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Estimation of Longitudinal Light Ship Hull Structure Shear Force and Bending Moment on Still Water

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Abstract Longitudinal estimation of shear force and bending moment is of almost important in the early stage of design analysis of ship for determination of the maximum bending stress of the hull girder. The paper considers various numerical approximation methods for estimation of longitudinal load distribution. The components of longitudinal load distribution include gravity and buoyant load distributions. The use of different numerical approximations enhances the elimination of complexity and errors. In this paper, the longitudinal buoyancy distribution was gotten from the offset table data with numerical integration method using trapezoidal rule. Few requirements are needed for the calculation of shear force and bending moment (hull geometry, distribution, machinery and equipment weight distribution and the L.C.G. of various weights). The method used is known as weight and buoyancy method. Simulation was carried out using offshore servicing vessel with characteristics shown in table 1. Results indicate that if the longitudinal weight distribution is not evenly distributed within the allowable strength of the ship, bending moment will start from zero and will not come to zero, which will make the ship to capsize and may eventually lead to catastrophe.

Keywords Ship Structure, Shear Force, Bending Moment, Offshore Servicing Vessel

Introduction

The nature and complexity of ship structure has changed significantly over decades. This has also affected the methodology of design from traditional ways to more robust and complex systems. This can be seen by the many sophisticated software for structural analysis. The bottom line in most of the complexity in the analysis is the application of computational tools without the basic or fundamental principles of the subject of naval architecture. This singular purpose has given birth to this paper on the development of naval architecture's practical knowledge on ship's structure.

The paper focuses on various structural responses steepness (load distribution, shear force and bending moment calculations) with developed algorithms that can be implemented in any programming language. The results generated from the numerical simulation of a typical ship, an offshore servicing vessel are presented and could enhance comparative study with other well-known methodologies.

It is the responsibility of naval architects to carry out proper analysis using the possible simplest method [1]. For a quick estimate of response steepness two different approximation methods are considered for weight and buoyancy distributions. This reduces time and complexity in the analysis. An unnamed Matlab code was written as a result. The response results obtained improve confidence in the procedure used in demonstrating satisfaction [2].

To this end, the importance of shear force and bending moment calculation cannot be overemphasized as the safety of the ship, human elements' comfort, ship's efficiency and even cost depend to a greater extent.

2. Literature Review

General Ship Theory

Ship's main dimensions determine many of her characteristics, e.g. stability, hold capacity, power requirements, and more importantly her economic efficiency. Therefore determining the main dimensions and ratios, as well as coordinating them in such a way that a ship satisfies the design conditions forms a particularly important phase in the overall design.

The characteristics desired by a shipping company can be usually achieved through various combinations of dimensions. Such characteristics could allow for an economic optimum design to be achieved if it were not for the restrictions imposed by size of locks, canals, slip waterways and bridges and most commonly water depth. A ship's economic efficiency is usually improved by increasing her size, and accordingly this could lead to the specific cost decreases. In general, the larger the ship, the more economically efficient is the ship.

According to the above mentioned aspects a perfect ship does not exist; however, weight reduction for a well-known design achieving its purpose without shape (main dimensions) alteration leads to a less fuel consumption, increased deadweight, more freeboard, less initial cost, more speed and even better accessibility to channels and harbors with lesser depths.

Weight Distribution Methods

A ship in water can be modeled as a rigid body acted upon by its weight (light weight), deadweight and the environmental loads. When she is in still water condition, the weights are generally identified as longitudinal load distribution, and are caused by gravity and pressure loads on the hull structure of the ship [3]. Figure 2 describes the two components of the force as described above. The forces with arrows pointing down represent the gravity load distribution whereas the doted solid arrows pointing upward show the buoyant load distribution. This is usually modeled in general as a beam under distributed loading for the purpose of theoretical analysis.

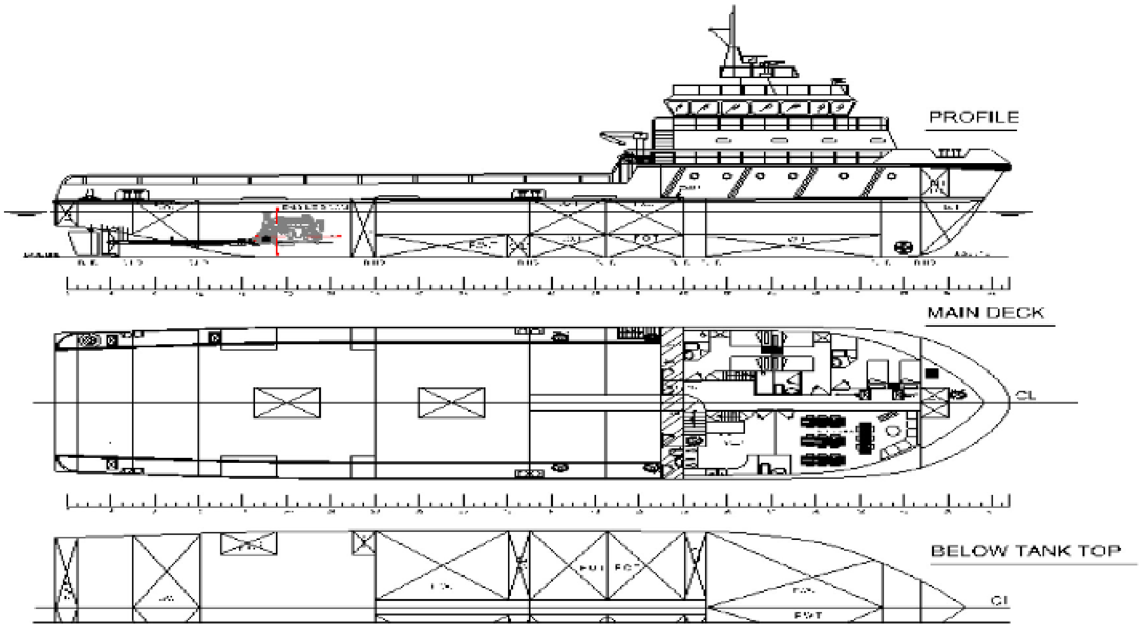


Figure 1: Depiction of Offshore Servicing Vessel in Two Different Views

Longitudinal Ship Weight Distribution Methods

In the determination of gravity load distribution, the weight of the ship's structures in light condition (hull, outfitting and machineries) is calculated using data of built ships. This method is employed in Bending moment and shear force calculations play a very dominant role in initial stage of the ship design as spelled out in a well-defined naval architecture design spiral [4]. This is used to analyze the ship strength and for preparing the loading booklet [5]. The application of various methods in calculation of ship structural responses becomes imperative.

In ship structural analysis, numerical approximation methods are usually used for hull weight distribution while grouping or bucket method is used for machinery and equipment distribution (Comstock, 1944). The various approximation methods are given below while other relevant methods are as well discussed.

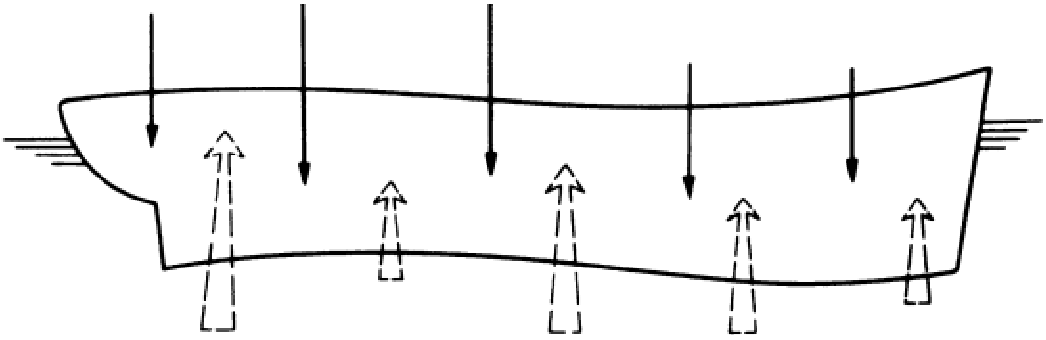


Figure 2: Action of gravity and buoyant loadings on a hull structure [3]

1. Approximation methods
   a. Comstock approximation
   b. Biles approximation
   c. Prohaska approximation
   d. Trapezoidal approximation [4]
2. Grouping methods (bucket method)
3. Direct distribution methods
   a. General philosophy methods (twenty one station methods)
      i. Calculate the weight of each station
      ii. Find the C.G of weight of each segment
      iii. Place the weight at the C.G
   b. Mechanics of distribution (trapezoids) [2].

3. Materials and Methods

Materials

Offshore Serving Ship Description

The main function of an offshore servicing vessel is to transport store materials, equipment and/or personnel to, from and between offshore installations. The class notation of the investigated existing vessel is Bureau Veritas, and the vessel is intended to operate in the benign sea of offshore Nigeria. It is worth mentioning that this vessel is selected as a case study because this type of vessels represents the highest percentage of the vessels building and operating in the area due to increase in offshore activities. The vessel main characteristics and capacities are mentioned below in Table 1. Fig. 2 shows an outline of the ship's general arrangement.

OSV environmental loads

Still water loads

When a ship is at sea, she is subjected to forces which cause the structure to deflect. The correct assessment of the magnitude of the forces is difficult. The forces may be divided into static and dynamic components. Still water forces are static in nature as the ship is considered to be floating in equilibrium. Still water load curve is obtained as the algebraic sum of weight and buoyancy curves. Different loading conditions are assigned to the ship in order to determine the worst one.

Table 2 summarizes these loading conditions. In order to determine the distribution of bending moment along the ship, the weight and buoyancy, load, shear and moment distributions for the worst loading condition are obtained.

Standard Estimate of Weight Distribution of Offshore Servicing Ship

A systematic method of estimating weight of ship has been used over time. This is achieved by using principal particulars of the ship. Table 1 shows the particulars of the servicing ship used in this work as a case study. Matlab subroutine was developed for analysis of light ship weight estimation and the method employed is discussed next.

Standard Estimation of Weight Distribution of Offshore Servicing Ship

Weight Estimation

Table 1: Principal particulars and weight distribution

Self-propelled offshore servicing ship	Double hull	L (m)	B (m)	D (m)	T (m)	LOA (m)
		108.15	11.50	4.7	3.55	110

Table 2: Actual Light Ship Weight Summary

Items	Weight (ton)	KG (m)	LCG (m)
Aft parts	112.988	2.07	10.57
Central part	487.926	1.36	58.92
Fore part	78.409	2.37	102.84
Deck house	53.6	4.84	10.87
Fitting	17.705	3.62	53.06
Completion weight	61.575	5	37.42
Total light ship weight	**812.203**	**2.11**	**51.57**

Table 3: Light Ship Weight Break Down

Items	Weight	L.C.G
Hull structure	679.323	-
Deck house	53.6	-
Main installation aft	4.625	-
Main machinery aft	15.4	-
Anchor equipment and Gear fore	12.35	-
Anchor equipment and Gear aft	4.35	-
Machinery installation Fore	1.935	-
Main machinery fore	4	-
Deck equipment	5.14	-
Fitting	17.705	-
Ballast piping system	0.85	-
Auxiliary machinery	2.15	-
Auxiliary machinery Installation	3.32	-

The offset table is use for the determination of ship hull shape (hull geometry) which will use to calculate the area, volume, buoyancy

Table 4: Offset Table (hull geometry)

Station No.	0	1	2	3	4	5	6	7	8	9
Length	0	0.925	6.3325	11.74	17.1475	22.555	27.9625	33.37	44.185	55
Water line(m)					**Half Breath(m)**					
8	0	0	0	0	0	0	0	0	0	5.75
7	0	0	0	0	0	0	0	0	0	5.75
6	0	0	0	0	0	0	0	0	0	5.75
5	0	0	0	0	0	0	0	0	0	5.75
4.7	5.307	5.728	5.75	5.75	5.75	5.75	5.75	5.75	5.75	5.75
4	5.303	5.725	5.749	5.749	5.75	5.75	5.75	5.75	5.75	5.75

3	2.925	3.791	4.955	5.487	5.658	5.713	5.735	5.743	5.748	5.749
2	0	0	1.176	2.704	4.108	4.972	5.408	5.602	5.708	5.717
1	0	0	0	0	0.789	2.113	3.423	4.539	5.364	5.442
0.5	0	0	0	0	0	0	1.615	2.958	4.667	4.884
0	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4

Station No.	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
Length	**65.815**	**76.63**	**82.0375**	**87.445**	**92.8525**	**98.26**	**100.9638**	**103.6675**	**106.3713**	**109.075**	**110**
Water line(m)				**Half Breath(m)**							
8	5.75	5.745	5.657	5.459	5.17	4.721	4.a412	4.047	3.578	2.91	2.019
7	5.75	5.702	5.59	5.349	5.022	4.519	4.178	3.76	3.212	2.474	1.47
6	5.749	5.654	5.418	5.232	4.853	4.284	3.897	3.416	2.795	1.993	0
5	5.749	5.598	5.397	5.101	4.65	3.995	3.55	3.002	2.318	1.441	0
4.7	5.749	5.58	5.367	5.056	4.582	3.898	3.432	2.865	2.167	1.255	0
4	5.743	5.519	5.283	4.929	4.396	3.642	3.139	2.536	1.793	0.722	0
3	5.73	5.407	5.116	4.7	4.075	3.211	2.667	2.019	1.188	0	0
2	5.671	5.216	4.847	4.338	3.581	2.607	2.021	1.336	0.426	0	0
1	5.307	4.685	4.166	3.487	2.588	1.619	1.054	0.472	0	0	0
0.5	4.647	3.716	3.039	2.304	1.584	0.848	0.438	0.012	0	0	0
0	0.4	0.4	0.4	0.4	0.275	0	0	0	0	0	0

The Grouping Method

The grouping method is known as the bucket method and the name is derived from the fact that the weight are positioned in different bucket based on the location of the local longitudinal center of gravity from the global reference point and it is grouped as uniform distributed load on each bucket (segment) as they fall on a particular bucket. Figure 3 is an illustration of this method.

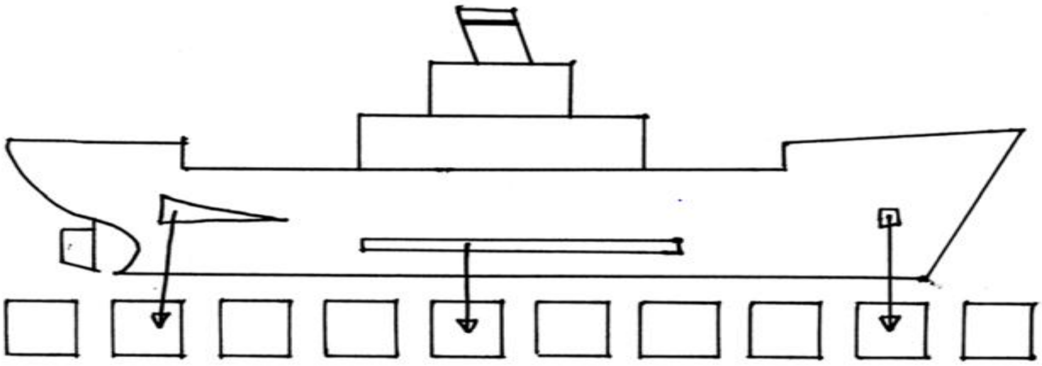


Figure 3: illustration of a bucket method [2]

Trapezoidal Method

Figure 4 illustrates the application of trapezoidal method

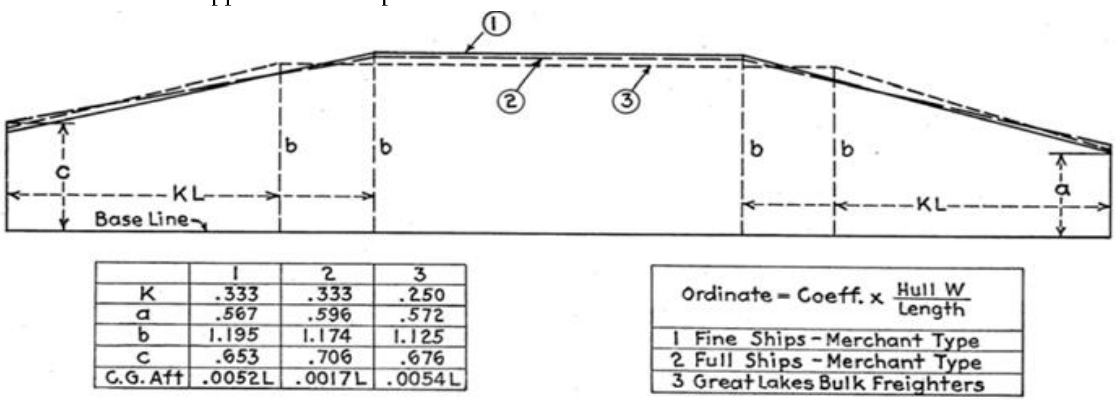


Figure 4: Approximation to Hull Weight of Mid Parallel Body

Models for Calculating light Ship Still Water Shear Force and Bending Moment

i. Area (m^2) = ½ ($y_0 + y_1$)h +½ ($y_1 + y_2$)h +……..½ ($y_9 + y_{10}$)h (1)

ii. volume (m^3) = ½ ($A_0 + A_1$)L +½ ($A_1 + A_2$)L +……½ ($A_9 + A_{10}$)L (2)

iii. Mass = volume displacement x ρ (Trim line) (3)

iv. Light ship weight (no cargo)

Light ship weight is the sum of the three main components

$W_{LS} = W_H + W_E + W_M$ (4)

v. Buoyancy is the Volume displaced at the total ship weight draught on a segment multiply by sea water density and gravity

Buoyancy = Δ × g (kN) (5)

vi. Net load = Buoyancy - weight (6)

vii. Shearing force (Area under the net load curve)

$$\rho\, g \int_o^L a(x)dx = g\int_o^L m(x)dx = g\Delta \quad (7)$$

viii. bending moment (Area under the shear force)

$$\rho\, g \int_o^L a(x)xdx = g\int_o^L m(x)xdx = g\Delta Lg \quad (8)$$

Procedures for Calculations in Matlab

The calculation process for shear force and bending moment distribution is given in figure 5.

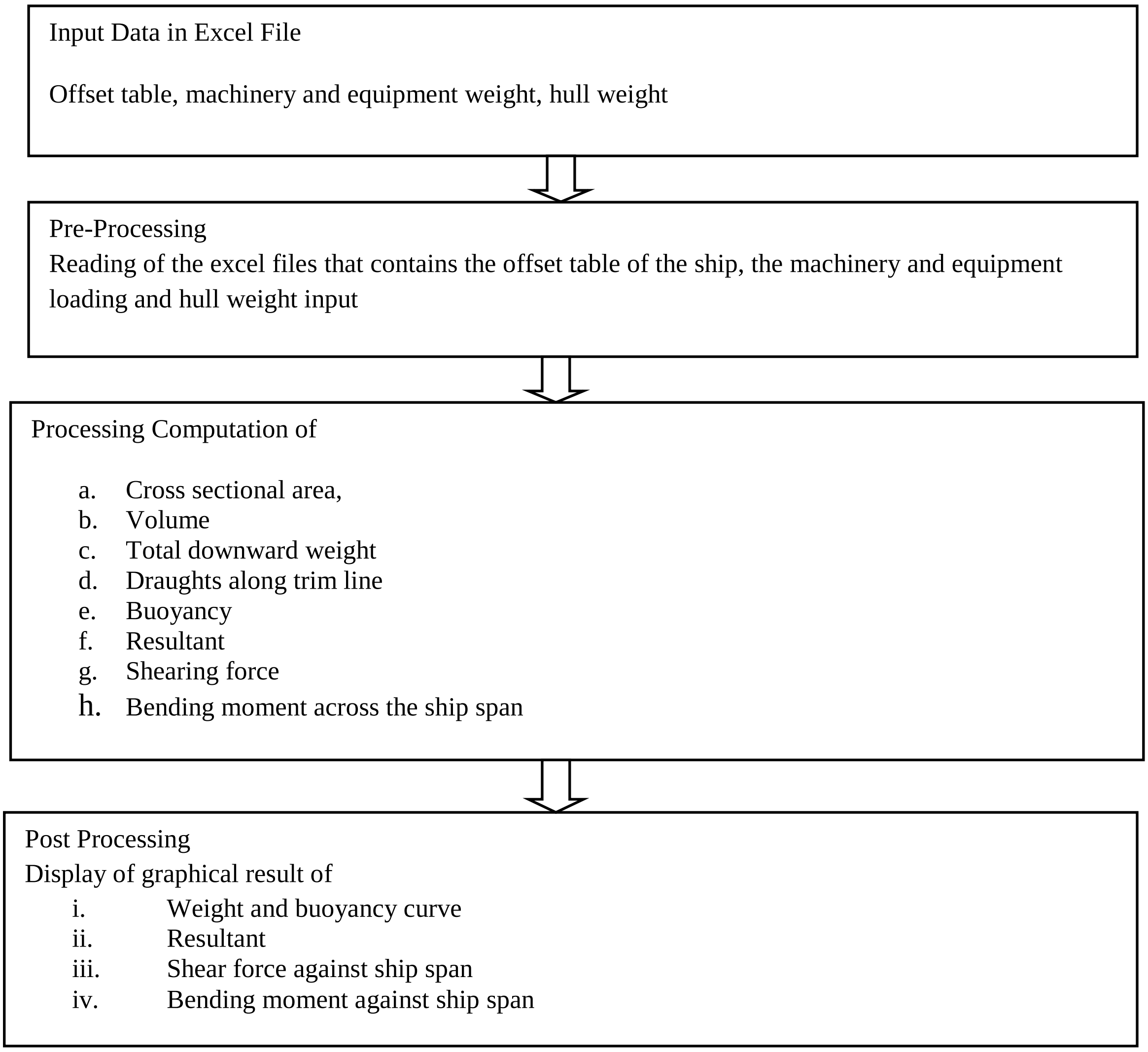


Figure 5: Block Diagram for Developing Shear Force and Bending Moment Mathlab Programmed

4. Results and Discussion

The result is obtained from the bucket method and is shown in table 5below using manual method.

Table 5: Estimation of equipment and machinery weight to each segment by grouping method (Bucket method)

Seg. No.	Length (m)	Weight (tonnes)
0	0	0
1	0.925	1.6
2	6.3325	17.74
3	11.7400	31.68
4	17.1475	40.725
5	22.555	1.295
6	27.9625	-
7	33.3700	-
8	44.185	-
9	55	-
10	65.8150	0.85
11	76.6300	-
12	82.0375	-
13	87.4450	-
14	92.8525	-
15	98.2600	-
16	100.9637	3.565
17	103.6675	6.0
18	106.37125	4.0
19	109.075	3.5
20	110	0.3
		132.88

Light ship weight is the summation of hull weight, equipment and machinery weight. And the hull weight is gotten from the trapezoidal approximation as in figure two above.

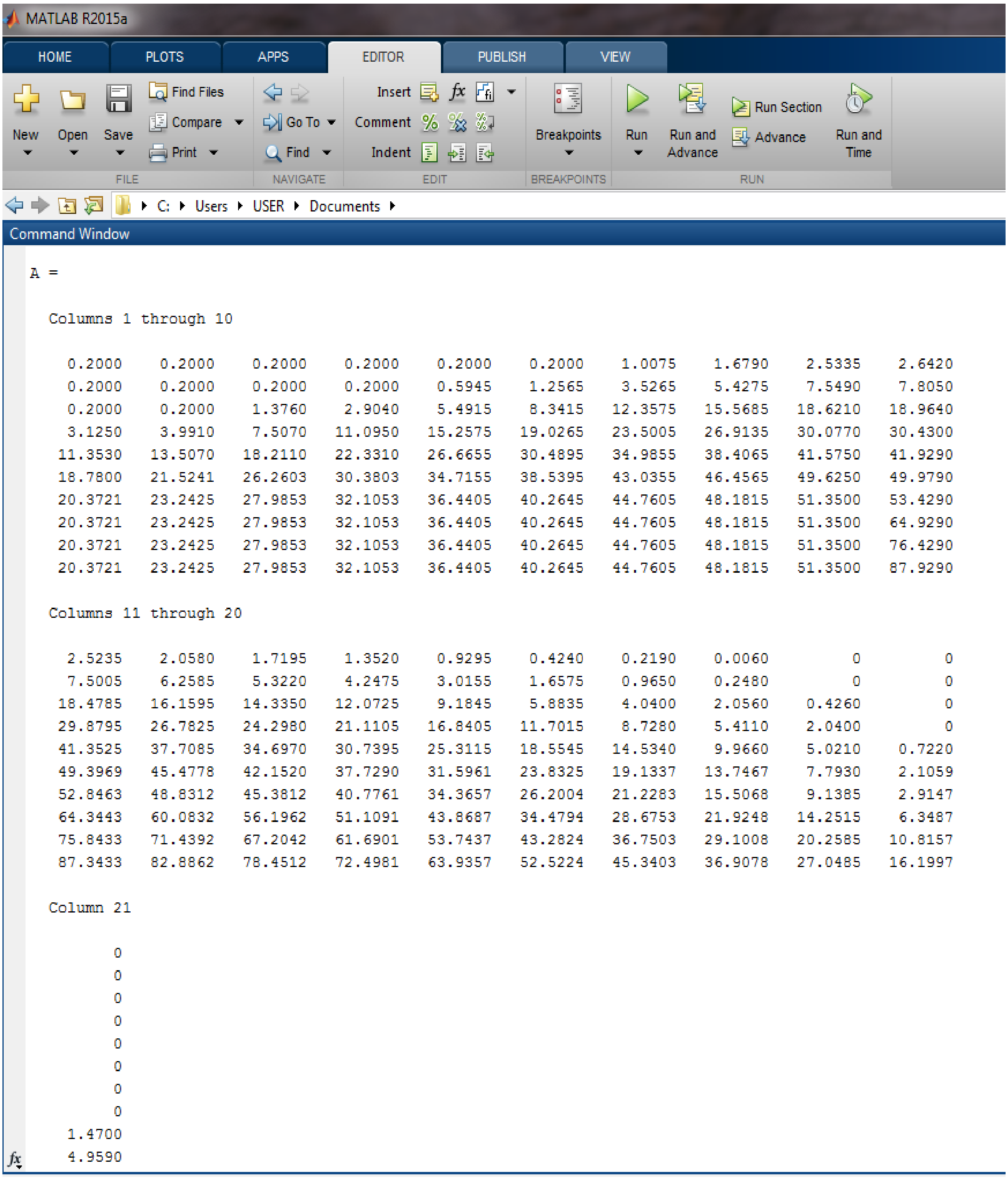
Table 6: Estimation of light ship weight distribution to each segment using trapezoidal approximation method

Seg. No	L (m)	Hull Weight (Ton)	Weight of mission equip and machinery (Ton)	Total (Ton) Weight
0	0	0	0	0
1	0.925	2.7725	1.6	4.3725
2	6.3325	9.5800	17.74	27.3200
3	11.7400	0.1775	31.68	31.8575
4	17.1475	0.6248	40.725	41.3498
5	22.555	7.9029	1.295	9.1979
6	27.9625	22.4427	-	22.4427
7	33.3700	30.7733	-	30.7733
8	44.185	107.1561	-	107.1561
9	55	120.0955	-	120.0955
10	65.8150	118.8621	0.85	119.7121
11	76.6300	103.4452	-	103.4452
12	82.0375	42.2358	-	42.2358
13	87.4450	33.8573	-	33.3573
14	92.8525	46.3258	-	46.3258
15	98.2600	35.5514	-	35.5514
16	100.9637	9.9653	3.565	13.5303
17	103.6675	4.5833	6.0	10.5833
18	106.37125	4.2278	4.0	8.2278
19	109.075	3.7183	3.5	7.2183
20	110	1.2641	0.3	1.5641
		679.323	**132.88**	**812.203**

4.1. Calculation of Cross Sectional Areas (m^2) (Trapezoidal Method)

The cross sectional area was calculated from the input off set table (hull geometry) in excel file on each station from the keel/bottom to the deck

Cross sectional area = $\int_{o}^{h} y(x)dx$




```
A =

  Columns 1 through 10

    0.2000    0.2000    0.2000    0.2000    0.2000    0.2000    1.0075    1.6790    2.5335    2.6420
    0.2000    0.2000    0.2000    0.2000    0.5945    1.2565    3.5265    5.4275    7.5490    7.8050
    0.2000    0.2000    1.3760    2.9040    5.4915    8.3415   12.3575   15.5685   18.6210   18.9640
    3.1250    3.9910    7.5070   11.0950   15.2575   19.0265   23.5005   26.9135   30.0770   30.4300
   11.3530   13.5070   18.2110   22.3310   26.6655   30.4895   34.9855   38.4065   41.5750   41.9290
   18.7800   21.5241   26.2603   30.3803   34.7155   38.5395   43.0355   46.4565   49.6250   49.9790
   20.3721   23.2425   27.9853   32.1053   36.4405   40.2645   44.7605   48.1815   51.3500   53.4290
   20.3721   23.2425   27.9853   32.1053   36.4405   40.2645   44.7605   48.1815   51.3500   64.9290
   20.3721   23.2425   27.9853   32.1053   36.4405   40.2645   44.7605   48.1815   51.3500   76.4290
   20.3721   23.2425   27.9853   32.1053   36.4405   40.2645   44.7605   48.1815   51.3500   87.9290

  Columns 11 through 20

    2.5235    2.0580    1.7195    1.3520    0.9295    0.4240    0.2190    0.0060         0         0
    7.5005    6.2585    5.3220    4.2475    3.0155    1.6575    0.9650    0.2480         0         0
   18.4785   16.1595   14.3350   12.0725    9.1845    5.8835    4.0400    2.0560    0.4260         0
   29.8795   26.7825   24.2980   21.1105   16.8405   11.7015    8.7280    5.4110    2.0400         0
   41.3525   37.7085   34.6970   30.7395   25.3115   18.5545   14.5340    9.9660    5.0210    0.7220
   49.3969   45.4778   42.1520   37.7290   31.5961   23.8325   19.1337   13.7467    7.7930    2.1059
   52.8463   48.8312   45.3812   40.7761   34.3657   26.2004   21.2283   15.5068    9.1385    2.9147
   64.3443   60.0832   56.1962   51.1091   43.8687   34.4794   28.6753   21.9248   14.2515    6.3487
   75.8433   71.4392   67.2042   61.6901   53.7437   43.2824   36.7503   29.1008   20.2585   10.8157
   87.3433   82.8862   78.4512   72.4981   63.9357   52.5224   45.3403   36.9078   27.0485   16.1997

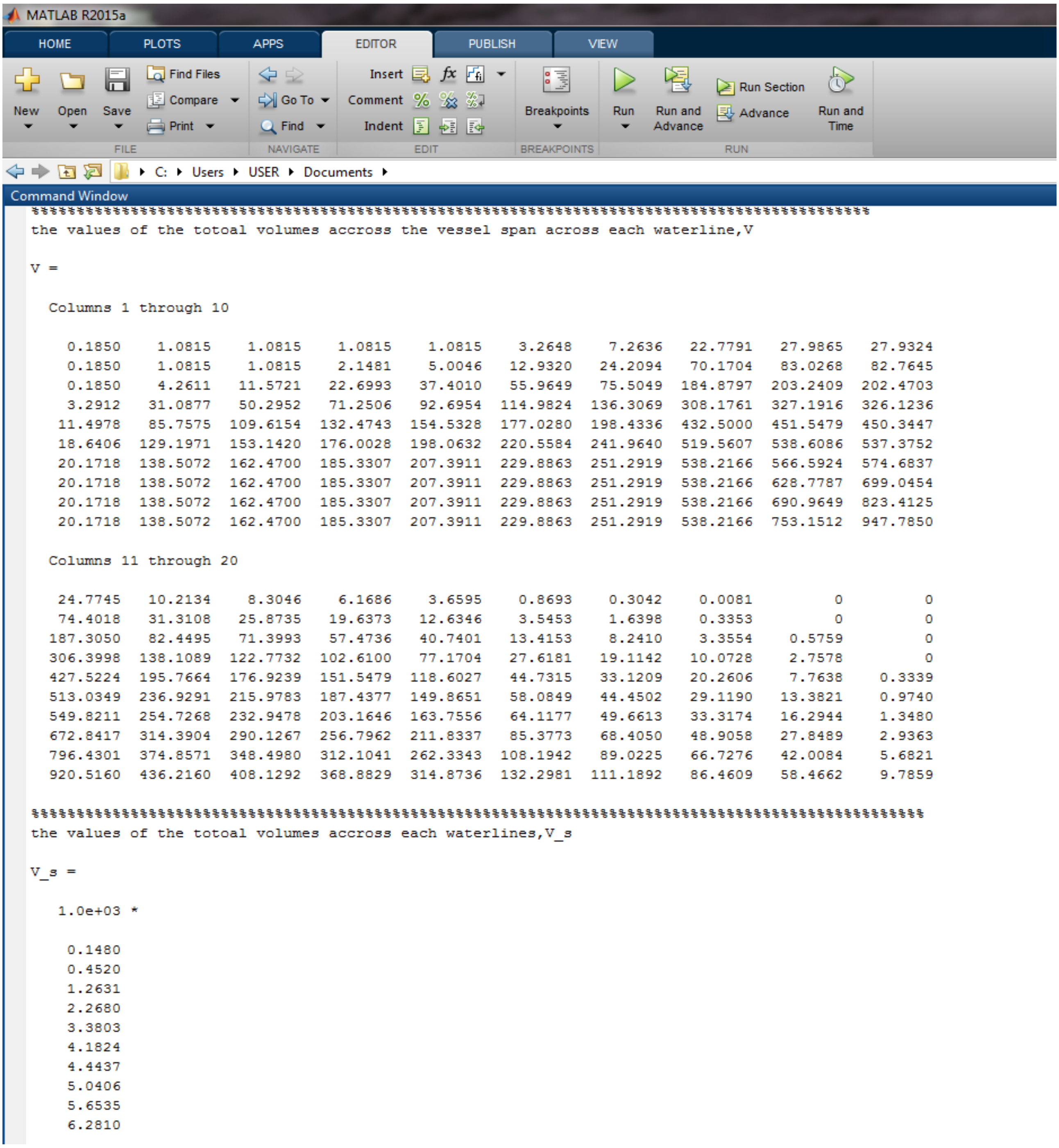
  Column 21

         0
         0
         0
         0
         0
         0
         0
         0
    1.4700
    4.9590
```

Figure 6: Result of Cross Sectional Area

4.2. Calculation of sectional volumes (m^3) (Trapezoidal Method)

The sectional volume displaced was calculated from the area, using the area as ordinate on each water line station, and the summation of section volume across the ship span is volume displaced at that particular draught.

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%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
the values of the totoal volumes accross the vessel span across each waterline,V

V =

  Columns 1 through 10

    0.1850    1.0815    1.0815    1.0815    1.0815    3.2648    7.2636   22.7791   27.9865   27.9324
    0.1850    1.0815    1.0815    2.1481    5.0046   12.9320   24.2094   70.1704   83.0268   82.7645
    0.1850    4.2611   11.5721   22.6993   37.4010   55.9649   75.5049  184.8797  203.2409  202.4703
    3.2912   31.0877   50.2952   71.2506   92.6954  114.9824  136.3069  308.1761  327.1916  326.1236
   11.4978   85.7575  109.6154  132.4743  154.5328  177.0280  198.4336  432.5000  451.5479  450.3447
   18.6406  129.1971  153.1420  176.0028  198.0632  220.5584  241.9640  519.5607  538.6086  537.3752
   20.1718  138.5072  162.4700  185.3307  207.3911  229.8863  251.2919  538.2166  566.5924  574.6837
   20.1718  138.5072  162.4700  185.3307  207.3911  229.8863  251.2919  538.2166  628.7787  699.0454
   20.1718  138.5072  162.4700  185.3307  207.3911  229.8863  251.2919  538.2166  690.9649  823.4125
   20.1718  138.5072  162.4700  185.3307  207.3911  229.8863  251.2919  538.2166  753.1512  947.7850

  Columns 11 through 20

   24.7745   10.2134    8.3046    6.1686    3.6595    0.8693    0.3042    0.0081         0         0
   74.4018   31.3108   25.8735   19.6373   12.6346    3.5453    1.6398    0.3353         0         0
  187.3050   82.4495   71.3993   57.4736   40.7401   13.4153    8.2410    3.3554    0.5759         0
  306.3998  138.1089  122.7732  102.6100   77.1704   27.6181   19.1142   10.0728    2.7578         0
  427.5224  195.7664  176.9239  151.5479  118.6027   44.7315   33.1209   20.2606    7.7638    0.3339
  513.0349  236.9291  215.9783  187.4377  149.8651   58.0849   44.4502   29.1190   13.3821    0.9740
  549.8211  254.7268  232.9478  203.1646  163.7556   64.1177   49.6613   33.3174   16.2944    1.3480
  672.8417  314.3904  290.1267  256.7962  211.8337   85.3773   68.4050   48.9058   27.8489    2.9363
  796.4301  374.8571  348.4980  312.1041  262.3343  108.1942   89.0225   66.7276   42.0084    5.6821
  920.5160  436.2160  408.1292  368.8829  314.8736  132.2981  111.1892   86.4609   58.4662    9.7859

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
the values of the totoal volumes accross each waterlines,V_s

V_s =

   1.0e+03 *

    0.1480
    0.4520
    1.2631
    2.2680
    3.3803
    4.1824
    4.4437
    5.0406
    5.6535
    6.2810
```

Figure 7: Result of Sectional Volume and Total Volume on Each Water Line

The total volume displaced is plotted to the different water line to determine the intermediate water line (draught) at certain amount of volume displaced and use the equivalent draught to interpolate across the volume of the ship span at each section to get the local volumes (buoyancy) across the ship.

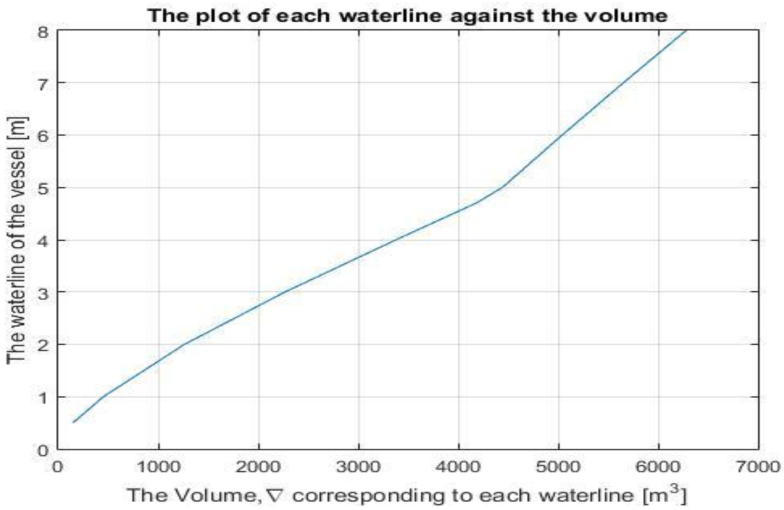

Figure 8: Graph of Water Line against Volume

4.3. Light Trim Ship Buoyancy Estimation Distribution

The various draughts at each stations spacing across the ship span was calculated along the trim line from fore draught (1.245m) and aft draught (1.605m) with similar triangle method. And using areas as ordinate with corresponding draught on each station to get the segment volume and the total summation of volume on a waterline give the total volume displaced with equivalent mass of (812.203 tonnes)

```
Columns 1 through 11

  1.6050    1.6020    1.5843    1.5666    1.5489    1.5312    1.5135    1.4958    1.4604    1.4250    1.3896

Columns 12 through 21

  1.3542    1.3365    1.3188    1.3011    1.2834    1.2746    1.2657    1.2569    1.2480    1.2450
```

Figure 9: Result of Light Ship trim draught at each station across the ship span

```
Columns 1 through 11

  0.2000    0.2000    0.8871    1.7320    3.2824    5.0199    8.0611   10.4553   12.6465   12.5476   11.7776

Columns 12 through 21

  9.7655    8.3550    6.7422    4.8731    2.8552    1.8093    0.7284    0.1094         0         0
```

Figure 10: Result of Light Ship trim area at each station across the ship span

```
Columns 1 through 11

       0    0.1896    3.0127    7.2585   13.8966   23.0085   36.2520   51.3153  128.0460  139.6428  134.8268

Columns 12 through 21

119.4068   50.2182   41.8396   32.1901   21.4179    6.4635    3.5165    1.1610    0.1516         0
```

Figure 11: Result of Light Ship Buoyancy Distribution to Each Segment

4.4. Light Ship Weight and Buoyancy Estimation to Each Section across the Ship

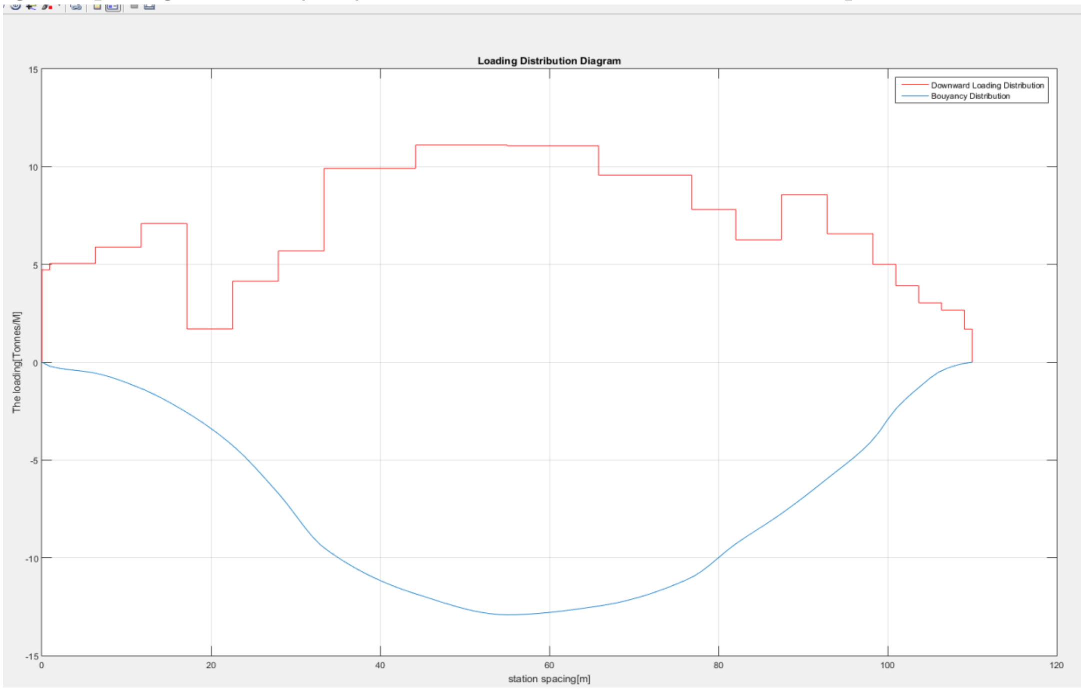

Figure 12: Light Ship Weight and Buoyancy Distribution curves

The light ship weight is seen as uniform distributed load on a section as the estimated local L.C.G from the global reference point fall into any bucket on that particular segment. And the buoyancy was distributed along the light trim ship hull geometry with intercept and cubic function in the mathlab programmed.

Table 7: Result of Light Trim Ship Shear Force and Bending Moment Using Trapezoidal Rule Approach

A **Ord**	**B** **Bouy**	**C** **Wt**	**D** **Ord spacing L (m)**	**E** **Resultant** **B – C**	**F** **S.F** **∑ E**	**G** **Mid S.F**	**H** **ϱ B.M** **G × D**	**I** **B.M** **∑ H**
0					0			0
	0.1896	4.3725	0.9250	- 4.1829		-2.0915	-1.9346	
1					- 4.1829			-1.9346
	3.0127	27.3200	5.4075	- 24.3073		-16.3366	-88.3401	
2					-28.4902			-90.2747
	7.2585	31.8575	5.4075	- 24.5993		-40.7899	-220.5714	
3					-53.0895			-310.8461
	13.8966	41.3498	5.4075	- 24.4533		-65.3162	-353.1974	
4					-77.5428			-664.0435
	23.0085	9.1979	5.4075	13.8102		-70.6377	-381.9734	
5					-63.7326			-1046.0169
	36.2520	22.4427	5.4075	13.8090		-56.8281	-307.2980	
6					-49.9236			-1353.3149
	51.3153	30.7733	5.4075	20.5420		-39.6526	-214.4214	
7					-29.3816			-1567.7363
	128.0460	107.1561	10.815	20.8881		-18.9376	-204.8104	
8					-8.4935			-1772.5467
	139.6428	120.0955	10.815	19.5481		1.2806	13.8497	
9					11.0546			-1758.6970
	134.8268	119.7121	10.815	15.1150		18.6121	201.2899	
10					26.1696			-1557.4071
	119.4068	103.4452	10.815	15.9619		34.1506	369.3387	
11					42.1315			-1188.0684
	50.2182	42.2358	5.4075	7.9826		46.1228	249.4090	
12					50.1141			-938.6594
	41.8396	33.3573	5.4075	7.9820		54.1051	292.5733	
13					58.0961			-646.0861
	32.1901	46.3258	5.4075	- 14.1336		51.0293	275.9409	

14					43.1315			-370.1452
	21.4179	35.5514	5.4075	- 14.1336		36.8957	199.5135	
15					29.8289			-170.6317
	6.4635	13.5303	2.70375	- 7.0668		26.2955	71.0965	
16					22.7621			-99.5352
	3.5165	10.5303	2.70375	- 7.0668		19.2287	51.9896	
17					15.6953			-47.5456
	1.1610	8.2278	2.70375	- 7.0668		12.1619	32.8827	
18					8.6285			-14.6629
	0.1516	7.2183	2.70375	- 7.0668		5.0951	13.7759	
19					1.5617			-0.887
	0	1.5641	0.9250	- 1.5641		0.7809	0.7223	
20					0			0

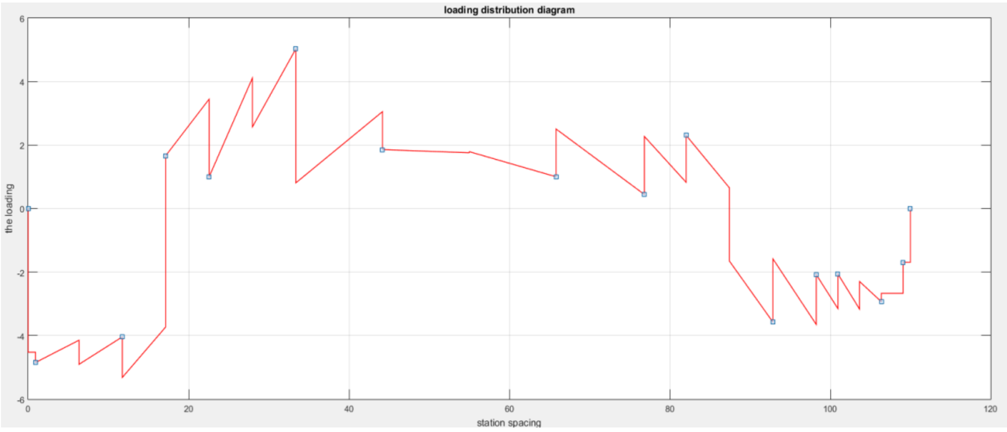

Figure 13: Light Ship net load Curve

The net load is the difference between the gravity load per unit length (W/L) and buoyancy per unit length (buoy/L)

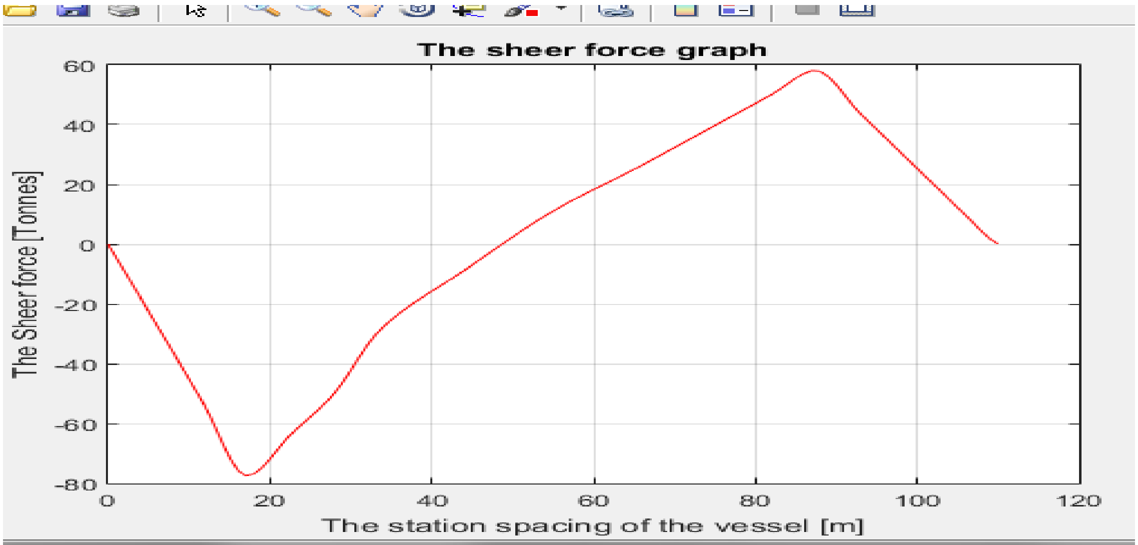

Figure 14: The Graph of the Light Ship Shear Forces

The algebraic summation of area from right or left is the shear force, indicating stable equilibrium of weight and buoyancy forces, and has it maximum shear at aft part of the ship

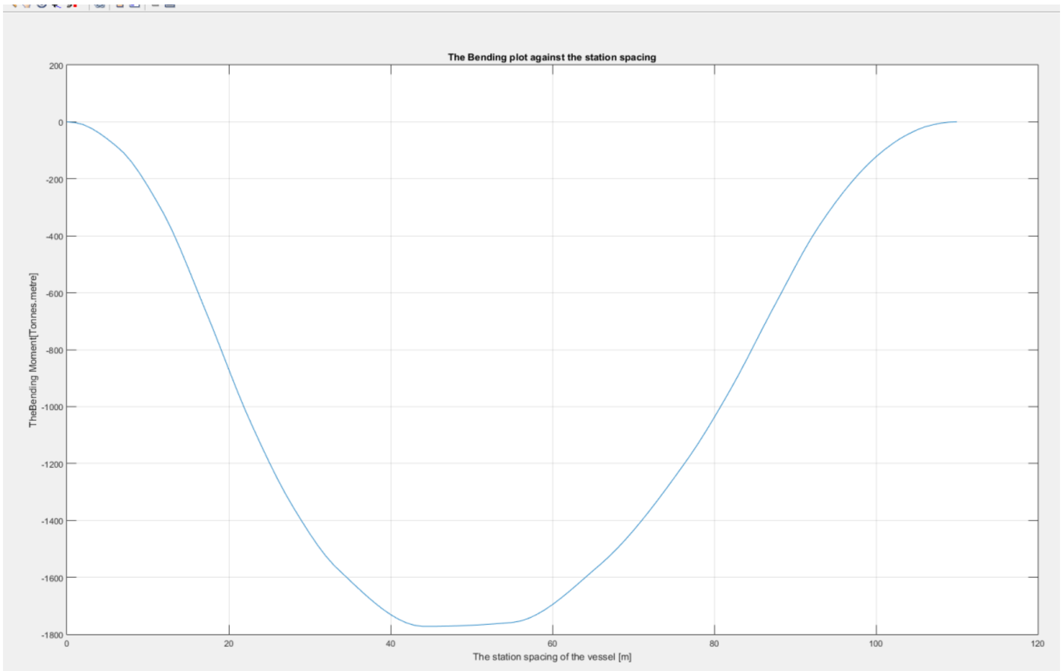

Figure 15: Light Ship Bending Moment Diagram

The bending moment graph simply indicate that the downward ship weight is evenly distributed and the maximum weight is acting on aft part of the ship which is stable equilibrium and trim, although it is ideal that the ship have little weight acting on the aft than the fore for proper submerged of the propeller and against sea keeping performance at sallow draught

5. Conclusion and Recommendation

Conclusion

The various methods of weight distribution such as approximation method (Comstock, Trapezoidal, Bile, Prohaska), direct method, and grouping method all have their own advantage and flaws and be justify by shear force and bending moment and the fidelity of the distribution is improve by the laid down method. The maximum bending moment is 1772.5467 T.M at 44.185m and maximum shearing force is 77.5428 Tonnes at 17.1475m from aft. Indicating that catastrophe will occur near amidships if steel selected is below the estimated maximum bending moment and heavier loads were on the aft part to maintain sea performance. The methods had improved structural integrity and a source code had been developed for flexibility of shear force and bending moment calculation.

Recommendation

However a vigorous research need to be carried out on longitudinal weight distribution with optimal loading plan taking into study of it route and structure constraints to eradicate the bending stress of ships

Developed Mathlab Source Code (trim ship)

```
[fileName,pathname]=uigetfile(('*.xlsx'),'Please select the offset file');%open the dialog
fullpathname=strcat(pathname,fileName);% obtain the file path
offset=xlsread(fullpathname);%pass it here to read the required file which is excel
%% get the half breadths of the vessel
a=offset;
b=a(2:end-3,2:end);%half breadth
disp('%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%')
```

```
disp('The offset table of the vessel')

[r,c]=size(b);

%% assign the first column to the  drafts of the vessel
h=a(2:end-3,1);%drafts
disp('%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%')
disp('The values of the waterlines of the vessel,h')
h

[q,w]=size(h);

h_s=h(2:end,1);
 %% create a variable for the station linr spacing
 s=a(1,2:end);
disp('%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%')
disp('The values of the station spacing ,s')
s

 %% The cargo loads
 c_1=a(end-2,2:end);
disp('%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%')
disp('The cargo loading,c_1')
c_1



 %% mechinery spacing and component weights
 m=a(end-1,2:end);
disp('%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%')
disp('The values of the mechinery and equipmenttsaccross the vessel span ,m')
m


 %% modified areas, A=zeros((r-1),c)

c_r=c;
  A=zeros((r-1),c);
sum=0;
for i=1:1:(r-1)
        t=(b(i,:)+b((i+1),:))*(h(i+1,:)-h(i,:));
sum=t+sum;
A(i,:)=sum;
end
```

```
disp('%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%')
disp('The values of the cross sectional areas at each station,A')
A
% A_m=zeros(size(A,1),(size(A,2)-2));
% for i=1:1:Size(A_m,2)
%     A_m(
% end
d_i=input('please enter the draught:');
h=input('please enter constant draft:');
d_r=zeros(size(s))
[r_d_r,c_d_r]=size(d_r);
d_trimed=size(d_r,2);%trimed draft
d_r(1)=d_i;


for i=2:1:c_d_r
d_r(i)=(d_r(i-1)*(s(:,end)-s(:,i))/(s(:,end)-s(:,i-1)));
d_r(i)=d_r(i);

end

d_r
for i=1:1:(c_d_r)
d_trimed(i)=d_r(i)+h;
end
d_trimed

%% trim diagram
figure(1)
plot(s,d_trimed);
xlabel('station spacing[m]')
ylabel('trimmed values[m]')
title('Trim diagram')

%% interpolating between each area station
%

%% interpolating between the totoal volumes across each drafts/waterlines to get the required corresponding drafts for the hull weigh waterline
%also the entire downward force is computed here as well
A_i=size(d_r,2);
for i=1:1:(c_d_r)
A_i(i)=interp1(h_s,A(:,i),d_trimed(i));
end
A_i
%% volume computation with station
V_i=zeros(1,size(d_r,2));
V_i(1)=0;
```

```
for i=1:1:(c_d_r)-1
V_i(i+1)=0.5*(A_i(i+1)+A_i(i))*(s(i+1)-s(i));
end
V_i
b_i=V_i*1.025

%% downward force
h_w =a(end,2:end);
de_t= zeros(1,size(s,2));
b_u=zeros(1,size(s,2));

for  i=1:1:size(d_r,2)-1
de_t(:,i+1)=(s(:,i+1)-s(:,i));

end
de_t

D_f=c_1+h_w+m;

for  i=2:1:size(d_r,2)
D_t(:,i)=D_f(:,i)./de_t(:,i);
end
D_t

%% resultant
r_s=(b_i)-(D_f)
s_m=min(s):1:max(s);
r_u=interp1(s,r_s,s_m,'PCHIP');
figure(2)
plot(s_m,r_u)

xlabel('The station spacing of the vessel [m]')
ylabel('The Resultant force [Tonnes]')
title('The resultant at each station')
grid on;

%% loading diagram for trim case

x=[0,0,0.925,0.925,6.3325,6.3325,11.74,11.74,17.1475,17.1475,22.555,22.555,27.9625,27.9625,33.37,33.37,44
.185,44.185,55,55,65.815,65.815,76.83,76.83,82.0373,82.0375,87.445,87.445,92.8525,92.8525,98.26,98.26,100
.9637,100.9637,103.6675,103.6675,106.37125,106.37125,109.075,109.075,110,110];
y=[0,4.7270,4.7270,5.0522,5.0522,5.8914,5.8914,7.0920,7.0920,1.7010,1.7010,4.1503,4.1503,5.6909,5.6909,9.
9081,9.9081,11.1045,11.1045,11.0691,11.0691,9.5650,9.5650,7.8106,7.8106,6.2612,6.2612,8.5666,8.5666,6.57
45,6.5745,5.0043,5.0043,3.9143,3.9143,3.0431,3.0431,2.6697,2.6697,1.6909,1.6909,0];

for  i=2:1:size(d_r,2)-1
b_u(:,i)=b_i(:,i)./de_t(:,i);
end
b_u
B_u=interp1(s,b_u,s_m,'PCHIP');
```

```
figure(3)
plot(x,y,'r')
hold on
plot(s_m,-B_u)
grid on;

legend({'Downward Loading Distribution ','Bouyancy Distribution'},'Location','northeast')
xlabel('station spacing[m]')
ylabel('The loading[Tonnes/M]')
title('Loading Distribution Diagram')

%% The net loading curve
N_loading=b_i-D_t
N_loadingy=interp1(s,N_loading,s_m,'PCHIP')

%plot the net loading
figure(4)
plot(s_m,N_loadingy);
grid on;
xlabel('Station Spacing [m]');
ylabel('Net loading [Tonnes/m]')
title('Netloading diagram')

 %% sheer force

S_f=cumsum(r_s,2)
disp('%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%%%%%%%%%%')
disp('the sheerforce values ,S_f')
S_f
Sheerforce=interp1(s,S_f,s_m,'cubic')
figure(5)
plot(s_m,Sheerforce,'r')
grid on
xlabel('The station spacing of the vessel [m]')
ylabel('The Sheer force [Tonnes]')
title('The sheer force graph')

%% Bending moments
a_m= zeros(1,size(S_f,2));
%w=0;

for i=1:1:size(S_f,2)-1
   u=(S_f(:,i)+S_f(:,(i+1)))*(s(:,i+1)-s(:,i))*0.5;

a_m(:,i)=u;
end
B_m=cumsum(a_m,2)
B_mm=zeros(1,size(B_m,2));
```

```
for i=1:1:size(B_m,2)-1
B_mm(:,i+1)=B_m(:,i);
end
disp('%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%')
disp('the bending moment values,B_mm')
B_mm


s_m=min(s):1:max(s);

y_B_mm=interp1(s,B_mm,s_m,'PCHIP')
figure(6)
plot(s_m,y_B_mm)
grid on
xlabel('The station spacing of the vessel [m]')
ylabel('TheBending Moment[Tonnes.metre]')
title('The Bending plot against the station spacing')
```

Reference

[1]. Cheng-Kuan, L., & Heiu-Jou, S. (2016). Preliminary Parametric Estimation of Steel Weight for New Ships. *Journal of Marine Science Technology*, 227–239.

[2]. David, L. H. (2008).*Method of determining the longitudinal weight distribution of a ship*. presented at a joint meeting between Hampton Roads Section of the Society of Naval Architects and Marine Engineers and the Hauton Roads Chapter of the Society of Allied Weight Engineers.

[3]. Rawson, K. J., & Tupper, E. C. (2001). *Basic Ship Theory*. Boston: Butterworth-Heinemann.

[4]. Tania, S. M. (2013). *Development of Empirical Formulas for Still Water Bending Moment*. Categena, Ingenieria Naval Oceanica.

[5]. Stood, R. K. (2017). *Introduction to longitudinal strength of ship*. New Delli, The Naval Archrte Ltd, 14 Robinson road #08-01A, far east finance building..