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Prediction of Main Dimension of Tugboats Basing on Gross Tonnage.

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ABSTRACT–Gross tonnage of a projected vessel is the input in the prediction of the dimensions of a projected tug boat. In order to assist the designer, the operator and owner of a prospective vessel to know the possible dimension of their projected vessel from the point of view of gross tonnage this paper is presented. This is important in consideration and inclusion of the commercial trade-offs connected with gross tonnage at the early design stage of tugboats. The result of this gross tonnage method can be compared with that of other technically existing methods in prediction of main dimension of the tugboat.

Keywords–Gross tonnage, Tugboat, dimensions, regression analysis,prediction.

I INTRODUCTION

Deadweight, speed, endurance range of voyage, propulsive machinery type and size are input factors to determine the dimensional parameters of a vessel[1], [2] and others. The bollard pull, the depth of the channel or the main power can amongst other factors also be the main bases for prediction of tugboat or other vessel main dimensions[3].

The gross tonnage is normally computed for a completed design ship or existing vessel and is rarely considered an input to the design of ships. Since the gross tonnage determine more than 50% of the operational cost of a vessel it will be valuable if it is included as a factor in the early stage of the ship design especially in determining the initial dimensions of the vessel in comparison to that of other known methods. This is what this paper hopes to achieve by finding the correlation between ship dimensional parameters with the gross tonnage for existing tugboats.

The ship operational costswhich are determined by the gross tonnage value are: port charges – towage, pilotage, harbour, mooring and light charges; cargo charges – stevedoring, crane, and tally and overtime charges for ships, ship charges,- master, crew, provisions, water, stores; Rules and regulation charges, ship survey charges and other charges stipulated by national and international port authorities.The entire charges are to be made with respect to the gross tonnage value of the vessel [4].A prospective vessel owner having optimized the sum of these charges can determine the expected gross tonnage of the new design vessel which in tune becomes an economic input used to determine the value of the main dimensional parameters of the new design vessel as presented in this paper.

In existing publications Amrie[5] shows how gross tonnage is the factor to minimise ship operating costs. Ridwan [6], and Vansudevan[7] and others stated how tonnage measurement is evaluated for ships. The regression analysis of Piko[8] is interesting as in it the parameters ship length L, breadth B (m), draft T(m), net register tonnage NRT, age(years), power P(kw), ships speed V(kt), and twenty feet equivalent unit TEU for container ships values where correlated with gross tonnage GT for these ships: container ships, roll on roll off, bulk carriers, ore carriers, tankers, general cargo ships and passenger ships respectively and exclusively. Other types of vessels like tugboats, fishing vessels and others, were not included in his regression analysis as is contained in this work.

II METHOD

The data for the regression analysis were obtained from the internet adverts for tugboats sales, and other publications of tugboat profiles [9], [10], [11]. A total of 366 existing tugboat data were collected, sorted and used in this analysis. A part of this data is shown in Table 1.

The well-known regression procedure [12]are used (as presented in the MicroSoft EXCEL add in) for this linear and non-linear regression analysis. The regression is between these hull parameters L, B, D, T, LB, BD, LT, BT, DT, LBD, LBT, P on the vertical and GT on the horizontal axes respectively. Where: L = Overall length (m), B = breadth(m), D = depth(m), T = Draft(m), P = main engine power (hp), GT = gross tonnage.

Regression of the GTxNT product on the hull parameters was done to help calculate the net tonnage NT on prediction ofthe main dimension. Other products or quotients of the hull parameters where also analysed, but whereas there regression coefficients are not upto 0.8 there results are not included in this paper.

Successive substitution of given gross tonnage value into the equations resulting from this work will give various values of the main dimensions of the vessel desired.

III. RESULTS AND DISCUSSION

The results of the correlation analysis are listed in Table 2. The sample sizes are also listed for the respective derived equations in this table. Fig 1 to Fig 10 show the scatter diagram, and the equation of the line of the regression analysis.

It can be observed that whereas most ship design equation in the past[1],[2] are based on non-dimensional quotients like L/B, B/D for empirical ship design formulas, tugboat formulas fitted better on dimensional LB, BD, LT, BT, DT, square numbers and LBD, LBT cubic numbers.

For example we can get the main dimentions of a projected vessel of 180gross tonnage By substituting gross tonnage of 180 into equations (1) to (12) according to (EXCEL formation of Table 3). This is done In thisway:

Eq1 = 4.1475*(F3)^0.3841 where F3 is the value of 180 in cell row3, column in Table 3. This Eq1 is taken from Table 2. In similar way all the cells of Table 3 are computed with respect to their respective equations indicated in each cell in Table3 relative to Table 2.

The resulting EXCEL computation for each cell is presented in Table 4. Computing the mean value of each column gives the expected result of themaine dimension of the tug boat as

L = 28.33m, B = 7.99m, D= 4.183m, T = 3.237m and P = 2507.87hp for the gross tonnage of 180GT.

The above values of L, B, D, and T computed, when being substituted in equations (14 to 18) of Table 2 predicts the expected net tonnage NT values as shown in table 5. It can be seen from this table that NT ranges from 55.39 to 98.11 NT with a mean value of 74.74NT for the vessel with 180GT. This will be a guide to the design of net spaces for the tugboat.

IV CONCLUSION

Regression analysis of tugboat main parameters presented in this paper show 12 equations. These equations were amongst many other correlations, but are those whose correlation factor R2 were greater than 0.8. The tugboat parameters were length L(m), Breadth B(m), Depth D(m), Draft T(m), and main engine power P(hp), correlated against gross tonnage GT. Equations showing correlations to determine the Net tonnage NT are also included. An example on the application of these equation in the prediction of the main dimensions of a projected Tugboat of GT = 180 is also presented to give L = 28.33m, B = 7.99m, D= 4.183m, T = 3.237m, P = 2507.87hp and NT =74.74 mean value.

It is also observed from this analysis that that whereas most ship design equation in the past are based on non-dimensional quotients like L/B, B/D for empirical ship design formulas, tugboat formulas fitted better on dimensional LB, BD, LT, BT, DT, square numbers and LBD, LBT cubic numbers.

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Table 1 A collection of the principal dimension of modern Tugboat

NAME/FLAG	BUILT/CLS	YRBIULT	LAO	B	D	T	GT	NRT
130718-VN	ISTANBUL RINA	2011	19.95	7	3.2	2.2	124	43
140421-VW	ABS	2006	29	9	4.25	3.5	284	74
141207-VO	SPAIN	2002	31.21	8.41	4.51	4	253	76
120322-VW	MALAY	2016	35	11.5	5.62	4.8	493	147
150633 VO	CHINA BV	2009	36.1	10.6	4.9	4	472	141
121111-VN	CCS CSA CSM	2012	37.7	10.4	4.8	3.65	484	165
9397-TG-OM	PANAMA/IRS	1967	50.33	12.2	5	4.78	1273	325
150632 VA	CHINABV	2012	58.7	14.6	5.5	4.75	1537	461
150611 VA	KEPPEL	2004	60	16	6	5	1705	511
150616-VA	SINGAPORE	2000	60	13.8	6.8	5.6	1527	458
150615 VA	SINGAPORE	2013	81	16.8	7.5	6.4	3208	962
150613-VA	SINGAPORE	2013	81	16.8	7.5	6.4	3208	962

NAME/FLAG	BUILT/CLS	YRBIULT	LAO	B	D	GRT	NRT
151223 VT	ITALY	2005	14.91	5	1.8	80	30
151221VN	ITALI RINA	2007	23	6.5	3.2	125	58
151131-VO	NKKMALAY		26	8	3.65	46	28
SGAPOR	MASIA/NKK	2001	27	8.5	4.15	217	66
140725-VN			27.89	8.17	4.27	160	109
120304-VM	SINGAPORENKK	2012	28.5	8.5	3.8	271	81
121108 VW	ITALI RINA	1985	28.55	6.56	3.82	149	44
140421-VW	SingaporeABS	2006	29	9	4.25	284	74
131035 VN	USSR	1991	29.3	8.24	3.4	182	54
140408-VO	NS	2014	32.4	9.15	4.48	272	76
141125-VO	UK	2014	32.6	9	4.3	272	86
120322-VW	MALAY	BV2016	35	11.5	5.62	493	147
150633 VO	CHINA BV	2009	36.1	10.6	4.9	472	141
141137-VA		2007	37	10.6	4.95	449	135
140827 VN	INDONESIA BK1	2006	37.41	9	4.56	411	124
121111-VN	CCS CSA CSM	2012	37.7	10.4	4.8	484	165

141138 va	singapore	2008	38.1	10.6	4.9	488	146
151204-VA	SINGAPORE ABS	1983	42	11.4	5	622	435
150632 VA	CHINABV	2012	58.7	14.6	5.5	1537	461
150611 VA	KEPPEL	2004	60	16	6	1705	511

Table 2 Tugboat design formulas as a function of gross tonnage(x = GT) .

N	R^2	Formula	Eq. no
120	0.902	$L = 4.1475x^{0.3841}$ -	**Eq1**
120	0.906	$B = 1.939x^{0.2782}$ -	**Eq2**
26	0.857	$D = 1.1288\ln(x) – 1.983$ - - - - - - - - - - - - - - - - - -	**Eq3**
120	0.928	$LB = 10.137x^{0.6034}$ -	**Eq4**
29	0.964	$BD = 9E\text{-}09x^3 – 5E\text{-}05x^2 + 0.1103x + 12.002$ - - - - -	**Eq5**
120	0.928	$LT = 4E\text{-}08x^3 – 0.0002x^2 + 0.3695x + 24.5$ - - - - -	**Eq6**
120	0.860	$BT = 8E\text{-}09x^3 - 4E\text{-}05x^2 + 0.0895x + 11.05$ - - - - -	**Eq7**
18	0.841	$DT = 1.5492x^{0.4155}$ -	**Eq8**
29	0.991	$LBD = 3.1067x + 363.64$ - - - - - - - - - - - - - - - - -	**Eq9**
120	0.961	$LBT = 2.6968x + 212.9$ - - - - - - - - - - - - - - - - - -	**Eq10**
26	0.827	$P = 1690\ln(x) – 6606.8$ - - - - - - - - - - - - - - - - - -	**Eq11**
115	0.967	$P = 841.35B – 4646.2$ - - - - - - - - - - - - - - - - - - -	**Eq13**
150	0.857	$P = 0.0002(LBD)^2 + 2.5382(LBD)$ - - - - - - - - - - -	**Eq14**
120	0.996	$GRT*NRT = 0.0443LBT)^2 - 33.105LBT + 10442$ - -	
120	0.996	$GRT*NRT = 0.5407LBT)^{1.5756}$ - - - - - - - - - - - - -	**Eq15**
119	0.984	$GRT*NRT = 0.0168(LT)^3 + 3.5184LT)^2 - 366.83LT$	**Eq16**
119	0.948	$GRT*NRT = 2.015(LT)^{2.0262}$ - - - - - - - - - - - - - - -	**Eq17**
119	0.992	$GRT*NRT = 0.0014(LB)^3 - 0.3146(LB)^2 - 90.89(LB) - 4500$ -	**Eq18**

Table 3 EXCEL layout for calculation of principal dimensionof tugboat

	A	**B**	**C**	**D**	**E**	**F**
1	**LOA(m)**	**B(m)**	**D(m)**	**T(m)**	**P(hp)**	**GRT**
2	Eq1	Eq2	Eq3	Eq6/A2	Eq11	GRT
3	Eq4/B2	Eq5/C2	Eq 5/B2	Eq7/B2	Eq12(B2)	
4	Eq6/D2	Eq4/A2	Eq8/D2	Eq8/C2	Eq13(A4*B4*C4)	
5	Eq9/Eq5	Eq10/Eq6	Eq9/Eq4	Eq10/Eq4	Eq13(A5*B5*C5)	
6	Eq6/D3	Eq4/A3	Eq8/D3	Eq8/C3	Eq13(A6*B6*C6)	
7	(Eq10*C3)/ (B2*Eq8)	(Eq10*C3)/ (Eq6*C2)	(Eq9*E7)/ (Eq4*Eq2*D2)	(Eq9*E7)/ (Eq4*Eq5)	Eq13(A7*B7*C7)	
	FIND AVERAGE OF EACH COLUMN					

Table 4 Calculation of principal dimensionof tugboat for Gross tonnage = 180 GRT

	A	**B**	**C**	**D**	**E**	**F**
1	LAO(m)	B(m)	D(m)	T(m)	P(hp)	GRT
2	30.481	8.222	3.879	2.781	2169	180
3	28.297	7.809	3.684	3.151	2272	
4	30.481	7.633	4.820	3.455	3098	

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5	30.469	8.239	3.966	3.001	2725	
6	26.898	8.222	4.253	3.638	2564	
7	23.344	7.824	4.495	3.393	2219	
8	**28.328**	**7.992**	**4.1826615**	**3.237**	**2507**	**MEAN**

Table 5 Calculation of net tonnage from regession equations for L=28.33m, B=7.99m, D=4.18m and T= 3.34m

CALCULATION OF NET TONNAGE							
from	Eq14	GT*NT =	9969.6004	Therefore,	NT	=	55.39
from	EQ15	GT*NT =	17659.142	Therefore,	NT	=	98.11
from	EQ16	GT*NT =	15330.231	THEN,	NT	=	85.17
from	EQ17	GT*NT =	14175.721	THEN,	NT	=	78.75
from	EQ18	GT*NT =	10135.752	THEN,	NT	=	56.31
				MEAN	**NT**	**=**	**74.74**
				MINIMUM	**NT**	**=**	**55.39**
				MAXIMIM	**NT**	**=**	**98.11**

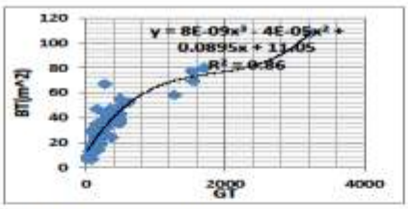

Fig 7.Regression of BT on GT

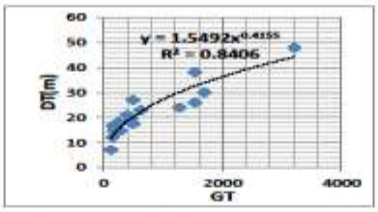

Fig 8. Regression of DT on GT

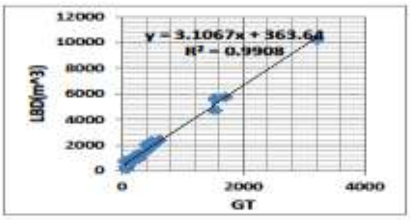

Fig 9 Regression of LBT on GT

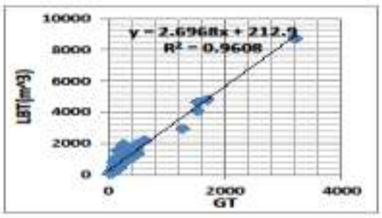

Fig 10. Regression of LBT on GT

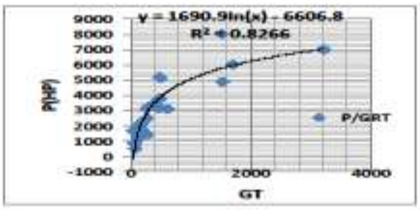

Fig 11.Regression of P on GT

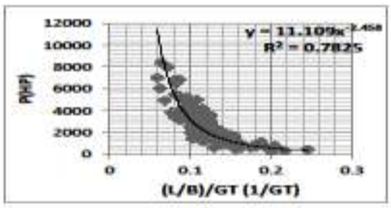

Fig 12. Regression of P on (L/B)/GT)

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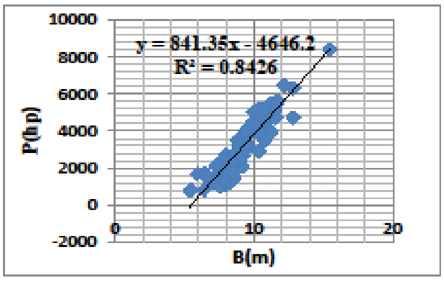

Fig 13.Regression of P on B.

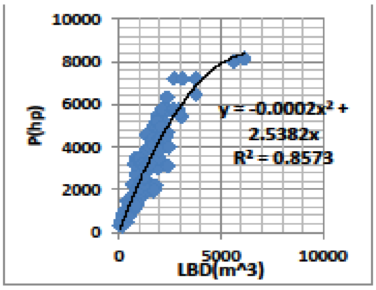

Fig 14. Regression of P on LBD

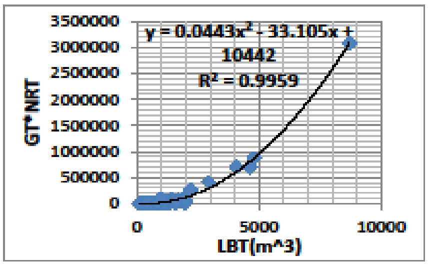

Fig 15..Regression of GT*NRT on LBT.

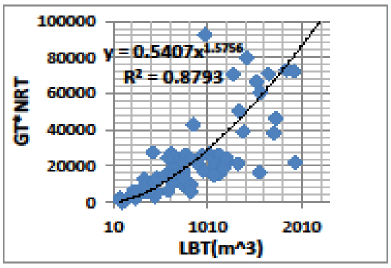

Fig 16.. Regression of GT*NRT on LBT

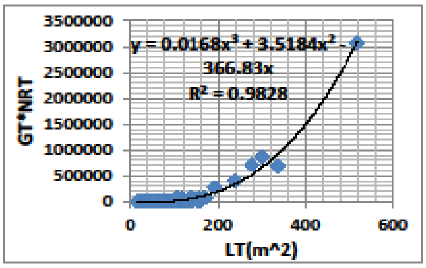

Fig 17.Regression of GT*NRT on LT.

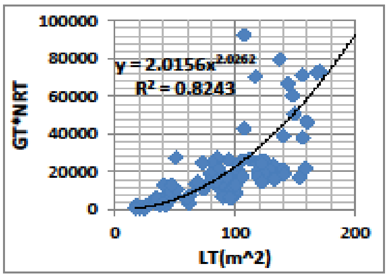

Fig 18.Regression of GT*NRT on LT.

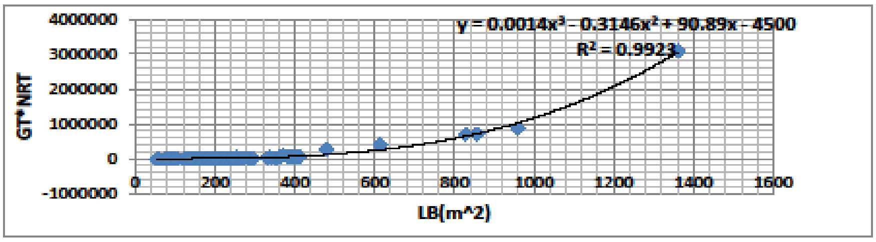

Fig 19. Regression of GT*NRT on LB