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Review of Maximum Bending Moment Estimation in Ship Hull Using Murray Method

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ABSTRACT
The paper aimed at reviewing the concept of maximum bending moment using Murray method in ship hull structure (self-propel offshore servicing ship, double hull) to improve ship strength, durable economic life and reliability. The material used to develop the paper are hull geometry (offset table) weight of items and their Longitudinal Centre of gravity (LCG) along the ship span. The paper explores Murray method. Bending moment analysis, which enable naval architects to select good materials, proper ship hull arrangement, minimizes structural failures and guarantee safety of personal. The result obtained from Murray method was validated with trapezoidal rule approach were both results agreed, indicating advanced robust and energy efficient methods for determining the optimal bending moment to satisfy structural integrity of a ship structure.

Keywords: Maximum Bending Moment, Ship Structure, Offshore Servicing Ship

I. INTRODUCTION.

The complexity and nature of ship structure has change significantly from traditional system to a more robust system(Claude, 2013). The design of ships nowadays is governed by design rules given by the classification societies and International Maritime Authorities. The design rules are continuously reviewed as the practice changes through the years. (Hansen, 1995). Ship structures are mainly formed of steel metal plates which are reinforced by stiffeners. As a consequence, the study of plate behavior or performance is of significant importance for the structural analysis of ship hulls. (GORDO, 1993). Ship hulls (plates) are subjected to varying degree of loading, ranging from uniaxial loading (common on deck plating) to biaxial loading with lateral pressure (predominant on bottom plating) and edge shear on side shell and bulkheads plating. When a ship is under the influence of longitudinal bending, the entire longitudinal members, namely girders, longitudinal and plate are loaded unidirectionally in their own geometric plane.

At the same time, there may also exist loadings in other direction due to secondary effect such as local lateral pressure. Longitudinal stresses are common in ship. Therefore, it is important to understand the behavior of the plate's members loaded longitudinally or transversely depending the kind of stiffening in a ships structure.

This paper focuses on various structural responses steepness i.e., computation of bending moment. The study was to examine the strength in ship hulls. Result of shipbuilding make us to understand that ship building encompasses a large number of features which leads to the deformation of ships, due to this effect, a vigorous calculation of maximum bending moment was done in design and construction practice.

The paper examined loads and deflections, longitudinal position, hull girder, equilibrium resultant, longitudinal Centre of gravity, longitudinal Centre of buoyancy, maximum bending moment under certain loading condition. Thus, the naval architects Centre more on bending moment in design studies to investigate the ship strength distribution for regulation standard.

The result obtained improves confidence to demonstrate satisfactory correlation between the other ship, hence it guarantees safety of human element, general ship arrangement, loading booklet, ship efficiency and cost effectiveness (GORDO, 1993). Figure 1.1 illustrate a ship hull distortion of inboard area at mid ship section due to improper strength calculation (Bending moment).

A sailing ship is a carrying tool that is subjected to different areas and various loadingstrength conditions which is different from any other engineering structure (Claude, 2013), Today application is complex in the trend of technology, therefore the naval architects must accumulate knowledge to solve ship problem (Liu and Yin, 2017).

Bending moment calculation play a very significant role in initial stage of the design spiral (Tania, 2013), which is used to analyses the ship strength and preparing the loading booklet (Stood, 2017). Systematic research was done on bending moment determination (Chioco, 1969), to the ship structure committee in wolverine state, where model test and law of comparison was observed. Naval architects also carried out analysis of thin hallow box know as hull girder in form of a beam (Dave, 2017). Murray also developed a method of calculating maximum bending moment (Dave, 2017). This paper assesses hydrostatic parameters (Stroke, 2001) and considered the Murray method for calculating the maximum bending moment. The result achieves satisfy design condition.

1.1. Loading Condition

The various ship loading conditions are,

I. Light ship
II. Fully loaded ship
III. Transitory condition (hogging and sagging when navigating or harbor) (Tania, 2013)

1.1.1. **Sagging**, the cargo is concentrated on amid ship which makes the stern and aft to be supported by seas making the top member to encounter compression and the down to encounter tension.

1.1.2. **Hogging**, the cargo is concentrated on stern and aft which makes the amidships to be supported by seas making the top member to encounter tension and the down member to encounter compression (Stood, 2017).

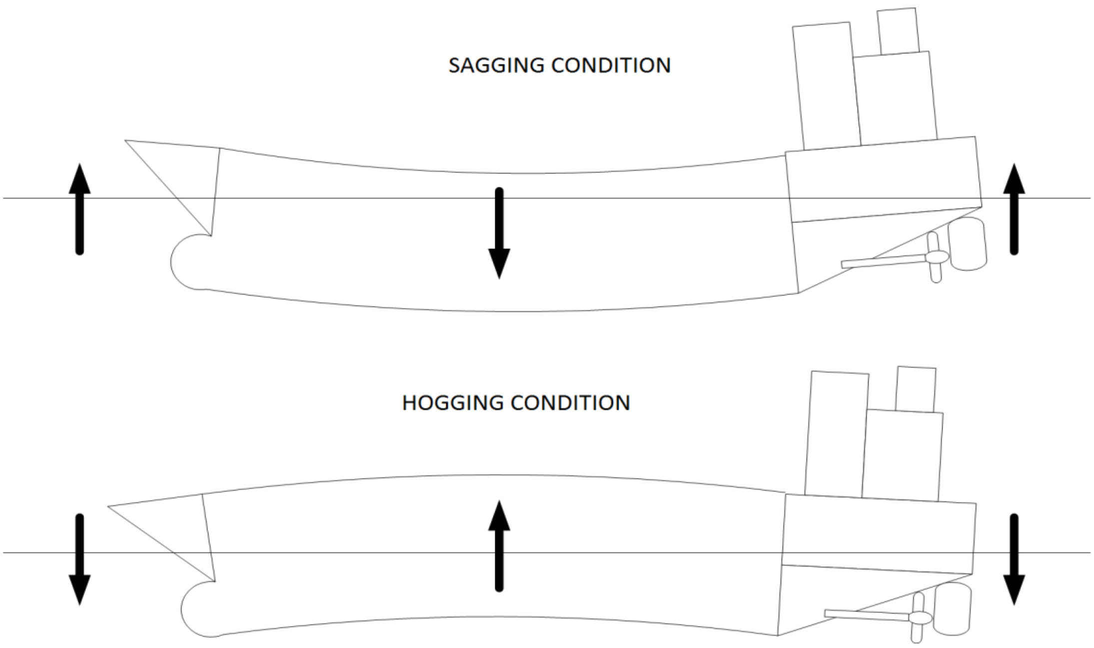

Figure: 1.2. Sagging and Hogging condition

1.2 Weight Estimation

This is the total force acting downward over the entire length of the ship

$$\text{Weight} = \Delta \times g \quad (\text{kN}) \qquad (1.1)$$

1.3 Hull Weight

These include

i. Weight of the structural steel (hull structure)
   a. Longitudinal: keel, carlings, stringers
   b. Latitudinal: transverse frames, beam, flooring
   c. Vertical: bulk heads, pillars
ii. Weight of outfit (foundation, ladder, etc)
iii. Weight of plate
iv. Weight of stiffeners (Dave, 2017)

1.4 Light Ship Weight Estimation (unchangeable items)

b. Components of the light weight
   i. Structure
   ii. Machinery
   iii. Out fitting
c. Centre of gravity
d. Longitudinal distribution of the light ship weight summary

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Light ship weight is the sum of the three main components

$W_{LS} = W_h + W_e + W_m$(1.2)

1.5 Dead Ship Weight Estimation (changeable items)

This comprises of fuel oil, cargo, fresh water, ballast etc. (Stood, 2017).

1.6 Full load Ship Weight Estimation

Longitudinal distributions of the full load ship weight summary.

a. Total ship weight is the sum of the four main components

$W_{Ts} = W_h + W_e + W_m + W_c$ (1.3)

Where

W_{Ts} Total weight of ship
W_h Weight of ship hull
W_e Weight of equipment
W_m Weight of machinery

II. MATERIALS AND METHODS

2.1Ship Hull Geometry

Table 2.1: Typical Table of Offsets of an Offshore Servicing Ship (Half Breadths, Mm)

Station No.	0	1	2	3	4	5	6	7	8	9
Length(m)	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(m)	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	4.412	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

Source: (Kho et al, 2009)

The offset table is use for the determination of ship hull shape (hull geometry) which will be used to calculate the area, volume, buoyancy, centre of gravity, etc.

2.2Light Ship Aft Weight and Moment Estimation

Detail weight and moment estimation acting on the aft part of the ship are shown in table 2.1 below to determine if the ship will trim about the centre of floatation.

Length Over All = 110m,
Mid Ship = 55m
Distance = LCG - Mid Ship
Moment = Weight × Distance

Table 2.2: Light Ship Aft Weight and Moment Estimation

S/N	Items	Weight (ton)	L.C.G	Moment (aft)
1	Anchor	1.6	0.25	87.7
2	Exhaust pipe main engine	0.8	5.45	39.64
3	Propeller shaft	0.95	2.71	49.4755
4	Propeller	0.95	2.71	49.4755
5	Nozzle	2.6	2.71	135.974
6	Anchor winch	2.2	1.83	116.974
7	Steel anchor cable	0.55	1.83	29.2435
8	Car crane	4.2	4.35	212.73
9	Rvs light mast	0.2	4.35	10.468
10	Steering mechanism	1.1	1.74	58.586
11	Rudder 2 pieces	2	1.5	107.00
12	Rudder seal	1.65	1.65	88.0275
13	Hydraulic unit car crane	0.25	2.2	13.2
14	Accommodation	25	10.7	1107.5
15	Aluminum stair to wheel house	0.35	11.1	15.365
16	Provision	1.25	10.9	55.125
17	Lighting	0.4	10.9	17.64
18	Inventory	1.1	10.9	48.51
19	Books	0.5	10.9	22.05
20	Air compressor	0.175	8.5	8.1375
21	Boiler	0.125	8.5	5.8125
22	Life boat	0.25	6.4	12.150
23	Firefighting installation	0.13	11.25	1.4625
24	Windows	0.35	9.2	16.03
25	Hydro foor	0.125	8.5	5.8125
26	Air conditioning unit	0.3	8.5	13.950
27	Hydraulic tank	0.15	9.5	6.825
28	Shaft seal	0.215	7.95	10.11575
29	Hydraulic unit steering	0.25	9.5	11.375
30	Hydraulic unit wheel house	0.2	9.5	9.1
31	Generator set off	0.5	11	22.0
32	Dirty water pump	0.06	8.5	2.79
33	Shaft bearing	0.25	8.5	11.625
34	Nautical equipment	2.25	16.85	85.8375
35	Bridge	14.5	15.4	574.200
36	Cylinder bridge	7.85	15.4	310.86
37	Aluminum door	0.05	13.0	2.1
38	Do filter	0.2	15.06	7.988

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39	Piping system engine room	1.5	16.0	58.5
40	Floor plate	1	12.0	43.0
41	Main engine	7.85	13.25	327.7375
42	Coupling	2.585	11.95	111.2843
43	Aluminum radar mast one bridge	0.45	12.0	19.35
44	Air conditioning unit on working bridge	0.25	12.65	10.5875
45	Small steel work	0.85	16.0	33.150
46	UV-filter	0.1	16.85	3.815
47	Locker	0.1	16.35	3.865
48	Accumulator	0.24	13.00	10.08
49	Electrical box	0.75	16.4	28.95
50	Jet pump	0.125	19.35	4.456
51	Lub. oil pump	0.1	18.0	3.7
52	Do pump	0.1	18.0	3.7
53	Cooling box	0.4	18.75	14.5
54	Cooling box small	0.1	18.75	3.625
55	Working table	0.2	18.5	7.5
56	All service pump	0.27	18.0	9.99
57	Structural weight Aft part	112.988	10.57	5020.057
		206.028		9100.7824

Source: (Tania 2013)

2.3 Light Ship Forward Weight and Moment Estimation

Detail weight and moment estimation acting on the fore part of the ship are shown in table 2.3 below to determine if the ship will trim about the centre of floatation

Length Over All = 110m
Mid Ship = 55m
Distance = LCG - Mid Ship
Moment = Weight × Distance

Table 2.3: Light Ship Forward Weight and Moment Estimation

S/N	Items	Weight(ton)	L.C.G	Moment (fwd)
1	Pipe line for ballast water	0.85	59.25	3.6125
2	All service pump (fore)	0.125	99.75	5.59375
3	Floor plates	0.6	100.5	27.30
4	Cooling box	0.6	100.25	27.15
5	Small steel work	0.65	100.5	29.575
6	Air conditioning unit	0.2	99.85	8.97
7	Hydraulic unit	0.4	99.7	1.788
8	Electrical box (fore)	1.35	99.75	60.4125
9	Dirty water pump (fore)	0.075	101.25	3.46875
10	Generator set fore	1.65	102.5	78.375
11	Hydraulic unit	0.25	102.75	11.9375
12	Accommodation	8.98	102.75	428.795
13	Bow thruster unit	5	102.25	236.25
14	Exhaust pipes	1.5	103.5	155.25
15	Piping system bow thruster room, inch manifold	0.55	101.5	25.575

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16	**Bow thruster engine**	**4**	**102.25**	**189**
17	**Anchor chain**	**5**	**106.06**	**255.3**
18	**Anchor winch dot**	**3.85**	**106.2**	**197.12**
19	**Boiler**	**0.135**	**104.5**	**6.6825**
20	**Fan**	**0.1**	**105.25**	**5.025**
21	**Hydro fan**	**0.055**	**105.35**	**2.76925**
22	**Firefighting installation**	**0.13**	**105.25**	**6.5325**
23	**Hydraulic unit seput tube**	**0.35**	**104.0**	**17.150**
24	**2 anchor ‘d’ hone**	**3.5**	**107.44**	**183.54**
25	**Paint in store**	**0.3**	**109.2**	**16.26**
26	**Structural weight central part**	**487.926**	**58.92**	**1912.6699**
27	**Structural weight fore part**	**78.403**	**102.85**	**3751.5836**
		606.175		7654.3691
	TOTAL	812.203		16755.1515

Source: (Tania, 2016)

The aft moment is greater than the fore moment; the ship will trim about the centroid because the LCB will not be in the same line of action with the LCG.

2.4 Light Ship Still Water Bending Moment calculation by Murray Method

The Murray method is based on the idea that forces and moment in the ship are self-balancing (no force or moment is transfer to the world) that weight and buoyancy are balance. Fig 2.1.

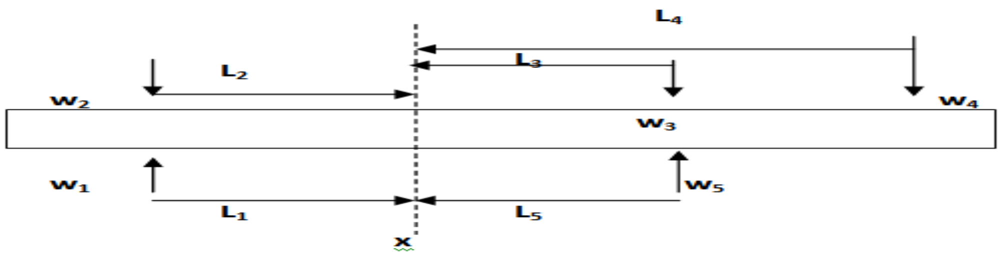

Fig. 2.1: Weight and Buoyancy (self-balance)

For cut at x the moment is determined in two ways:

$BM = W_1L_1 – W_2L_2$

$BM = W_5L_5 – W_3L_3 – W_4W_4$ (2.1)

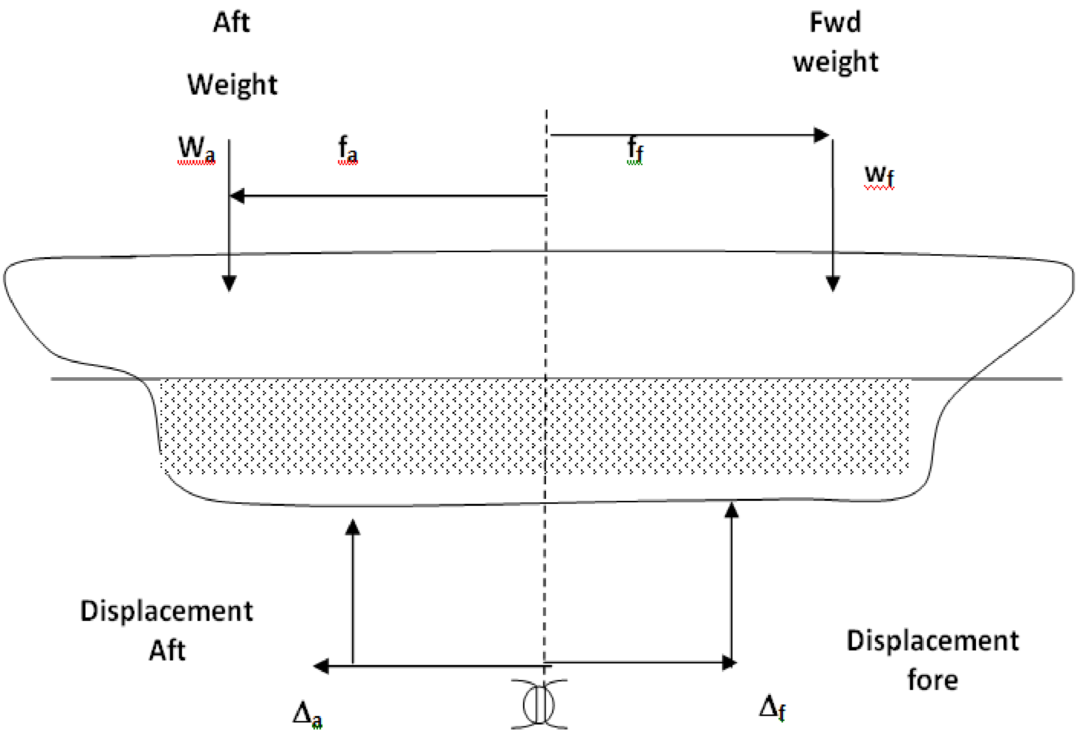

Fig. 2.2:Weight and Buoyancy (self-balance) on Still water

Hence, to determine the bending moment at mid ship

$$B_m\phi = w_a f_a - \Delta_a g_a \qquad (2.2)$$

$$B_m\phi = w_f f_f - \Delta_f g_f \qquad (2.3)$$

For maximum bending moment will combine the two equations and take average to decrease error

$$B_m\phi = \tfrac{1}{2}\left(w_a f_a + w_f f_f\right) - \left(\Delta_a g_a + \Delta_f g_f\right) \qquad (2.4)$$

BM_w BM_b

To get the buoyancy part Murray given

$BM_b = (\Delta_a g_a + \Delta_f g_f) = ½\, \Delta \cdot x$ (2.5)

Where $\bar{x}$ = average moment arm

2.4.1 Murray Suggested Values

Murray also suggests a set of values for $\bar{x}$as a function of the ship length and block coefficient

$\bar{x} = L\,(a.\, C_B + b)$ (2.6)

Table 2.4: Murray Values (Constant) Source (Claude, 2013)

T/L	A	B
0.03	0.209	0.03
0.04	0.199	0.014

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0.06	0.179	0.063

The adequate equation for a and b is given as
a = 0.239-T/L
b = 1.1T/L- 0.003

2.4.2 Simulation by Murray Method

$\therefore BM_w = \frac{1}{2}$ x Total Moment (2.7)

$BM_b = \frac{1}{2} x\Delta\bar{x}$ (2.8)

$\bar{x} = L \times (a.\ c_B + b)$

L = 108.15m (from 0.925m to 109.075m)

T= 1.42m

note: B = is obtained from offset table by interpolation (see table 3.1)

$$\begin{Bmatrix} 2.0 \\ 1.42 \\ 1.0 \end{Bmatrix} \qquad B \begin{Bmatrix} 5717 \\ \\ 5442 \end{Bmatrix}$$

Volume displacement = $\frac{\text{mass}}{\text{density}}$ (2.9)

Murray values for

$$a = 0.239 - \frac{\text{draught}}{\text{lenght}}$$

$$b = 1.1 \text{ x} \frac{\text{draught}}{\text{lenght} - 0.003}$$

$$C_B = \frac{\text{volumedisplacement}}{\text{LxBxT}} \quad (2.10)$$

$\therefore \bar{x}$ = length $[(a \times C_B) + b]$

$\therefore BM_B = \frac{1}{2}$ x weight x $\bar{x}$ (2.11)

$\therefore BM_x = BM_W - BM_B$

Sag Hog

III. RESULTS AND DISCUSSION

Table 3.1: Result from Murray Method Simulation

The simulation result was obtained using MURRY method as shown in section 2.2

Parameters	Results
Mass	812.203T
Breath	11.115m
Volume displaced	792.3932m^3
A	0.226
B	0.014
C_B	0.4
$\bar{x}$	12.84
BM_B	2606.1103TM
BM_W	4188.5758TM
BM_X	1582.4655TM (sag)

The maximum bending moment will occur at 42.16m from aft using Murray method with 1582.4655 T.M at a level keel position. Murray did not consider the various bending moment on each station along the ship span, only the maximum bending moment was considered

Table 3.2 Validation of Maximum Bending Moment UsingTrapezoidal 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

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	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

IV. CONCLUSION AND RECOMMENDATION

4.1 Conclusion

The various method of calculating bending moment for ship hull structure had their own merit and demerit. The maximum bending moment will occur at 42.16m from aft using Murray method with 1582.4655T.M at a level keel position while trapezoidal approach agrees with Murray method. Indicating that catastrophe will occur near amidships if steel material selection is below calculated. Hence Murray method had improved the fidelity of bending moment calculation, ship structural integrity and flexibility in ship bending moment calculation.

4.2 Recommendation

However vigorous research needs to be done with optimal loading condition, taking it route and constraints.

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