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Recommendations on Reduction Gear Ratio for Tugboats Basing on Existing Vessels

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Abstract:- The reduction gear ratio ensue that the require thrust is delivered to the boat by the propeller without overloading or over speeding the main engine. This ratio depends on the resistance of the hull, the main engine specifications, and the propeller characteristics – pitch and diameter inclusive. This work carries out a regression analysis on existing tugboats relating main tug boat parameters against their reduction gear ratio. This is in other to determine the optimum gear ratio basing on the experience from the existing tugboats. Interesting recommendations emerging from this work will help in the proper matching of the propeller to the main engine power for tug boats.

***Keywords**:- Tugboats, Main Parameters, Reduction Gear Ratio, Regression Analysis, Recommendations.*

I. INTRODUCTION

Tug boats propellers produce trust to move the vessel at higher torques and lower revolutions than their main engines through reduction gear. Reduction gear ratio is the ratio of the main engine revolution denoted as neng to the propeller revolution per time denoted as nprop stated normally as r:1.

Where $r = n_{eng} / n_{prop}$…………………………...(1)

The factor r can also be calculated by the ratio of number of teeth of the output gear to that of the input pinion gear of the gearbox itself.

The reduction gear is important for medium and high speed engine of revolution per minute ranging 1500 to 1800 used in most tugboats. Generally the reduction gear enables the propeller to work at the best possible efficiency while the main engine is working at the manufacturers designed rating of revolutions against output power. This eliminates power or speed overloading of the main engine leading to durability, less fuel consumption and better thermal performance of the engine.

These are achievable when the propeller sizing with respect to the resistance, speed curves of the vessel is well calculated. Methods of these computations are well known from the following references [1] ,[2], [3], [4] to mention a few.

Existing tugboat parameters are hereby collected and used in correlation analysis between the main dimensions, power and speed factors on one hand, and the reduction ratio r on the other hand. This resulted in obtaining 28 new equations useful in the selection of reduction gear ratio for the design of Tug boat propulsion system.

II. MATERIAL AND METHOD

The parameters collected from 365 tug boats, part of which are shown in Table 1 are: length overall L(m), Breadth B(m), Depth D(m), draft T(m), Main Power P(hp), speed of vessel v(kt), and reduction gear ratio r. These data are obtained from the internet adverts of various companies such as in [5], [6],[7], and others.

The mathematical model for regression formulas fitted to the data were linear and none linear function executed by Microsoft EXCEL add in software. The fitted functions are of these types:

Linear, $Y = mx + c$ 2
Power, $Y = m X^c$. 3
Exponential $Y = m e^{cx}$. 4
Logarithmic, $Y = m \ln(X) + c$ 5
Polynomial $Y=aX_n+ aX_{n-1}+..+ aX_1+c$……6

Where Y a main dimension function and, X is the gear ratio factors of the tugboats m, c, and n are constants determined by the regression analysis – an existing mathematical procedure according to [8], and others.

The formulated variables are many but variable that resulted in a correlation coefficient R2 equal to or greater than 0.8 are published in this paper. These variables are :

L(m), B(m), P(hp), Pv(hp/kt), v/(LB)(kt/m2), LB(m2), P/L(hp/m), P/B(kt/m), PLB(ktm2), (P/L)B(kt/m2), P/v(hp/kt) for X-axes. Pr(hp), P/r(hp), Pr/B(hp/m), r/(LB)(1/m2), (Pr/L)B(hp/m2), for Y-axes.

III. RESULT AND DISCUSSION

The 28 diagrams of the regression analysis are shown in fig.1 to fig 28 with the regression equation shown in each diagram. The equations are collected in Table 2 where the data sample numbers N and the correlation coefficient R2 are included. The r value is made the subject of each equation which resulted in r1, r2,……… r28 equations to calculate the value of the reduction gear ratio for any given tugboat main parameters of length overall L(m), breadth B(m), main power P(hp), and vessel speed v(kt).

For instance, reference to the resultant equations numbers in table2 and making r the subject of the equations: r1=eq1(P)/P, r2=P/eq2(P),….and so on……r28=eq28(LB)(LB).

In Table 1 and Table 1-continued the values of reduction Gear Ratio r1, r2,………, r28 as well as their mean value rm are computed and shown for each of the existing vessels listed.

The actual reduction gear ratio ra can be compared with the predicted rm values from Table 1 and Table 1-continued. This show that reduction gear ratio for proper design of tug boats should range between 4.09 to 6.10 irrespective of the main parameters, power or running boat speed of a tugboat for medium to high revolution main engines. These equations can also be used for estimation of reduction gear ratio rm at the propulsion design stage of a projected tug boat.

IV. CONCLUSIONS

Reduction gear ratio is the determinant parameter in the matching of the propeller to the main engine power, and revolutions, in order to ensure the trouble free and longevity of the main engine and maximum propeller thrust. Here the collection of 365 existing world tugboats parameters were subjected to regression analysis resulting in 28 equations with correlation factor R2 greater than or equal to 0.8. These parameters are correlated with the reduction ratio r laced into quotient, cubic, quadratic, or other hull factors. Although these derived equations can give first hand value of the reduction gear ratio during the early design stage for tug boats, it shows that the reduction gear ratio for tug boats should range from 4.09 – 6.10 irrespective of the main parameters of length, breadth, depth, main power or speed of a projected tug boats.

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EXISTING	VESSEL			PARAMETERS				PREDICTED VALUES			
NAME/NO.	BUILT	L(m)	B(m)	T(m)	P(HP)	v(kt)	r_a	r_1	r_2	r_3	r_4
140220 VN	1978	26.3	8.8	2.8	1716	11	3	4.83	4.84	5.18	5.57
12985 TG OM	2008	32	9.2	3.8	3150	11	3.97	4.80	4.80	5.81	5.47
13039 TG OM	1983	26.84	7.64	3.445	2400	10	3	4.81	4.82	5.96	5.03
13040-TG-OM	1985	28.87	7.55	3.478	2150	10	3	4.82	4.82	5.84	5.04
11326-TG-OM	1977	28.956	8.6	3.36	2750	11	3	4.80	4.81	5.66	5.49
151227-VA	2011	38	10.8	4.5	5150	14	6.03	4.76	4.77	5.25	6.81
DAMEN 2608	2015	26.15	7.95	3.45	2720	12	5.57	4.80	4.81	5.27	5.98
2987-TG-OM	1975	25.93	8.54	1.98	2600	11	7	4.81	4.81	5.60	5.50
131937 VO	2014	36	10.97	4.1	3200	12	5.95	4.79	4.80	5.43	5.95
130937 VO	2014	36	10.97	4.1	3200	12	5.95	4.79	4.80	5.43	5.95
13112-TG-OM	2009	36	10.6	4	3200	12	6	4.79	4.80	5.43	5.95
10045-TG-OM	1980	10.98	4.91	1.53	400	9	4	4.93	4.93	4.62	4.78
160107 VN	2011	14.33	5.18	1.68	600	10	4.5	4.90	4.91	4.58	5.23
140321 VT	1979	15.24	6.1	1.71	600	7.5	4.13	4.90	4.91	5.78	3.96
4669-TG-OM	2011	15.86	5.71	1.35	600	9	4.5	4.90	4.91	4.99	4.72
120109 VW		18.29	6.1	2.01	405	10	5.16	4.93	4.93	4.25	5.29
10750-TG-OM	2011	19.83	7.32	1.73	1200	10	5	4.86	4.86	5.23	5.13
OceanMAR	1981	21.35	7.32	2.26	1500	12	5	4.84	4.85	4.70	6.08
1611-TG-OM	2007	22.88	7.02	1.83	1200	10	6	4.86	4.86	5.23	5.13
10265 TG OM	1975	22.88	6.86	2.75	1300	11	6	4.85	4.86	4.91	5.61
1664-TG-OM	1978	23.62	6.71	1.96	1800	10	6	4.83	4.84	5.64	5.07
151131-VO		26	8	3	1650	10	6	4.84	4.84	5.55	5.08
121068-VO	2012	27	9	3.485	2000	10	5.12	4.82	4.83	5.76	5.05
141043-VO		29.1	9	3.5	2400	11	7.35	4.81	4.82	5.52	5.51
140409 VO	2009	30.22	9	3.68	2400	10	5.947	4.81	4.82	5.96	5.03
150825 VA NIG	2014	31.65	9.14	3.65	3200	12	5.95	4.79	4.80	5.43	5.95
13082 TG-OM	2011	32	9.144	3.5	3200	10	6	4.79	4.80	6.30	4.98
140412-VO	2011	32.1	9	3.68	3200	12	5.95	4.79	4.80	5.43	5.95
140408-VO	2014	32.4	9.15	3.68	3200	12	6	4.79	4.80	5.43	5.95
5922-TG-OM	1975	33.55	10.27	4.04	4300	12	5	4.78	4.78	5.75	5.90
140413-VO	2014	34.5	9.5	3.65	3200	11.5	6	4.79	4.80	5.62	5.71
Leslie Foss	1970	36.576	9.4488	4.1148	3000	12	4.128	4.80	4.80	5.37	5.96
141138 va	2008	38.1	10.6	4.1	3800	12	5.75	4.78	4.79	5.61	5.92
11153-OT-OM	1944	30.5	7.65	2.75	1200	10	4	4.86	4.86	5.23	5.13
432236EA	1978	37.3	10.84	4.3	3500	9	5	4.79	4.79	6.98	4.49
432236Boatson	1978	37.2	10.84	4.3	3500	9	5	4.79	4.79	6.98	4.49
150633 VO	2009	36.1	10.6	4	3200	12	6	4.79	4.80	5.43	5.95
6968 TG OM	1987	24.4	7.43	3.2	1800	12	4	4.83	4.84	4.87	6.05
13048-TG OM	1998	37.5	9.25	3.4	5000	12	4	4.77	4.77	5.91	5.87
151150 VT	2015	22	7.7	2.2	600	12	4.5	4.90	4.91	3.95	6.25
151228 VW	2007	26	11.5	2.25	2400	10	5.95	4.81	4.82	5.96	5.03
131028-vo	2005	26.09	7.94	3.75	3500	12.7	7.087	4.79	4.79	5.28	6.27
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**

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CONTINUATION OF PREDICTED REDUCTION GEAR r RATIO														
NAME/NO.	r_5	r_6	r_7	r_8	r_9	r_{10}	r_{11}	r_{12}	r_{13}	r_{14}	r_{15}	r_{16}	r_{17}	r_{18}
140220 VN	**4.60**	**5.67**	**4.03**	**7.36**	**4.39**	**4.22**	**5.06**	**4.55**	**5.86**	**5.52**	**4.84**	**4.74**	**5.63**	**5.43**
12985 TG OM	**5.76**	**4.65**	**6.63**	**4.58**	**5.90**	**5.93**	**5.23**	**5.37**	**4.98**	**4.79**	**5.50**	**5.32**	**5.04**	**4.75**
13039 TG OM	**6.18**	**4.23**	**8.00**	**3.44**	**6.34**	**6.78**	**5.91**	**6.26**	**4.27**	**4.44**	**6.00**	**5.49**	**4.87**	**4.27**
13040-TG-OM	**4.81**	**5.50**	**7.38**	**3.71**	**5.25**	**5.66**	**4.96**	**6.11**	**4.37**	**4.82**	**5.52**	**6.07**	**4.39**	**4.36**
11326-TG-OM	**6.11**	**4.33**	**6.84**	**4.28**	**6.40**	**6.23**	**5.66**	**5.60**	**4.77**	**4.64**	**5.70**	**5.19**	**5.16**	**4.62**
151227-VA	**6.75**	**4.08**	**7.29**	**4.54**	**8.58**	**6.77**	**5.26**	**5.18**	**5.17**	**4.60**	**5.65**	**5.19**	**5.21**	**4.83**
DAMEN 2608	**7.37**	**3.53**	**8.21**	**3.42**	**8.94**	**7.56**	**6.60**	**6.21**	**4.30**	**4.23**	**6.28**	**5.07**	**5.29**	**4.29**
2987-TG-OM	**7.16**	**3.63**	**6.58**	**4.44**	**7.04**	**6.73**	**6.52**	**5.53**	**4.83**	**4.47**	**5.94**	**4.67**	**5.75**	**4.66**
131937 VO	**4.66**	**5.86**	**4.36**	**7.66**	**4.59**	**4.38**	**4.39**	**4.24**	**6.30**	**5.59**	**4.70**	**4.99**	**5.38**	**5.64**
130937 VO	**4.66**	**5.86**	**4.36**	**7.66**	**4.59**	**4.38**	**4.39**	**4.24**	**6.30**	**5.59**	**4.70**	**4.99**	**5.38**	**5.64**
13112-TG-OM	**4.66**	**5.86**	**4.74**	**6.91**	**4.80**	**4.55**	**4.39**	**4.44**	**6.01**	**5.48**	**4.79**	**5.18**	**5.18**	**5.45**
10045-TG-OM	**5.86**	**3.91**	**3.98**	**5.46**	**5.18**	**7.32**	**8.77**	**5.88**	**4.52**	**4.79**	**5.83**	**3.88**	**6.76**	**4.64**
160107 VN	**5.24**	**4.55**	**5.23**	**4.28**	**5.89**	**6.32**	**7.26**	**6.35**	**4.19**	**4.75**	**5.81**	**4.73**	**5.56**	**4.35**
140321 VT	**4.65**	**5.18**	**3.49**	**6.99**	**3.04**	**4.55**	**6.60**	**5.08**	**5.24**	**5.38**	**5.12**	**4.24**	**6.21**	**5.12**
4669-TG-OM	**4.30**	**5.63**	**4.11**	**5.73**	**3.98**	**4.72**	**6.20**	**5.56**	**4.78**	**5.30**	**5.20**	**4.75**	**5.53**	**4.79**
120109 VW	**2.20**	**11.23**	**2.35**	**10.36**	**2.35**	**2.40**	**3.99**	**4.38**	**6.06**	**7.10**	**3.89**	**5.32**	**4.91**	**5.74**
10750-TG-OM	**5.57**	**4.49**	**4.44**	**6.05**	**4.95**	**5.10**	**6.44**	**5.12**	**5.20**	**5.02**	**5.39**	**4.38**	**6.06**	**5.01**
0ceanMAR	**6.03**	**4.19**	**5.56**	**4.84**	**7.12**	**5.83**	**6.50**	**5.57**	**4.79**	**4.73**	**5.69**	**4.66**	**5.71**	**4.70**
1611- TG-OM	**4.22**	**6.06**	**4.93**	**5.33**	**4.35**	**4.51**	**5.15**	**5.42**	**4.91**	**5.31**	**5.09**	**5.35**	**4.95**	**4.81**
10265 TG OM	**4.57**	**5.59**	**5.65**	**4.59**	**5.49**	**5.02**	**5.39**	**5.77**	**4.62**	**5.06**	**5.34**	**5.45**	**4.87**	**4.59**
1664-TG-OM	**5.94**	**4.32**	**8.27**	**3.10**	**6.63**	**6.88**	**6.14**	**6.72**	**3.97**	**4.39**	**6.12**	**5.63**	**4.73**	**4.08**
151131-VO	**4.52**	**5.75**	**4.91**	**5.75**	**4.28**	**4.59**	**5.04**	**5.11**	**5.22**	**5.30**	**5.05**	**5.20**	**5.12**	**4.99**
121068-VO	**5.09**	**5.14**	**4.44**	**6.75**	**4.25**	**4.66**	**5.29**	**4.67**	**5.71**	**5.29**	**5.03**	**4.70**	**5.69**	**5.31**
141043-VO	**5.28**	**5.01**	**5.33**	**5.63**	**5.23**	**5.14**	**5.21**	**5.00**	**5.34**	**5.08**	**5.22**	**5.02**	**5.33**	**5.03**
140409 VO	**4.91**	**5.42**	**5.33**	**5.63**	**4.40**	**4.93**	**4.91**	**5.00**	**5.34**	**5.18**	**5.11**	**5.23**	**5.11**	**5.03**
150825 VA	**5.98**	**4.48**	**6.84**	**4.42**	**6.86**	**6.14**	**5.37**	**5.45**	**4.90**	**4.71**	**5.60**	**5.29**	**5.08**	**4.70**
13082 TG-OM	**5.86**	**4.58**	**6.84**	**4.43**	**5.34**	**6.07**	**5.27**	**5.45**	**4.91**	**4.74**	**5.56**	**5.35**	**5.02**	**4.70**
140412-VO	**5.82**	**4.61**	**7.11**	**4.22**	**6.87**	**6.15**	**5.25**	**5.57**	**4.80**	**4.71**	**5.60**	**5.46**	**4.91**	**4.63**
140408-VO	**5.72**	**4.70**	**6.83**	**4.44**	**6.65**	**5.98**	**5.17**	**5.44**	**4.91**	**4.77**	**5.52**	**5.42**	**4.95**	**4.70**
5922-TG-OM	**7.18**	**3.76**	**6.89**	**4.67**	**7.36**	**6.82**	**5.77**	**5.18**	**5.16**	**4.54**	**5.77**	**4.86**	**5.56**	**4.84**
140413-VO	**5.06**	**5.36**	**6.22**	**4.97**	**5.53**	**5.36**	**4.69**	**5.17**	**5.17**	**5.04**	**5.22**	**5.57**	**4.82**	**4.88**
Leslie Foss	**4.23**	**6.46**	**5.91**	**5.21**	**5.11**	**4.74**	**4.13**	**5.08**	**5.26**	**5.35**	**4.92**	**6.00**	**4.47**	**4.95**
141138 va	**4.95**	**5.56**	**5.63**	**5.81**	**5.30**	**5.08**	**4.42**	**4.74**	**5.64**	**5.23**	**5.00**	**5.43**	**4.95**	**5.18**
11153-OT-OM	**2.41**	**11.05**	**3.99**	**6.91**	**2.68**	**2.93**	**3.30**	**4.82**	**5.52**	**6.52**	**4.12**	**6.64**	**3.98**	**5.24**
432236EA	**4.75**	**5.77**	**4.91**	**6.75**	**3.36**	**4.67**	**4.37**	**4.46**	**5.99**	**5.43**	**4.82**	**5.22**	**5.15**	**5.43**
432236Bo	**4.78**	**5.74**	**4.91**	**6.75**	**3.37**	**4.69**	**4.39**	**4.46**	**5.99**	**5.43**	**4.83**	**5.20**	**5.17**	**5.43**
150633 VO	**4.63**	**5.90**	**4.74**	**6.91**	**4.78**	**4.53**	**4.37**	**4.44**	**6.01**	**5.49**	**4.78**	**5.20**	**5.17**	**5.45**
6968 TG OM	**5.58**	**4.62**	**6.43**	**4.22**	**7.06**	**5.86**	**5.84**	**5.84**	**4.57**	**4.73**	**5.67**	**5.22**	**5.10**	**4.52**
13048-TG OM	**6.72**	**4.09**	**10.38**	**2.93**	**8.48**	**7.87**	**5.28**	**6.33**	**4.23**	**4.25**	**6.14**	**6.06**	**4.45**	**4.17**
151150 VT	**2.27**	**11.16**	**1.96**	**14.09**	**2.57**	**2.12**	**3.73**	**3.68**	**7.20**	**7.48**	**3.65**	**4.90**	**5.37**	**6.46**
151228 VW	**6.58**	**3.96**	**2.91**	**11.76**	**3.90**	**4.44**	**6.21**	**3.57**	**7.47**	**5.46**	**4.85**	**3.42**	**7.87**	**6.43**
131028-vo	**9.53**	**2.73**	**10.60**	**2.65**	**12.43**	**9.77**	**7.62**	**6.84**	**3.91**	**3.77**	**7.03**	**4.97**	**5.42**	**3.98**
1	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**22**	**23**	**24**	**25**	**26**	**27**

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PREDICTED RED GEAR r RATIO CONTINUED											
NAME/NO.	r_{19}	r_{20}	r_{21}	r_{22}	r_{23}	r_{24}	r_{25}	r_{26}	r_{27}	r_{28}	r_m
140220 VN	5.42	5.82	6.10	5.64	6.17	4.53	5.63	5.27	4.71	4.84	5.23
12985 TG OM	5.02	4.91	4.63	4.88	4.38	4.88	4.42	4.77	5.31	4.79	5.12
13039 TG OM	4.75	4.22	3.75	4.29	3.62	5.10	3.82	4.51	5.91	4.87	5.07
13040-TG-OM	4.80	4.34	4.37	4.89	4.27	5.64	4.43	4.22	6.46	4.86	5.06
11326-TG-OM	4.82	4.81	4.40	4.50	4.09	4.81	4.16	4.80	5.38	4.83	5.10
151227-VA	4.40	5.65	5.22	4.26	4.07	4.63	4.16	4.92	4.57	4.73	5.26
DAMEN 2608	4.17	4.73	3.99	3.58	3.31	4.70	3.50	4.78	5.46	4.87	5.19
2987-TG-OM	4.84	4.88	4.10	4.14	3.83	4.37	3.87	5.17	4.87	4.85	5.13
131937 VO	5.57	6.15	6.60	6.13	6.36	4.60	5.85	5.21	4.18	4.73	5.32
130937 VO	5.57	6.15	6.60	6.13	6.36	4.60	5.85	5.21	4.18	4.73	5.32
13112-TG-OM	5.38	5.95	6.38	5.92	6.03	4.76	5.65	5.03	4.52	4.74	5.28
10045-TG-OM	4.75	4.79	4.12	3.78	4.50	4.09	4.17	5.63	3.54	5.16	5.02
160107 VN	4.25	4.68	4.40	3.76	4.25	4.81	4.16	4.87	4.49	5.09	4.96
140321 VT	6.30	4.58	4.31	5.65	5.82	4.34	5.21	5.48	4.26	5.04	5.05
4669-TG-OM	5.10	4.82	4.91	4.90	5.47	4.83	5.08	4.98	4.67	5.04	5.00
120109 VW	5.42	6.34	9.22	7.25	10.35	5.48	8.55	4.79	5.12	5.00	5.69
10750-TG-OM	5.23	5.17	4.78	4.72	5.01	4.30	4.69	5.41	4.61	4.94	5.08
OceanMAR	4.32	5.37	4.97	3.93	4.32	4.50	4.23	5.12	4.96	4.93	5.11
1611- TG-OM	5.02	4.96	5.29	5.23	5.42	5.18	5.19	4.67	5.58	4.92	5.07
10265 TG OM	4.47	5.01	5.23	4.57	4.83	5.24	4.76	4.56	5.73	4.92	5.06
1664-TG-OM	4.42	4.10	3.70	3.98	3.48	5.31	3.71	4.36	6.05	4.92	5.05
151131-VO	5.36	5.05	5.22	5.53	5.48	4.96	5.22	4.84	5.38	4.87	5.11
121068-VO	5.80	5.30	5.19	5.71	5.63	4.46	5.23	5.29	4.65	4.83	5.16
141043-VO	5.19	5.29	5.19	5.16	5.05	4.70	4.88	5.00	5.02	4.82	5.14
140409 VO	5.60	4.97	4.97	5.69	5.25	4.88	5.06	4.86	5.21	4.81	5.12
150825 VA NIG	4.64	5.13	4.84	4.49	4.22	4.85	4.28	4.77	5.31	4.80	5.15
13082 TG-OM	5.37	4.56	4.19	5.10	4.27	4.90	4.33	4.74	5.37	4.79	5.09
140412-VO	4.57	5.05	4.83	4.48	4.18	4.99	4.28	4.65	5.53	4.80	5.14
140408-VO	4.64	5.13	4.96	4.60	4.33	4.96	4.39	4.70	5.43	4.79	5.15
5922-TG-OM	4.91	5.19	4.48	4.43	3.98	4.40	4.04	5.14	4.50	4.76	5.19
140413-VO	4.99	5.19	5.29	5.22	4.88	5.09	4.85	4.65	5.40	4.77	5.15
Leslie Foss	4.86	5.42	6.10	5.59	5.48	5.47	5.39	4.43	5.78	4.76	5.22
141138 va	5.20	5.60	5.84	5.62	5.38	4.92	5.22	4.82	4.78	4.73	5.22
11153-OT-OM	5.47	5.40	7.68	7.59	8.25	6.33	7.54	4.11	6.71	4.84	5.50
432236EA	6.80	4.89	4.91	7.12	5.91	4.76	5.58	5.01	4.45	4.73	5.23
432236Bo	6.80	4.89	4.90	7.10	5.90	4.75	5.56	5.02	4.44	4.73	5.22
150633 VO	5.38	5.95	6.40	5.94	6.05	4.77	5.67	5.02	4.53	4.74	5.28
6968 TG OM	4.23	5.11	4.94	4.06	4.21	4.95	4.24	4.71	5.57	4.89	5.10
13048-TG OM	4.29	4.43	3.97	4.05	3.26	5.36	3.60	4.26	6.16	4.76	5.25
151150 VT	5.46	7.82	11.71	7.63	12.02	4.96	9.50	5.27	4.80	4.91	6.10
151228 VW	7.15	6.35	5.47	6.26	6.58	3.29	5.57	6.95	2.70	4.79	5.52
131028-vo	3.78	4.48	3.37	2.93	2.56	4.55	2.86	4.79	5.46	4.87	5.43
1	28	29	30	31	32	33	34	35	36	37	38

Table 1:- Some Existing Tugboat parameters and the predicted values of reduction gear ratio r

ISSN No:-2456-2165

N	R^2	Formula	Eq. no
98	0.909	$Pr = 5.5744*P^{0.9855}$ -	**1**
98	0.915	$P/r = 0.1794*P^{1.0145}$ -	**2**
42	0.925	$P/r = 0.1141(Pv)^{0.8099}$ -	**3**
43	0.958	$Pr = 0.6753(Pv)^{0.9707}$ -	4
36	0.907	$P/r = 0.8333L^{1.8583}$ -	5
38	0.897	$Pr = 9.954L^{2.104}$ -	6
43	0.802	$P/r = 1.9665B^{2.4727}$ -	**7**
53	0.808	$Pr = 18.257B^{3.0068}$ -	**8**
31	0.881	$P/r = 7.4453\{v/(LB)\}^{-1.286}$ -	**9**
75	0.818	$P/r = 1.997(LB) – 57.335$ -	**10**
72	0.845	$Pr = 11.714(P/L)^{1.5806}$ -	**11**
72	0.873	$Pr = 5.7001(P/B)^{1.369}$ -	**12**
92	0.881	$P/r = 0.2224(P/B)^{1.3628}$ -	**13**
72	0.902	$Pr = 10.715(PLB)^{0.526}$ -	**14**
106	0.859	$P/r= 0.1974(PLB)^{0.5873}$ -	**15**
72	0.898	$P/r = 0.2863\{(P/L)B\}^{1.1248}$ - - - - - - - - - - - - - - - - - - -	**16**
91	0.903	$Pr = 8.2712\{((P/L)B\}^{1.1084}$ - - - - - - - - - - - - - - - - - - -	**17**
56	0.843	$Pr/B = 5.130P^{0.7169}$ -	**18**
56	0.810	$Pr/B = 18.746(P/v)^{0.7957}$ -	**19**
50	0.810	$Pr/B = 2.3253(Pv)^{0.6261}$ -	**20**
63	0.801	$r/(LB) = 1.9073(P/v)^{-0.848}$ -	**21**
50	0.823	$r/(LB) = 12.843(Pv)^{-0.637}$ -	**22**
57	0.804	$(Pr/L)B = 11.457B^{2.6487}$ -	**23**
63	0.808	$(Pr/L)B = 4.032P^{0.8695}$ -	**24**
86	0.825	$r/(LB) = 8.767(P)^{-0.737}$ -	**25**
86	0.865	$r/(LB) = 6.8025L^{-0.743}$ -	**26**
96	0.819	$r/(LB) = 0.2876e^{-0.301B}$ -	**27**
106	0.826	$r/(LB) = 6.1205(LB)^{-1.043}$ -	**28**

Table 2 Tugboat design formulas as a function of bollard pull(x = bp) in metric tonnes.

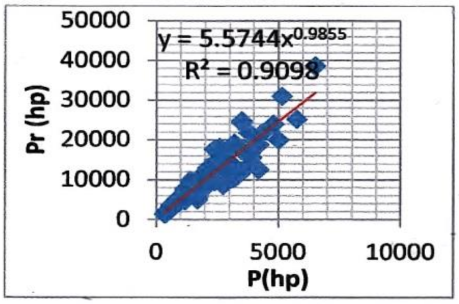

Fig 1. Power and ratio of the gear Pr correlated with power P.

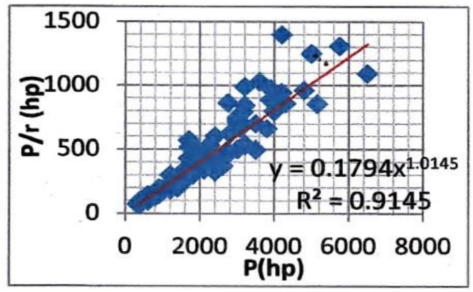

Fig 2. Power by gear ratio P/r correlated with main power P

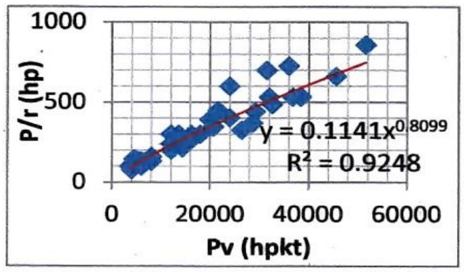

Fig 3. Power by gear ratio P/r correlated correlated with power P and speed v.

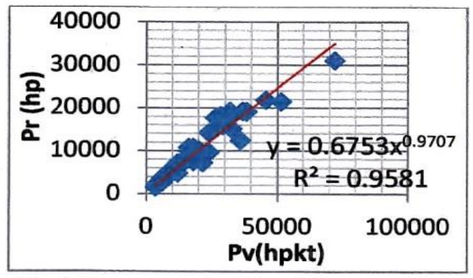

Fig 4. Power and ratio of the gear Pr correlated with main power P and speed v

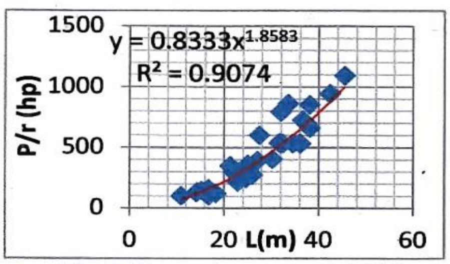

Fig 5. Power by gear ratio P/r correlated with length overall L .

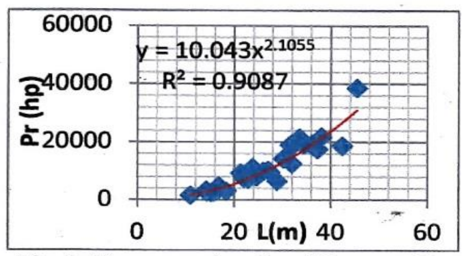

Fig 6. Power and ratio of the gear Pr correlated with length overall L

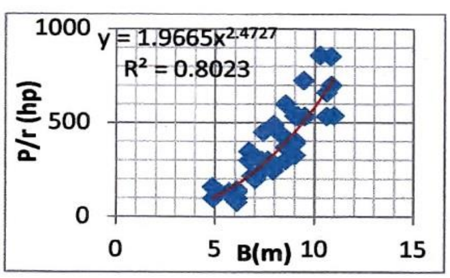

Fig 7. Power by gear ratio P/r correlated with breath B .

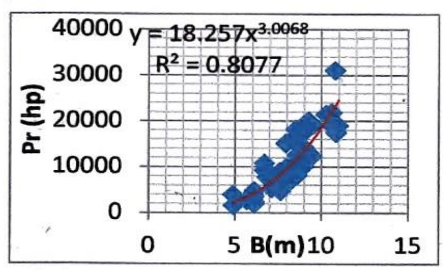

Fig 8. Power and ratio of the gear Pr correlated with breath B

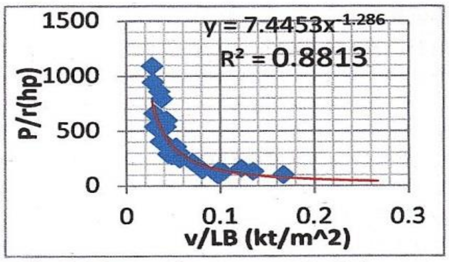

Fig 9. Power by gear ratio P/r correlated with v/LB factor.

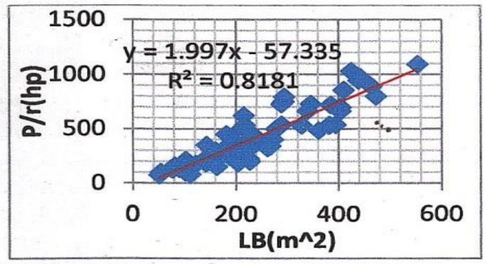

Fig 10. Power by gear ratio P/r correlated with v/LB factor.

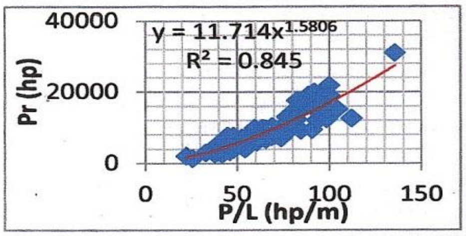

Fig 11. Power and ratio of the gear Pr correlated with P/L factor.

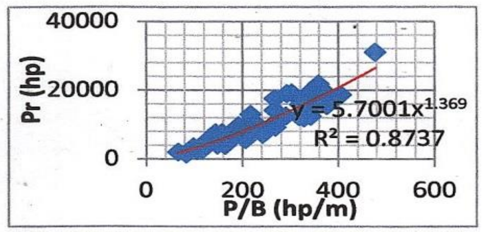

Fig 12. Power and ratio of the gear Pr correlated with P/L factor.

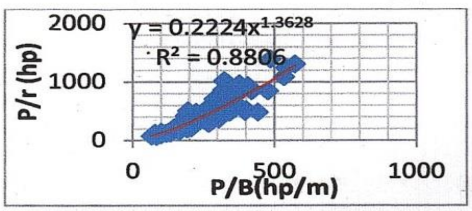

Fig 13. Power by gear ratio P/r

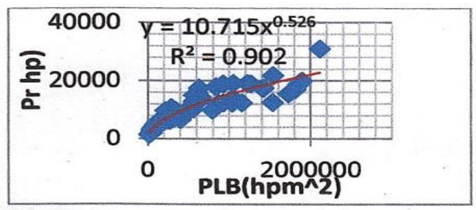

Fig 14. Power and ratio of the gear Pr

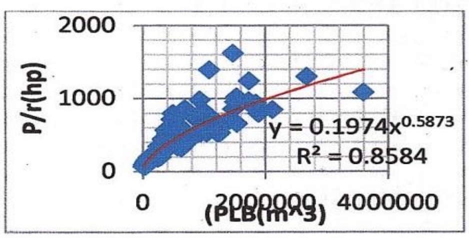

Fig 15. Power by gear ratio P/r correlated with PLB factor.

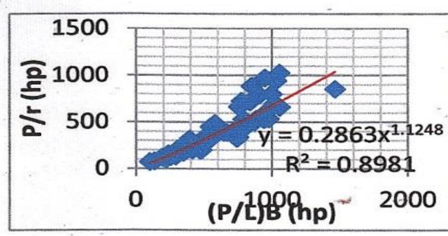

Fig 16. Power by gear ratio P/r correlated with (P/L)B factor.

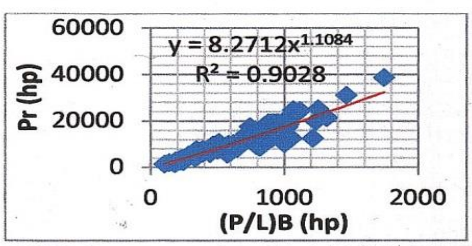

Fig 17 Pr factor correlated with PLB factor.

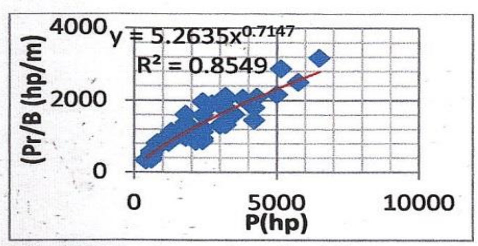

Fig 18 Pr/B factor correlated with power P.

- 8 -

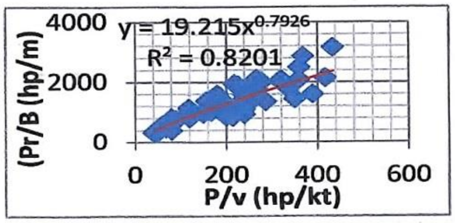

Fig 19 Pr/B factor correlated with P/v.

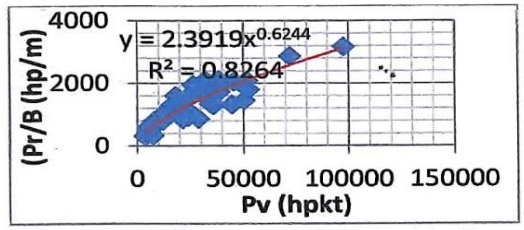

Fig 20 Pr/B factor correlated with Pv

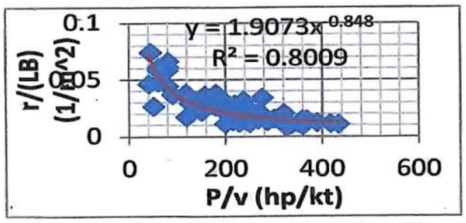

Fig 21 r/(LB) factor correlated with P/v.

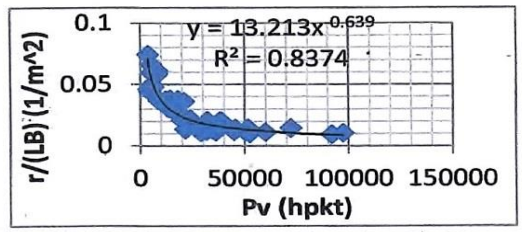

Fig 22 r/(LB) factor correlated with Pv

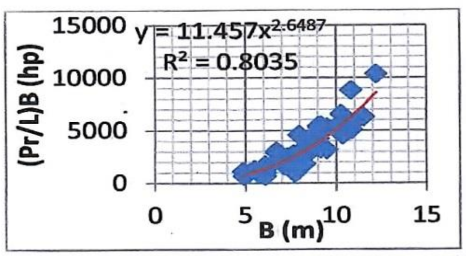

Fig 23 (Pr/L)B factor correlated with B.

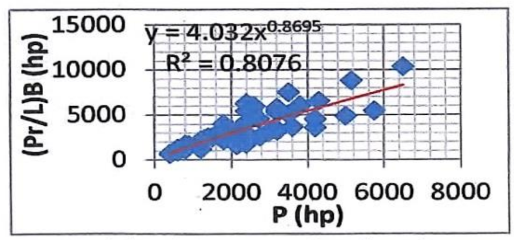

Fig 24 (Pr/L)B factor correlated with power P

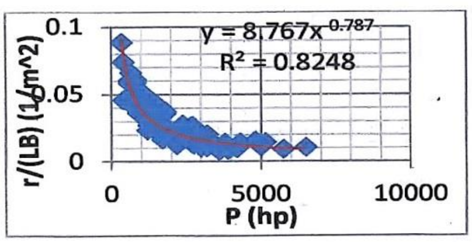

Fig 25 r/(LB) factor correlated with P.

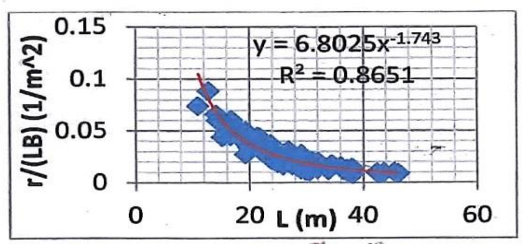

Fig 26 r/(LB) factor correlated with L

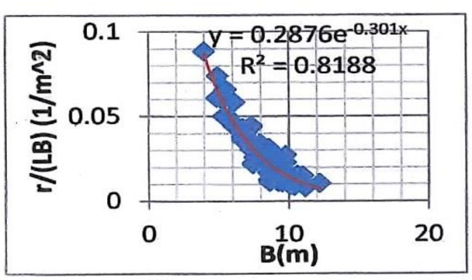

Fig 27 r/(LB) factor correlated with B.

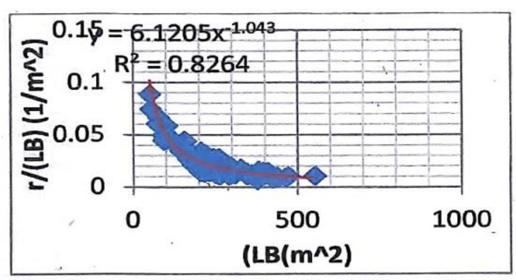

Fig 28 r/(LB) factor correlated with LB