^2 + 0.0743X + 9.0269)} \tag{34}$$

with regression coefficient $R^2 = 0.9917$.
where, $X = P_{crit}$ given above in (33).

3. Discussion and Results

The optimal best choice of projected design has to satisfy the following rules with respect to the main power $P_{(Kw)}$ and speed $v_{(Kn)}$:

- A, Power P should be the minimum alternative, but must have a lower value and minimum deviation from the criterion power P_{crit} predicted.

- B, The average v predicted should be higher than then the criterion v. This means that power P is minimized while average speed v is maximized.

The P_{crit}, v_{crit} calculated, for instance, shown in Tables 5, 6, and 7 for three respective projected vessel sample dimensions, are compared with the V_{avg} and P_{avg} as well as the minimum $P_{(kw)}$. The vessel that meets A and B rules is the best vessel and in our example Table 5, 6 and 7 for A1, A2, and A3 options respectively, these are the results:

Taking:

$$\%P_{DEV} = \frac{100 \cdot (P - P_{crit}}{P_{crit}} \tag{35}$$

Where: P_{crit} calculated from equation 33 above, $P_{(Kn)}$ is the design minimum power from column 3 of Table 5, 6, 7. $v_{crit} = v_2$. And $v_{(Kn)}$ is the design v_{avg}

The best option in A2 vessel, A1 is also very good choice. A3 option is no longer in the race.

Table 1: Choosing the optimal design vessel from the final result

	P_{Kw}	$\%P_{DEV}$	V_{Kn}	V_{CRIT}
A1	1135.1	-17.63	13.05	12.03
A2	1274.5	-12.73	12.63	11.99
A3	1701.9	-22.77	13.50	12.08

Further optimization method with respect to stability, and structural weight prognoses could be done between A1 and A2 to choose which one would be the best option.

4. Conclusion

This work has presented 35 regression equations based on 197 data from existing world fishing fleet for the preliminary calculation of main power P and vessel speed V of modern fishing vessels of various types. A new procedure for obtaining optimized value of P and V at the early stage of design is described with an example for main dimensions of three comparative design designated as A1, A2, and A3 for a projected vessel of 1000 *tonnes* deadweight. The approach presented can be used for production of ship design software for optimum preliminary design of ships in respect to main power and speed prediction.

Table 2: List of some of the fishing vessels used in the regression analysis

S/N	Name of vessel	P(kw)	LBP(m)	B(m)	D(m)	T(m)	v(kn)	LBT(m3)	LBD(m3)	B/D	L/B etc
1	”	5215	106	17	10.2	7.32	16.5	13176	18372.6	1.67	6.23
2		1825.3	56.51	15.6	6.85	6.5	14.2	5730	6038.6	2.28	3.62
3		1005.8	45.91	8	4	3.7	12	1359	1469.25	2	5.74
4	VZ10	1095.9	71.18	14	10	6.5	14	6477	9965.22	1.4	5.08
5	JAS10	89.4	8.15	3.4	1.6	1	8	27.71	44.34	2.13	2.4
6	DMX10	335.25	19.02	6.15	6.15	2.5	9	292.4	719.29	1	3.09
7	MHL10	3352.5	93.01	16	9.9	6.8	18	10119	14732	1.62	5.81
8	ASP10	596	28.07	8	6.25	6.07	10	1363	1403.68	1.28	3.51
9	RAU10	800	30.34	8.84	6.4	3.35	11	898.4	1716.38	1.38	3.43
10	DTR10	634.74	49.63	9.8	5	4.14	12	2013	2431.72	1.96	5.06
11	AQUIILA	3874	91.97	17	10.4	5.72	14.6	8944	16260.3	1.63	5.41
12	ATRIA	1280	85	15.6	9.7	5.6	15	7425.6	12862.2	1.61	5.45
13	CARINA	512	80	14.52	9.75	5.25	13	6098	11325.6	1.49	5.51
14	FOKAB	3725	80	14.14	9.75	5.36	14	6063	11029.2	1.45	5.66
			117	17.8	10.2	7.32	16.5	15234	21242.5	1.75	6.57
140	Gorizont										
147	Kerchanin	167.63	22.38	6.49	3.04	2.27	9.5	329.71	441.55	2.13	3.45
148	Kociewie	7375.5	130	20	12.6	7.4	17	19240	32760	1.59	6.5
149	Kronshtadt	1490	79.43	14	10.01	5.61	12.5	6238	11131.3	1.4	5.67
184	Fishing V	223.5	15.26	5.26	2.6	1.83	10.2	146.89	208.7	2.02	2.9
185	Fishing V	171.35	16.7	5.5	2.43	1.6	9.8	146.96	223.2	2.26	3.04
186	Kristall al	7673.5	142	22.2	13.6	7.98	17.2	25140	42872.6	1.63	6.4
187	LF RYB A	234.68	37.98	7.2	3.2	2.1	9.1	574.26	875.06	2.25	5.28
188	MRS-225	167.63	20.97	6	2.67	1.94	9	243.46	335.94	2.25	3.5
189	RB-150	119.2	24	5.5	2.5	1.84	6	242.88	330	2.2	4.36
190	Refrig Sein	167.63	22.4	6.5	3.06	2.36	9.4	343.62	445.54	2.12	3.45
191	Refrig T	167.63	24.6	5.66	2.5	1.93	10	268.73	348.09	2.26	4.35
192	Sola TR27	338.23	26.23	7.5	4	2.85	10.5	560.67	786.9	1.88	3.5
193	RS=150	111.75	24.6	5.5	2.5	1.7	8.5	229.33	338.25	2.2	4.47
194	Storem 4	89.4	16.1	5.2	2.6	2.55	8.5	213.49	217.67	2	3.1
195	Storem 4c	89.4	16.1	5.3	2.6	2.55	8.6	217.59	221.86	2.04	3.04
196	Storem 7	186.25	19.47	5.59	3	2.6	8.8	282.98	326.51	1.86	3.48
197	Sohispan 1	465.63	25.48	7.5	5.39	3.6	10	687.96	1030.03	1.39	3.4

http://www.soviet trawler.narod.ru and http://www.marintimesale.com/dtr10.htm

Figure 1: Power $P(Kw)$ to Length $L(m)$ Regression

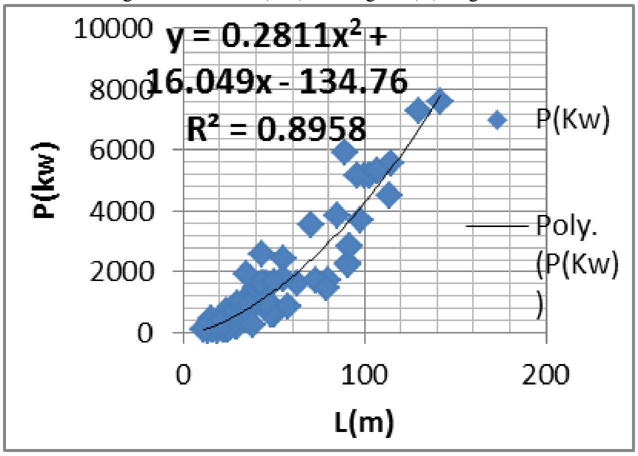

Figure 2: Power-Speed Ratio P/V to Length (m) Regression Formula

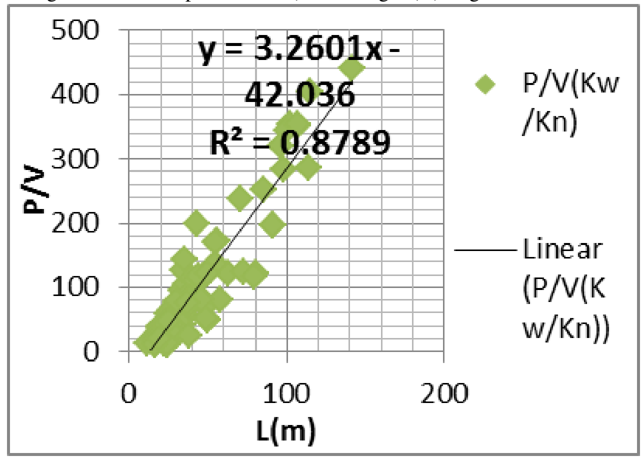

Figure 3: Power(Kw) to $D(m)$, $T(m)$, $B(m)$, $v(m)$ Regression

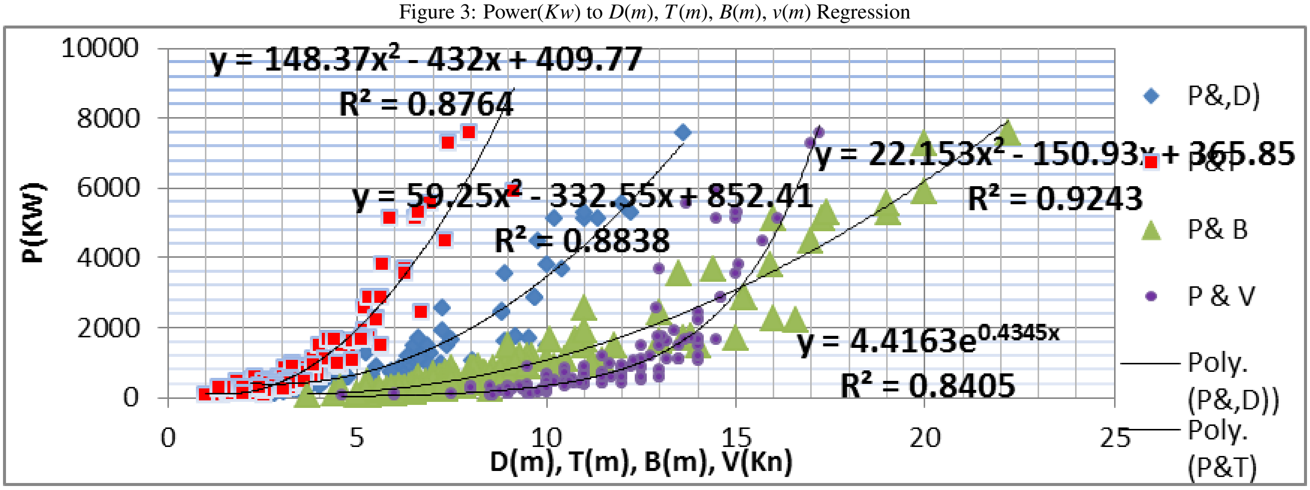

Figure 4: Power-Speed, Draft to length

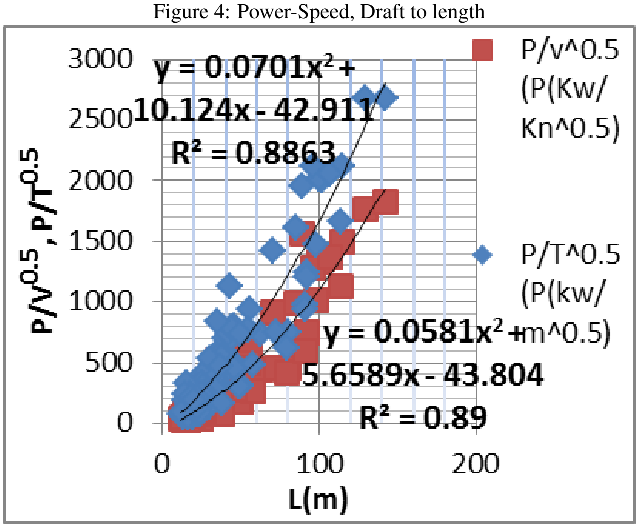

Figure 5: Power to cubic length Regression

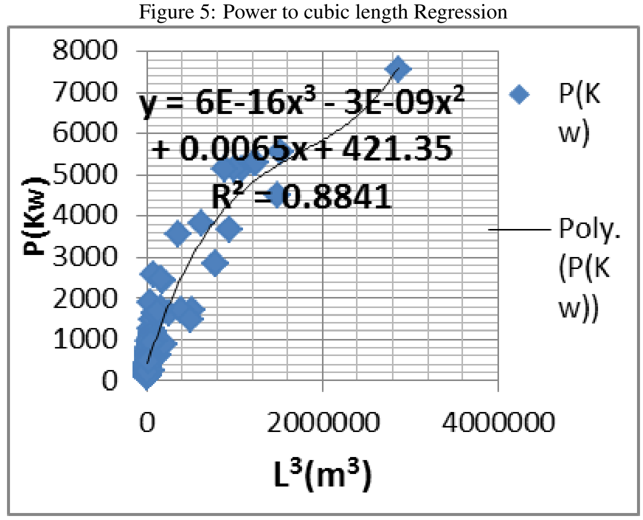

Figure 6: Power-Speed Ratio P/V to P Regression

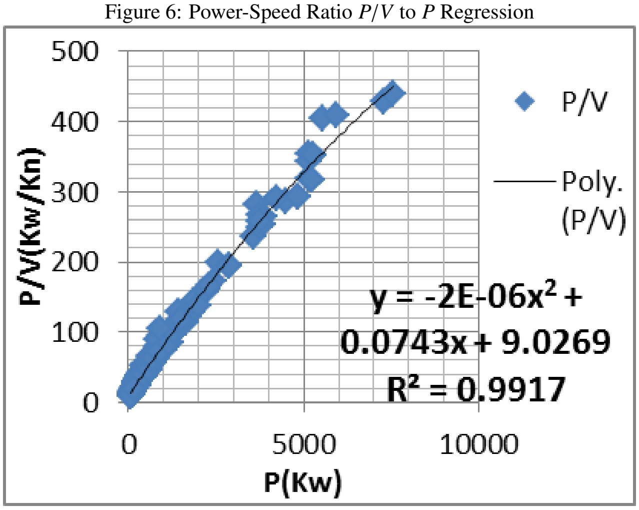

Figure 7: Speed V to Main Power P Regression

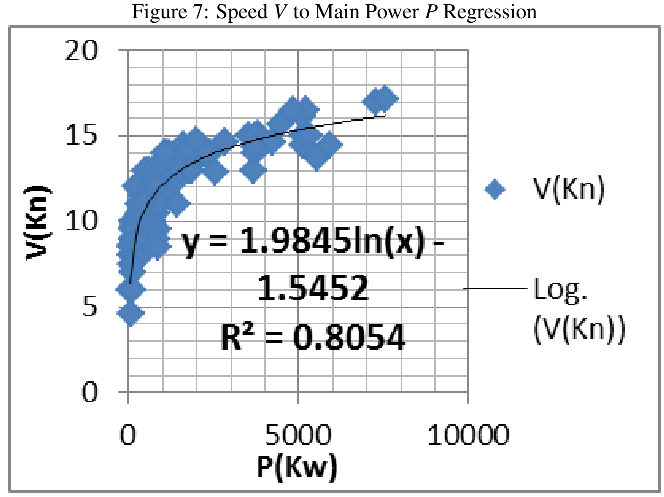

Figure 8: Power $P-D$, B to length Regression

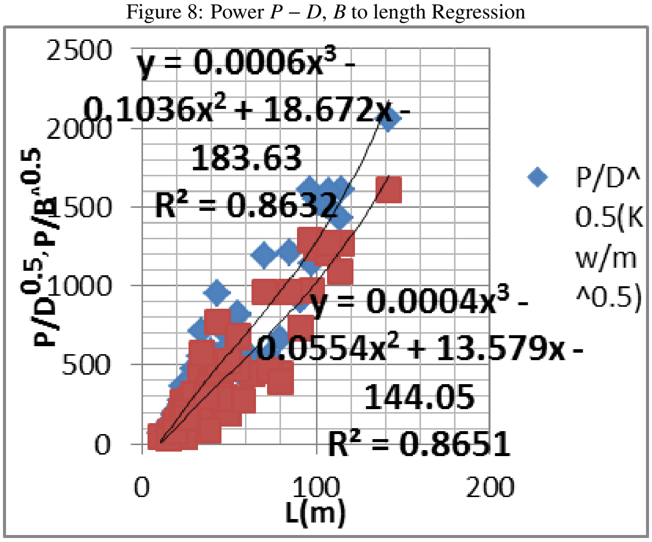

Figure 9: Power $P/BeamB$ to Length $L(m)$ Regression

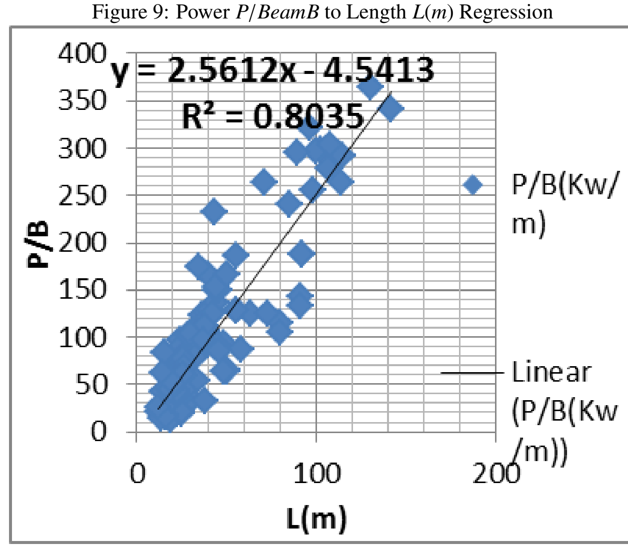

Figure 10: Power P-Draft T, $\sqrt{L}$ to Length L

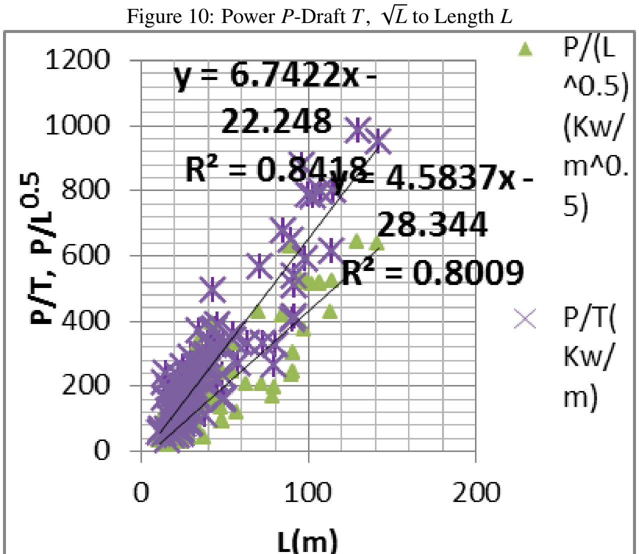

Figure 11: Power $P/V^{4/3}$ to L Regression

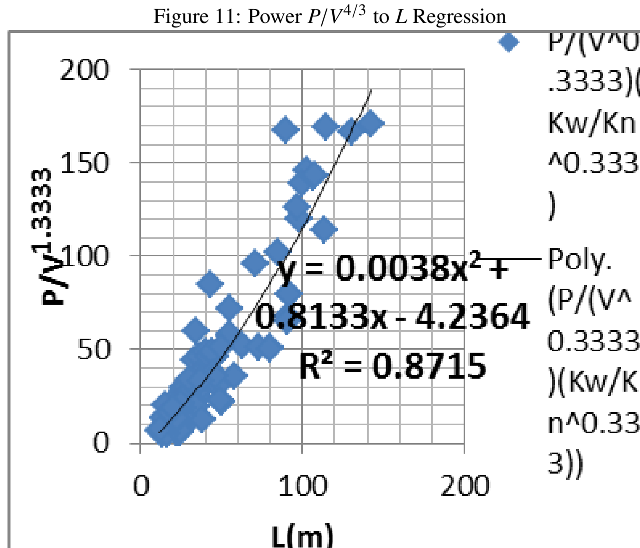

Figure 12: Power P-Draft T, $\sqrt{L}$ to Length L

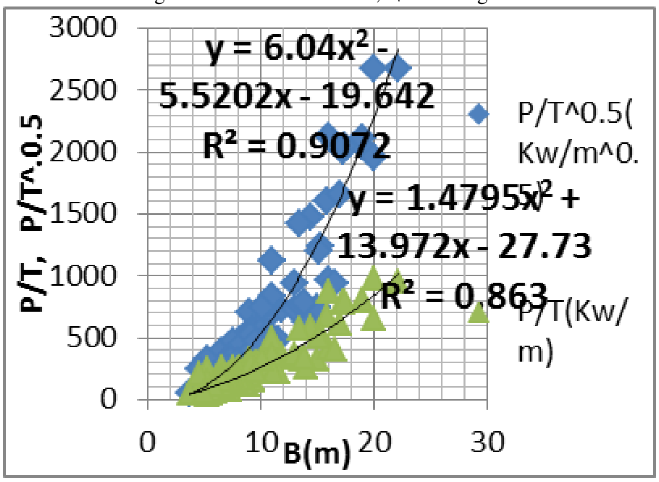

Figure 13: $P/\sqrt{B}$, and $P/\sqrt{T}$ to Beam B Regression

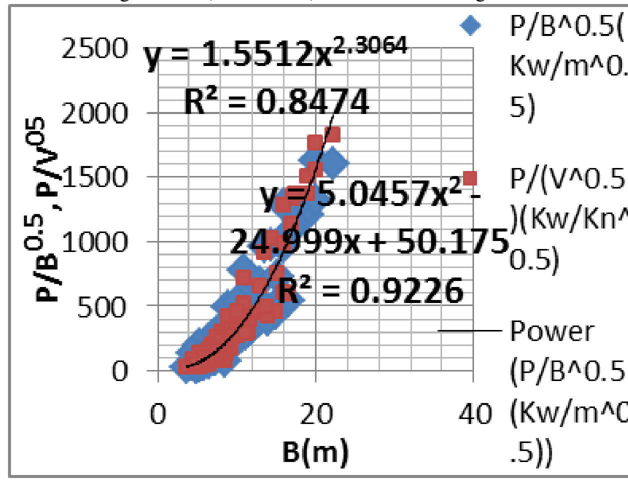

Figure 14: P/B, and $P/\sqrt{L}$ to Beam B Regression

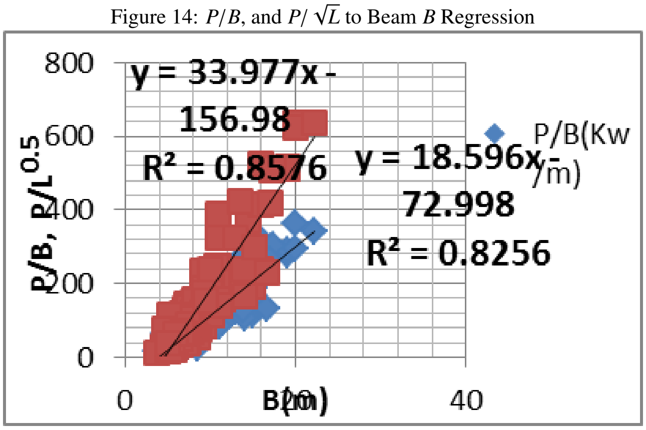

Figure 15: P/v, and $P/\sqrt{B}$ to Beam B Regression

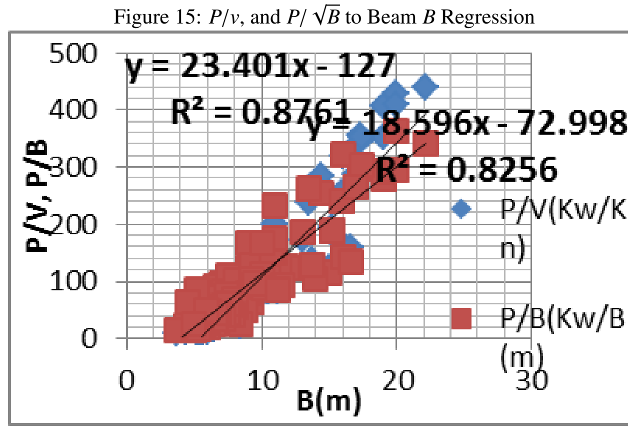

Figure 16: $P/\sqrt{T}$, and $P/\sqrt{V}$ to Beam D Relation

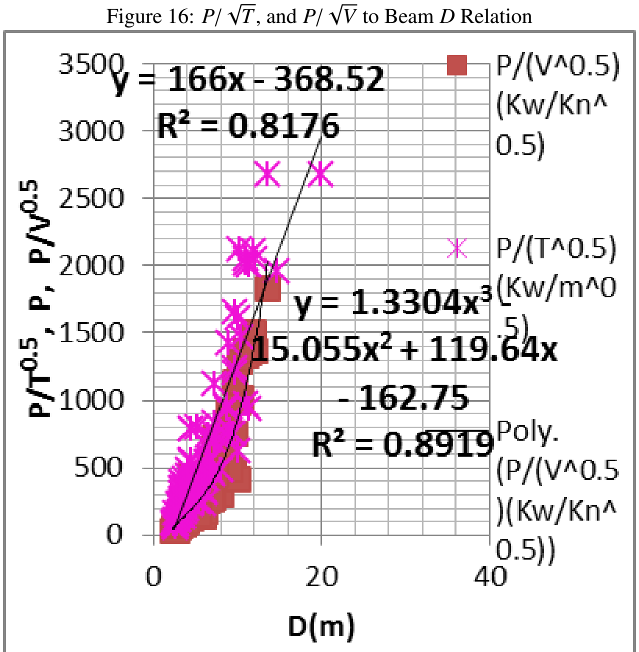

Figure 17: P/v, P/B, and $P/\sqrt{L}$ to Beam D Regression

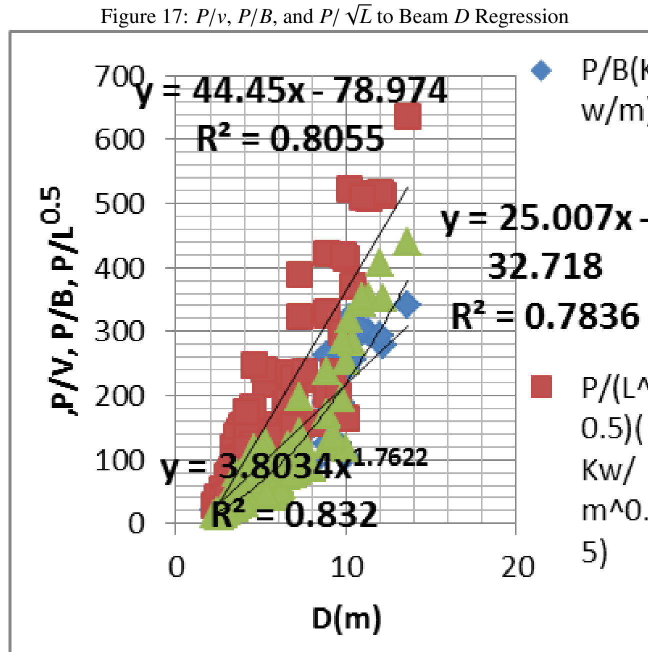

Figure 18: $P/\sqrt{B}$, $P/\sqrt{T}$,and $P/\sqrt{v}$ to Beam T Regression

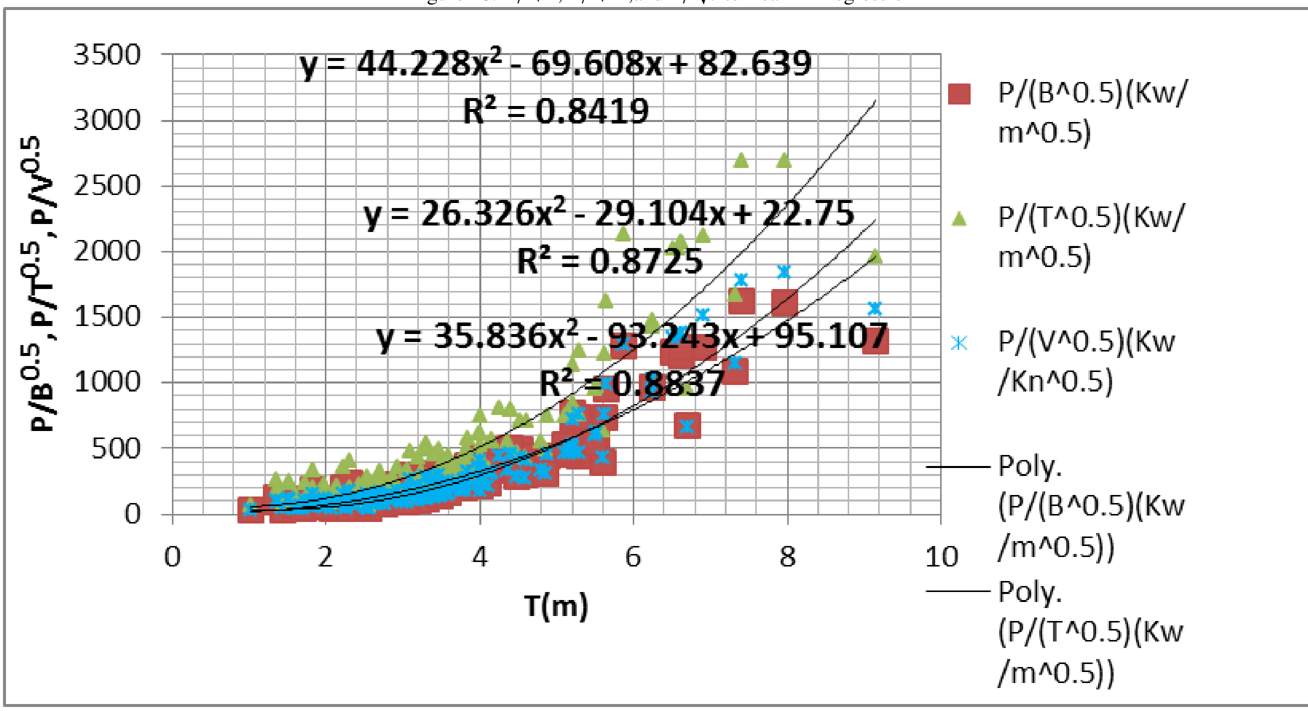

Figure 19: P/v and P/B, to Beam D

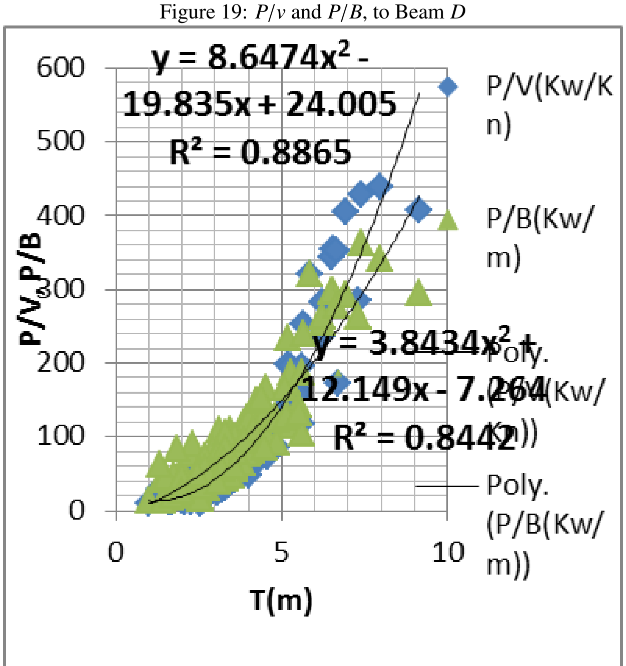

Figure 20: P/B and $P/\sqrt{L}$ to Beam T Regression

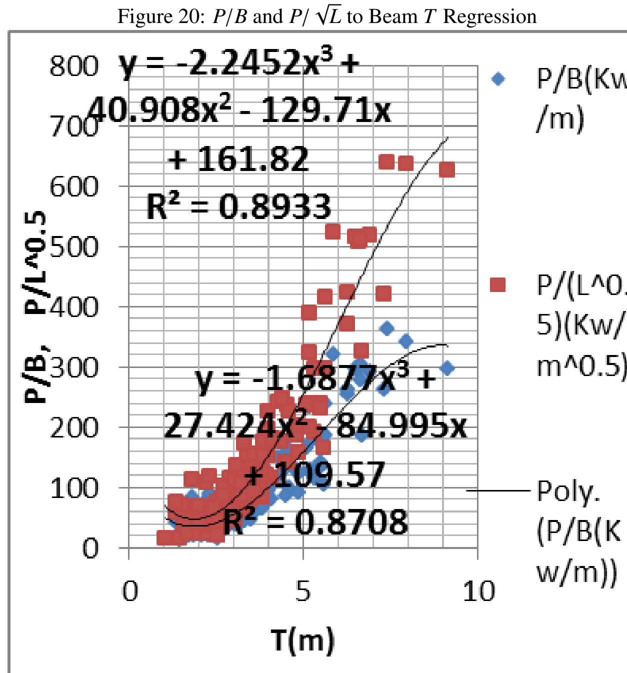

Table 3: Derived regression equation for main power formulas as written in fig 1 to 20

FORMULAR FROM REGRESSION ANALYSIS OF 197 FISHING VESSELS DATA ON MAIN POWER $P(Kw)$

R2 = Square Correlation coefficient.

1, Length L(m) Related Main Power P(Kw) Regression Derived Equations.
Let L = X1, L = Length Between Perpendiculars

$$R2 = 0.896, P1 = 0.2811X12 + 16.049X1 - 138.76 \tag{1}$$
$$R2 = 0.886, P2/T = 0.0701X12 + 10.124X1 - 42.911 \tag{2}$$
$$R2 = 0.884, P3 = 6E - 16X16 - 3E - 09X15 + 0.0065X13 + 421.35 \tag{3}$$
$$R2 = 0.863, P4 = 6E - 16X16 - 3E - 09X15 + 0.0065X13 - 421.35 \tag{4}$$
$$R2 = 0.865, P5 = 0.0004X13 - 0.0554X12 + 13.579X1 - 144.05 \tag{5}$$
$$R2 = 0.842, P6 = 6.7422X1 - 22.248 \tag{6}$$
$$R2 = 0.801, P7/L = 4.5837X1 - 28.344 \tag{7}$$

2. Breadth(moulded) B(m) regression Derived Equations.
Let B = X2

$$R2 = 0.924, P8 = 22.153X22 - 150.93X2 + 365.85 \tag{8}$$
$$R2 = 0.863, P9/T = 1.4795X22 + 13.972X2 - 27.73 \tag{9}$$
$$R2 = 0.907, P10/T = 6.04X22 - 5.5202X2 - 19.642 \tag{10}$$
$$R2 = 0.923, P11/B = 5.0457X22 - 24.999X2 + 50.175 \tag{11}$$
$$R2 = 0.857, P12/L = 33.9772X2 - 156.98 \tag{12}$$
$$R2 = 0.826, P13/B = 18.596X2 - 72.998 \tag{13}$$

3. DEPTH(moulded) D(m) regression Derived Equations.
Let D = X3

$$R2 = 0.884, P14 = 59.25X32 - 332.55X2 + 852.41 \tag{14}$$
$$R2 = 0.818, P15/T = 166X3 - 368.52 \tag{15}$$
$$R2 = 0.806, P16/L = 44.45X3?78.974X3 \tag{16}$$

4. DESIGN DRAFT T(m) regression Derived Equations.
LET T = X4

$$R2 = 0.896, P17 = 148.37X42 - 432X1 + 409.77 \tag{17}$$
$$R2 = 0.884, P18/B = 35.836X42 - 93.243X4 + 95.107 \tag{18}$$
$$R2 = 0.842, P19/T = 044.228X42 - 69.608X4 + 82.639 \tag{19}$$
$$R2 = 0.871, P20/B = -1.6877X43 + 27.424X42 - 84.995X4 + 109.57 \tag{20}$$
$$R2 = 0.893, P11/L = -2.2452X43 + 40.908X42 - 129.71X4 + 161.82 \tag{21}$$
$$\tag{22}$$

Table 4: Derived regression equation for vessel speed formulas as written in figures

FORMULAS FROM REGRESSION ANALYSIS OF 197 FISHING VESSELS DATA ON VESSELS SPEED $v(Kn)$

R^2 =Square Correlation coefficient.

1, Main Power $P(Kw)$ Relation with Fishing Vessels Speed $v(Kn)$ Power to Speed ratio formulas.

$$R^2 = 0.805, \qquad v_1 = 1.9845 \cdot ln(P) - 1.5452 \tag{23}$$

$$R^2 = 0.992, \qquad P/v^2 = -2e^{-06}P2 + 0.0743P + 0.0269 \tag{24}$$

2, Length L(m) Related to Main Power P(Kw) to Vessel Speed Regression formulas.

$$R^2 = 0.879, \qquad P/v3 = 3.260X1 + 42.036 \tag{25}$$

$$R^2 = 0.890, \qquad P/v4 = 0.0581X12 + 5.6589X1 - 43.804 \tag{26}$$

$$R^2 = 0.872, \qquad P/V54/3 = 0.0038X12 + 0.8133X1 - 4.2364 \tag{27}$$

X1=L

3, Breadth B(m) Related to Main Power P(Kw) to Vessel Speed Regression formulas.

$$R^2 = 0.847, \qquad P/v6 = 1.5512X22.3064 \tag{28}$$

$$R^2 = 0.879, \qquad P/v7 = 23.401X2 - 127 \tag{29}$$

X2=B

4. Depth D(m) Related to Main Power P(Kw) to Vessel Speed Regression formulas.

$$R^2 = 0.892, \qquad P/v8 = 1.3304X33 - 15.055X32 + 119.64X1 - 162.75 \tag{30}$$

$$R^2 = 0.832, \qquad P/v9 = 3.8034X31.7622 \tag{31}$$

X3=D

5. Draft T(m) Related to Main Power P(Kw) to Vessel Speed Regression formulas.

$$R^2 = 0.872, \qquad P/V10 = 26.326X12 - 29.104X1 + 22.75 \tag{32}$$

$$R^2 = 0.887, \qquad P/V11 = 8.647X12 - 19.835X1 + 24.005 \tag{33}$$

Table 5: Projected 100 tonnes deadweight fishing vessel. Design option A1 data analysis and result.

0	**1 A1**	**2**	**3**
1	VESSEL DATA	POWER $P(Kw)$	SPEED $V(Kn)$
2	$L(m) = 53.40$	$P_1 = 1519.81$	$V_1 = 13.36$
3	$B(m) = 12.47$	$P_2 = 1586.96$	$V_2 = 12.06$
4	$D(m) = 7.58$	$P_3 = 1409.82$	$V_3 = 12.15$
5	$T(m) = 5.18$	$P_4 = 1677.89$	$V_4 = 14.32$
6	$L/T = 10.32$	$P_5 = 1709.22$	$V_5 = 13.48$
7	$D/T = 1.46$	$P_6 = 1748.04$	$V_6 = 13.66$
8	$LBD = 5048.58$	$P_7 = 1581.54$	$V_7 = 11.72$
9	$LBT = 3446.30$	$P_{(L)} = 1604.75$	$V_8 = 13.72$
10	$B/D = 1.65$	$P_8 = 1928.97$	$V_9 = 12.58$
11	$L/B = 4.28$	$P_9 = 1948.98$	$V_{10} = 12.90$
12	$L/D = 7.04$	$P_{10} = 1935.66$	$V_{11} = 13.55$
13	$F/D = 0.32$	$P_{11} = 1847.46$	$V_{(avg)} = 13.05$
14	$P(Kw) = 1335.16$	$P_{12} = 1949.26$	$V_{crit} = 12.03$
15	$V(Kn) = 13.05$	$P_{13} = 1981.80$	
16		$P_{(B)} = 1932.02$	
17	$P/V = 102.31$	$P_{14} = 1736.54$	
18	$P_{CRIT} = 1620.85$	$P_{15} = 2024.46$	
19	$PDEV = -285.69$	$P_{16} = 1335.16$	
20	$\%PDEV = -17.63$	$P_{(D)} = 1698.72$	
21		$P_{17} = 2147.61$	
22		$P_{18} = 2020.98$	
23		$P_{19} = 2063.01$	
24		$P_{20} = 2123.25$	
25		$P_{21} = 2009.21$	
26		$P_{(T)} = 2072.81$	
27		$P_{AVG} = 1823.13$	

Table 6: Projected 100 tonnes deadweight fishing vessel. Design option A2 data analysis and result.

0	**1 A1**	**2**	**3**
1	VESSEL DATA	POWER $P(Kw)$	SPEED $V(Kn)$
2	$L(m) = 48.686$	$P_1 = 1308.88$	$V_1 = 13.04$
3	$B(m) = 10.986$	$P_2 = 1380.77$	$V_2 = 12.02$
4	$D(m) = 7.740$	$P_3 = 1170.64$	$V_3 = 11.89$
5	$T(m) = 5.022$	$P_4 = 1527.67$	$V_3 = 14.12$
6	$L/T = 9.695$	$P_5 = 1431.54$	$V_4 = 13.23$
7	$D/T = 1.541$	$P_6 = 1536.75$	$V_5 = 13.46$
8	$LBD = 4139.85$	$P_7 = 1359.35$	$V_6 = 11.01$
9	$LBT = 2686.09$	$P_{(L)} = 1387.94$	$V_7 = 13.20$
10	$B/D = 1.419$	$P_8 = 1381.43$	$V_8 = 12.41$
11	$L/B = 4.432$	$P_9 = 1528.35$	$V_9 = 11.60$
12	$L/D = 6.290$	$P_{10} = 1453.71$	$V_{10} = 12.92$
13	$F/D = 0.351$	$P_{11} = 1274.47$	$V_{(avg)} = 12.63$
14	$P(Kw) = 1274.47$	$P_{12} = 1509.18$	$V_{crit} = 11.99$
15	$V(Kn) = 12.630$	$P_{13} = 1442.44$	
16		$P_{(B)} = 1431.60$	
17	$P/V = 100.91$	$P_{14} = 1828.00$	
18	$P_{CRIT} = 1460.43$	$P_{15} = 2053.46$	
19	$PDEV = -186.0$	$P_{16} = 1331.18$	
20	$\%PDEV = -12.732$	$P_{(D)} = 1737.54$	
21		$P_{17} = 1982.23$	
22		$P_{18} = 1758.82$	
23		$P_{19} = 1901.52$	
24		$P_{20} = 1764.49$	
25		$P_{21} = 1798.56$	
26		$P_{(T)} = 1841.12$	
27		$P_{AVG} = 1558.26$	

Table 7: Projected 100 tonnes deadweight fishing vessel. Design option A3 data analysis and result.

0	**1 A1**	**2**	**3**
1	VESSEL DATA	POWER $P(Kw)$	SPEED $V(Kn)$
2	$L(m) = 62.04$	$P_1 = 1939.00$	$V_1 = 13.805$
3	$B(m) = 12.12$	$P_2 = 2076.91$	$V_2 = 12.07$
4	$D(m) = 9.41$	$P_3 = 1970.95$	$V_3 = 12.99$
5	$T(m) = 5.90$	$P_4 = 2206.63$	$V_4 = 15.367$
6	$L/T = 10.52$	$P_5 = 2022.00$	$V_5 = 14.143$
7	$D/T = 1.59$	$P_6 = 2336.74$	$V_6 = 15.092$
8	$LBD = 7078.29$	$P_7 = 2016.78$	$V_7 = 12.141$
9	$LBT = 4438.04$	$P_{(L)} = 2081.29$	$V_8 = 12.62$
10	$B/D = 1.29$	$P_8 = 1792.27$	$V_9 = 13.276$
11	$L/B = 5.12$	$P_9 = 2118.93$	$V_{10} = 13.654$
12	$L/D = 6.59$	$P_{10} = 1946.25$	$V_{11} = 13.634$
13	$F/D = 0.37$	$P_{11} = 1701.84$	$V_{(avg)} = 13.50$
14	$P(Kw) = 1701.85$	$P_{12} = 2008.23$	$V_{crit} = 12.08$
15	$V(Kn) = 13.50$	$P_{13} = 1848.42$	
16		$P_{(B)} = 1902.66$	
17	$P/V = 126.06$	$P_{14} = 2969.59$	
18	$P_{CRIT} = 2203.63$	$P_{15} = 2899.10$	
19	$PDEV = -501.79$	$P_{16} = 2001.87$	
20	$\%PDEV = -22.77$	$P_{(D)} = 2623.52$	
21		$P_{17} = 3025.73$	
22		$P_{18} = 2759.19$	
23		$P_{19} = 2942.79$	
24		$P_{20} = 2620.13$	
25		$P_{21} = 2831.07$	
26		$P_{(T)} = 2835.78$	
27		$P_{AVG} = 2287.35$	

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