International Journal of Engineering Applied Sciences and Technology, 2022
Vol. 6, Issue 9, ISSN No. 2455-2143, Pages 180-195
Published Online January 2022 in IJEAST (http://www.ijeast.com)

EMPIRICAL FORMULAS FOR DESIGN OF GAS CARRIER SHIPS

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***Abstract* - A total of 42 formulas derived from regression analysis of parameters collected from 207 gas carrier ships are presented in this work. These formulas together with a method necessary for the prediction of optimal preliminary main dimensions for the projected design of gas carrier ships of different types. The main input to this method is the known ship owners' requirement of volume of capacity of gas tank, and ships speed amongst other parameters. The regression analysis program used is the well accepted Microsoft statistical Analysis add-in in EXCEL for Windows 2015 version.**

Keywords: **Design, LNG, LPG, Gas-Tankers, Formulas, Dimensions**

I. INTRODUCTION

Gas carrier ships also called Gas Tankers transport Liquefied Petroleum Gas LPG, Liquefied Natural gas LNG, Compressed Natural Gas CNG, Liquefied Ethylene Gas LEC, Ammonia Gas NH_3, and other chemical gases as cargo.

The cargos are carried in different types of tanks namely: Membrane, Semi-membrane tanks which are built as integral part of the ship's hull; Types A, B, and C tanks which are independently built and installed into the ship's hull. There are other tank types classified as Type 1, 2, 3 which are barrier insulated tanks. Types of gas tanks also depends on the group type of gas cargo categorized basing on the gas boiling point, chemical binding, toxicity and flammability hazard level.

These gas tanks maybe fully pressurized, semi pressurized and refrigerated, or fully refrigerated for liquefaction of the gas cargo. The pressure ranges from ambient pressure to 10kg/cm while the temperature ranges from -10^{oc} to -162^{oc}

Volume contraction ratio are 1: 250 for LPG and 1:600 for LNG. The review stated above can be found in the following references [1], [2] and [3] to mention a few.

Current state of art for these type of vessels can be found in [4], [5] and other references. The main dimensions prediction empirical formulas for gas tankers exist scantly in literature [6], [7]. These types of vessels are relatively new in operation in the world [8]. This led to the limited publication concerning the design formulas for her design. This work is a study and analysis of existing ships aimed at obtaining useful method and formulas for the design of projected gas carrier ships

II. METHODOLOGY

The data for this work are obtained from the internet and include the principal dimensions of gas carrier ship in existence [8], [9], [10], and others. These data is partially shown in table [1]. Totally 207 gas carrier ships dimensions were collated analyzed by fitting list square regression function [11] to obtain results published hereunder. The main dimensions of a projected gas carrier vessel can be obtained by systematic substitution of the owners requirements stated as the volume of gas the vessel is intended to carry as cargo for transportation, the speed of the projected vessel amongst other factors.

III. MODELING AND ANALYSIS

Regression analysis used in the analysis of data points is the Microsoft EXCELL ad-in which is well accepted and known program. This software gives the least square fit of a set of two variables obtaining a formula which could be linear, power, exponential, or a polynomial function [11], etc. 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 and presented formulas stated in this work. The variables considered from the data collected are:

- LOA (L), LBP, B, D, T_D, T_{MAX} and V_T which are length overall L, length between perpendiculars, breadth, depth, design draft, maximum loaded draft, and total volume of the gas tanks of the gas carrier ship respectively.
- The variables squared units such as LB, LT, BD, BT and DT.
- The variables cubic units, LBD, and LBT.

IV. RESULTS AND DISCUSSION

The collected data covered these ranges of dimensions for all the gas tanker used in this analysis:
L = 63m to 333m, B = 11m to 55m,
D = 4.5m to 32.3m, T = 4.2m to 13.1m.

The scatter plot diagrams with the respective fitted lines or curves together with the derived formula are shown in Fig 1 to 31. Table 2 present the entirely derived formulas showing the number of data points and the R^2 correlation value for each regression analysis formula derived in this work.

Normally the ship design process starts with owners requirements which in this case includes amongst other factors: Gas tank capacity Tc (m^3), and Speed of ship v (kt). Basing on Table 2, equation 38[12], 39 and 40 the ships deadweight Dwt

(t) breadth B(m), and the can be calculated for the given Tc value. Similarly from Dwt calculated and the ships speed v given the expected main propulsive power P (kw)[12] can be easily calculated.

The mean value of B calculated above is the entry point in the utilization of equations 1 to 37c in the prediction of the optimal values of projected gas tanker dimensions L, B, D, T and P by systematic substitution and cumulative averaging.

To validate this presentation, a gas tanker with tank capacity Tc of 3500m^3 is desired to operate at a speed of 15 kts, 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.

Reference to equation 38 to 42 from Table 2 the computed value for Dwt, B, economic main power P [ ] for 13.9kts are 4357.85t, 16.595m, 3643.47Kw respectively for Tc = 3500m^3

This of B is the main entry variable use to begin the successive systematic substitution of values in equation 1 to 37c of table 2. The result of this calculation is shown in Table 3.

The calculate parameters predicted are:

LOA = L = 101.93m, LBP = 95.60 m B = 16.64m, T = 6.83m, T_{max} = 7.37m D = 8.83m. The main parameters of L, B, T and D are checked for consistency with the predicted values of the squared and cubic values of BT = 108.11m^2, LT = 638.65 m^2, BD = 148.04 m^2, LD = 901.33 m^2, LB = 1706.66 m^2, LBD = 15314.98 m^3, LBT = 12008.67 m^3 in table 4. The result the predicted main particulars is very much acceptable with overall consistency error of 0.8%.

V. CONCLUSION

The 42 formulas presented here are for the preliminary design of gas tankers of all existing types. The formulas are derived with regression analysis models of different types of functions – linear, power, exponential, logarithmic, or polynomial function models. The published formulas have square correlation coefficient R^2 values ranging from 0.8 to 0.99. The total number of data points was from 207 exiting steel constructed gas carrier ships. The method presented will give a prediction of optimum preliminary dimension of length overall LOA, length between perpendiculars LBP, breadth B, design draft T, maximum draft TMAX, depth D and deadweight Dwt of the projected vessel where the cubic capacity of gas volume and speed of the projected vessel is specified by the owner of the vessel.

VI. REFERENCES

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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	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 DANUBEGAS	98.5	15.2	6.5

10	LNT A-	146	24	7	POLA EAGLE	239	40	11.02
11	q-max	345	55	27	DL ZINNIA	106	17.6	5.739
12	MT DANU-	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	159.9	24.8	16.7	GAS MYTH	99.9	17.6	6.15
16	ELLINGTON	159.9	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 CER-	99.9	19.6	8	AMAGI MARU	42.2	8.3	3.2
20	SEAGAS	105.6	17.6	7.7	AMAN BINTULU	130	25.7	7.1
21	MT GAS-	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	188.3	29	17.5	AMANAH	70.6	12.6	4.4
24	ECOSTAR	231.6	36.6	22	AN LONG	67.9	11	4.2
25	GASCHEM	114.8	16.8	11.83	SENNA 2	100	16.4	5.9
26	GASCHEM	128.8	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 ME-	117.8	18.6	10.6	SERI ALAM	283.1	43.4	12.4
31	KENDAL	119.0	20	10	SERI AMANAH	283	43.4	11.4
32	KESWICK	119.9	20	10	GAS CERBERUS	99.9	19.6	6.165
33	KINGCRAFT	119.9	21.024	10.01	SEAGAS GENER-	105.62	17.6	5.91
34	KISBER	119.9	21.024	10.01	MT GASCHEM	173.7	28.04	10.42
35	KRIS KIN	119.9	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 WER-	114.89	16.8	8.1
39	QEM STAR	95.3	16.5	7.25	GASCHEM CA-	128.81	17.8	8.6
40	SUMMER	96.7	16.5	7.25	JS JAGUAR	99.9	17.4	7.2
41	DIAMOND	97.69	16	7.2	GASCHEM	99.9	18	5.8
42	ORCHID	97.69	16	7.2	M/V GRAJAU	134	19	8.4
43	LOTUS	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

International Journal of Engineering Applied Sciences and Technology, 2022
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Published Online January 2022 in IJEAST (http://www.ijeast.com)

Table 2. Formulas Derived From Main Dimensions of 207 Gas Carrier ships.

Data Coefficient	Formula	Unit	Equation number
N = 176, R2= 0.957,	L2 = 33.023B2.0463	(m2)	(1)
N = 176, R2= 0.969,	L = 6.376B – 3.6024	(m)	(2)
N = 122, R2= 0.956,	D = 0.6401B – 1.7389	(m)	(3)
N = 124, R2= 0.973,	D = 0.1007L – 1.3834	(m)	(4)
N = 155, R2= 0.866,	ln(T) = -0.001B2 + 0.086B + 0.6385	(m)	(5)
N = 155, R2= 0.900,	ln(T) = -2E-05L2+0.0115L+0.85	(m)	(6)
N = 127, R2= 0.999,	LBP = 0.9644LOA – 2.7074	(m)	(7)
N = 11, R2= 0.987,	TMAX = 1.0492T + 0.204	(m)	(8)
N = 176, R2= 0.993,	L.B = 6.2887B2	(m2)	(9)
N = 176, R2= 0.989,	L.B = 5.7465B2.0232	(m2)	(10)
N = 176, R2= 0.993,	L.B = 0.1576L2	(m2)	(11)
N = 176, R2= 0.990,	L.B = 0.2234L1.9354	(m2)	(12)
N = 122, R2= 0.954,	D = 0.1279(LB)0.5688	(m)	(13)
N = 122, R2= 0.961,	L.D = 2.0902B2.1555	(m2)	(14)
N = 123, R2= 0.992,	L.D = 0.091L2+2.09L – 256.63	(m2)	(15)
N = 120, R2= 0.988,	L.D = 0.606LB – 111.78	(m2)	(16)
N = 122, R2 = 0.995,	L.D = 6.3177 BD – 36.539	(m2)	(17)
N = 123, R2 = 0.991,	D = 0.2329(LD)0.5334	(m)	(18)
N = 176, R2 = 0.989,	B2 = (0.1946LB)0.9773	(m2)	(19)
N = 155, R2 = 0.956,	L.T = 95.15B – 910.01	(m2)	(20)
N = 155, R2 = 0.974,	B.T = 15.054B – 143.13	(m2)	(21)
N = 155, R2 = 0.966,	B.T = 0.0539L1.6344	(m2)	(22)
N = 155, R2 = 0.976,	L.T = -1E-05(LB)2+0.4012LB	(m2)	(23)
N = 155, R2 = 0.978,	B.T = -1E-06(LB)2+0.0592LB+12.5	(m2)	(24)
N = 155, R2 = 0.991,	L.T = 6.3513BT – 13.559	(m2)	(25)
N = 155, R2 = 0.883,	T = 0.0289(ln(L))3.5009	(m)	(26)
N = 155, R2 = 0.840,	ln(T) = 0.4802(LB)0.1771	(m)	(27)
N = 155, R2 = 0.953,	T = 0.1935(ln(BT))2.2579	(m)	(28)
N = 155, R2 = 0.951,	LT = 110.42e0.28(T)	(m2)	(29)
N = 155, R2 = 0.957,	ln(T) = 0.4248ln(LT) – 0.9308	(m2)	(30)
N = 122, R2 = 0.987,	B.D = 2.8495D1.8211	(m2)	(31a)
N = 122, R2 = 0.981,	B.D = 0.3553B2.1413	(m2)	(31b)
N = 122, R2 = 0.972,	B.D = 0.0107L2.0624	(m2)	(31c)
N = 122, R2 = 0.989,	L.D = 16.065D1.8554	(m2)	(32a)
N = 122, R2 = 0.961,	L.D = 2.0902B2.1555	(m2)	(32b)
N = 122, R2 = 0.986,	L.D = 0.0514L2.1129	(m2)	(32c)
N = 122, R2 = 0.954,	L.B = 45.778D1.6765	(m2)	(33a)
N = 122, R2 = 0.990,	L.B = 5.8835B2.0142	(m2)	(33b)
N = 122, R2 = 0.991,	L.B = 0.2088L1.9494	(m2)	(33c)
N = 122, R2 = 0.981,	L.B.D = 45.778D2.6765	(m3)	(34a)
N = 122, R2 = 0.981,	L.B.D = 2.0902B3.1555	(m3)	(34b)
N = 122, R2 = 0.987,	L.B.D = 0.0107L3.0624	(m3)	(34c)
N = 122, R2 = 0.997,	L.B.D = 9.7233(BD)1.4715	(m3)	(35a)
N = 122, R2 = 0.996,	L.B.D = 0.8143(LD)1.4457	(m3)	(35b)
N = 122, R2 = 0.994,	L.B.D = 0.1279(LB)1.5688	(m3)	(35c)
N = 122, R2 = 0.925,	L.B.T = 23.588T3.4204	(m3)	(36a)
N = 122, R2 = 0.982,	L.B.T = 92.415B2 – 809.44B	(m3)	(36b)
N = 122, R2 = 0.987,	L.B.T = 0.0539L2.6344	(m3)	(36c)
N = 122, R2 = 0.995,	L.B.T = 6.6687(BT)1.591	(m3)	(37a)
N = 122, R2 = 0.992,	L.B.T = 0.548(LT)1.5398	(m3)	(37b)

N = 122, R2 = 0.991, L.B.T = 12.724LB -11140	**(m3)**	**(37c)**
N= 093, R2 = 0.985, Dwt = 0.4873Tc + 2652.3	**(t)**	**(38)[12]**
N = 083, R2 = 0.986, B = 1.5407Tc0.2828	**(m)**	**(39)**
N = 101, R2 = 0.937, B = 1.2303 (Dwt)0.3182	**(m)**	**(40)**
N = 037, R2 = 0.901, P = 38.243(v/(Dwt))-0.793	**(kw)**	**(41)[12]**
N = 037, R2=0.906,P = 93.262v3-3557.2v2+45659v-194203	**(kw)**	**(42)[12]**

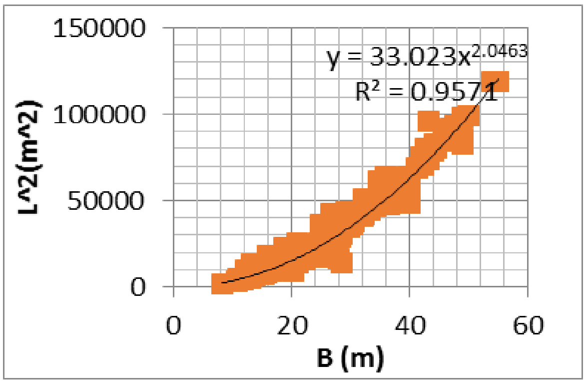


FIG. 1: LENGTH L2 TO BREADTH (L2to B).

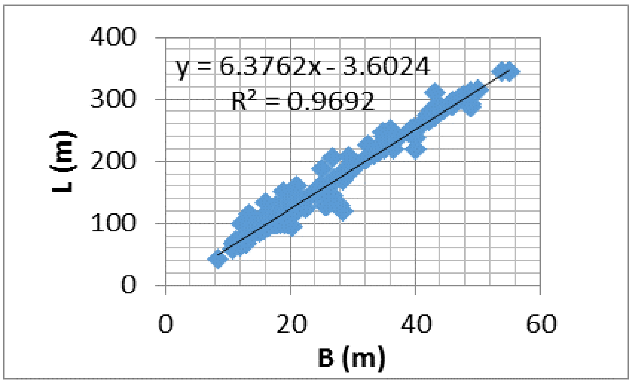


FIG 2: VESSELS LENGTH L TO BEAM B

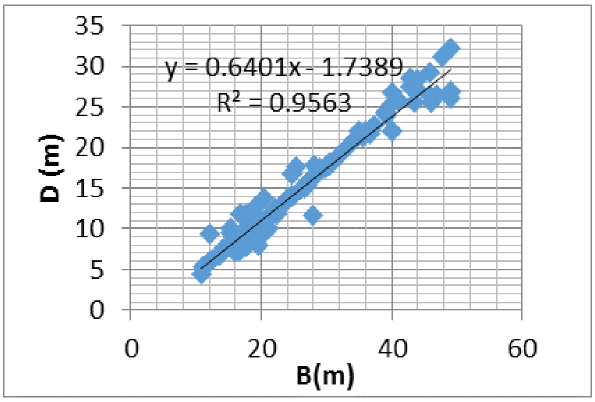


FIG. 3: DEPTH D TO BREADTH (B)

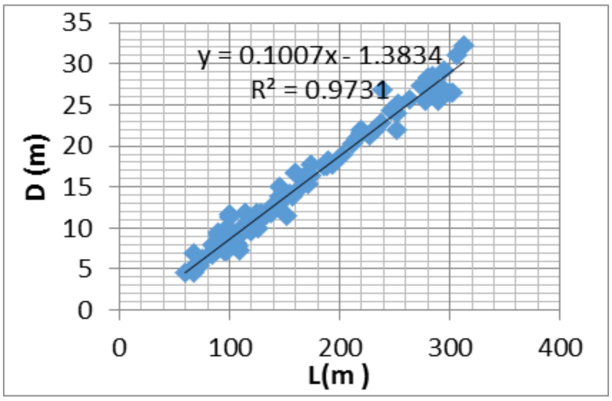


FIG 4: VESSELS DEPTH D TO LENGTH L

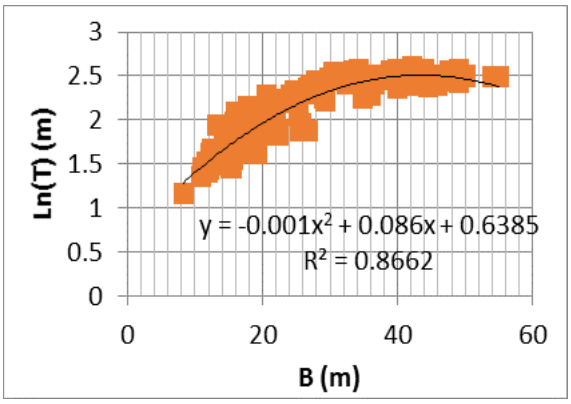


FIG. 5: LOG(base e) OF DRAFT T TO BEAM B

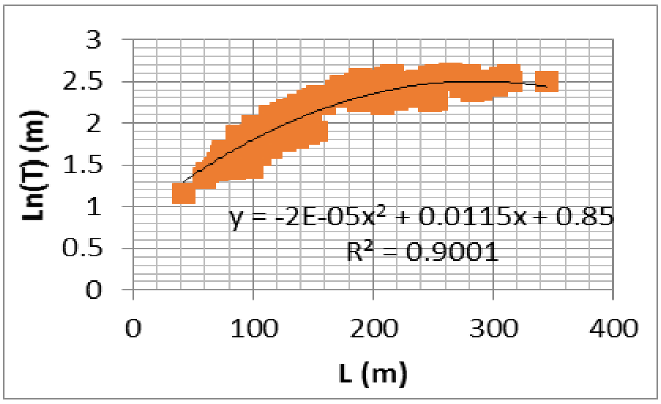
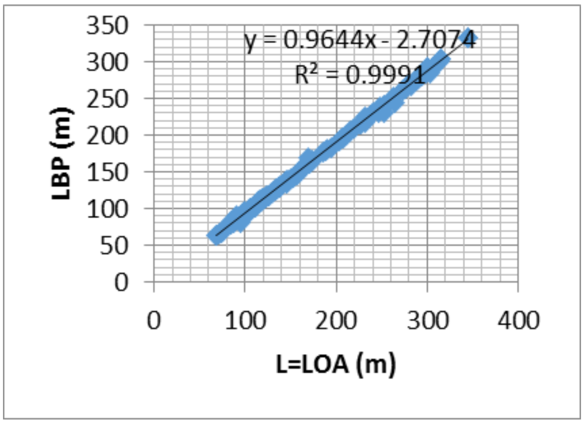


FIG. 6.: LOG(base e) OF DRAFT T TO LENGTH L



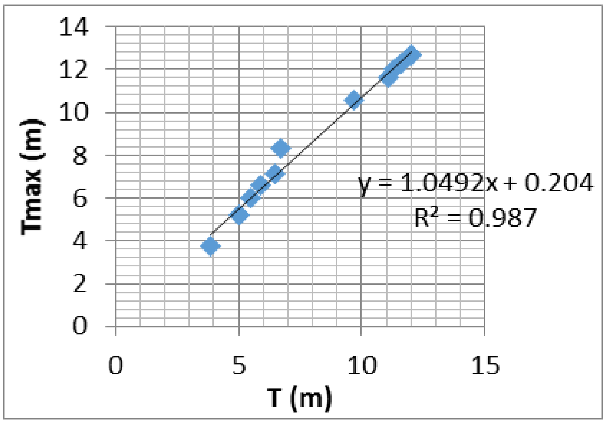


FIG. 7: length between perpendiculars lbp tooverall length loa regression. FIG. 8.: maximum draft t to design draft t

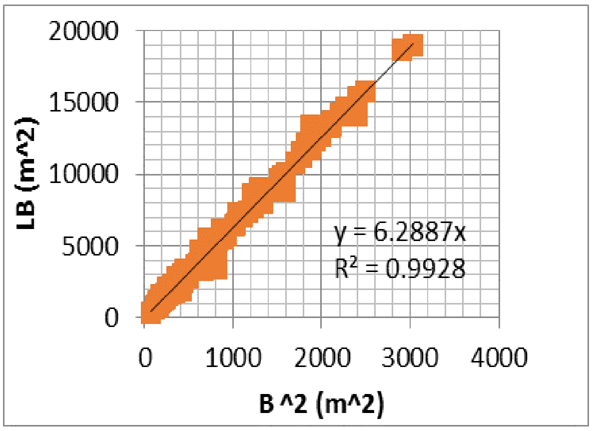


FIG. 9: LENGTHx BREADTH LxB
TO SQUARED BREADTH B2 REGRESSION.

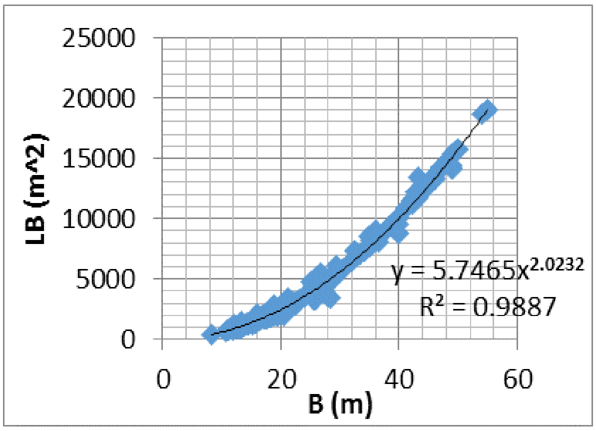


FIG. 10: LxB TO B REGRESSION

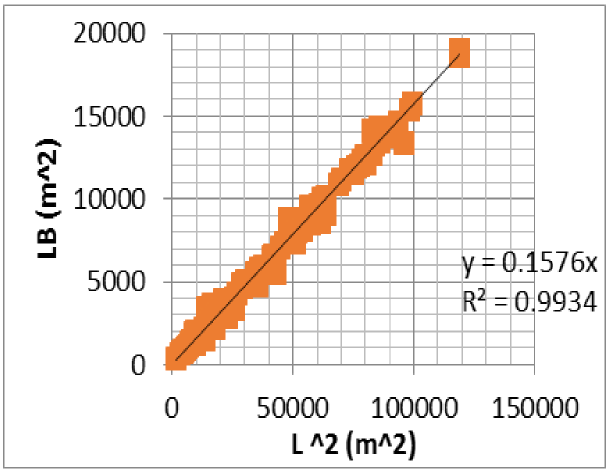


FIG. 11: LxB TO L2 REGRESSION.

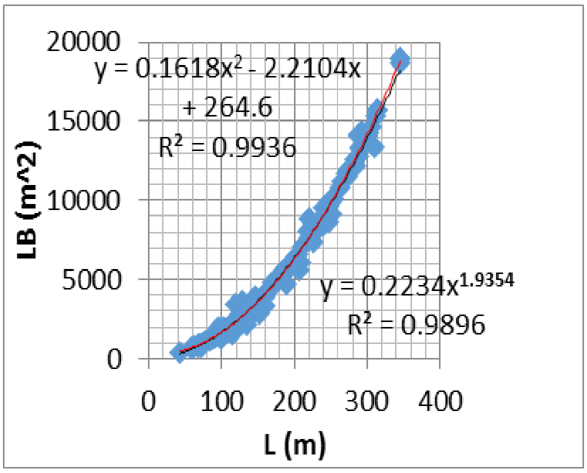


FIG 12: VESSEL LxB TO L REGRESSION.

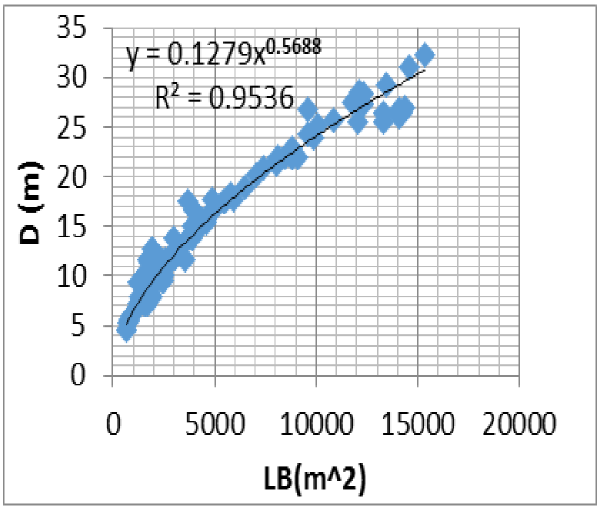


FIG. 13: SHIPS DEPTH D TO LxB REGRESION.

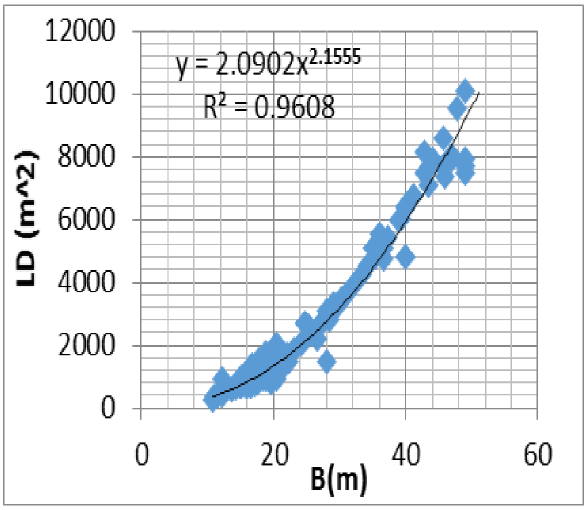


FIG. 14: VESSEL LxD TO BREADTH B REGRESSION.

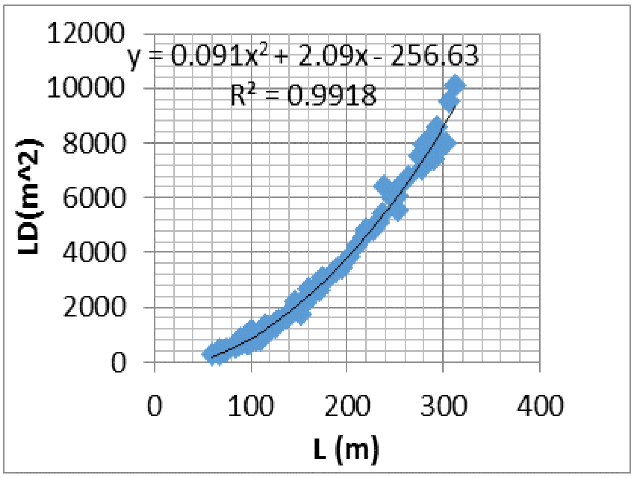


FIG. 15: VESSEL LxD TO BREADTH B

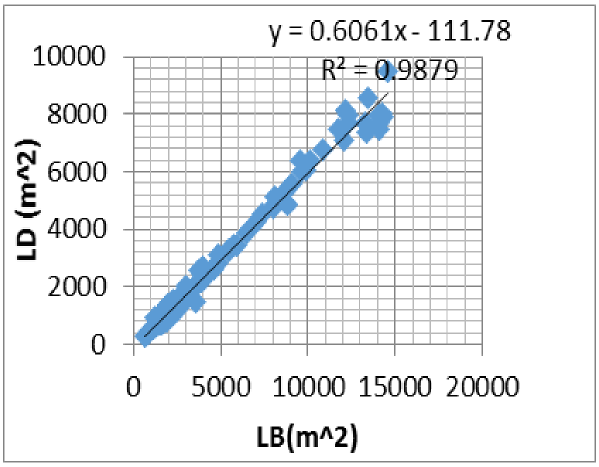


FIG. 16: VESSEL LxD TO LxB

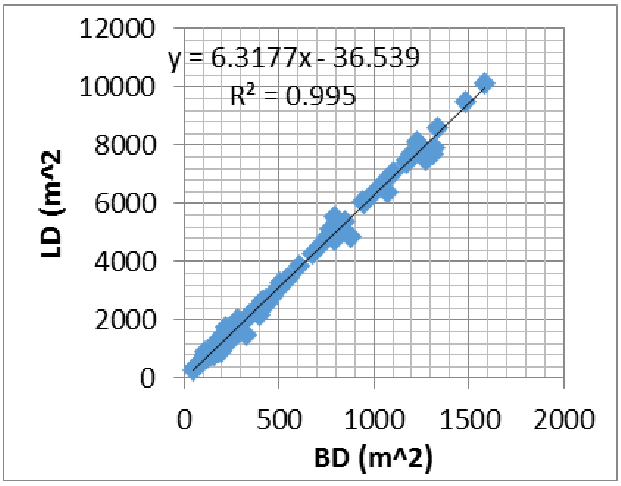


FIG. 17: LxD TO BxD REGRESSION.

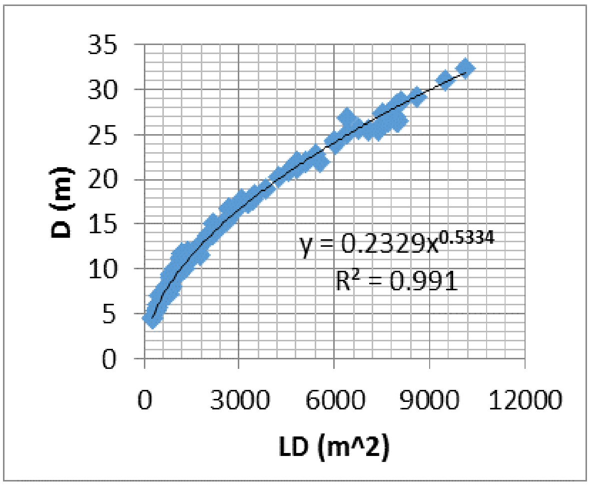


FIG. 18 VESSEL DEPTH TO LxD REGRESSION

International Journal of Engineering Applied Sciences and Technology, 2022
Vol. 6, Issue 9, ISSN No. 2455-2143, Pages 180-195
Published Online January 2022 in IJEAST (http://www.ijeast.com)

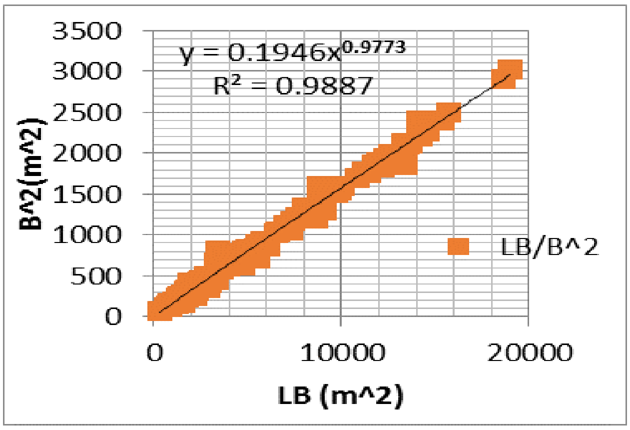


FIG. 19: B2 TO LxB REGRESSION.

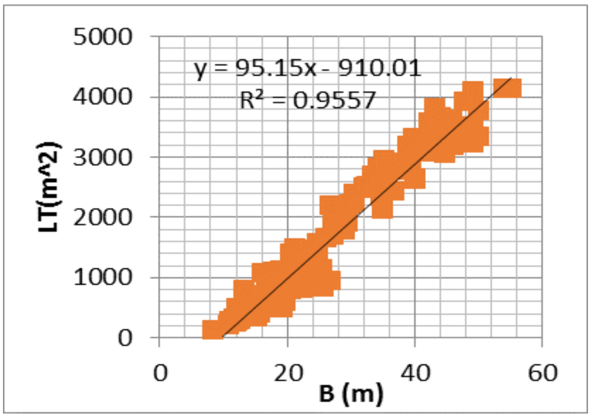


FIG. 20: VESSELS LxT TO B REGRESSION

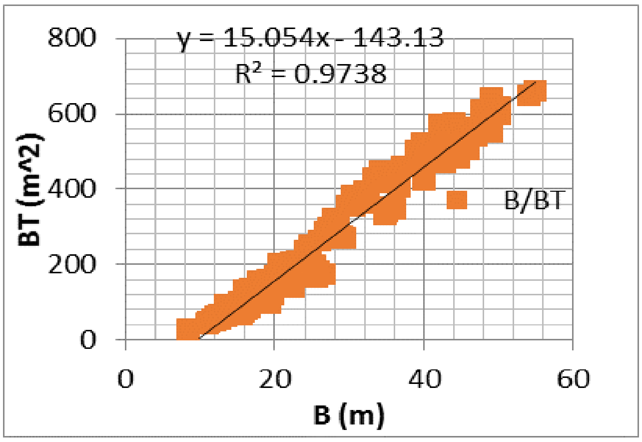


FIG. 21: BxT TO B REGRESSION.

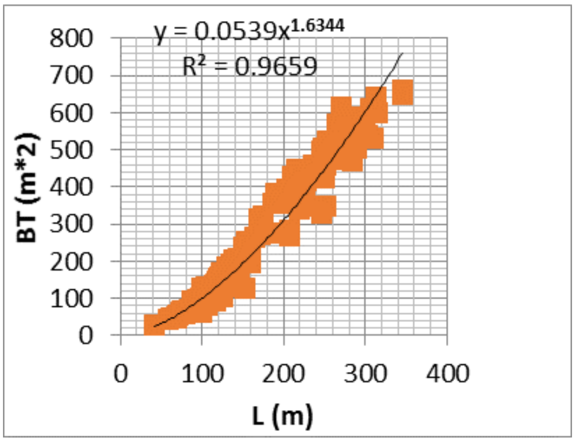


FIG: 22: VESSEL BxT TO LENGTH L

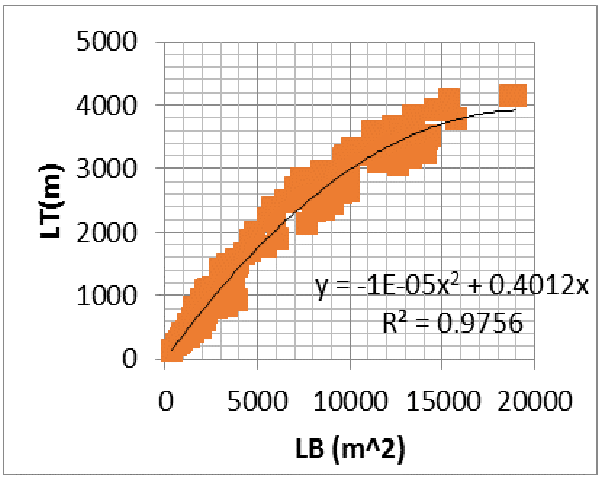


FIG. 23: LxT TO LxB SHIP DIMENSIONS REGRESSION.

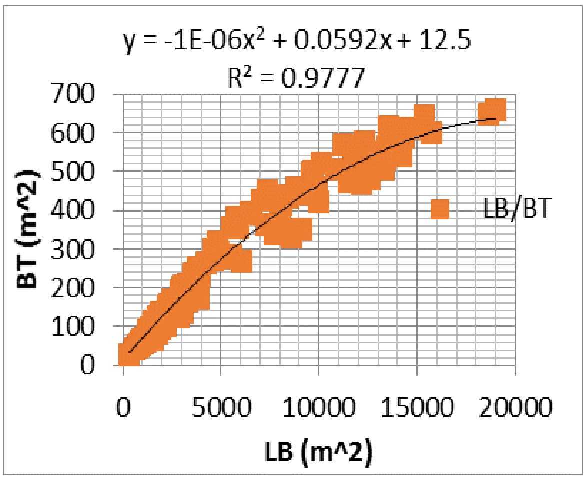


FIG: 24 VESSEL BEAMxDRAFT BxT TO Lx REGRESSION.

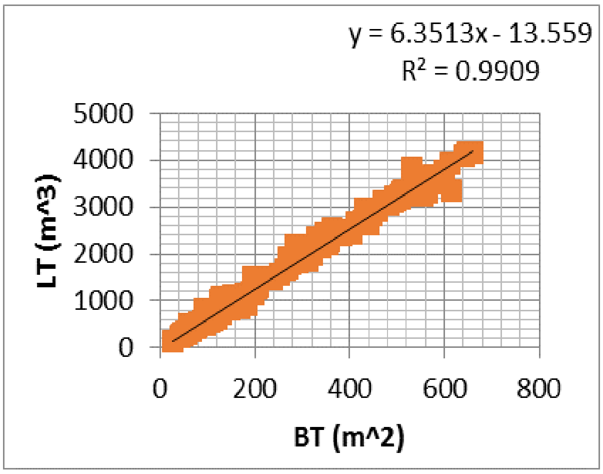


FIG. 25: LxT TO BxT SHIP DIMENSIONS REGRESSION.

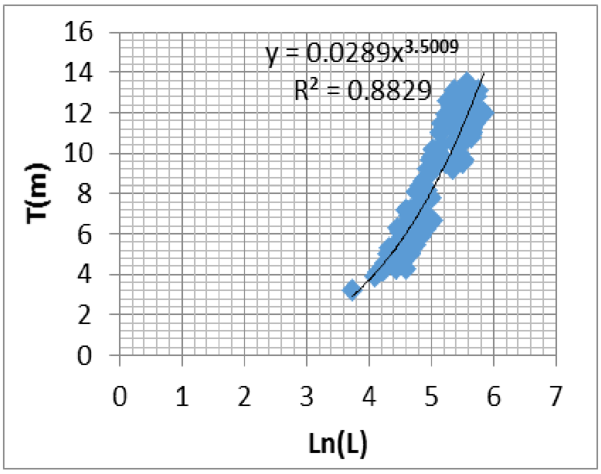


FIG. 26 VESSEL DRAFT T TO LOGe (L).

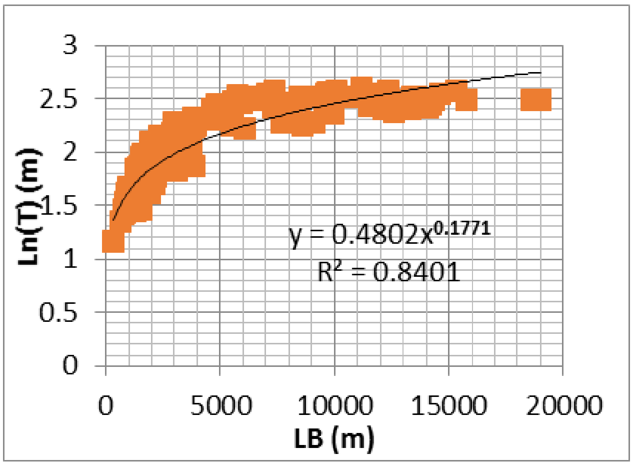


FIG. 27: LOGe(T) TO LxB REGRESSION.

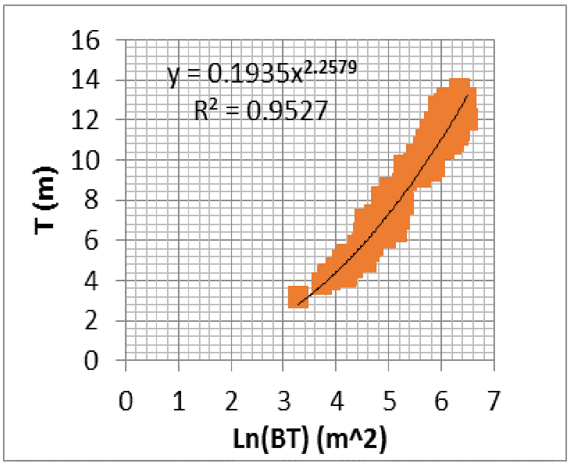


FIG. 28: DRAFT TO LOGe(BT)

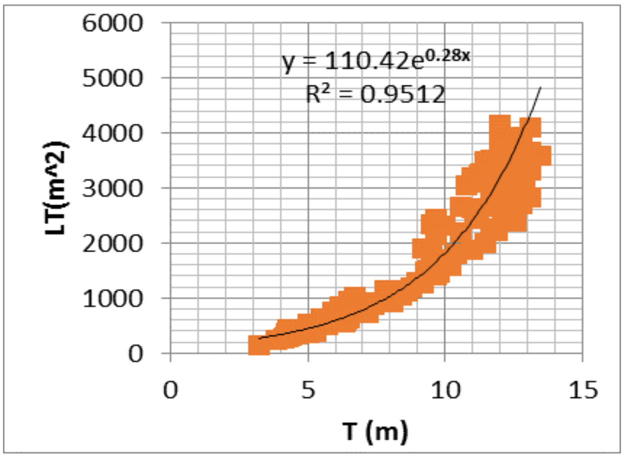


FIG. 29: LxT TO T SHIP DIMENSIONS REGRESSION.

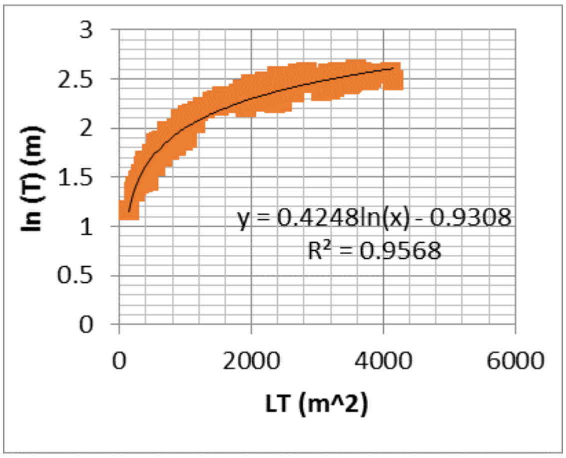


FIG. 30: LOGe(T) TO LxT REGRESSION

International Journal of Engineering Applied Sciences and Technology, 2022
Vol. 6, Issue 9, ISSN No. 2455-2143, Pages 180-195
Published Online January 2022 in IJEAST (http://www.ijeast.com)

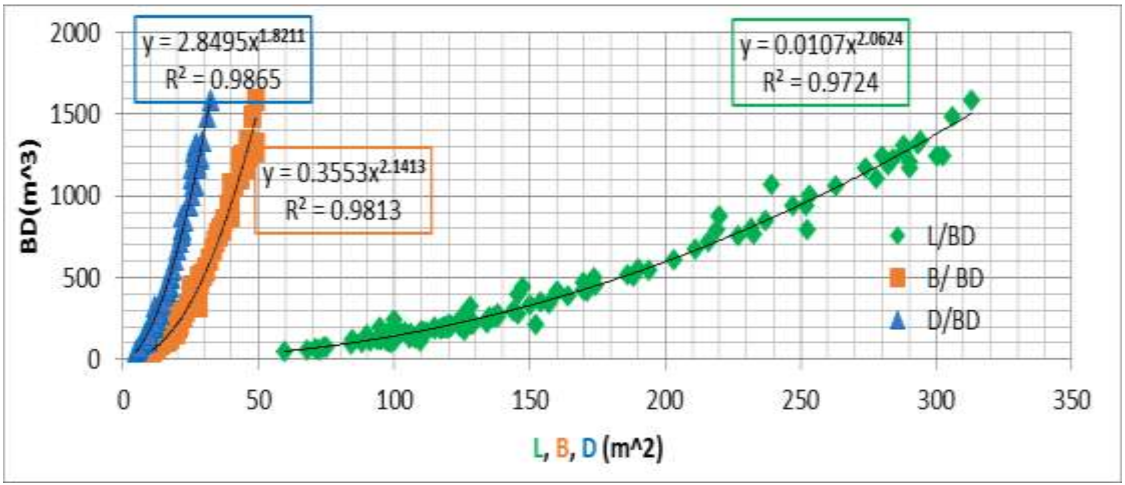


FIG. 31a, 31b. 31c: BxD TO D, B, AND L RESPECTIVE DIMENSIONS REGRESSION.

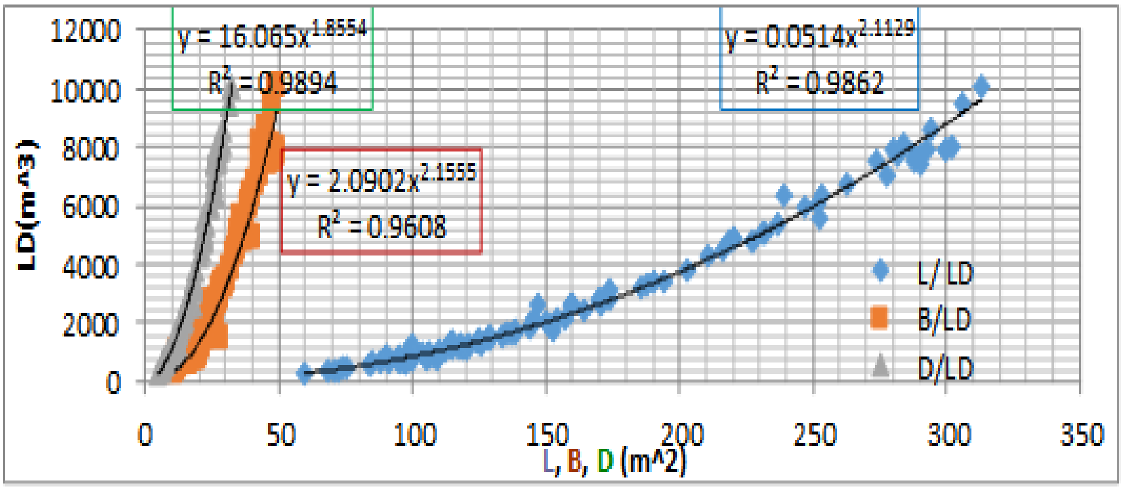


FIG. 32a, 32b, 32c : LxD TO D, B, AND L RESPECTIVE DIMENSIONS REGRESSION.

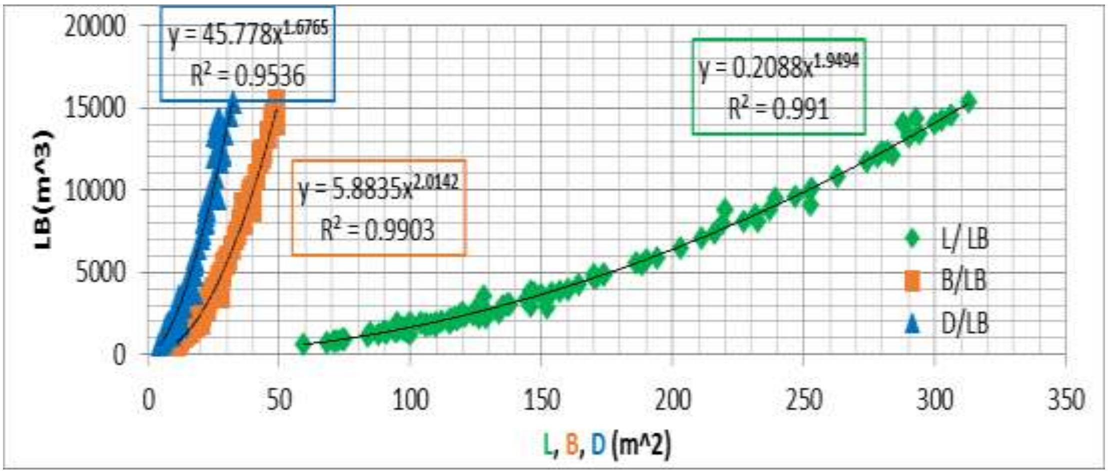


FIG. 33a, 33b, 33c : LxB TO D, B, AND L RESPECTIVE DIMENSIONS REGRESSION.

International Journal of Engineering Applied Sciences and Technology, 2022
Vol. 6, Issue 9, ISSN No. 2455-2143, Pages 180-195
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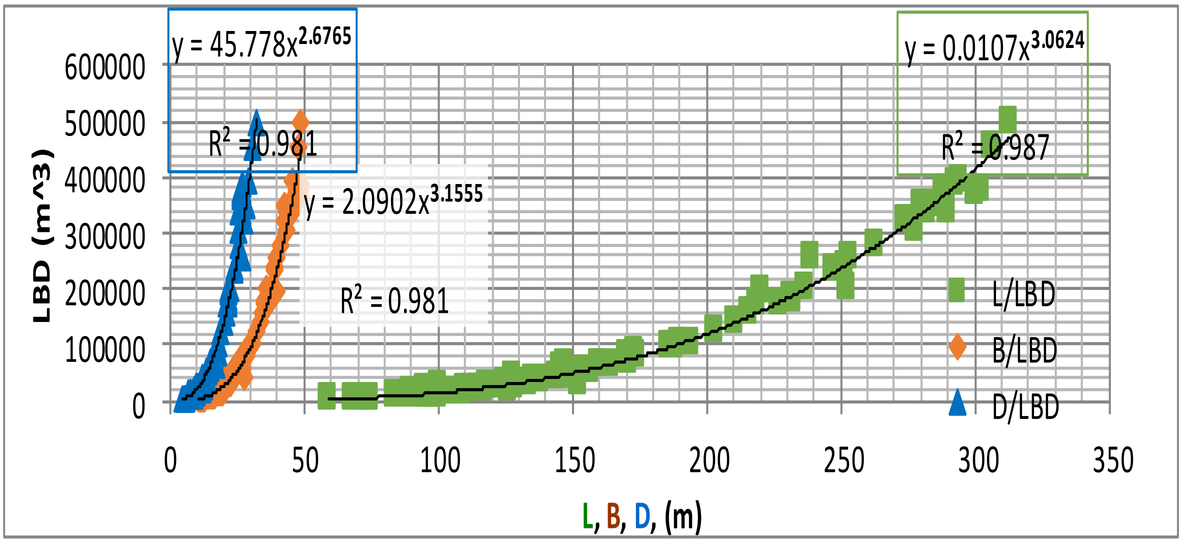

FIG. 34a, 34b, 34c : LxBxD TO D, B, AND L RESPECTIVE DIMENSIONS REGRESSION.

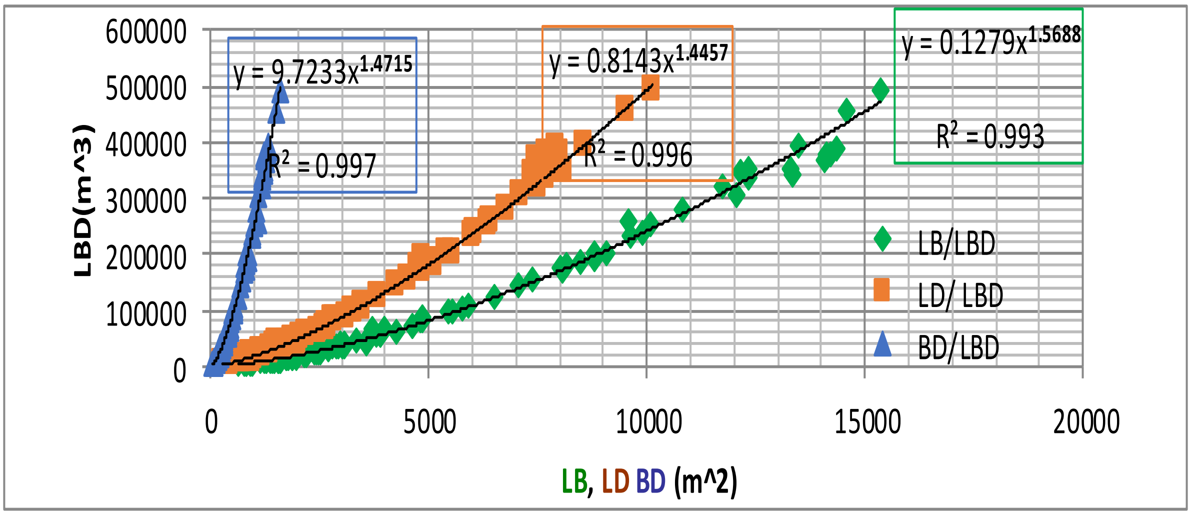

FIG. 35a, 35b, 35c : LxBxD TO BxD, LxD, AND LxB RESPECTIVE DIMENSIONS REGRESSION.

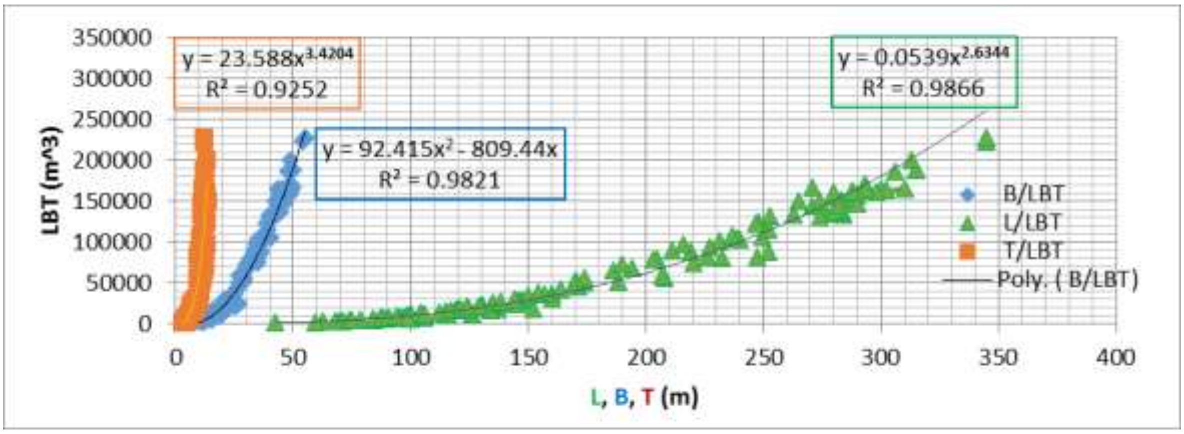

FIG. 36a, 36b, 36c : LxBxT TO T, B, AND L RESPECTIVE DIMENSIONS REGRESSION.

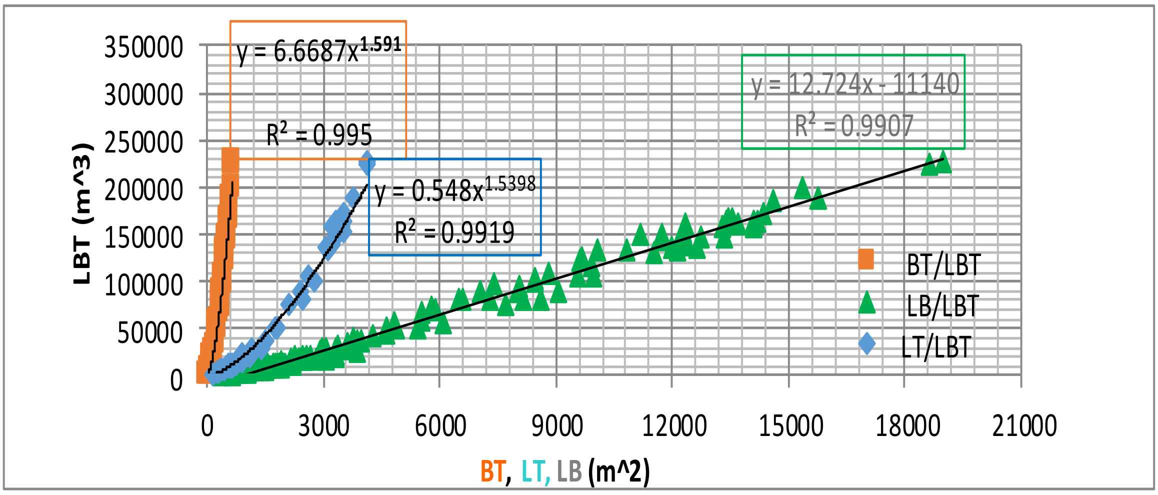

FIG. 37a, 37b, 37c : LxBxD TO BxD, LxD, AND LxB RESPECTIVE DIMENSIONS REGRESSION.

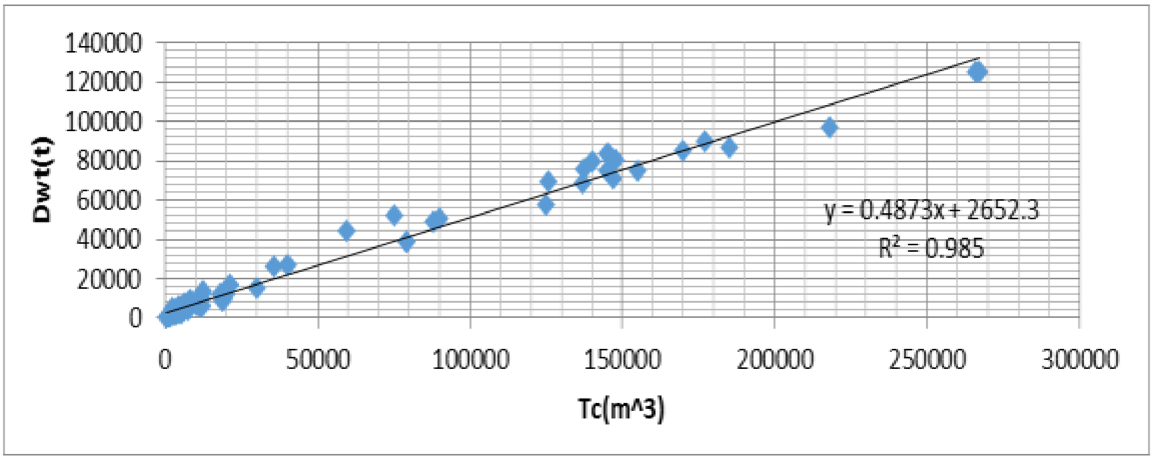

FIG. 38: DEAD WEIGHT Dwt TO GAS TANK CAPACITY Tc DIMENSIONS FOR GAS CARRIERS REGRESSION.

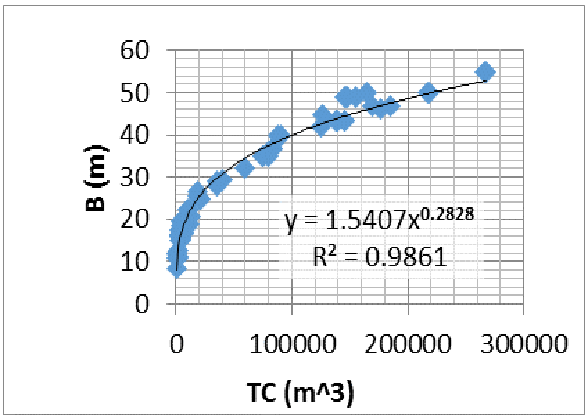

FIG. 39: B TO Tc REGRESSION.

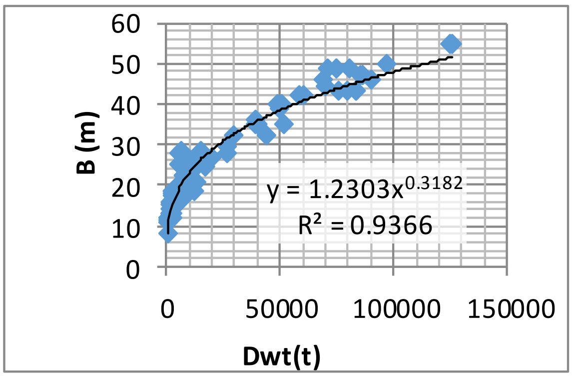

FIG. 40: B TO Dwt REGRESSION

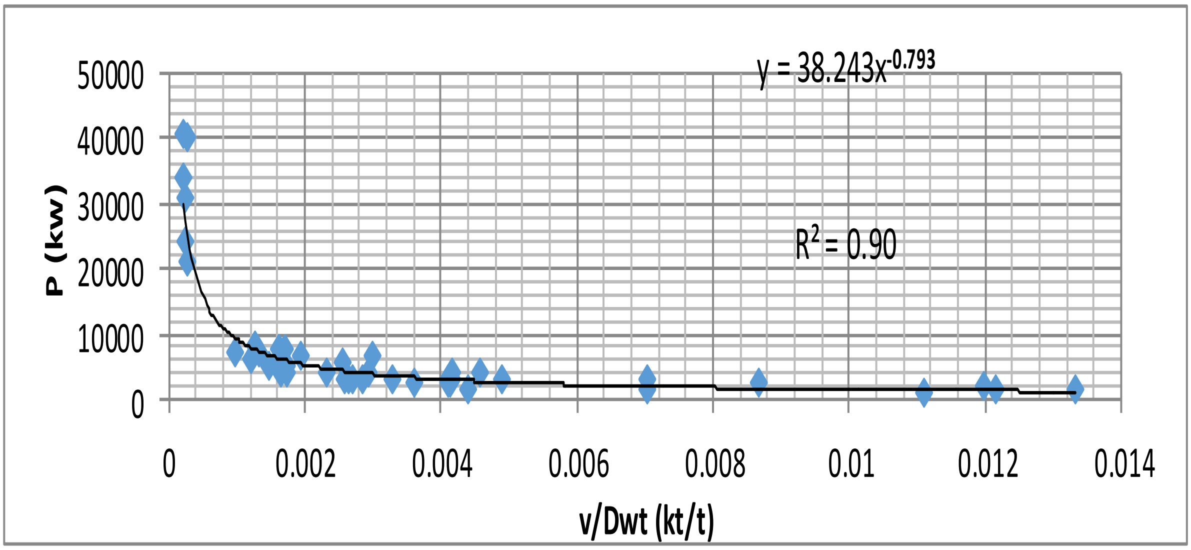

FIG. 41: MAIN ENGINE POWER P TO SHIP'S SPEED PER DEADWEIGHT (v/Dwt) ratio REGRESSION.

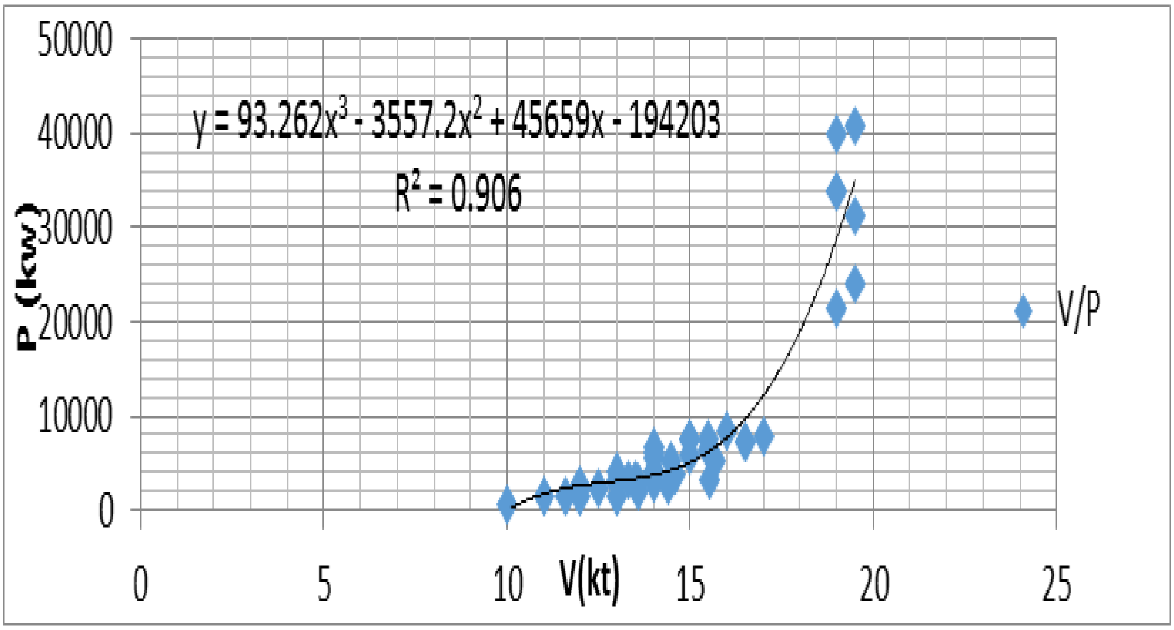

FIG. 42 : MAIN ENGINE POWER P TO SHIP'S SPEED (v) REGRESSION.

TABLE 3. PREDICTION OF MAIN DIMENSION OF GAS CARRIER SHIP OF TANK CAPACITY Tc OF 3500m^3

	Formulas	Substituted	Values	computed	values	Average
1	$L^2 = 33.023B^{2.0463}$	B =	16.595	L =	101.771m	
2	$L = 6.376B - 3.6024$	B =	16.595	L =	102.107m	**101.929 m**
3	$D = 0.6401B - 1.7389$	B =	16.595	D =	8.883 m	
4	$D = 0.1007L - 1.3834$	L =	101.929	D =	8.881 m	
5	$\ln(T) = -0.001B^2 + 0.086B + 0.6385$	B =	16.595	T =	5.991	
6	$\ln(T) = -2E\text{-}05L^2 + 0.0115L + 0.85$	L =	101.929	T =	6.137	**6.064 m**
7	$L_{BP} = 0.9644L_{OA} - 2.7074$	L =	101.929	LBP =	**95.593**	
8	$T_{MAX} = 1.0492T + 0.204$	T =	6.833	TMAX =	7.373	
9	$L.B = 6.2887B^2$	B =	16.595	LB =	1731.837	
10	$L.B = 5.7465B^{2.0232}$	B =	16.595	LB =	1689.091	
11	$L.B = 0.1576L^2$	L =	101.929	LB =	1637.382	
12	$L.B = 0.2234L^{1.9354}$	L =	101.929	LB =	1721.635	**1694.986 m^2**
13	$D = 0.1279(LB)^{0.5688}$	LB =	1694.986	D =	8.783	**8.849 m**
14	$L.D = 2.0902B^{2.1555}$	B =	16.595	LD =	890.922	
15	$L.D = 0.091L^2 + 2.09L - 256.63$	L =	101.929	LD =	901.844	
16	$L.D = 0.606LB - 111.78$	LB =	1694.986	LD =	915.382	
17	$L.D = 6.3177\ BD - 36.539$	BD =	146.847	LD =	891.195	**900.279 m^2**
18	$D = 0.2329(LD)^{0.5334}$	LD =	899.836	D =	8.768	**8.829 m**
19	B^2 = 0.1946(LB)^0.9773	LB =	1694.986	B =	16.601	**16.643 m**
20	$L.T = 95.15B - 910.01$	B =	16.643	LT =	673.603	
21	$B.T = 15.054B - 143.13$	B =	16.643	BT =	107.352	
22	$B.T = 0.0539L^{1.6344}$	L =	101.929	BT =	103.264	**108.113 m^2**
23	$L.T = -1E\text{-}05(LB)^2 + 0.4012LB$	LB =	1694.986	LT =	651.299	
24	$B.T = -1E\text{-}06(LB)^2 + 0.0592LB + 12.5$	LB =	1694.986	BT =	109.987	**105.456 m^2**
25	$L.T = 6.3513BT - 13.559$	BT =	105.456	LT =	656.226	**644.339 m^2**
26	$T = 0.0289(\ln(L))^{3.5009}$	L =	101.939	T =	6.154	

27	$\ln(T) = 0.4802(LB)^{0.1771}$	L B =	1694.986	T =	6.001	
28	$T = 0.1935(\ln(BT))^{2.2579}$	BT =	105.456	T =	6.244	**6.106 m^2**
29	$LT = 110.42e^{0.28(T)}$	T =	6.106	**LT =**	6.10.229	**638.654 m^2**
30	$\ln(T) = 0.4248\ln(LT) - 0.9308$	LT =	638.654	**T =**	10.47	**6.833 m**
31a	$B.D = 2.8495D^{1.8211}$	D =	8.829	BD =	150.432	
31b	$B.D = 0.3553B^{2.1413}$	B =	16.643	BD =	146.432	
31c	$B.D = 0.0107L^{2.0624}$	L =	101.929	**BD =**	148.353	**148.04 m^2**
32a	$L.D = 16.065D^{1.8554}$	D =	8.829	LD =	913.918	
32b	$L.D = 2.0902B^{2.1555}$	B =	16.643	LD =	896.543	
32c	$L.D = 0.0514L^{2.1129}$	L =	101.929	**LD =**	900.101	**901.329 m^2**
33a	$L.B = 45.778D^{1.6765}$	D =	8.829	LB =	1763.849	
33b	$L.B = 5.8835B^{2.0142}$	B =	16.643	LB =	1696.125	
33c	$L.B = 0.2088L^{1.9494}$	L =	101.929	**LB =**	1716.74	**1706.657 m^2**
34a	$L.B.D = 45.778D^{2.6765}$	D =	8.829	LBD =	15569.962	
34b	$L.B.D = 2.0902B^{3.1555}$	B =	16.643	LBD =	14921.462	
34c	$L.B.D = 0.0107L^{3.0624}$	L =	101.929	LBD =	14132.157	
35a	$L.B.D = 9.7233(BD)^{1.4715}$	BD =	148.040	LBD =	15188.951	
35b	$L.B.D = 0.8143(LD)^{1.4457}$	LD =	901.329	LBD =	18150.773	
35c	$L.B.D = 0.1279(LB)^{1.5688}$	LB =	1706.657	**LBD =**	15047.404	**15314.96 m^3**
36a	$L.B.T = 23.588T^{3.4204}$	T =	6.833	LBT =	16880.553	
36b	$L.B.T = 92.415B^2 - 809.44B$	B =	16.643	LBT =	25450.137	
3ca	$L.B.T = 0.0539L^{2.6344}$	L =	101.929	LBT =	10525.583	
37a	$L.B.T = 6.6687(BT)^{1.591}$	BT =	108.113	LBT =	11479.992	
37b	$L.B.T = 0.548(LT)^{1.5398}$	LT =	638.654	LBT =	11437.423	
37c	$L.B.T = 12.724LB - 11140$	LB =	1706.657	**LBT =**	10575.504	**12008.67 m^3**
38	$DWT = 0.4873Tc + 2652.3$	Tc =	3500.000	DWT =	4357.85 t	
39	$B = 1.5407Tc^{0.2828}$	Tc =	3500.000	B =	15.487	
40	$B = 1.2303(Dwt)^{0.3182}$	Dwt =	4357.85	**B =**	17.702	**16.595 m**
41	$P = 38.243(v/(Dwt))^{0.793}$	v/Dwt =	0.003	P =	3648.246	
42	$P = 93.262v^3 - 3557.2v^2 + 45659v - 194203$	V =	13.900	**P =**	3636.687	**3642.467 kw**

TABLE 4 PREDICTED SHIP MAIN DIMENSIONS
FOR GAS TANK CAPACITY OF 3500m^3

PREDICTED		VALUES			
LOA	=	101.925			
LBP	=	95.595			
B	=	16.643			
D	=	8.829			
T	=	6.833			
TMAX	=	7.373		DEVIATIONS	%CONSISTENCY
BT	=	108.113	113.7216	5.608619	4.931884587

International Journal of Engineering Applied Sciences and Technology, 2022
Vol. 6, Issue 9, ISSN No. 2455-2143, Pages 180-195
Published Online January 2022 in IJEAST (http://www.ijeast.com)

LT =	638.654	696.4535	57.799525	8.29912161
BD =	148.04	146.941	-1.098953	-0.747887008
LD =	901.329	899.8958	-1.433175	-0.159260101
LB =	1706.657	1696.338	-10.319225	-0.608323717
LBD =	15314.98	14976.97	-338.01378	-2.256890879
LBT =	12008.67	11591.08	-417.59398	-3.602719737
P =	3642.467			0.836560679