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Strength Appraisal of Hull Components of a Barge Under a Load Using Numerical Analysis

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ABSTRACT

The study of the strength appraisal of hull components of a barge under a load using numerical analysis has been carried out. The calculation of the ship hull strength is done by the use of the classification society rules and regulations giving guidelines and formulae to the estimation, selection and calculation of various components, machineries, and systems etc. of the offshore service barge. The results achieved from this work show that the maximum design stress is 83.33MN/m^2. The strength of the model of the barge assessed the various forces to which the barge structure is subjected during its lifetime; the results of the analysis indicated that there is variation in the weight of the structure throughout the length of the barge. Although the total weight of the barge is balanced by the total force of buoyancy, neither is it uniformly distributed throughout the barge length. The result also shows that the weight of each end section exceeds the buoyancy which they provide at these sections. The load curve results indicate that there is a difference between weight and buoyancy of each section throughout the length of the barge. In still water, the uneven loading which occurs throughout the length of a ship varies considerably with different conditions which may reach very high values. It is recommended that Finite Element Method should be used in determining the hull strength and the development of international standards that can be utilized also to assess components and system structures.

1. Introduction

The structure of a ship gives the strength together with stiffness to bear all forces which it experience. The structure of the ship also gives local aid to the hull, electrical and electronic equipment, auxiliary machinery equipment coupled with much needful equipment for the ship to accomplish its purposeful operation [1]. The hull girder is the structural part that resists longitudinal bending which includes the following: shell plating, deck, inner bottom together with longitudinal bulkhead. It has the capacity to give strength to resist the complete range of external or buoyancy load from water or dynamic storm [2]. Factor of safety, cost of weight, shock, vibration, fatigue, corrosion, fabrication together with maintenance are the fundamentals to be considered in strength coupled with the stiffness development of ship's structure [3, 4]. Also, the structural element of the ship's hull which encompasses its form of a barge is not different as such when comparable with other marine ships thereby making the structural characteristics general for all kind of vessels. The cardinal elements found in the structure of the ship is depicted in Figure 1 and the structural member arrangement which most times must agree with other considering for instance the space, arrangement, cargo handling or access and this include bulkheads [5, 7, 8].

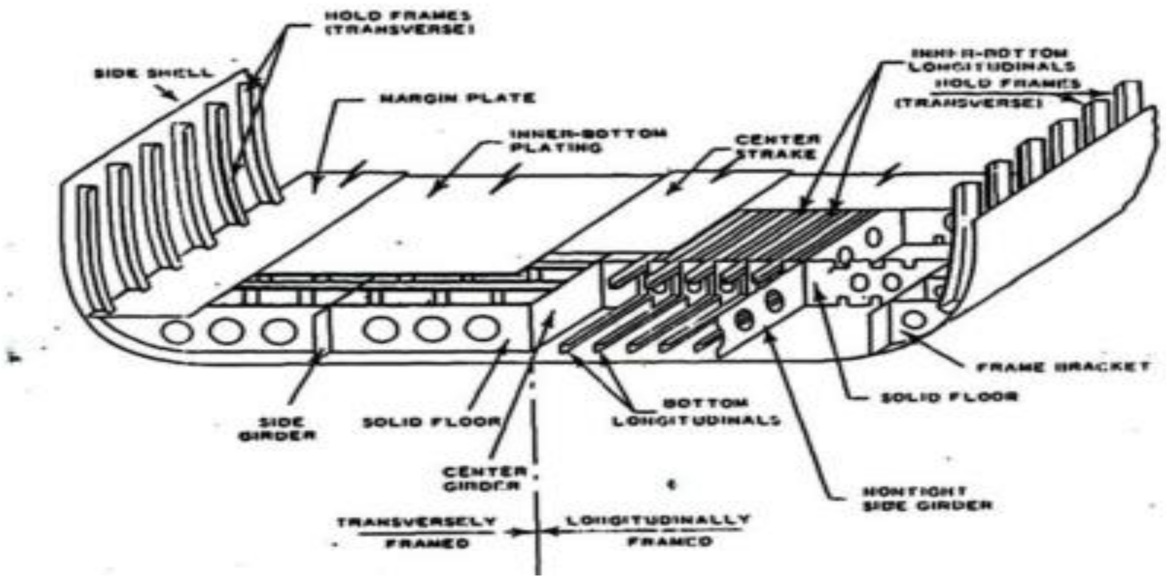

Figure 1. Diagrammatic View of the Vessel's Structural Elements [6,7].

2. Materials and Methods

Analytical method is used for the assessment of the ultimate strength of a 1000 tons self-propelled barge utilized for offshore services in Warri, Delta state, Nigeria. The developmental appraisal is on the basis of comparing two vessels that are the same together with the concept of stability ratio [9]. By utilizing geometrically similar ship, the design displacement was approximated from the known displaced (See Figure. 2).

Figure 2. Arrangement of the Barge

2.1. Modeling of the Barge Hull Components

Deck plating

Lloyd's rule and regulations for the classification of ships for deck plating of 1000tons of offshore work barge with thickness from 0.075l at the fore part is given[10, 11].

t= (6.5+02.0L) C$\sqrt{ks_{i/S_b}}$ (1)

Where: t= thickness of plate and L=length

Double Bottom Plate

The depth together with the center girder thickness of the double bottom is given by [11, 12].

d_{DB} =32B+190$\sqrt{d}$ (mm) (2)

t = (0.008d_{DB}+4)$\sqrt{K}$ (mm) (3)

Where:

d=molded draft

B=breadth of the vessel

Transverse frame thickness is expressed as:

t= (0.008d_{DB}+1)$\sqrt{K}$ (4)

Longitudinal frame thickness is expressed as:

t=(0.0075d_{DB}+1)$\sqrt{K}$ (5)

Precisely, for the double bottom plate of this capacity of work barge - Lloyds rule and regulation for the classification of ships with reference to the various chapters and sections is expressed as [10, 11]:

t=0.00136(S+660)$^4\sqrt{K^2}LT$ (6)

Side Plate

The side plate of the barge, according to Lloyd's rules and regulation for the classification of ships citing the various sections and chapters appropriately, the plate thickness is expressed as [10]:

t = (6.5+0.033L)$\sqrt{K}\ S/S_b$ (7)

Bulkheads

The bulkheads plate of this capacity of work barge, according to Lloyd's rule and regulation for the classification of ships citing the various sections and chapters appropriately, the bulkhead thickness is expressed as [10]:

t=0004Sf$\sqrt{k}h_4$ (8)

f=1.1-$\frac{h}{2500S}$ (9)

Stiffness

The calculation of the stiffness of the work barge is taken from the Lloyd's rules and regulations for the classification of ships:

Section Modulus

From basic strength of materials, the stress can be expressed as in [12]

$$\text{Stress} = \frac{\text{Force}}{\text{Unit Area}} \quad (10)$$

$$\therefore \text{Fator of Safety} = \frac{\text{Yield Stress}}{\text{Maximum Design Stress}} \quad (11)$$

Also, from Equations 10 and 11, the following can be derived:

$$\frac{\text{Force}}{\text{Unit Area}} = \frac{\text{Yield Stress}}{\text{Factor of Safty}} \quad (12)$$

$$\therefore \text{Unit area} = \text{Force} * \frac{\text{Factor of Safety}}{\text{Yield Stress}} \quad (13)$$

From Simple beam theory

M_B= $S_M\sigma$ (14)

Where,

M_B= Bending moment

S_M= Sectional Modulus

σ= Unit Stress

$\sigma = \frac{M}{M_M}$ (15)

$\sigma = M_B * \frac{C}{I}$ (16)

Where:

C = the distance from the neutral axis (a line parallel to the baseline from the Centroid of all the effective longitudinal strength members comprising the section).

I = the Sectional moment of inertia about the neutral axis.

$\text{Height of Neutral Axis } (h_{NA}) = \frac{\sum ah}{\sum a}$ (17)

This implies that the height above the keel is second moment of area at the half section above the base and is expressed as:

$\sum a\, h^2 + I_0$ (18)

$\sum \text{parallel axis term} = \sum a * h_{NA}^2$ (19)

Where:

I_{NA}= Second moment of area of half section about the base–parallel axis term

Z–Deck= I_{NA} FULL/SHIP HEIGHT * I_{NA} (20)

Z–Base= I_{NA} FULL/h_{NA} (21)

From Equation 11,

$\text{Maximum Design Stress} = \frac{\text{Yield Stress}}{\text{Fator of Safety}}$ (22)

Factor of safety is design criteria that an engineered component or structure must achieve and is expressed as [13]:

FS = UTSR (23)

Where:

FS = the factor of safety

R = the applied stress

UTS = Ultimate Stress (N/m^2)

Using the maximum bending moment included in the steel structure

Stress on Deck= M_B/Z_D (24)

Stress on base= M_B/Z_B (25)

Table 1: Principal Dimensions of 1000 tons self-propelled barge

PARTICULARS	VALUES (M)
Length Overall	48.00
Length Between Perpendicular	45.00
Breadth Molded	12.00
Breadth Extreme	12.30
Depth	3.50
Draught	2.50

Table 2: Section Modulus of 1000 tons self-propelled

S/N	Items	Scantlings	Area (m^2)	Height (m)	Moment $(ah)_{m3}$	2nd moment $(ah^2)m^4$	Local 2nd moment $(I_o)m^4$
1	Strength deck	4.5×1	4.5	3.5	15.75	55.125	-
2	Bottom plating	5.0×1	5.0	0	0	0	-
3	Side plating	3.5×1	3.5	1.75	6.125	10.115	-
4	Deck longitudinal	12.06	12.06	3.5	42.21	147.735	3.57293
5	Longitudinal bulkhead	3.5×8mm	0.28	1.75	0.49	0.8575	1.44257
6	Bottom longitudinal	12.06	12.06	0.05	0.603	0.03015	1.33257
Total			37.4	10.55	65.178	213.86	6.3481

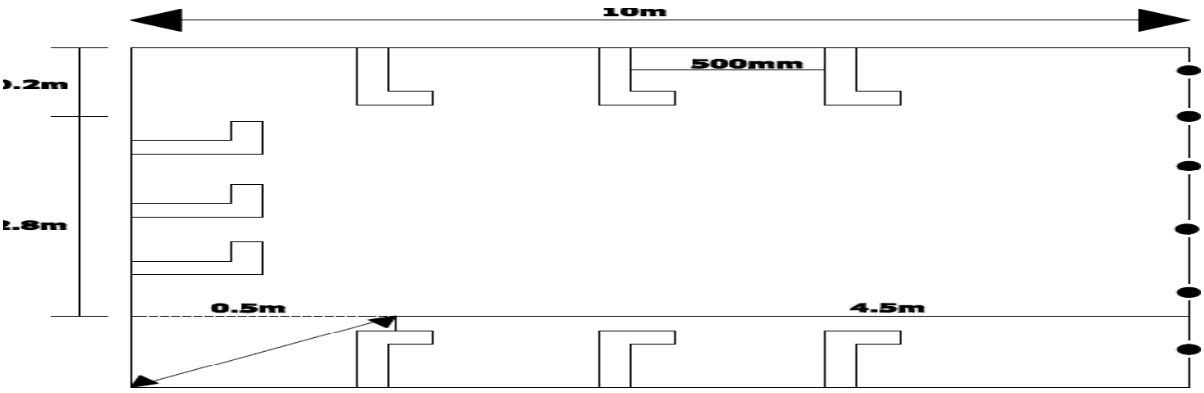

Figure 3. Offshore Services Barge Transverse Section Amidship

3. Results and Discussion

Table 1 contains all the principal dimensions of the offshore barge while **Table 2** is the calculations of the section modulus. The calculation of the various particulars of the barge is done utilizing equations 1 - 25 respectively. The characteristic features of Load distribution curve on the offshore barge when in operation; Weight distribution curve of the offshore barge components; Stiffener induced load distribution on the offshore barge components and Stress distribution are done utilizing excel software program and it is represented in Figures 4 to 7 respectively. Also, the maximum stress was calculated to be 83.33MN/m^2

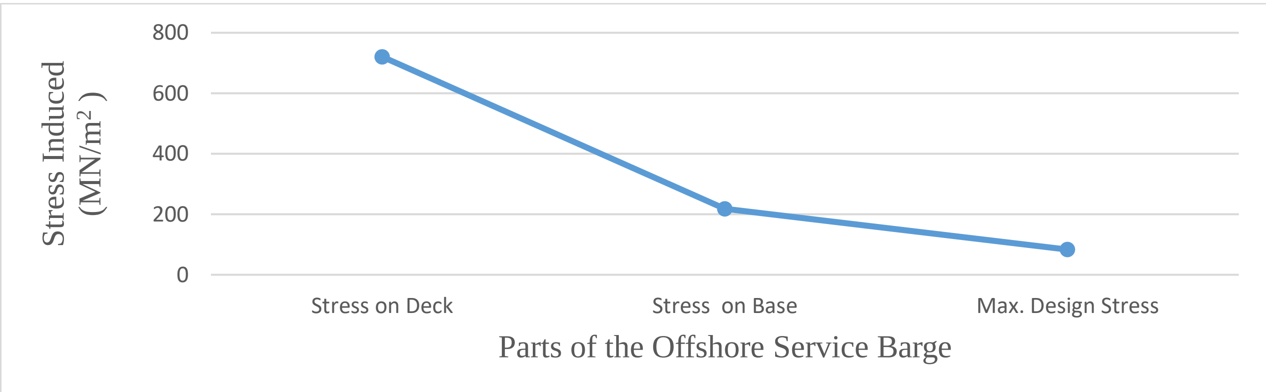

Figure 4: Stress Distribution Curve

Figure 4 is the stress distribution curve and it indicates that a decrease from the stress on deck to the stress on base down to the maximum design stress which is 83.33MN/m2. It also shows that that the deck experiences much stress during loading and operation. Precisely, there is high stress on the deck than the base because the deck carries the entire load.

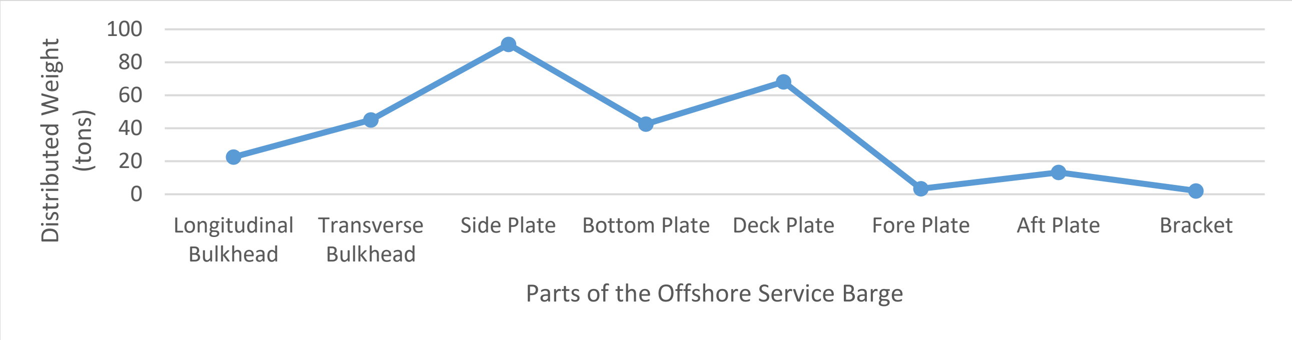

Figure 5: Weight Distribution Curve of the Offshore Service Barge Components

Figure 5 is the weight distribution curve of the offshore service barge components. It depicts that the weight increases from the longitudinal bulkhead to the side plate and decreases haphazardly down to the bracket thereby showing unevenly distribution of the weight in the offshore service barge. It also reveals that the distributed load is less at the bracket.

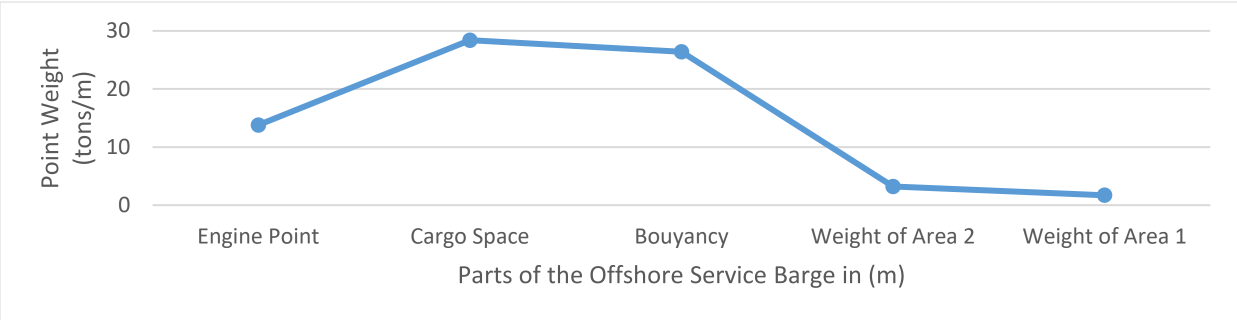

Figure 6: Load Distribution curve on the offshore Service Barge when is in Operation

Figure 6 is the load distribution curve on the offshore service barge when is in operation. This graph reveals that the load start to increase from the engine point and it reaches the highest peak at the cargo space thereby showing that the offshore service barge carries more loads at the cargo space. The representation also reveals that that weight in Area 2 is slightly lighter than the weight in Area.

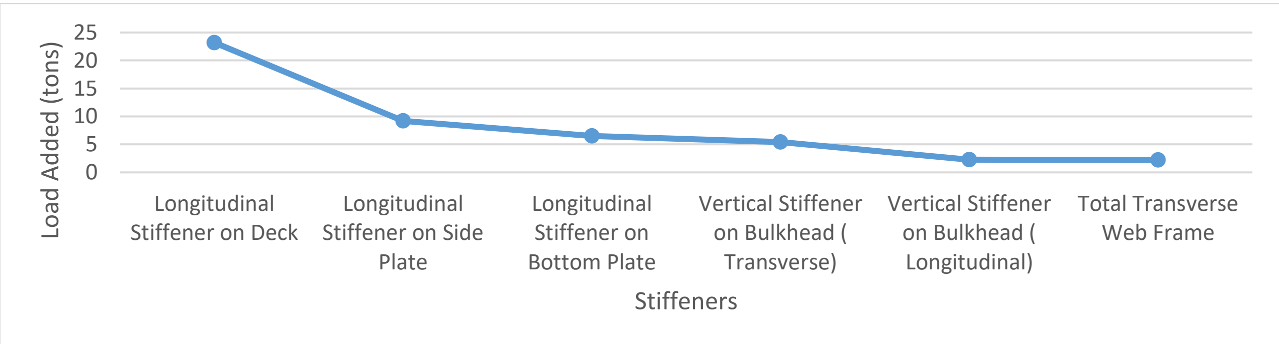

Figure 7: Stiffener Induced Load Distribution on the Offshore Service Barge Components

Figure 7 is the stiffener induced load distribution on the offshore service barge components. The graph indicates a decrease from the longitudinal stiffener on deck to the total transverse web frame components. It also depicts that the vertical stiffeners on bulkhead and total traverse is lighter than the longitudinal stiffeners on the deck and the bottom plate thereby showing that stiffener on the deck bears the highest stress and load.

4.0. Conclusion and Recommendation

The study of the strength appraisal of hull components of a barge under a load using numerical analysis has been done. The calculation of the ship hull strength is done by the use of the classification society rules and regulations giving guidelines and formulae to the estimation, selection and calculation of various components, machineries, and systems etc. of the offshore service barge. The results obtained from this work show that the maximum design stress is 83.33MN/m^2.

The strength of the model of the barge assessed the various forces to which the barge structure is subjected during its lifetime; the results of the analysis indicated that there is variation in the weight of the structure throughout the length of the barge. Although the total weight of the barge is balanced by the total force of buoyancy, neither is it uniformly distributed throughout the barge length. The result show that the weight of each ends section exceeds the buoyancy which they provide at these sections.

The load curve results indicated that there is difference between weight and buoyancy of each section throughout the length of the barge. In still water, the uneven loading which occurs throughout the length of a ship varies considerably with different conditions which may reach very high values.

While the weight decreases from the longitudinal bulkhead to the bracket indicating that there is an evenly distribution of weight in relation to its components. Also, the load distribution curve indicates that higher load is needed at the cargo space.

The following recommendations are hereby projected:

1. Finite Element Method should be used in determining the hull strength.
2. The ultimate strength should be calculated using the method of determining the partial safety.

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