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Tanker Conversion into FPSO vessel: Part 1 - Longitudinal Strength Assessment of the Candidate Tanker

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ABSTRACT

Longitudinal strength assessment is a regulatory requirement that precedes Tanker conversion to FPSO vessel in order to verify capacity and reveal the extent of renewal necessary for structural members of Tanker for the new service. This paper therefore presents Part 1, Longitudinal strength assessment of a Tanker "MV Energy concentration" for the actual conversion project that will be presented in Part 11. Use is made of elastic-plastic principles together with IACS (International Association of Classification Societies) Common Structural Rules and DnV design Codes for the prescribed analyses. Results reveal that the candidate Tanker requires structural modification in a few but critical structural elements for the new service. The section modulus for deck Longitudinals determined as 332543.296cm^3 fell short by about 94% relative to the Rule required minimum value requiring serious intervention as do the deck girders with a Section modulus of 559421.4579 cm^3 and capacity inadequacy of 99% relative to Rule required minimum. The deck plate thickness requirement also fell short by a minimum of about 30% requiring intervention. Conclusively, even with the confirmed buckling capacity adequacies of the longitudinal bulkheads and side-shells and section moduli at the deck and keel, some level of renewal is still necessary considering the effect of the severe site-specific environmental forces when being converted into FPSO and constrained to maintain position without dry-docking. Besides this, a very conservative analysis has been conducted as corrosion wastages were not considered and so, renewal is recommended as actual values will be lower than reported.

KEYWORDS: Capacity verification, hull girder, longitudinal strength, IACS Rule-based, Structural Strength.

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1. INTRODUCTION

FPSO systems have been identified to provide a relatively recent answer to meet the ever-increasing demand for oil/energy recovery especially, in the underdeveloped and undiscovered fields of the World (Allen, *et al.*, 2006). These systems are adaptable to ever increasing depths (Ultra-deep waters) where most of the undiscovered global offshore reserve (estimated at about 300bn bbl. representing 47% of the estimated undiscovered global oil) lie as existing reserves depletes (Juliussen & Diessen, 2008). As Deep and ultra-deep-water exploration becoming the main-stay of oil and gas producers and as almost half of the remaining reserves are found offshore, the demand for more modern offshore equipment is alarming.

While there is a perceived gap in modern technology to develop new hull forms suitable for the ultra-deep exploration because of the huge capital involved as complexity broadens, increased patronage is received by the field development with conventional ship-shaped hull forms. Converted tankers, among these have received and are still receiving more patronages because of their relative advantage (in terms of cost, project delivery time, etc.,) over new-build ship-shaped FPSO vessels.

Structurally, FPSO units have shapes very similar to tankers and most of them are converted from existing tankers. Both, have similar hull girder arrangements and so many of the results available for tankers directly applies to FPSO except for the new strength requirement due to additional top side loads and that due to more severe

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environmental loads (Sun & Soares, 2003). According to (DnV-OSS-102, 2009); preliminary to a Tanker to FPSO conversion project, suitability of the candidate Tanker for the new service must be evaluated. One of such requirements is the assessment of the strength of the candidate Tanker particularly because of corrosion wastages suffered during its use as a tanker in order to identify the extent of renewal required for its new service.

Structural strength assessment of a ship commonly consists of three strength components which are longitudinal strength, transverse strength and local strength. Among these, longitudinal strength, that is hull girder strength when exposed to bending or shearing loads, is the most fundamental and important strength to ensure the safety of a ship structure**.** This section of the ship assessed for longitudinal strength spans between 0.4 and 0.65 of the ship's length known as the midship's region which is most critical to ship's strength.

Many literatures exist in this category of research such as the works presented in (Rutherford & Caldwell, 1990), (Tetsuya, 2002), (Hu, Zhang, & Sun, 2001), (Paik, Kim, & Seo, 2007), (Moan & Amlashi, 2009), however, it was Young who first attempted to calculate the Shear force and bending moment distributions in a ship's hull caused by distributed weights of the hull girder and cargoes as well as distributed buoyancy force and force wave.

Advancing from Young's model according to (Tetsuya, 2002), other researchers leveraged on both analytical and numerical solution methods performing strength analyses on actual ships and on ship models.

In fact, the solution methods were categorized into simple and advanced methods of analyses with the advanced method more accurate as the following works revealed (Vu & Dong, 2021), (Tekgoa, Garbatov, & C. Guedes, 2020), (Paik & Thayamballi, 2003). One such advanced method being the Ultimate limit state method incorporating both elastic and plastic analyses (Paik & Thayamballi, 2003) which this work will adopt complementing Ship's Classification Society's design Standards.

This work therefore aims at performing a longitudinal strength analysis on the candidate Tanker, MV ENERGY CONCENTRATION in order to verify strength and reveal structural members of the Tanker requiring critical renewal for the FPSO service. However, since recent corrosion survey data of the Tanker were beyond reach, only as-built dimensions of hull girder structural elements will be used for analysis.

This being noted, the Objectives of the study are thus the following:

i. Section moduli determination of the mid-ships' hull girder at the deck and keel for primary support members at cargo tank area; deck transverse; deck longitudinal and deck girders.
ii. Assessment of the buckling strength capacities of Longitudinal bulkheads and side-shells;
iii. Deck plate thickness verification for capacity under imposed top side lateral load and
iv. Combined envelope values of the static and dynamic components of still water and wave induced bending moments along the ship will also be determined.
v. Decision for structural modification to be made, based on results from the above determined sectional properties, using minimum requirement from IACS CSR Rule as a guide.

2. MATERIALS AND METHODS

2.1. Materials

2.1.1. Tanker Principal Particulars.

Table 2.1 below shows principal particulars for the candidate Tanker needed for analysis.

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Table 2.1: Principal Particulars of "MV Energy Concentration"

PRINCIPAL PARTICULARS	DIMENSIONS (m)
Length Overall	326.75
Length between Perpendiculars	313.00
Breadth Moulded	48.19
Depth moulded	25.20
Draft summer extreme	19.597

(Rutherford & Caldwell, 1990)

2.1.2. Midship Sectional Properties of the Candidate Tanker

Figure 2.1 below shows midship section spanning between 0.4 and 0.65 of the ship's Rule length critical to longitudinal strength. In the same manner, Table 2.2 provides midships sectional dimensions and material grades of construction. Both shall be used to determine strength properties of structural elements at the midships' region.

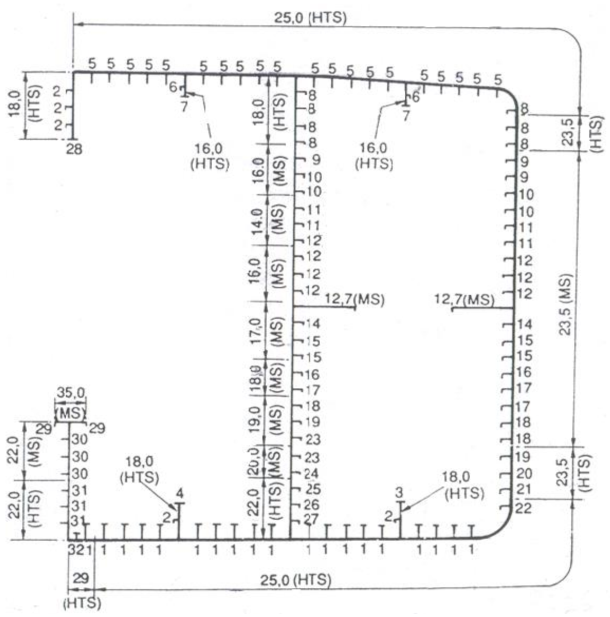

Fig. 2.1 Scantling arrangements at Midships of Energy Concentration (Rutherford & Caldwell, 1990)

Table 2.2: Midships Sectional Dimensions and Material grades of "MV Energy Concentration"

STIFFENERS	WEB	FLANGE	STEEL
1	797 X 15	200 X 33	HTS
2	297 X 11.5	100 X 16	HTS
3	370 X 16		HTS
4	425 X 25		HTS
5	480 X 32		HTS
6	297 X 11.5	100 X 16	HTS
7	370 X 16		HTS
8	447 X 11.5	125 X 22	HTS
9	549 X 11.5	125 X 22	MS
10	597 X 11.5	125 X 22	MS
11	597 X 11.5	125 X 25	MS
12	647 X 11.5	125 X 25	MS
13	350 X 25.4		MS
14	647 X 12.7	150 X 25	MS
15	697 X 12.7	150 X 25	MS
16	747 X 12.7	150 X 25	MS
17	747 X 12.7	180 X 25	MS
18	797 X 14	180 X 25	MS
19	847 X 14	180 X 25	MS
20	847 X 14	180 X 32	MS
21	847 X 15	180 X 25	HTS
22	847 X 15	180 X 32	HTS
23	897 X 15	200 X 25	MS
24	945 X 16	200 X 25	MS
25	897 X 15	200 X 25	HTS
26	797 X 15	180 X 25	HTS
27	347 X 11.5	125 X 22	HTS
28	397 X 25		HTS
29	300 X 35		MS
30	230 X 12.7		MS
31	230 X 12.7		HTS
32	397 X 11.5	100 X 25	HTS

(Rutherford & Caldwell, 1990)

2.2. Method of Analysis

Hull girder strength assessment requirements as provided by IACS (IACS, Common Structural Rule for double hull oil Tankers, 2012), (DnV, 2009) and (IACS, Common Structural Rule for double hull oil Tankers, 2008) will be used to verify strength of structural members of the Candidate Tanker. This will be complemented by Elastic-plastic analysis to validate structural properties of the hull girder structural elements as a basis for acceptance or rejection using

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Classification Rule's required minimum value as the standard.

2.2.1. Section Modulus Determination for structural elements.

2.2.1.1. Analytical Section Modulus Determination

All analytical section moduli at the deck, keel of the midships region; deck longitudinals and deck girders shall be analysed according to (Hughes, 1988) by the following expressions:

$$\frac{M}{I} = \frac{E}{R} = \frac{\sigma}{y} \qquad (1)$$

And;

$$\sum(a\bar{Y}^2 + I_{OWN}) = I_{NA} + A\bar{x}^2 \qquad (2)$$

Where;
M = bending moment in N.m
I = Moment of Inertia in m^4
E = Elastic Modulus of rigidity in KN/mm^2
R = Radius of curvature in m
σ = Bending stress in KN/mm^2
Y = Distance from Neutral axis to the outermost external fibre of material in m
$a\ \bar{y}^2$ = second moment of area of individual structural element within the hull girder relative to a chosen datum in m^4
A = Total area of all structural members composed within the hull girder in m^2
$\bar{x}^2$ = Square of the Neutral axis or centroid of the hull girder section from the chosen datum in m^2
I_{NA} = moment of inertia of an axis through the centroid in m^4

2.2.1.2. Rule-based Section Modulus at the Midships:

Minimum required section modulus at the deck and keel according to IACS CSR, section 8/1.2.2.2 shall be:

$$Z_{v-min} = 0.9\,K * C_{wv} * L^2\,B(C_b + 0.7) \text{x } 10^{-6}\ \text{m}^3 \qquad (3)$$

Where; K is higher strength steel factor,

C_{wv} = wave coefficient ; L= ship's rule length in m; B = ship's moulded breadth in m and $C_b = block\ coefficient.$

2.2.1.3. Rule-based Section Modulus at the Deck longitudinals

For stiffeners subjected to lateral pressure, net section modulus for all applicable load sets should be:

$$Z_{net} = \frac{|p|s l_{bdg}^{\ 2}}{f_{bdg}\,C_s\,\sigma_{yd}} \quad \text{cm}^3 \qquad (4)$$

Where, P = design pressure for the design load set in KN/m^2; s = stiffener spacing in mm; l_{bdg}= effective bending span in m; f_{bdg} = bending moment factor; C_s = permissible bending stress coefficient and σ_{yd} = SMYS of the material N/mm^2

2.2.1.4. Rule-based Section Modulus at Deck Girders

For each deck girder, the goss section modulus should not be less than the value given by following expression:

$$Z_{t-grs} = 4.74\,b_{dk}\,l_{bdg}^{\ 2}\ h_{tier}\,k \quad \text{cm}^3 \qquad (5)$$

Where; b_{dk} = mean breadth of the deck area supported in m; l_{bdg}= effective bending span in m; h_{tier} = load head in relation to the deck house tier; k = higher strength steel factor

2.2.2. Buckling Analysis of longitudinal Bulkheads and Side-shells

2.2.2.1. Analytical Buckling Analysis

Analytical buckling analysis on the longitudinal bulkheads and side-shells will be performed according to the following equation for wide plates under the action of the compressive lateral pressure on the deck as postulated by Faulkner, (Faulkner, 1975).

$$\min \sigma_{cr} = \frac{\pi^2 E}{12(1-v^2)}\left(\frac{t}{b}\right)^2 = \frac{0.904}{\beta^2}\sigma_{yield} \; for \; v = 0.3 \quad (6)$$

Where; Slenderness ratio = $\beta = \frac{b}{t}\sqrt{\frac{\sigma_{yield}}{E}}$

b = breadth of plate in meters
t = thickness of plate in meters

2.2.2.2. Rule-based Buckling Analysis

This analysis shall be performed according to IACS CSR sections 8/1.4.2 and 10/3.1.
Here, hull girder compressive stress due to bending to be used for buckling assessment using net hull girder sectional properties was chosen as $30/K(N/mm^2) = \sigma_{hg-compressive}$ (7)
Where; K is higher strength steel factor.

Minimum critical compressive stress then becomes:

$$\sigma_{min-cr} = \frac{\sigma_{hg-compressive}}{\Upsilon} \quad (8)$$

Where;

$$\Upsilon = buckling \; utilization \; factor$$

2.2.3. Plate Analysis for Yield and Ultimate Strength

2.2.3.1. Analytical Plate Analysis

Plate equations for long clamped plates under uniform lateral pressure, P, resulting from top-side load as postulated by Timoshenko and Shi for first yield and ultimate strength criteria as presented below will be used to determine the plate thickness for capacity (Timoshenko & Woinowsky-Krieger, 1987), (Shi, Zhu, & Yu, 2018).

$$t = b\sqrt{\frac{p}{2\sigma_{yield}}}, \text{ for first yield condition} \quad (9)$$

and

$$t = b\sqrt{\frac{p}{4\sigma_{yield}}}, \text{ for ultimate strength condition} \quad (10)$$

2.2.3.2. Rule-based Plate Analysis

Rule minimum deck plate thickness against uniform lateral pressure ((DnV, 2009)) is given as:

$$t = \frac{1.58\, K_a\, s\sqrt{p}}{\sqrt{\sigma}} + t_k, \quad mm \quad (11)$$

Where;

S = stiffener spacing in m; K_a = correction factor for aspect ratio of plate field; P = Lateral pressure in KN/m^2; σ = allowable stress within 0.4L = $120f_1$ and f_1 is material factor; t_k = corrosion addition in mm.

2.2.4. Combined Dynamic and Static Load effect on Hull girder strength (IACS CSR, 2012; section 7)

2.2.4.1. Hull Girder Dynamic Load Components

Envelope values of the vertical wave-induced bending moments in hogging and sagging conditions shall be determined by the following respective expressions:

$$M_{wv-hog} = f_{prob} * 0.19 * f_{wv-v} * C_{wv} * L^2 B\, C_b \quad (12)$$

And;

$$M_{wv-hog} = f_{prob} * 0.19 * f_{wv-v} * C_{wv} * L^2 B\, C_b \quad (13)$$

All measured in KN.m where;

f_{wv-v} = distribution factor for vertical wave bending moment along the length of ship, 0 at Forward and after perpendiculars and 1 for 0.4L to 0.65L from After perpendicular; 4 f_{prob} = 1; C_{wv} = wave coefficient whose value depends on ship's rule length, L, B = Moulded breadth in m and C_b = block coefficient.

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2.2.4.2. Hull Girder Static Load Component

Minimum hull girder hogging and sagging still water bending moment for sea-going operations at midships are respectively determined by the following expressions:

$$M_{sw-min-sea-mid} = 0.01 * C_{wv} * L^2 B\,(11.97 - 1.9C_b) \quad (14)$$

And

$$M_{sw-min-sea-mid} = -0.05185 * C_{wv} * L^2 B\,(C_b + 0.7) \quad (15)$$

All measured in KN.m

2.2.4.3. Permissible Hull Girder Bending Stress for the Static and Dynamic Design Load Combination.

This is expressed as the following according to (IACS, CSR 2012 section 8):

$$\sigma_{hg-per} = 190/K \text{ within 0.4L amidships} \quad (16)$$

Where, K =higher strength steel factor

It is worth noting that IACS, CSR requires minimum vertical section modulus at the deck and keel to be greater than the section modulus arising from the combined effect of both static and dynamic load components and so expressions of section 2.2.4 will be used as the basis for comparison for structural stability.

3. RESULTS AND DISCUSSION

3.1. Section Modulus Results for Vessel Midship Cross Section

Rule-required mid-ships net hull girder section modulus at the deck and keel was determined as 55.22334m^3 (IACS, Common Structural Rule for double hull oil Tankers, 2012), (IACS, Common Structural Rule for double hull oil Tankers, 2008) whereas analytical calculation gave 71.34378067m^3 and 66.69391683m^3 respectively at the keel and deck. This result suggests adequate strength for Rule's envisaged stress as available strength is more than Rule's prescribed minimum. See Table 3.1 below showing a truncated table of analysis for about One Hundred and Ten (110) structural elements of the midship's region:

Table 3.1: Extract from Midship Section Modulus Calculation

TABLE: MIDSHIP'S SECTION MODULUS CALCULATION								LOCAL
ITEMS	LENGTH (m)	THICKNESS (m)	QTY.	AREA (m^2)	HEIGHT (m)	MOMENT (m^3)	SECOND MOMENT (m^4)	SECOND MOMENT (m^4)
S.D PLATING	23	0.025	1	0.58	26	14.95	388.7	
S.D PLATING LONG. (WEB)(CCT)	0.48	0.032	13	0.2	25.76	5.143757	132.5032	
S.D PLATING Long. (WEB)(WT)	0.48	0.032	7	0.11	24.96	2.683699	66.98513	
STRENGTH DECK GIRDER (CCT)	1.3	0.016	1	0.02	25.35	0.52728	13.36655	0.002929333
STRENGTH DECK GIRDER (WT)	1.3	0.016	1	0.02	25.05	0.52104	13.05205	0.002929333
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
B.P. LONG. STIFF. 1 (WT) (W797X11.5; F200X33)	0.012	0.0066	7	0.13	0.2965	0.038511	0.011418	
BILGE CURVE (DECK) R=0.8; t= 0.0235	0.8235	0.8	1	0.03	24.4	0.731234	17.8421	0.001818645
BILGE CURVE (BOTTOM) R=0.8; t= 0.0235	0.8235	0.8	1	0.03	0.2908	0.008714	0.002534	0.001818645
SUM				4.01		48.76644	1018.391	9.693478408

HEIGHT OF NEUTRAL AXIS, h_{NA} 12.17556316 M
1/2 MOMENT OF INERTIA ABOUT ZZ AXIS 1028.084245m^4
PARALLEL AXIS TERM = 593.7588917
1/2 MOMENT OF INERTIA 434.3253537m^4
AREA (m^2) 8.01054393
MOMENT OF INERTIA, I (m^4) 868.6507075
SECTION MODULUS AT THE DECK, Z_{de} (m^3) 66.69391683
SECTION MODULUS AT THE KEEL, Z_k (m^3) 71.34378067

3.2. Section Modulus for Deck Longitudinals

Section modulus for all Twenty (20) longitudinal stiffeners within the strength deck at cargo tank no.4 was determined as 332543.296cm^3 while Rule's net section modulus required for deck longitudinal stiffeners under lateral pressure (IACS, Common Structural Rule for double hull oil Tankers, 2008), (IACS, Common Structural Rule for double hull oil Tankers, 2012) Section 8/3.9.2.2, gave 5523792cm^3. This shows that the strength of the deck longitudinal cannot sustain the effect of the lateral load as a result of the conversion. Hence, structural strengthening is

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instructive. See table 3.2 below for detailed analysis:

Table 3.2: Section Modulus result for Deck Longitudinals

MEMBERS:	DECK LONGITUDINAL STIFFENERS (FLAT BARS) SECTION PROPERTIES						
ITEM	LENGTH (mm)	THICKNESS (mm)	AREA (mm^2)	Y (m)	A*Y (mm^2-m)	($A*Y^2$) (mm^2-m^2)	I(own) (mm^2-m^2)
WEB	480	32	15360	0.24	3686.4	884.736	294.912
ATTACHED PLATE	1000	25	25000	0.493	12312.5	6063.90625	1.302083333
TOTAL			40360	0.396	15998.9	6948.64225	296.2140833
	I(N.A) + AY^2 = SUM(AY^2 + I(own), FROM PARALLEL AXIS THEOREM						
	I(N.A) =	902.814678					
	FULL MOMENT OF INERTIA =		1805.629				
	MAXIMUM, y, AT THE PLATE =		0.108595				
	HENCE SECTION MODULUS, Z, mm^2-m =		16627.16				
	TOTAL SECTION MODULUS FOR ALL DECK LONGITUDINAL					332543.297	Cm^3

3.3. Section Modulus for Deck Girders

The section modulus for all the strength deck girders was found to be 559421.4579cm^3 while minimum Rule requirement (IACS, Common Structural Rule for double hull oil Tankers, 2012) Section 11/1.4.7.2, gave 47901515cm^3. Obviously, the capacity is not enough and needs structural strengthening. See table 3.3 below for detailed analysis:

Table 3.3: Section Modulus Result for Two deck girders and attached stiffeners

MEMBERS	LENGTH (mm)	THICKNESS (mm)	AREA (mm^2)	CENTROID, Y (m)	(AY) mm^2-m	(AY^2) (mm^2-m^2)	I(own) (mm^2-m^2)
FLANGE(A)	370	16	5920	0.008	47.36	0.37888	0.126293333
WEB(A)	1284	16	20544	0.658	13517.95	8894.812	2822.499072
FLANGE(B)	100	16	1600	0.608	972.8	591.4624	1.333333333
WEB(B)	297	11.5	3415.5	0.65225	2227.76	1453.056	0.037641656
ATTACHED PLATE	6000	25	150000	1.3125	196875	258398.4	7.8125
TOTAL			181479.5	1.177217658	213640.9	269338.1	2831.80884
			TOTAL AREA		362959		
	I(N.A) + AY^2 = SUM(AY^2 + I(own), FROM PARALLEL AXIS THEOREM						
	I(N.A) =	20668.14968			41336.3		
	MAXIMUM, y, AT THE PLATE =		0.147782342				
	HENCE SECTION MODULUS, Z (mm^2-m) =		279710.679				
	TOTAL SECTION MODULUS FOR TWO DECK GIRDERS =			559421.3579	Cm^3		

3.4. Buckling Assessment for the Side-Shell and Longitudinal Bulkhead Plating.

Table3.4: Results from Buckling analysisi

MEMBERS	ALLOWABLE RULE CRITICAL COMPRESSIVE STRESS (N/mm^2)	ANALYTICAL CRITICAL COMPRESSIVE STRESS (N/mm^2)
LONGITUDINAL BULKHEAD	40.48582996	80.23035932
SIDE SHELL	40.48582996	41.75946622

Table 3.4 above compares analytically and IACS CSR rule-based determined buckling capacity for longitudinal bulkhead and the side-shell. Since analytically determined critical compressive stresses (third column in Table 3.4) are higher than Rule critical compressive stresses (second column in Table 3.3) for the structural members considered, then it is safe to conclude that the buckling capacity will assure stability of plates as the structure possesses more buckling strength against compressive loads.

3.5. Plate Strength Analysis

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Analytical determination of plate thickness for the intended deck lateral pressure of 29.4KN/m^2, assuming clamped boundary edges for the plate and considering two design criteria such as first yield for elastic analysis and ultimate strength for plastic analysis, produced plate thicknesses of 6.83m and 4.83m respectively. These values fell below Rule's specified minimum of 9mm using equation (11) (DnV, 2009) and so capacity is inadequate. See Table 3.5 below.

Table 3.5: Plate analysis

Breadth (mm)	SMYS N/mm^2	YOUNG's Modulus KN/mm^2	Uniform Lateral pressure KN/mm^2	Design thickness against pressure (mm)	Design Criteria
1000	315	208	29.36241	6.8269 4.8274	First Yield Ultimate strength

3.6. Combined Static and Dynamic Load Effects

Rule requires the minimum hull girder section modulus to be greater than that due to the combined effect of both static and dynamic load components incorporating nominal permissible bending stress for structural stability. Hence, largest value of the total bending moment in the sagging condition incorporating both static and wave induced components (highlighted in red colour on third column of table 3.6 below) used to determine the hull girder section modulus for 0.4L amidships together with Rule's nominal permissible bending stress produced 26.6187 m^3 as against 55. 22334m^3, the Rules required minimum hull girder section modulus, satisfying the condition for structural stability.

Table 3.6: Combined Static and Dynamic Load components

Position from A.P	Total Hogging bending Moment (Still water & wave) (KNm)	Total Sagging Bending Moment (Still water & wave) (KNm)
0	0	0
31.3	73060.12	-62614.3
62.6	374222.1	-336288
93.9	1026459	-951385
125.2	2152742	-2037552
156.5	3363659	-3183674
187.8	4843670	-4584491
219.1	6039396	-5655786
250.4	6806798	-6245493
266.05	7269420	-6484042
281.7	7155658	-6084690
313	0	0

2.1

3.7. Decision for Structural Re-enforcement

The use of as-built sectional properties of structural elements for analysis has clearly shown that the candidate Tanker has capacity to be used as a "Trading Tanker". It can also fit FPSO service since the hull girder composition of a Tanker and Tanker-converted FPSO are alike, (Sun & Soares, 2003).

However, as alluded to by Sun and Soares in their paper, (Sun & Soares, 2003), there is still need for structural modification due to the difference in operating conditions and environment and the additional top-side load resulting from the installation of production modules on the deck of the Tanker. This additional strength requirement, due to top-side load in form of uniform lateral pressure, the analyses have revealed are at locations around the deck and deck's primary support members (whose capacities fell short of minimum required strength) and so, structural re-enforcement is necessary around the deck area. The form it will take however will be analyzed in Part 11 of this research.

4. CONCLUSION

A longitudinal strength assessment that precedes a Tanker to FPSO vessel conversion project has been performed to verify capacity and to reveal the extent of renewal necessary for structural members of the Tanker for the new FPSO service. Elastic-plastic method of analysis complemented Classification Societies' Rule-based analysis to verify strength and revealed structural members of the Tanker requiring renewal for the new service.

Critical structural elements requiring attention for renewal as revealed by the analyses are the deck plate, deck girder and the deck longitudinals. These members function to absorb deck loads and transfer same to other adjoining structural members, whether they are dynamic or static in nature and they fell short of required capacities according to the respective percentages, 30%, 99% and 94%. Indeed, these results are expected because of the additional top-side lateral pressure imposed by the production modules upon conversion.

It must be noted however that even when the structural members requiring serious attention during the actual conversion project have been revealed, this being the main thrust of the current research, the analyses results are conservative as corrosion wastages were not considered and so, it is proper to conclude that the extent of renewal is under-quoted.

Considering also the effect of the severe site-specific environmental forces the Tanker would face upon conversion and when constrained to maintain position for as much as the design life without dry-docking, it is also necessary to recommend that more structural redundancy be built into these structural elements during the conversion project on a global scale to assure adequate strength.

Finally, it can be concluded that, results from this analysis, though under-quoted, has provided the needed direction as to which structural members require the most attention and so, will serve as a veritable input into Part 11 of this research that will perform the actual conversion analysis.

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