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Form Factors Method in the Design of Gas Carrier Ships

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ABSTRACT: Six scatter plot diagrams and eight empirical equations derived from regression analysis of parameters collected from 207 ships, together with a simple but efficient method for the prediction of preliminary main dimensions of projected gas carrier ships is presented in this work. The main input to this method is the ship owners' requirements comprising of total gas tank capacity, deadweight and ships speed amongst other parameters. The well accepted Microsoft statistical Analysis add-in in parameters. The regression analysis program used is the well accepted statistical analysis add-in of EXCEL for Windows 2010 version.

KEYWORDS: Gas, Carriers, ship, Form, factors Formulas, Design, and Dimensions

I. INTRODUCTION

Gas carrier ships transport, Liquefied Natural gas (LNG), Compressed Natural Gas (CNG), Liquefied Petroleum Gas (LPG), Liquefied Ethylene carrier (LEC), Ammonia Gas Carrier (NH3C), and other chemical gases. These ships are the type of ships referenced to in this paper. These type of vessels are described in literature [1], [2] and [3] to mention a few. The origin and state of art for these type of vessels can be found in [4], [5] and other references. Design formulas and method for these type of vessels can found in [6], [7] references. This paper presents a modern perspective considering form factors values as a basis for the preliminary design of these vessels. The form factors are important part of the ship design process [8], [9] to mention a few. The form factors depends on type and size of ship so we consider these factors for gas carriers particularly as, L/B, L/D, B/D, correlated with L, B, D, LD, BD, LBD respectively. L, B, and D, are ships length overall, breath, and depth respectively. To obtain the design draft T, the maximum draft T_{MAX}, the length between perpendiculars LBP, and main power estimate P, eight empirical formulas of my previous publication on gas carrier ship are employed.

II. METHOD

The data for this work are obtained from the internet and include the principal dimensions of gas carrier ships in current existence [8], [9], [10], and others. These data is partially shown in table [1]. Totally, 207 gas carrier ships dimensions were collated analysed by fitting list square regression function [11] to obtain the equation 1 to 8 in table 2. In this table N and R^2 are the respective number of data points and the correlation factor of the analysis. The values Min, Max, Mean, in Table 2 are the minimum, maximum, and mean values for the form ratio of the respective L/B, L/D, B/D ratio of the actual ships data collected. The main dimensions of a projected gas carrier vessel can be obtained by systematic substitution of the owners requirements stated as T_C (m^3) the total volume of gas the vessel is intending to carry as cargo for transportation and ship speed v(kt). Eight equations in the Table 2 are to obtain Dwt(t) - deadweight, B(m) - ship breath and P(Kw) (main ship power). These formulas are taken from the author's previous work [13]. The mean of the values predicted for B is used to get the other design parameters required for the ship basing on the mean values of form ratio stated in Table 2. The procedure stated above is illustrated and exemplified below under Result and Discussion.

III. MODELING AND ANALYSIS

The regression analysis used in the analysis of data points is the Microsoft EXCELL ad-in. This software gives the least square fit of a set of two variables data points to a formula which could be linear, power, exponential, or a polynomial function according to the theory in books [11] and others. The chosen number of data points and the R^2 correlation factors not less than 0.8 are quite high and adequate for the derived formulas stated in this work.

The variables considered from the data collected are:

LOA (L), LBP, B, D, T_D, T_{MAX} and TC which are length overall L, length between perpendiculars LBP, breadth B, depth D, design draft T_D, maximum loaded draft T_{MAX}, and total volume of the gas tanks T_C for the gas carrier ships.

IV. RESULTS AND DISCUSSION

The collected data covered the ranges of dimensions:

L = 63m to 333m, B = 11m to 55m,

D = 4.5m to 32.3m, T = 4.2m to 13.1m.

The scatter plot diagrams are shown in Fig 1 to 6. Table 2 present the mean value for the variables calculated from the entire collected data. In Table 2 also the relevant derived formulas from the author previous work [12] and [13] are shown.

Normally the ship design process starts with owners requirements which in this case includes amongst other factors: Gas tank capacity Tc (m3) , and Speed of ship v (kt). Basing on Table 2, equation 1[12], 2[13] and 3[13] the ships deadweight Dwt (t) breadth B(m), are calculated for the given Tc value. Similarly from Dwt calculated and the ships speed v the expected main propulsive power P (kw)[12] is calculated.

The mean value of the predicted values of B calculated is the entry point in the prediction of the dimensions L, B, D, T and P by systematic substitution and averaging as shown in Table 3. For gas tankers the breath of the ship will consider the minimum clearance distance from the gas tank outer diameter and the ship side. This distance is normally stipulated in the rules for construction of gas carrier ships of the classification societies and will be calculated at later ship design stage.

A gas tanker, with tank capacity Tc of $3500m^3$ is desired to operate at a speed of 14 kts for example, what will be the main dimension of this projected vessel using the formulas proposed in this paper? This example is meant to validate the method proposed in this work and the result is shown in table 3 below. The parameters of the projected vessel predicted in this table are: LOA = 102.39m, LBP = 76.04m, B = 16.60m, D = 9.134m, T = 6.08m, Tmax = 6.578m, deadweight Dwt = 4357.85t, Main Power P = 3675.15Kw.

The mean percentage difference between the actual existing ships values and that predicted by the method presented in this paper are as follows:

For input values of Tc and v the values are 0.43%, and -2.90% respectively. The computed parameters of LOA (L) is (-2.90%), LBP (-2.98%), B (-2.11%), D, (-15.03%), T, (-9.53%), P, –(11.06%), Dwt (-5.67%), v = (- 6.25%) less than the existing respective parameters of the existing ships. These deviation are quite acceptable at the preliminary design stages of the vessels.

CONCLUSION

The 8 formulas presented here together with six scatter diagram plots are derived from data collated from existing gas carrier ship of different types and capacities. The formulas presented are derived with regression analysis models of different types of functions – linear, power, exponential, logarithmic, or polynomial function models. The formulas presented have square correlation coefficient R^2 values ranging from 0.8 to 0.99. The total number of data points was from 207 ships. The method presented give a prediction of acceptable preliminary dimension of length overall L, length between perpendiculars LBP, breadth B, design draft T, maximum draft Tmax, depth D, deadweight Dwt and main power P of the projected vessel. The input values are the total capacity Tc of the gas tanks, and speed v of the projected vessel is prescribed by the owner of the ship. The method proposed in this paper is validated by computation of main dimension of a gas carrier ship of total tank capacity of 3500m3.

Table 4 show a comparison of the predicted parameters values with that of similar existing ships to authenticate the method proposed in this paper for the purposes of designing similar vessels of other different ship owner's requirements. The percentage deviations are acceptable for the preliminary design stage when compared with existing ships parameters for gas carrier ships.

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Table 1. List of Gas Carrier Ships and there Main Parameters

S/N	VESSEL	L0A	B	D	VESSEL	L0A	B	T
1	WSD50-5K	99.99	19.2	9.3	WSD50-5K	99.99	19.2	5
2	WSD50-7.5K	115.1	18.6	10.5	WSD50-7.5K	115.1	18.6	5.5
3	CLASSNK	107.8	17.2	7.8	SAYENDO	288	48.94	11.55
4	SAYENDO	288	48.94	26	AVONDALE	284	42.8	11
5	AVONDALE	284	42.8	28.6	GASCHEM	99.9	17.4	7.2
6	Puteri intan satu	278	43.4	25.5	MINI LNG	152.3	18.8	6.7
7	GASCHEM	99.9	17.4	11.7	q-max	345	55	12
8	MINI LNG	152.3	18.8	11.5	qflex	315	50	12
9	LNT A-BOX	94.9	20.4	9.6	MT DANUBEGA S	98.5	15.2	6.5
10	LNT A-BOX18	146	24	7	POLA EAGLE	239	40	11.02
11	q-max	345	55	27	DL ZINNIA	106	17.6	5.739
12	MT DANUBEGA S	98.5	15.2	10	EARTH SUMMIT	159.99	24.8	9.4
13	POLA EAGLE	239	40	26.8	ELLINGTON	159.99	24.8	9.4
14	DL ZINNIA	106	17.6	8.1	FATME	106	17.6	5.95
15	EARTH SUMMIT	159.9 9	24.8	16.7	GAS MYTH	99.9	17.6	6.15
16	ELLINGTON	159.9 9	24.8	16.7	ALRAR	204.9	32.2	12.1
17	FATME	106	17.6	8.1	ALSTERGAS	99.9	15.9	7.2
18	GAS MYTH	99.9	17.6	8	ALTO ACRUX	288	49	11.3
19	GAS CERBERUS	99.9	19.6	8	AMAGI MARU	42.2	8.3	3.2
20	SEAGAS	105.6	17.6	7.7	AMAN	130	25.7	7.1

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	GENERAL	2			BINTULU			
21	MT GASCHEM	173.7	28.04	17.8	AMAN HAKATA	130	25.7	7.1
22	EMSHIP	293	49	27	AMAN SENDAI	130	25.7	7.1
23	ECOSTAR 36K	188.3	29	17.5	AMANAH	70.6	12.6	4.4
24	ECOSTAR 85K	231.6	36.6	22	AN LONG	67.9	11	4.2
25	GASCHEM WERRA	114.8 9	16.8	11.83	SENNA 2	100	16.4	5.9
26	GASCHEM CARIBIC	128.8 1	17.8	11.9	SENNA 4	105.9	16.1	5
27	GASCHEM	99.9	18	11.25	SENRYU MARU	62.5	11.9	4.1
28	M/V GRAJAU	134	19	11.7	SENYO MARU	69.5	12	4.2
29	KAHYASI	119	20.63	9.635	SEOUL GAS	105.9	16.1	5
30	KORAL METHANE	117.8	18.6	10.6	SERI ALAM	283.1	43.4	12.4
31	KENDAL	119.0 5	20	10	SERI AMANAH	283	43.4	11.4
32	KESWICK	119.9 5	20	10	GAS CERBERUS	99.9	19.6	6.165
33	KINGCRAFT 2015	119.9 8	21.024	10.01 35	SEAGAS GENERAL	105.62	17.6	5.91
34	KISBER	119.9 8	21.024	10.01 35	MT GASCHEM HAMBURG	173.7	28.04	10.42
35	KRIS KIN	119.9 2	20.63	9.635	EMSHIP	293	49	12
36	ABADI	290	46	25.5	ECOSTAR 36K	188.3	29	9.5
37	WSD50 5K	99.9	12.2	9.3	ECOSTAR 85K	231.6	36.6	12
38	CNC32000	220	40	22	GASCHEM WERRA 2011	114.89	16.8	8.1
39	QEM STAR	95.3	16.5	7.25	GASCHEM CARIBIC	128.81	17.8	8.6
40	SUMMER CORAL	96.7	16.5	7.25	JS JAGUAR	99.9	17.4	7.2
41	DIAMOND CORAL	97.69	16	7.2	GASCHEM	99.9	18	5.8
42	ORCHID CORAL	97.69	16	7.2	M/V GRAJAU	134	19	8.4
43	LOTUS CORAL	97.67	16	7.2	KAHYASI	119	20.63	6.815
44	JASMINE CORAL	97.6	16	7.2	KENDAL	119.05	20	7.365

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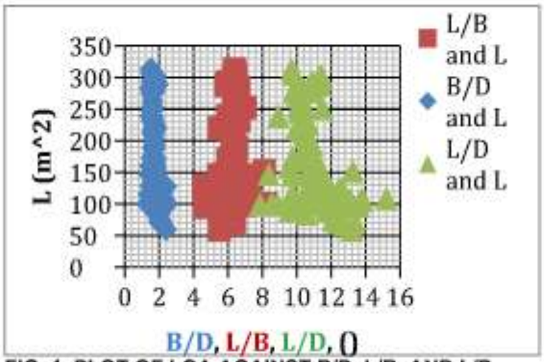

FIG. 1. PLOT OF LOA AGAINST B/D, L/B, AND L/D

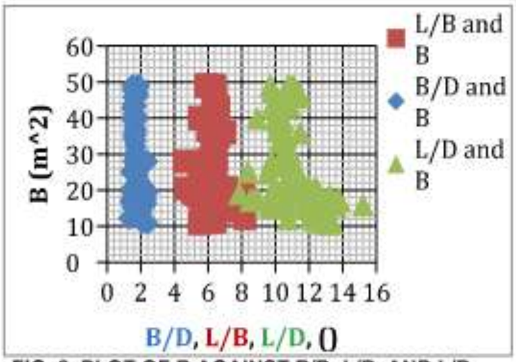

FIG. 2. PLOT OF B AGAINST B/D, L/B, AND L/D

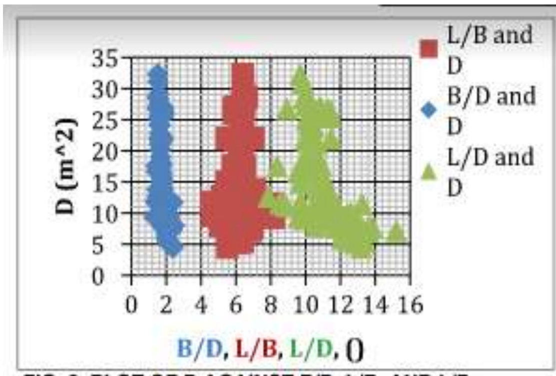

FIG. 3. PLOT OF D AGAINST B/D, L/B, AND L/D

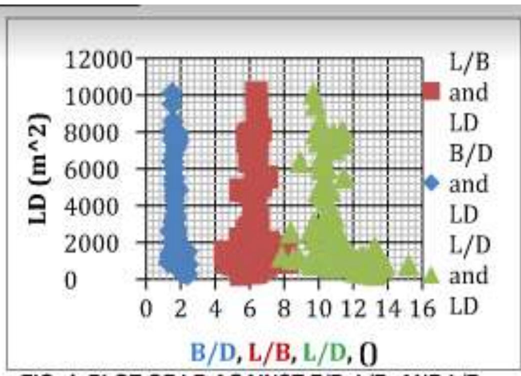

FIG. 4. PLOT OF LD AGAINST B/D, L/B, AND L/D

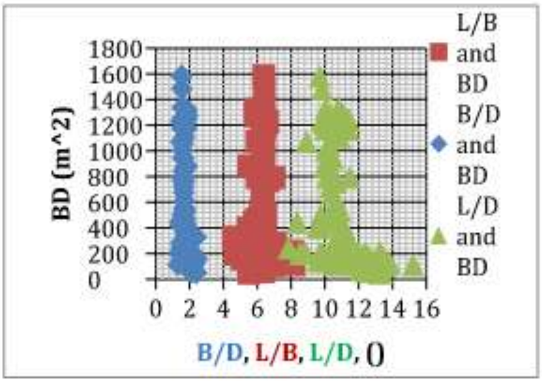

FIG. 5. PLOT OF BD AGAINST B/D, L/B, AND L/D

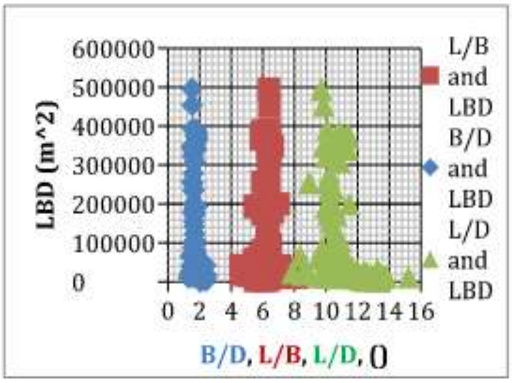

FIG. 6. PLOT OF LBD AGAINST B/D, L/B, AND L/D

TABLE 2. STATISTICS AND REGRESSION ANALYSIS FORMULAS DERIVED FROM THE DATA OF GAS CARRIER SHIPS COLLETED.

S/N	SHIP FORM RATIO	Min	Max	Mean	N
1	L/B	4.57	8.19	6.17	122
2	L/D	7.86	15.21	11.19	122
3	B/D	1.312	2.45	1.82	122
	REGRESSION	EQUATIONS	unit	(.) Eqn No.	[ref.]

N= 093, R^2 = 0.985, Dwt = 0.4873Tc + 2652.3	**(t)**	**(1)[12]**
N = 083, R^2 = 0.986, B = $1.5407Tc^{0.2828}$	**(m)**	**(2)[13]**
N = 101, R^2 = 0.937, B = $1.2303 (Dwt)^{0.3182}$	**(m)**	**(3)[13]**
N = 037, R^2 = 0.901, P = $38.243(v/(Dwt))^{-0.793}$	**(kw)**	**(4)[12]**
N = 037, R^2=0.906, P = $93.262v^3$-$3557.2v^2$+45659v-194203	**(kw)**	**(5)[12]**
N = 155, R2= 0.866, ln(T) = -$0.001B^2$ + 0.086B + 0.6385	**(m)**	**(5)[13]**
N = 155, R2= 0.900, ln(T) = -2E-$05L^2$+0.0115L+0.85	**(m)**	**(6)[13]**
N = 127, R2= 0.999, LBP = 0.9644L – 2.7074	**(m)**	**(7)[13]**
N = 11, R2= 0.987, T_{MAX} = 1.0492T + 0.204	**(m)**	**(8)[13]**

TABLE 3. EXAMPLE OF PREDICTION OF SHIP DIMENSIONS FOR FULL GAS TANK CAPACITY T_C OF 3500m^3

TC =	**3500**	**m^3**
v =	**14**	**kt**
Dwt = 0.4873Tc + 2652.3 =	**4357.850**	**t**
B = $1.5407Tc^{0.2828}$ =	**15.487**	**m**
B = $1.2303 (Dwt)^{0.3182}$ =	**17.702**	**m**
P = $38.243(v/(Dwt))^{-0.793}$ =	**3627.566**	**Kw**
P = $93.262v^3$-$3557.2v^2$+45659v-194203 =	**3722.728**	**Kw**
B =	**16.595**	**m**
P =	**3675.147**	**Kw**
L/B =6.17 \ L =	**102.390**	**m**
L/D =11.19 \□ □ □ □D =	**9.150**	**m**
B/D =1.82 \ D =	**9.118**	**m**
D =	**9.134**	**m**
ln(T) = -$0.001B^2$ + 0.086B + 0.6385, T =	**5.991**	**m**
ln(T) = -2E-$05L^2$+0.0115L+0.85, T=	**6.158**	**m**
T =	**6.075**	**m**
L_{BP} = 0.9644L – 2.7074 =	**96.038**	**m**
T_{MAX} = 1.0492T + 0.204 =	**6.578**	**m**