OPTIMAL FISHING VESSEL DESIGN FORMULAS BASED ON POWER, SPEED AND DEADWEIGHT

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Abstract— This work presents 75 formulas derived from regression analysis of the main dimensions of 199 fishing boats taken from world fleet. These formulas have vessels main dimensions and ratios as dependent variable on one hand and main engine power and its derivatives on as independent variables on the other for the whole analysis. The aim is to provide the equations necessary for the optimal preliminary design of fishing vessels of all types by obtaining the main dimension of a projected fishing vessel where the main engine power is the input value specified by the owner to the naval architect. The regression analysis program used is the well accepted Microsoft statistical Analysis add-in in EXCEL for Windows versions.

Index Terms— Design, Fishing Vessels, Formulas, Deadweight, Power, Speed, Dimensions

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1 Introduction

CLASSICALLY, the preliminary design of a vessel starts with the owner requirements of vessel speed, deadweight including volume of hold, endurance, operational zone and functions amongst other variables. The use of regression equations for the design of fishing vessels presented previously by various authors [1], [2], ([3], [4], amongst others follow this classic procedure.

However, where the available facilities, crew, management, and maintenance operatives for particular engine type and power ranges are predominant, designing the vessel could depend on main engine power. Therefore, main engine power becomes the main input to the preliminary design process and this work presents the formulas based on this focus for the design optimization process.

The vessels data for the regression taken from Lloyds Register of Ships, [5], and [6], are presented in Table 1 in an abridged form.

The aims and reasons for predicting all possible regression formulas from the data is to get a **multi-variate and multi-relational evaluation (MME)** of the data. This will give a holistic perspective of the relational correlation between the main particulars of the fishing vessels and their main power for the world fleet.

2 Methods

The theories of best fit least square regression analysis for both linear and none linear are well known ([7], [8], [9] and others. Both simple and multiple regression analysis linear and none linear regression analysis models were used as shown in the result Table 2. The parameters for the regression are, the vessel length between perpendiculars L, moulded breadth B, depth to main deck D, registered draft T, all in meters, main engine power P(kw), vessels speed v(kn), and deadweight Dwt(t). The derivatives of these parameters used are, P/v, P/T, P/B, LBD, LBT, $P/\sqrt{T}$, $P/\sqrt{L}$, $P/\sqrt{D}$, $P/\sqrt{B}$, P/L, P/B, P/D, P/T, $P/\sqrt{v}$, and $P/v^{0.333}$. These parameters have relevance to the theoretical and empirical factors associated with resistance and powering of ships namely, Froude number, and Reynolds number [10]. The square correlation coefficients R^2 are shown in Table 2. Only the formulas with R^2 = 0.8 to 0.9 which are the best fit lines or curves are published in this paper.

3 Results

The graphical scatter plot diagrams with the respective, fitted lines or curves together with the derived formulas are shown in Fig 1 to 31. These derived formulas are explicitly presented in Table 2 also.

The scope of this analysis includes all types of existing fishing vessels, namely: long liners, side trawlers, stern trawlers, demersal trawlers, king crab vessels, factory fishing vessels, purse seiner, and small gillnet fishing boats. Dimensional ranges of basic variable values are:

L = 11.5m to 142m, B = 3.68m to 22.2m,
D = 2.20m to 13.6m, T = 1.02m to 9.15m,
V = 4.60kn to 17.2kn, P = 53.66kw to 7570.5kw

To check our results, as an example, let us design a fishing vessel were the type and main power of the vessel is Catapiller model rated 1900hp (1396.5Kw).

Substitute P = 1396.5kw into equations (1), (3), (4), (5), (9) and (47) of Table 2, to get :

L = 50.06m, B = 10.92m, D = 6.56m, T = 4.56, DWT = 592.6, and v = 12.82Kn as the projected fishing vessel dimension.

Enter this result as shown cells A2, B2, C2, D2, E3, and F2 in Table 4. Below respectively.

Table 3. show this substitution format in the equivalent cells in row 2.

Follow the same step for the entire rows according to the

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respective equation numbers shown in the cells to get the result listed in Table 4 respectively. Then calculate the mean values of each column of L, B, D, T, DWT, and v to get the predicted design vessel parameters to be:

L=46.413m, B=10.896m, D=6.463m, T=4.570, DWT=590.75t and v = 13.322Kn as the new design fishing vessel. These calculations are be done easily using EXCEL software spreadsheet. From Table 1 existing vessel with power close to P= 1396.5kw is in row 12 namely Persford has dimensions ***L=40.04m, B=9.00m, D=6.51m, T=4.53, DWT=549t and v = 13.0Kn, P=1492, and DWT = 549.0t. This evidently compare very well with the above result of the calculations using the formulas presented.***

Note that all the 75 formulas could be used in this manner to predict the ultimate best dimensions of the design fishing vessel.

The above procedure can be basis for a fishing vessel computer design optimization program.

Table 2. Validation of result substitution format

P(Kw)	A	B	C	D	E	F
1	L	B	D	T	DWT	V
2	eq(1)	eq(3)	eq(4)	eq(5)	eq(9)	eq(47)
3	eq(12)	eq(13)	eq(14)	eq(14)	eq(10)	eq(49)
4	eq(19)	eq(17)	eq(18)	eq(5)	eq(11)	eq(47)
5	eq(20)	eq(24)	eq(25)	eq(27)	eq(32)	eq(50)
6	eq(21)	eq(29)	eq(30)	eq(31)	eq(11)	eq(51)
MEAN	*L*	*B*	*D*	*T*	*DWT*	*V*

Table 3. Validation result calculation according to Table 2.

P(kw) =	1396.5					
	A	B	C	D	E	F
1	L	B	D	T	DWT	V
2	50.06	10.92	6.56	4.56	592.60	12.82
3	47.09	10.92	6.56	4.40	445.39	12.83
4	44.76	10.92	6.25	4.96	722.25	13.64
5	44.31	11.15	6.68	4.51	570.61	13.63
6	45.84	10.56	6.27	4.42	622.90	13.70
MEAN	46.413	10.896	6.463	4.570	590.750	13.322
MEAN	*Length*	*Breadth*	*Depth*	*Tdraft*	*DWT*	*Vspeed*

4 DISCUSSION

The formulas presented can be used in various optimization models, linear [11], or nonlinear or applied to the methods presented in the papers of [12],. The importance of good preliminary design lies in the reduction on number of iteration circles dictated by advanced design stages. This leads to saving in design work load and time and a better result in the parametric design optimization processes.

The formulas presented are many and varied because the entire parametric perspective relationships has to be captured so as to help the designer predict the best optimal vessel at early design stage basing on formulated constraints, and criteria. Existing criteria concerning stability of vessels and ship motions, freeboard, slamming etc. can be some of the constraints determining the best optimal choice for a projected design. These could be issues of further research work.

5 CONCLUSION

The 52 formulas presented are for the preliminary design of fishing vessels of almost all types currently reported in the world fleet made of steel, fiberglass, aluminum and wood. The formulas are derived with regression analysis and have square correlation coefficient R^2 values ranging from 0.8 to 0.99 and can be utilized to produce optimum main dimension of a projected fishing vessel at preliminary design stages.

The production of a design computer program for the design of fishing vessel can incorporate the use of these formulas.

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TABLE 1 LIST OF SOME OF THE FISHING VESSELS USED IN THE REGRESSION ANALYSIS[5],[6].

	Vessel	LBP(m)	B(m)	D(m)	T(m)	v(kn)	P(kw)	Dwt(t)
1	Pimental	26.45	7.68	3.69	3.32	12.00	412	274.0
2	Rairo	39.90	9.00	6.46	4.58	12.25	895	520.0
3	Andensfisk	40.01	9.00	6.51	4.35	12.50	1119	320.0
4	Ibin Magd	32.01	8.01	3.81	3.48	10.00	671	241.0
5	Havhestur	33.00	8.18	5.49	3.47	9.50	895	236.0
6	Penta	34.02	8.21	4.22	4.10	11.50	671	406.0
7	Ksar Albah	30.33	8.34	4.6	3.77	11.50	716	480.0
8	Leonardo B	23.02	6.58	3.41	2.24	12.50	514	41.0
9	P. D.Aream	26.52	7.01	3.81	3.50	11.00	671	106.0
10	Massira II	28.07	7.50	5.41	3.70	11.00	671	59.0
11	Menabe 5	25.00	6.80	3	2.71	10.00	373	106.0
12	Persford	40.04	9.00	6.51	4.53	13.00	1492	549.0
13	Ibnon Sina	30.99	8.60	6.1	3.80	12.50	821	221.0
14	No. 519		6.86		3.20		280	55.0
31	Domensh	49.99	9.22	4.75	3.81	12.00	597	318.0
32	Don Won	48.49	9.50	4.45	3.80	12.50	895	624.0
33	E81 HB	19.99	6.41	3.46	3.20	10.00	276	96.0
34	Gallic Rose	26.55	8.01	4.35	3.58	10.00	634	268.0
35	Gornovoy	48.72	9.30	4.73	3.81	11.72	597	314.0
36	Starina	20.05	6.45	3.30	2.66	10.54	373	37.0
37	Geestemun	44.00	11.00	7.35	4.60	14.00	1492	460.0
38	P. Giedlei	80.00	15.00	6.60	5.30	14.00	1716	1100.0
39	Centromor	23.00	7.20	3.50	2.85	11.00	425	45.0
40	Atair	23.00	7.20	3.49	2.70	11.00	425	60.0
41	Centromor	20.00	7.00	3.80	2.80	9.50	373	65.0
42	Massena	23.00	7.20	3.49	2.70	11.00	425	69.0
43	Centromor	28.50	8.40	4.10	3.10	10.00	425	100.0
44	Centromor	28.50	8.10	4.10	3.60	12.00	821	140.0
45	Centrom		11.00	5.20		13.20	1097	190.0
187	P. Atltik	91.80	15.20	9.70	5.62	14.60	2852	2063.0
188	P.Meridian	96.40	16.00	10.20	5.87	16.10	5145	1904.0
189	Rembrant	91.00	16.60	11.30	5.50	14.00	2205	2560.0
190	RS-300GD	25.00	6.20	3.00	2.66	10.00	221	64.0
191	RS-300 388	30.00	6.60	3.50	2.58	9.00	221	70.0
192	S. 697BKR	24.60	5.50	2.50	2.09	9.00	110	37.1
193	Sprut B-400	107.45	17.43	11.00	6.63	15.00	5292	3541.0
194	Tarkhansk	114.00	17.00	9.80	7.32	15.70	4484	5816.0
195	Tibiya 1348	49.82	10.09	7.50	5.11	13.65	1672	529.0
196	Tuntselov	30.00	7.85	3.70	2.88	11.00	425	97.0
197	Tyulen	33.98	8.09	3.60	2.55	10.50	441	107.6
198	Uragannyy	24.00	7.81	3.16	2.43	9.30	328	65.0
199	BChS-300	23.20	6.00	3.00	2.33	10.00	221	31.0

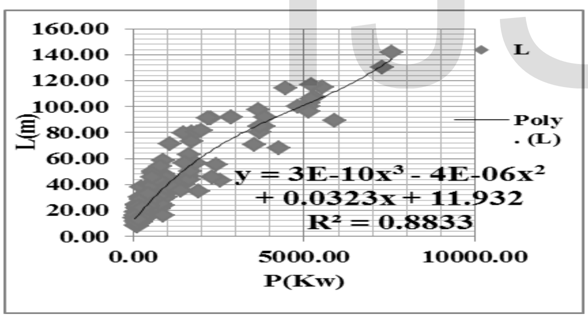

Fig 1 Ship Length L and Power P Correlation.

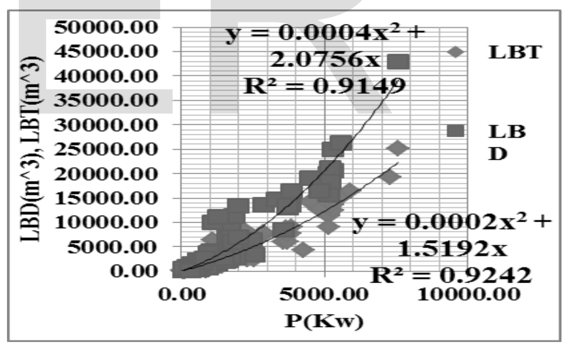

Fig 2. LBT and LBT correlation with P.

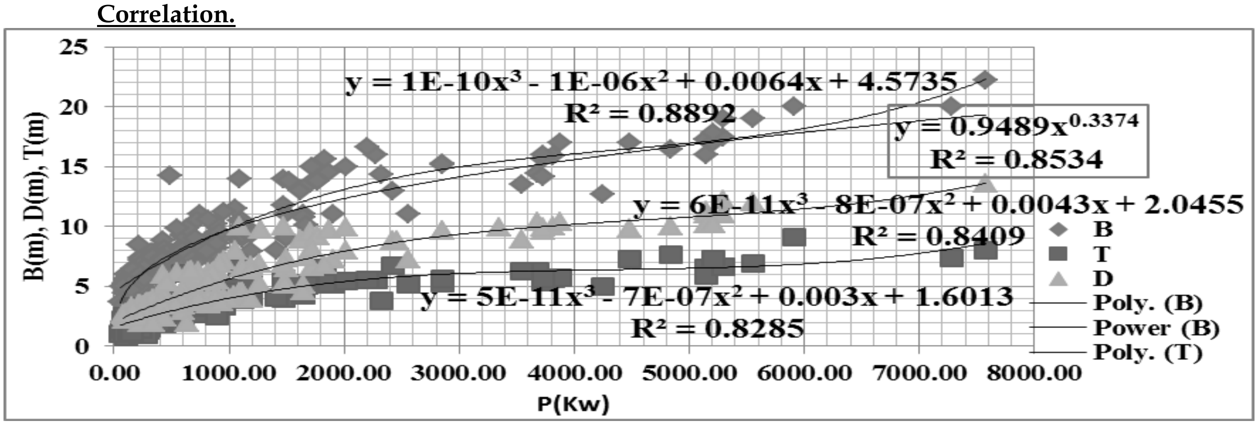

Fig 3. Ship moulded dimension B, D, and T correlation with power P.

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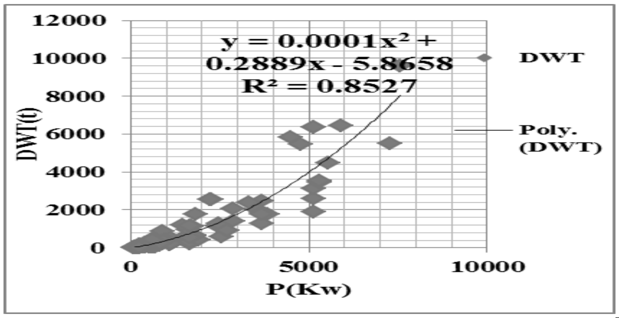

Fig 4. Deadweight DWT correlation with Power P.

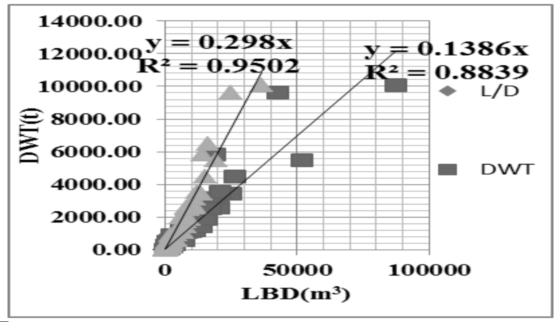

Fig 5. Deadweight DWT correlation with power P.

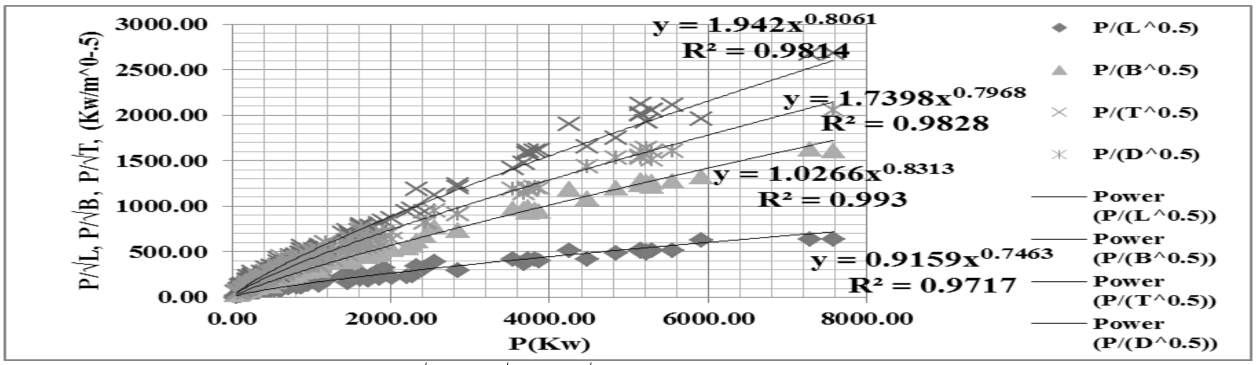

Fig 6. (P/√L), (P/√B), (P/√T), factors correlation with vessels Power P.

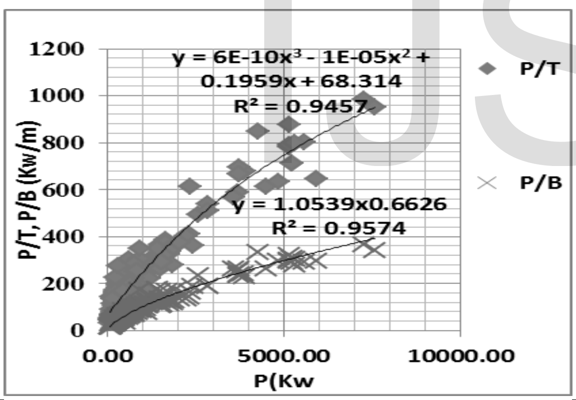

Fig 7. P/T, and P/B factor correlation.

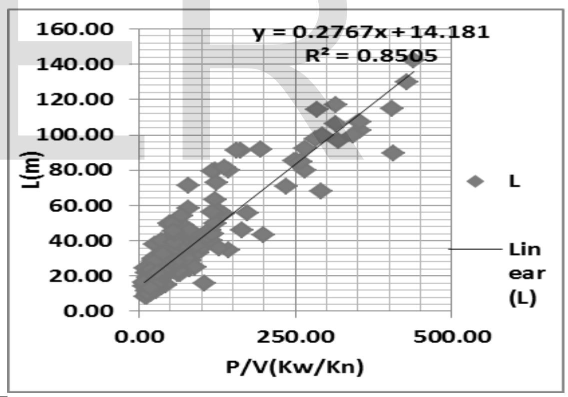

Fig 8. Correlation of L against P/v.

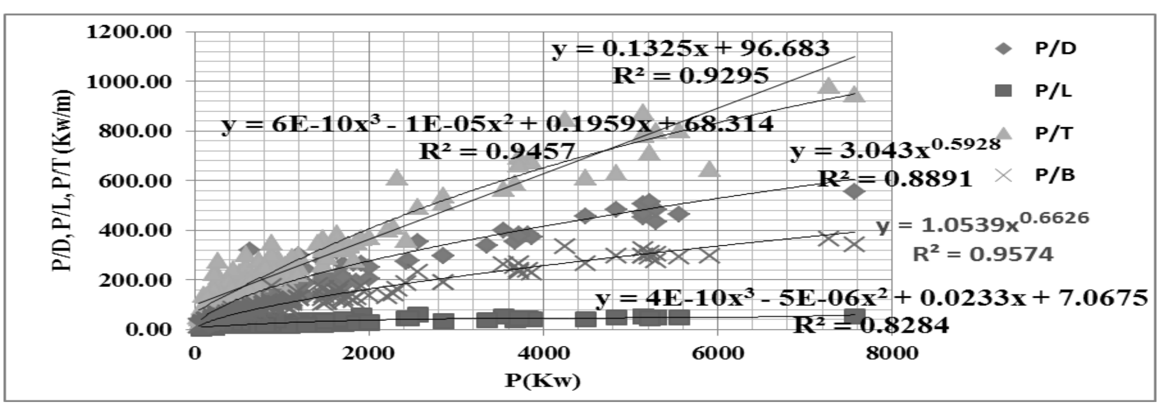

Fig 9. Correlation of P/D, P/L, and P/T with P.

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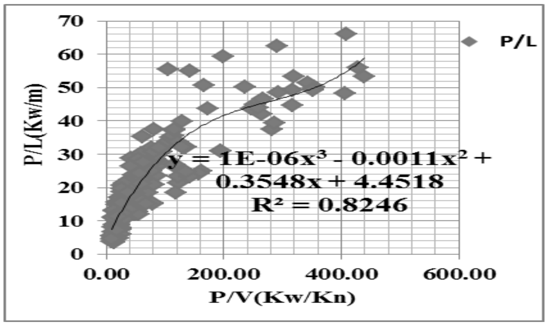

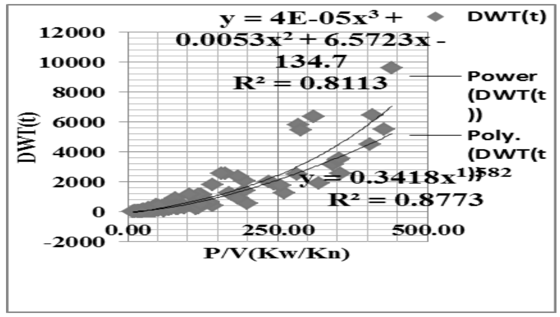

Fig 10. Factor P/L correlation with P/v.

Fig 11. DWT correlation with P/v.

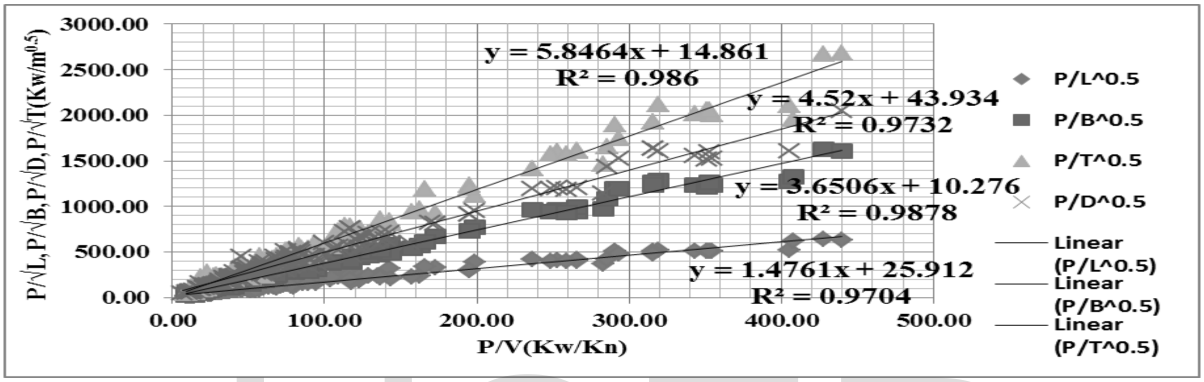

Fig 12. (P/√L), (P/√B), (P/√D), (P/√T), factors correlation with P/v.

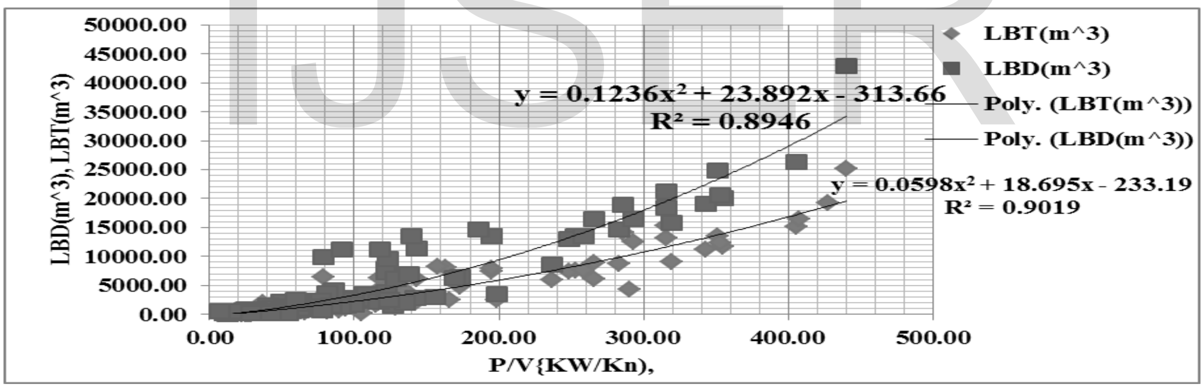

Fig 13. LBD, and LBT Correlation with P/v.

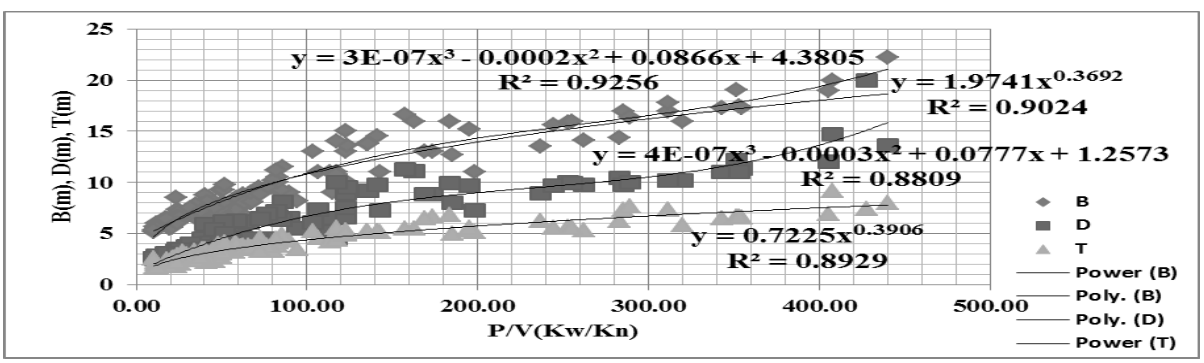

Fig 14. Ship moulded B, D(to main deck), and T(draft) correlation with P/v.

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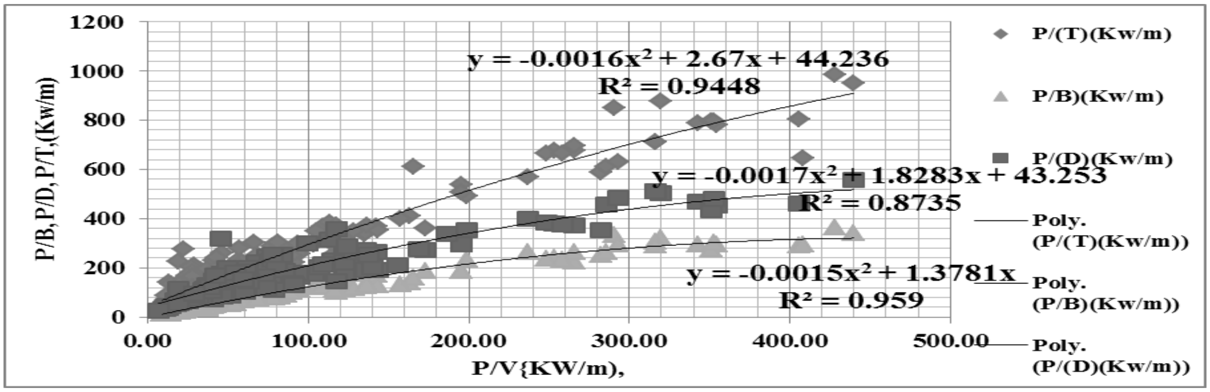


Fig 15. Factor power P/B, P/D, and P/T correlation with P/v.

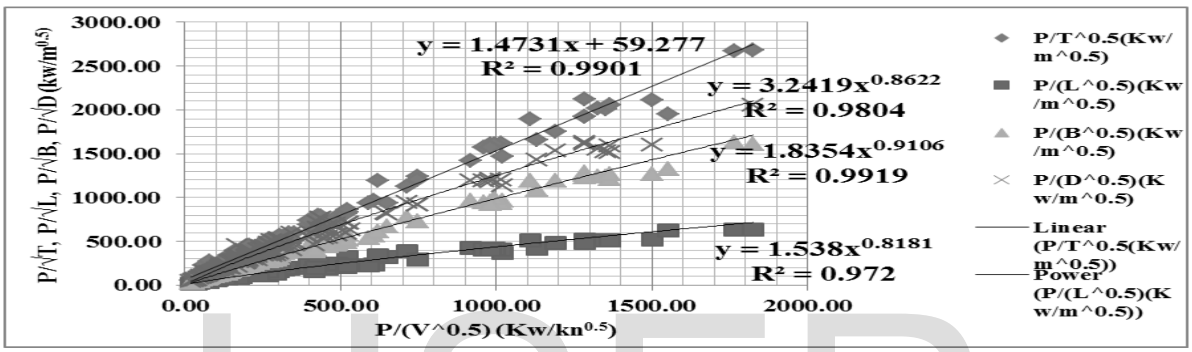
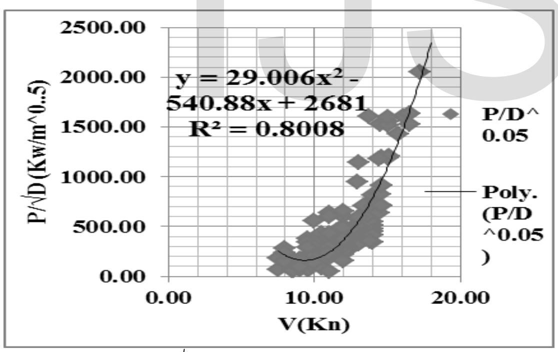


Fig 16. (P/√L), (P/√B), (P/√D), (P/√T), factors correlation with P/√v.



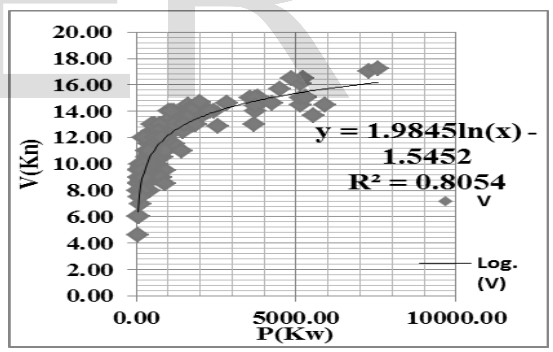


Fig 17, (P/√D), factors correlation with v.

Fig 18. v correlation with power P.

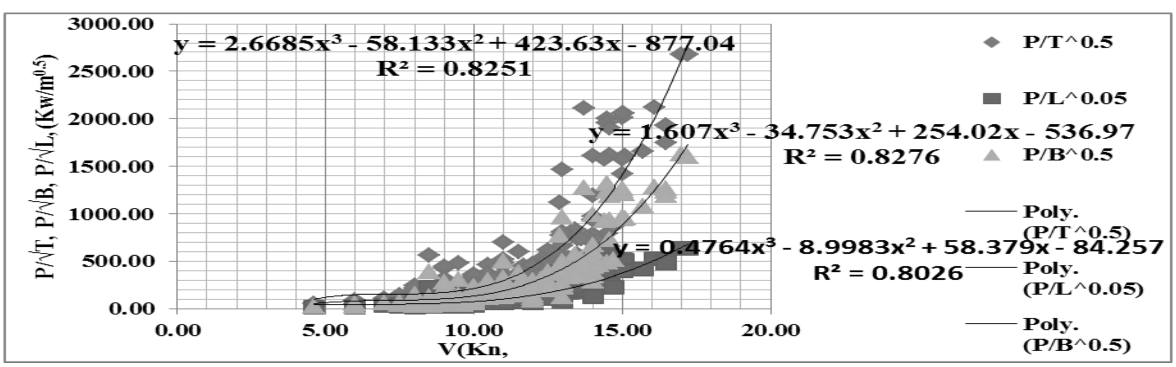


Fig 19, , (P/√L), (P/√B), (P/√T), factors correlation with v.

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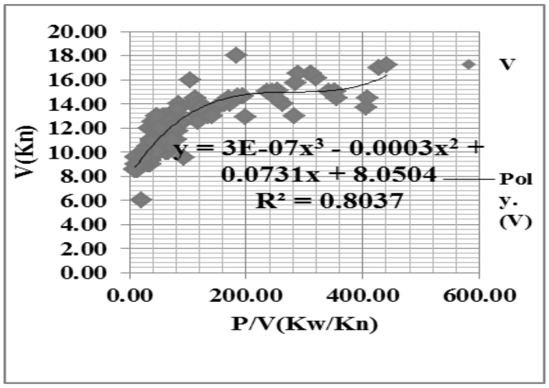

Fig 20. v correlation with P/v.

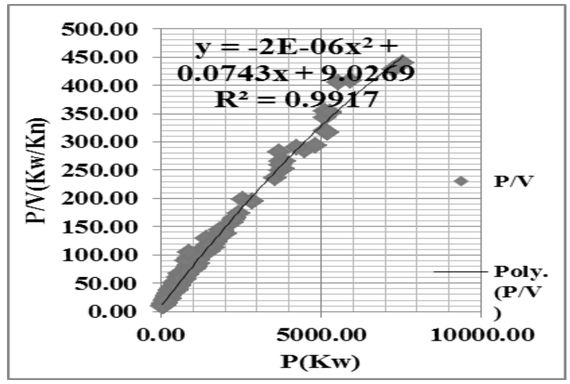

Fig 21. Factor P/v, correlation with P.

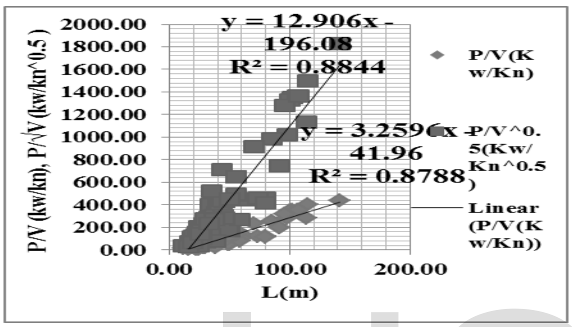

Fig 22. (P/v), (P/√v), correlation with L.

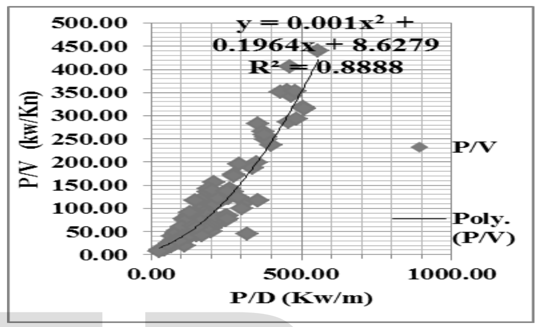

Fig 23. (P/v), correlation with P/D,

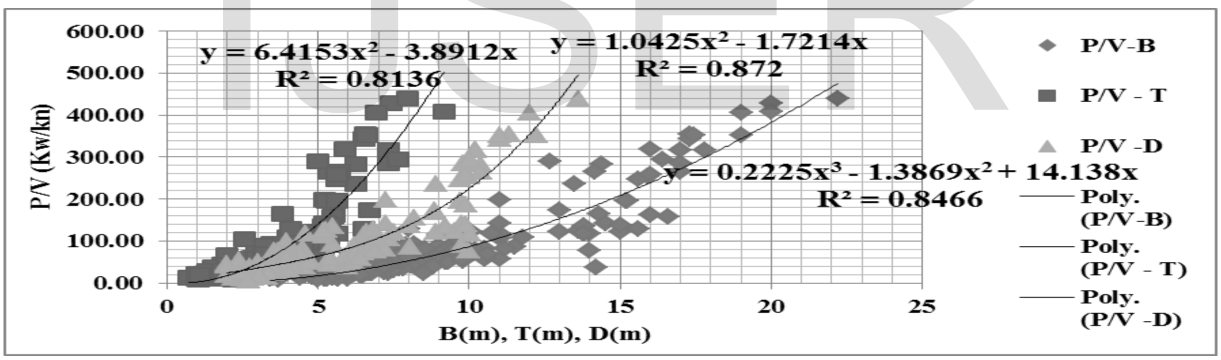

Fig 24 Correlation of P/V on B, T, and D respectively.

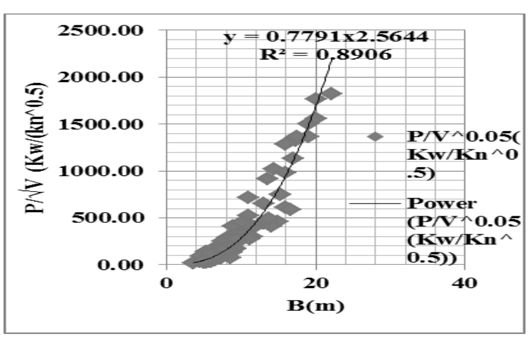

Fig 25. (P/√v), regression with B.

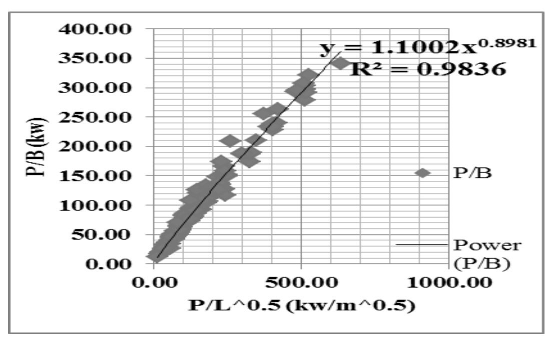

Fig 26. (P/B), regression with P/√L.

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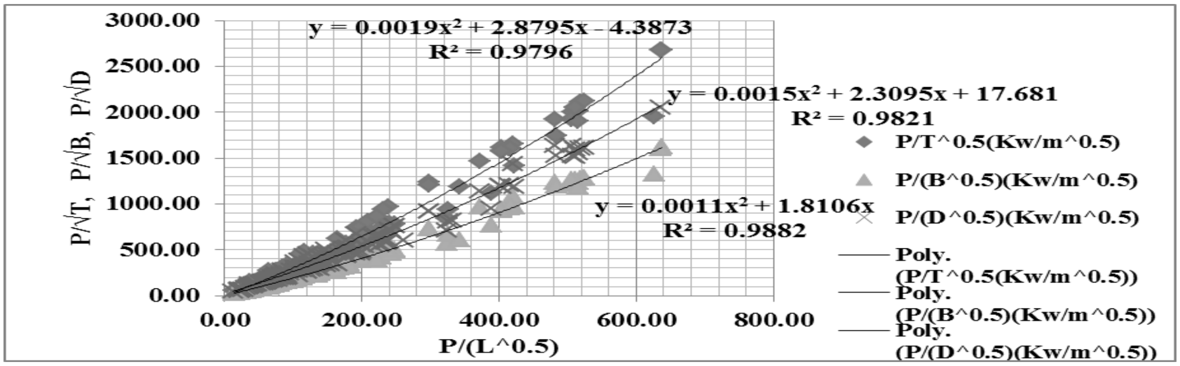

Fig 27.(P/√B), (P/√D), (P/√T), factors regression with P/√L.

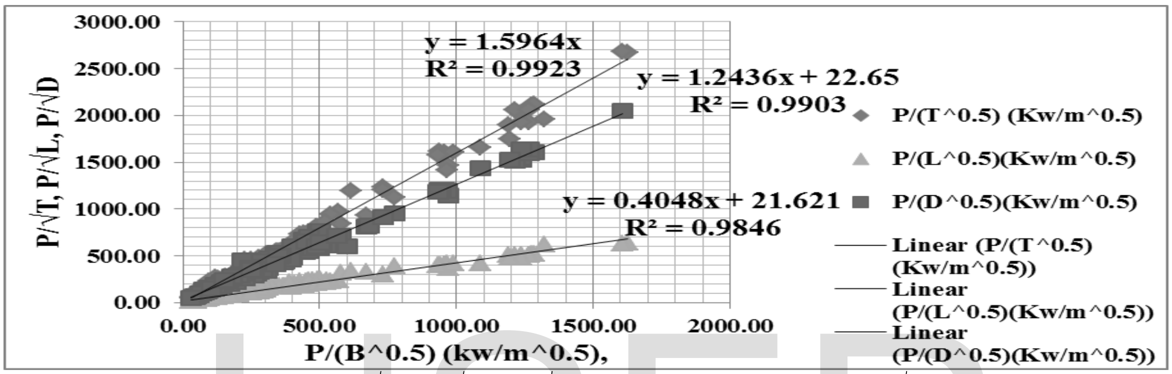

Fig 28.(P/√T), (P/√L), (P/√D), factors regression with P/√B.

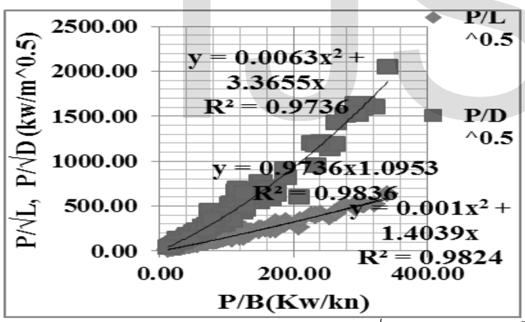

Fig 29 regression of P/√T, with (P/B).

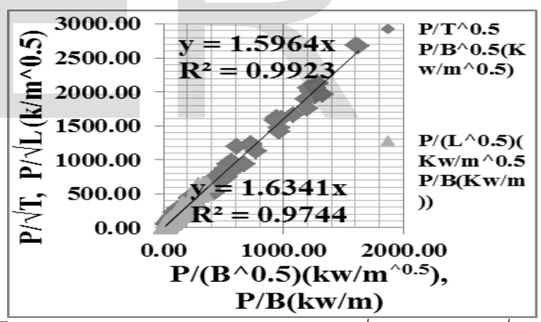

Fig 30. Regression of P/√T, with (P/√B) and (P/√L), with P/B.

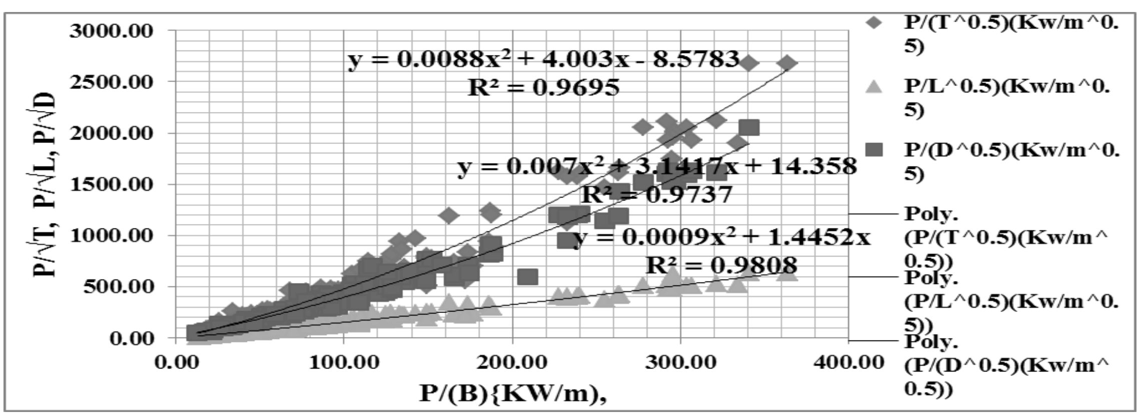

Fig 31. (P/√T), (P/√L), (P/√D), factors regression with P/B.

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Table 2 Derived regression equation for main power formulars as written in fig 1 to 31

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

R2 = Square Correlation coefficient.

1, Main Power P(Kw) Relation with Main Dimensions Regression Equations.

Let P = X1, P = Main Power P(Kw)

R^2 = 0.883, L = 3E-10X13 – 4E-06X12 + 0.0323X1 + 11.932 (1)
R^2 = 0.889, B = 1E-10X13 – 1E-06X12 + 0.0064X1 + 4.5735 (2)
R^2 = 0.853 B = 0.9489 X10.3374 (3)
R^2 = 0.834, D = 5E-11 X13 – 8E-07X12 + 0.0042X1 + 2.1153 (4)
R^2 = 0.829, T = 5E-11 X13 – 7E-07X12 + 0.003X1 + 1.6013 (5)
R^2 = 0.930, P/T = 0.1325X1 + 96.683 (6)
R^2 = 0.914, LBD = 0.0004X12 + 2.0737X1 (7)
R^2 = 0.924, LBT = 0.0002X12 + 1.5192X1 (8)
R^2 = 0.853, DWT = 0.0001X12 + 0.2889X1- 5.866 (9)
R^2 = 0.884, DWT = 0.1386*LBD (10)
R^2 = 0.950, DWT = 0.298*LBT (11)
R^2 = 0.972, P/√L = X4 = 0.9150. X17463 (12)
R^2 = 0.993, P/√B = X5 = 1.02660 X1.8313 (13)
R^2 = 0.982, P/√D = X6 = 1.67710. X18021 (14)
R^2 = 0.981, P/√T = X7 = 1.9420 X1.8061 (15)
R^2 = 0.946, P/T = X9 = 6E-10X13- 1E-05X12 + 0.1959X1 + 68.314 (16)
R^2 = 0.930, P/T = X9 = 0.1325X1 + 96.683 (17)
R^2 = 0.957, P/B = X8 = 1.0539X10.6626 (18)
R^2 = 0.884, P/D = X8 = 2.8125X10.6041 (19)
R^2 = 0.830, P/L = X8 = 4E-10X13-5E-06X1+0.0236X1+6.9026 (20)

2, P/v (Kw/Kn) = X2 Relation with Main Dimensions Regression Equations.

P/V = X2 P = Main Power P(Kw) v = vessel speed(Kn).

R^2 = 0.851, L = 0.2767X2 + 14.181 (21)
R^2 = 0.980, P/√L = 3E-06X23- 0.0031X22 + 2.1856X1 + 1.1387 (22)
R^2 = 0.970, P/√L = 1.4761X2 + 25.912 (23)
R^2 = 0.988, P/√B = 3.6506X2 + 10.276 (24)
R^2 = 0.973, P/√D = 4.52X2 + 43.934 (25)
R^2 = 0.986, P/√T = 5.8464X2 + 14.861 (26)
R^2 = 0.825, P/L = 1E-06X23- 0.0011X22 + 0.3548X2 + 4.4518 (27)
R^2 = 0.926, B = 3E-07X23 – 0.0002X22 + 0.0866X2 + 4.3805 (28)
R^2 = 0.902, B = 1.9741X20.3692 (29)
R^2 = 0.881, D = 4E-07 X23 – 0.0003X22 + 0.0777X2 + 1.2573 (30)
R^2 = 0.912, T = 2E-07 X23 – 0.0001X22 + 0.0417X2 + 1.5358 (31)
R^2 = 0.893, T = 0.7225 X20.3906 (32)
R^2 = 0.959, P/B = X8 = - 0.0015X22 + 1.3781X2 (33)
R^2 = 0.874, P/D = X6 = - 0.0017X22 + 1.8414X2 + 42.352 (34)
R^2 = 0.945, P/T = X7 = - 0.0016X22 + 2.67X2 + 44.236 (35)
R^2 = 0.877, DWT = 0.3418X21.582 (36)
R^2 = 0.894, LBD = 0.1236X22 + 23.892X2 – 313.66 (37)
R^2 = 0.902, LBT = 0.0598X22 + 18.695X2 – 233.19 (38)
R^2 = 0.970, P/√L = 1.4761X2 + 25.915 (39)
R^2 = 0.988, P/√B = 3.6506X2 + 10.276 (40)
R^2 = 0.972, P/√D = 4.5367X2 + 43.066 (41)
R^2 = 0.986, P/√T = 5.8464X2 + 14.861 (42)

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3, P/√v (Kw/√Kn)=X10 Relation with Main Dimensions Regression Equations.

P/√v = X10 P = Main Power P(Kw) v = vessel speed(Kn).

R^2 = 0.972, P/√L = X4 = 1.538X100.8181 (43)
R^2 = 0.992, P/√B = X5 = 1.8354X100.9106 (44)
R^2 = 0.981, P/√D = X6 = 3.1663X100.8664 (45)
R^2 = 0.990, P/√T = X7 = 1.4731X10 + 59.277 (46)

4, v (Kn) = X3 Relation with Main Dimensions Regression Equations.

R^2 = 0.803, P/√L = X4 = 0.4764X33- 8.9983X32 + 58.379X1 – 84.254 (47)
R^2 = 0.828, P/√B = X5 = 1.607X33- 34.753X32 + 254.02X1 – 536.97 (48)
R^2 = 0.825, P/√T = X6 = 2.6685X33- 58.133X32 + 423.63X1 – 877.04 (49)
R^2 = 0.801, P/√D = X6 = 29.006X32 – 540.88X1 + 2681 (50)
R^2 = 0.805, V = X3 = 1.9845ln(X1) – 1.545 (51)
R^2 = 0.804, v = 3E-07X23 – 0.0003X22 + 0.0731X2 + 8.0504 (52)
R^2 = 0.992, P/V = X2 = - 2E-06X12 + 0.0743X1 + 9.0269 (53)
R^2 = 0.879, P/V = X2 = 3.2596L – 41.96 (54)
R^2 =0.884, P/√v= 12.906L – 196.08 (55)
R^2 = 0.889, P/V = X2 = 0.001X62 + 0.1964 X6 + 8.6279 (56)
R^2 = 0.847, P/v = 0.2225D3-1.3869D2 +14.138D (57)
R^2 = 0.872, P/v = 1.0425B2-1.7214B (58)
R^2 =0.814, P/v = 6.4153T2-3.8912T (59)
R^2 = 0.846, v/T = 6.7889T-0.585 (60)
R^2 = 0.890, P/√v = O.7792B2.5644 (61)
R^2 = 0.889, P/v = 1.2803B2 -7.3737B + 28.416 (62)

5, P/√L (Kw/√m) Relation with Main Dimensions Regression Equations.

P/√L = X4

R^2 =0.984, P/B = X8 = 1.1002X40.8981 (63)
R^2 = 0.988, P/√B = X5 = 0.0011X42 + 1.8106X4 (64)
R^2 = 0.982, P/√D = X6 = 0.0015X42 + 2.3095X1 +17.681 (65)
R^2 = 0.980, P/√T = X7 = 0.0019X42 + 2.8795X1 – 4.3873 (66)
R^2 = 0.984, P/B = X8 = 1.1002X40.8981 (67)

6, P/√B (Kw/√m) Relation with Main Dimensions Regression Equations.

P/√B = X5

R^2 = 0.985, P/√L = X4 = 0.4048X5 + 21.621 (68)
R^2 = 0.991, P/√D = X6 = 1.244X5 + 22.343 (69)
R^2 = 0.992, P/√T = X7 = 1.5964X5 (70)

7, P/B (Kw/m) Relation with Main Dimensions Regression Equations.

P/B = X8

R^2 = 0.982, P/√L = X4 = 0.0009X82 + 1.4452X8 (71)
R^2 = 0.974, P/√L = X4 = 1.6341X8 (72)
R^2 = 0.974, P/√D = X6 = 0.0063X82 + 3.3655X8 (73)
R^2 = 0.970, P/√T = X6 = 0.0088X82 + 4.003X8 – 8.5783 (74)
R^2 = 0.984, P/√L = X4 = 0.9736X81.0953 (75)