Prediction of Main Dimension of Tugboats Basing on Gross Tonnage.

Stephen Chidozie Duru, Amula Emomotimi

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 costs which 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 turn 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 of the 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, square numbers and LBD, LBT cubic numbers.

For example we can get the main dimensions 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 this way:

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 the main dimensions 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 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, square numbers and LBD, LBT cubic numbers.

REFERENCES


[6]. RidwanSaputra Bin Nursal “Tonnage measurement for Fishing Vessels in MalaysiaB.Eng Thesis , Mechanical Engineering department,
Table 1: A collection of the principal dimension of modern Tugboat

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<th>LAO</th>
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Table 2 Tugboat design formulas as a function of gross tonnage (x = GT)

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<th>R</th>
<th>Formula</th>
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<td>120</td>
<td>0.902</td>
<td>$L = 4.1475x^{0.3841}$</td>
<td>Eq1</td>
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<td>120</td>
<td>0.906</td>
<td>$B = 1.939x^{0.2782}$</td>
<td>Eq2</td>
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<tr>
<td>26</td>
<td>0.857</td>
<td>$D = 1.1288ln(x) − 1.983$</td>
<td>Eq3</td>
</tr>
<tr>
<td>120</td>
<td>0.928</td>
<td>$LB = 10.137x^{0.034}$</td>
<td>Eq4</td>
</tr>
<tr>
<td>29</td>
<td>0.964</td>
<td>$BD = 9E - 0.89x^3 - 5E - 0.5x^2 + 0.1103x + 12.002$</td>
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<tr>
<td>120</td>
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<td>$LT = 4E - 0.89x^3 - 0.0002x^2 + 0.3695x + 24.5$</td>
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<td>$BT = 9E - 0.89x^3 - 4E - 0.5x^2 + 0.0895x + 11.05$</td>
<td>Eq7</td>
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<tr>
<td>18</td>
<td>0.841</td>
<td>$DT = 1.5492x^{0.4155}$</td>
<td>Eq8</td>
</tr>
<tr>
<td>29</td>
<td>0.991</td>
<td>$LBD = 3.1067x + 363.64$</td>
<td>Eq9</td>
</tr>
<tr>
<td>120</td>
<td>0.961</td>
<td>$LB = 2.6968x + 212.9$</td>
<td>Eq10</td>
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<tr>
<td>26</td>
<td>0.827</td>
<td>$P = 1690ln(x) - 6606.8$</td>
<td>Eq11</td>
</tr>
<tr>
<td>115</td>
<td>0.967</td>
<td>$P = 841.35B - 4646.2$</td>
<td>Eq13</td>
</tr>
<tr>
<td>150</td>
<td>0.857</td>
<td>$P = 0.00002(LBD)^2 + 2.5382(LBD)$</td>
<td>Eq14</td>
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<td>120</td>
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<td>$GRT*NRT = 0.0443(LBT)^2 + 33.05LBT +10442$</td>
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<td>120</td>
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<td>$GRT*NRT = 0.5407LBT1.576$</td>
<td>Eq16</td>
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<td>$GRT*NRT = 0.0168(LT)^3 + 3.5184(LT)^2 - 366.83LT$</td>
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<td>$GRT*NRT = 2.015(LT)^2 + 0.3146(LB)^2 + 90.89(LB) - 4500$</td>
<td>Eq18</td>
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Table 3 EXCEL layout for calculation of principal dimension of tugboat

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>LOA(m)</td>
<td>Eq1</td>
<td>Eq2</td>
<td>Eq3</td>
<td>Eq6/A2</td>
</tr>
<tr>
<td>2</td>
<td>Eq4/B2</td>
<td>Eq5/C2</td>
<td>Eq 5/B2</td>
<td>Eq7/B2</td>
<td>Eq12(B2)</td>
</tr>
<tr>
<td>3</td>
<td>Eq6/D2</td>
<td>Eq4/A2</td>
<td>Eq8/D2</td>
<td>Eq8/C2</td>
<td>Eq13(A4<em>B4</em>C4)</td>
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<td>Eq10/Eq6</td>
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<td>Eq13(A5<em>B5</em>C5)</td>
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<td>Eq8/D3</td>
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<td>7</td>
<td>(Eq10<em>C3)/(B2</em>Eq8)</td>
<td>(Eq10<em>C3)/(Eq6</em>C2)</td>
<td>(Eq9<em>Eq7)/(Eq4</em>Eq2*D2)</td>
<td>(Eq9<em>Eq7)/(Eq4</em>Eq5)</td>
<td>Eq13(A7<em>B7</em>C7)</td>
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Table 4 Calculation of principal dimension of tugboat for Gross tonnage = 180 GRT

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<th>E</th>
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Table 5 Calculation of net tonnage from regression equations for L=28.33m, B=7.99m, D=4.18m and T=3.34m

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<tr>
<th></th>
<th>Eq14</th>
<th>Eq15</th>
<th>Eq16</th>
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<td><strong>7.992</strong></td>
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<td></td>
<td></td>
<td></td>
<td><strong>MEAN</strong></td>
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Therefore, from Eq14, \( \text{GT} \times \text{NT} = 9969.6004 \), Therefore, \( \text{NT} = 55.39 \) from Eq15, \( \text{GT} \times \text{NT} = 17659.142 \), Therefore, \( \text{NT} = 98.11 \) from Eq16, \( \text{GT} \times \text{NT} = 15330.231 \), THEN, \( \text{NT} = 85.17 \) from Eq17, \( \text{GT} \times \text{NT} = 14175.721 \), THEN, \( \text{NT} = 78.75 \) from Eq18, \( \text{GT} \times \text{NT} = 10135.752 \), THEN, \( \text{NT} = 56.31 \)

**MEAN** \( \text{NT} = 74.74 \)

**MINIMUM** \( \text{NT} = 55.39 \)

**MAXIMUM** \( \text{NT} = 98.11 \)