International Research Journal of Advanced Engineering and Science
ISSN (Online): 2455-9024

Selection of FPSO Spread Mooring Systems in (Deep Water) Offshore Nigeria

Ubani, Chikwendu[1]; Ikpaisong, Ubong[1]
[1]Department of Petroleum and Gas Engineering, University of Port Harcourt, Port Harcourt, Rivers state, Nigeria

Abstract— *Selecting FPSO spread mooring composition for use in deep water environments entails evaluating the fatigue performance of the composition together with other very important factors. In this work, 4x3 spread mooring composition and 4x2 spread mooring composition were compared for suitability in deep water offshore Nigeria on basis of fatigue performance and the following objective criteria; Cost, Restoring characteristics, Tandem offloading, Environmental applicability, Loads on the mooring line, Length of line, Redundancy and Maintenance ease.*

The hydrodynamic analysis was performed using Orcaflex software with appropriate metocean data typical to conditions offshore Nigeria for JONSWAP spectrum. Fatigue results derived from Orcaflex (hang-off and TDP) for the two compositions with similar material configurations of chain-wire-rope-chain indicated high values of (867 years: hang-off, 3232years: at the touch down point) for the 4x3 composition and less values of (349 years: hang-off, 975 years: TDP) for the 4x2 composition. The outcome of the analysis shows that fatigue results at TDP (1626 m) and hang-off (0.00 m) satisfy the minimum acceptable fatigue requirement of 200 years.

I. Introduction

A Floating Production Storage and Offloading (FPSO) unit is a ship – shaped structure normal situated within an offshore oil and gas production field to process the production fluid received from the production wells. FPSOs are relatively not affected by the operating water depth, therefore are widely used in deep and very deep waters for crude oil production, storage and offloading. FPSOs are stationed within the production field footprint with the help of mooring systems that comprise of an arrangement of materials (chains and wire rope or polyester) and a seabed anchor. Srinivasan (2015).

Mooring systems take various configurations; one of such is the catenary configuration. These catenary mooring systems are vulnerable to large cyclic bending stresses near the vessel fairlead hang off and touch down region where the line makes contact with the seabed, Brown et al., (2010). These stresses are normally induced by a combination of hydrodynamic loads and vessel responses such as heave and surge creating undue tension on the mooring system. Continuous exposure to these stresses over a long duration of time results in fatigue induced failure on the mooring lines. To ameliorate fatigue effects, different mooring line materials like polyester are also becoming more commonly used as a result of their highly improved fatigue characteristics and dynamic response

The indicators appraising the performance of a mooring considering the various stages of life cycle of the mooring system are; cost of component, Manufacturing and logistics, installation, Restoring characteristic, maintenance performance, and operation and ease of decommissioning, Mohammad (2015). (Larsen, 2014) reported that the capability of the various mooring line compositions is a basic criterion for choosing a specific type for a specific offshore region. The reliability of the mooring line and their selection criteria will be based on operation water depth, breaking strength at minimum pre tensioned value, system cost, fatigue resistance, mooring material, corrosion. According to Fontaine et al, (2012), damage due to fatigue on mooring line can be performed adopting the unique approach like, application of S-N, rain flow counting of time domain tension history and Palm green-miner fatigue damage rule. It is worthy of note that the Spread mooring systems are designed for shallow and deep water anchorage, in slight to moderately harsh environments. The efficacy of the spread moored system is subject to the prevailing weather and it is considered suitable for regions with a fairly restricted range of weather direction. They are not so effective, however, in harsh or multi-directional environments where changing wind, waves currents may impose severe loads on the anchoring system and create excessive motions on the unit. API RP 2SK (2005).

This work is intended to minimize fatigue induced failures of catenary mooring lines during operations Offshore Nigeria by using a performance based selection process which involves evaluating the dynamic response and fatigue damage life of mooring lines with different compositions in a typical field in offshore Nigeria (Gulf of Guinea).

It also provides recommendation for selection of an efficient spread mooring composition suitable for Offshore Nigeria through weighted objective model.

II. Methodology

Description of Reference FPSO

An FPSO installed offshore Nigeria in a field of about 1000 meter water depth was considered as the data source for this study.

TABLE 1. Main FPSO specifications

PARAMETERS		VALUES
Length (m)		300
Breadth (m)		61
Depth (m)		32
LOADING CONDITIONS	**BALLAST**	**FULL**
Draft (m)	11.69	23.04
Displacement (metric ton)	205573	417645
COG from the stern (m)	162.35	158.34
COG from the keel (m)	22.85	18.47
Roll gyration radius (m)	25.55	22.04
Pitch gyration radius (m)	85.67	80.69
Yaw gyration radius (m)	85.9	81.24

International Research Journal of Advanced Engineering and Science
ISSN (Online): 2455-9024

The seabed characteristics is taken to be even slope, the heading of the FPSO is zero degrees (0) in east direction from true north and FPSO is kept in position by spread mooring system. The major parameters of the FPSO with two types of loading conditions for a coupled fatigue analysis is presented in Table 1 below. This study was limited to the ballast loading condition for redundancy reasons.

Reference FPSO Mooring System

The mooring system comprises of 12 mooring lines (ML's) located at the stern and bow of the FPSO. The ML's are arranged with 1600m design radius and are made up of three sections which are top chain, wire rope and bottom chain. The range of ML's is from the FPSO fairlead point to the Theoretical Anchor Point (TAP). The top chain is connected to the fairleads of the FPSO aided by chain stoppers and bottom chain is connected to the suction anchor pile of the sea-bed. The parts of bottom chains buried, linking the suction anchor point are not part of the design consideration. The ML's parameters and the model plan view are shown in Table 2

TABLE 2. Mooring line parameters

COMPONENTS	CHARACTERISTICS	UNIT	VALUES
Top chain	i. Material property	mm	R3 stud less
	ii. Diameter	m	147
	iii. Line length	KN	100
	iv. Breaking strength	MN Kg/m	15536
	v. Axial stiffness		1319.26
	vi. Weight in water		380.0
Wire rope	i. Material property	mm	Spiral strand wire rope
	ii. Diameter	m	111
	iii. Line length	KN	1500
	iv. Breaking strength	MN Kg/m	12500
	v. Axial stiffness		1200.48
	vi. Weight in water		50.68
Bottom chain	i. Material property	mm	R 3 stud less
	ii. Diameter	m	132
	iii. Line length	KN	800
	iv. Breaking strength	MN Kg/m	14508
	v. Axial stiffness		1189.06
	vi. Weight in water		306.0

Environmental Loads

The structural responses of the ML with respect to environmental element were evaluated under sea state conditions by the ORCAFLEX software as load case as shown in (appendix A). It matches with the wave and wind conditions having time range of 100 year and 10 years return for current conditions. The sea state climatic variations such as wave, current and wind were derived from data collected within Offshore West Africa. The long-term sea state is made up of several short-term sea states, the sea states were taken from the different scattered diagrams with JONSWAP wave spectrum and API wind spectrum used for each sea state.

Wave Spectra

Repeated loadings on ML's due to waves represent a vital role in the integrity and reliability of the offshore design process and so is a vital parameter in the design of such structures.Waves are sinusoidal by nature with some key parameters which include; wave height h, period T and wave length λ. Waves could be regular or irregular by nature at a specific water depth d, regular waves are typically sinusoidal with small amplitudes and are described by their significant height, hs and period, T (DNV, 2010).

Irregular wave spectrum such the the Joint North Sea Wave Project (JONSWAP) was adopted in this research for dynamic simulations and analysis of fatigue because it replicate real time conditions of typical sea states of offshore Nigeria.

The JONSWAP spectrum is a modification of Pierson Moskowitz, and is expressed in equation 1 below.

$$S_\eta = \frac{\alpha g^2}{\omega^5}\exp[\frac{-5}{4}\left(\frac{\omega_p}{\omega}\right)^4]\gamma^9 \qquad (1)$$

Meteorological and Oceanographic Data (Metocean Data)

The metocean data used as input parameters in this study are those related to the reference field in offshore Nigeria. The metocean data represent the sea state, the dynamic analysis was performed to evaluate the fatigue life of the ML's.

A typical offshore Nigeria environmental data used is shown in Table 3 below.

TABLE 3. Metocean Data for 100 years Return Period, Source: Chanhoe et al, 2016

METOCEAN PARAMETERS	VALUES
Significant wave height, Hs (m)	1.8
Most probable maximum wave height (m)	2.3
Peak spectral period (s)	15
Mean wave direction	45°
Wind speed (m/s)	1.27
Wind direction	180°
Water depth (m)	1000

Governing Equations

The equations applied on the Orcaflex algorithm consists of; Newton's second law of motion, Catenary equation and Morrison's equation.

Orcaflex software program by Orcina limited was carefully selected for this study because of its ability to perform time domain analysis. Many research confirmation exercises have been performed to compare results obtained using Orcaflex and that of other programs with marginal variations in terms of the results. It also has an accessible interface which permits easy data management and modeling.

Case Modelling

Orcaflex software is used to model the FPSO, its mooring lines configurations and that of the check object to perform a coupled dynamic, static and fatigue failure analysis. Orcaflex software program by Orcina limited was carefully selected for this study because of its ability to perform time domain analysis. It has an accessible interface which permits easy data management and modelling.

International Research Journal of Advanced Engineering and Science
ISSN (Online): 2455-9024

The fatigue life of the 4x3 mooring lines is modelled and results compared to the results of the 4x2 composition's fatigue life.

TABLE 4. Mooring line parameters

PARAMETERS		4x3 SPREAD	4x2 SPREAD
Line length (m)	Top chain	100	100
	Wire rope	1500	1500
	Bottom chain	800	800
	Top chain	380	475
Weight in water (kg/m)	Wire rope	50.68	70.68
	Bottom chain	306	401
	Top chain	147	167
Diameter (mm)	Wire rope	111	128
	Bottom chain	132	152
	Top chain	15536	17350
MBL (KN)	Wire Rope	12500	14280
	Bottom Chain	14508	16320
Total length (m)		2400	2400
Pretension (KN)		3746	4613
Buried length		0	0
Suspended length		1626	1626
Horizontal distance		1600	1600

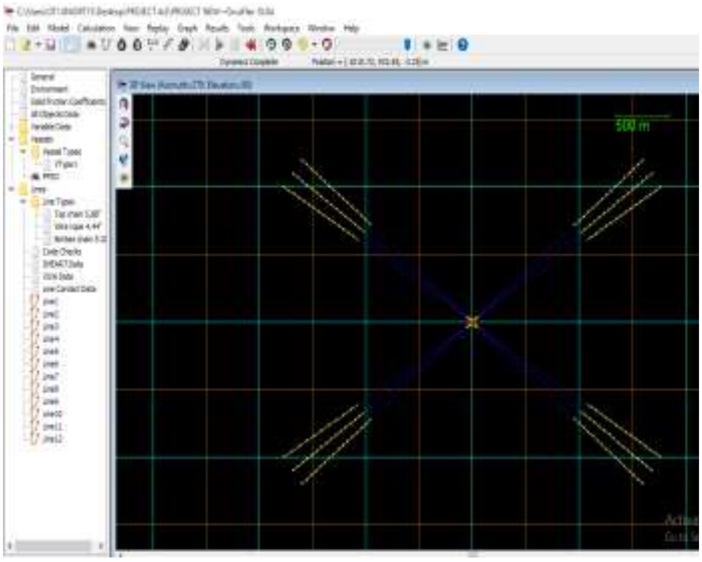


Figure 1: FPSO/mooring line model (plan)

Static Analysis

Static analysis was performed for the two FPSO spread mooring compositions; (4x3) and (4x2) with the aid of Orcaflex software upon completion of their modelling using data from tables 1, 2 and 3 to determine the equilibrium positions of the models. The static analysis was performed on the model for 400 iterations, and static convergence was achieved signifying correct input data and model formation. it was done with negligible effect of environmental forces, drag, added mass and buoyancy with mooring lines modelled with a laid tensions of 3746KN and 4613KN for each composition.

Dynamic Analysis

Dynamic analysis also called Dynamic simulation was carried out on the two systems as a continuation of the analysis process at the end of the static analysis for a simulation time of (72.000s). The environmental data from wave scatter tables measured in offshore West Africa as shown in appendix A were used as input elements for this simulation, and it was performed for the JONSWAP wave spectrum.

Fatigue Analysis

Fatigue analysis was performed on both the (4x3) and (4x2) compositions using Orcaflex software (dynamic analysis software developed by Orcina limited) with the same chain-wire rope-chain configuration. The spread mooring system model was analyzed fatigue using the Rain Flow Cycle Counting Method. The load cases developed with JONSWAP wave spectrum was loaded as simulation files for this analysis. An exposure time of 20 years (175,200 hours) which is the expected design life, a total simulation time of 72.000s is used for the fatigue analyses.

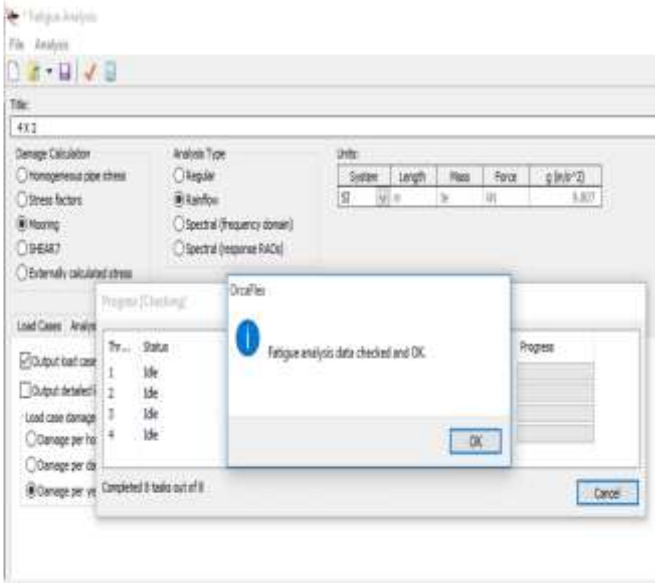


Figure 2: Fatigue data check

Weighted Objective Model

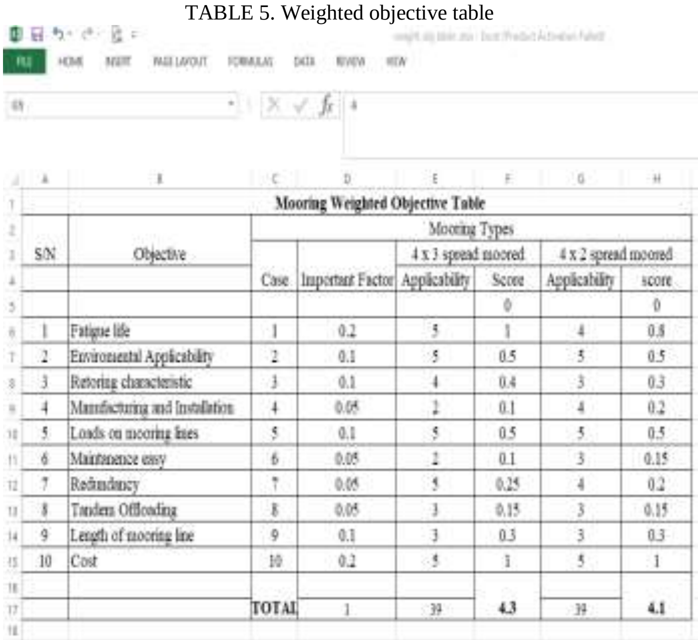
A mooring weighted objective table is formulated by means of Microsoft excel software for this study. The criteria considered for this study include; fatigue life, environmental applicability, manufacturing and installation, restoring characteristic, maintenance easy, Tandem offloading, redundancy, length of mooring line and cost. After performing global analysis centered on fatigue life using the Orcaflex software. The weighted table is used to perform the final selection analysis based on selected performance criteria for the spread mooring system suitable for offshore Nigeria.

A fuzzy performance selection procedure centered on the above listed ten objective criteria is done by assigning numerical values of important factor and applicability to each spread mooring system based on each criteria in progressive format of low values for worst factor scores to high values for best factor scores by using Microsoft excel spreadsheet for the multiplication and addition of scores

An important factor range of 0.05 to 0.2 and applicability of objective ranging from 0 to 5 is decided for this study through a fuzzy method.

International Research Journal of Advanced Engineering and Science
ISSN (Online): 2455-9024

TABLE 5. Weighted objective table



Mooring Weighted Objective Table							
S/N	Objective	Mooring Types					
		Case	Important Factor	4 x 3 spread moored		4 x 2 spread moored	
				Applicability	Score	Applicability	score
					0		0
1	Fatigue life	1	0.2	5	1	4	0.8
2	Enviromental Applicability	2	0.1	5	0.5	5	0.5
3	Retoring characteristic	3	0.1	4	0.4	3	0.3
4	Manufacturing and Installation	4	0.05	2	0.1	4	0.2
5	Loads on mooring lines	5	0.1	5	0.5	5	0.5
6	Maintanence easy	6	0.05	2	0.1	3	0.15
7	Redundancy	7	0.05	5	0.25	4	0.2
8	Tandem Offloading	8	0.05	3	0.15	3	0.15
9	Length of mooring line	9	0.1	3	0.3	3	0.3
10	Cost	10	0.2	5	1	5	1
		TOTAL	1	39	4.3	39	4.1

III. Results And Discussion

Results of Orcaflex Analysis

The Orcaflex analysis for this study produced three main results which are static, dynamic and fatigue life for the two models.

Static Analysis Results

The static results for the external line one of the 4x3 composition shows a top tension force of 1091KN at end A (Hang off point) because of the enormous weight due to the high water column of 1000m with an observed TDP at 1626m having a tension value of 410KN. However, the 4x2 system, the line one results shows a much higher top tension force of 1558KN at end A and an effective tension of 611KN at the 1626m TDP. The line results are higher for 4x2 because it has less redundancy to distribute the weight and the environmental loads as in the 4x3 composition. Table 6, shows the static result analysis.

TABLE 6. Static results

RESULT PARAMETERS	4x3 COMPOSITION	4X2 COMPOSITION
Shear force	6.582 KN	8.9143 KN
TDP	1626.667 m	1626.667 m
Effective tension @ TDP	410 KN	611 KN
END A		
Total force	1091.6605 KN	1558.8914 KN
End tension	1091.6407 KN	1558.8659 KN
END B		
Total force	2538.3566 KN	2859.9555KN
End tension	1576.8759 KN	2059.767 KN

Dynamic Analysis Results

The dynamic parameter of effective tension observed after performing dynamic simulation for both the 4x3 and 4x2 shows a gradual decrease in the effective tension versus arc length curve as it approaches the TDP and increases as it passes the TDP towards the anchor shackle location. The high tension observed at the hang off location and anchor end point for both compositions is as a result of combination of wave forces, FPSO motions and subsea laid tension. The dynamic simulation results are presented in the range graph is shown in Figure 3 below.

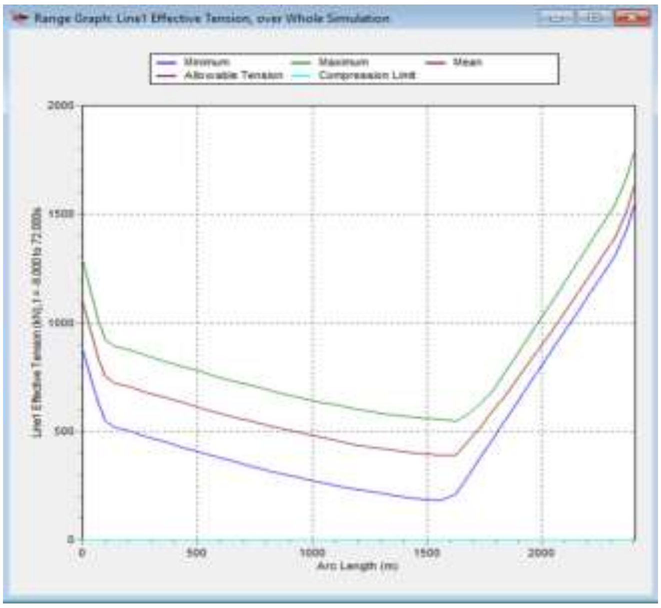


Figure 3: Effective Tension vs Arc Length

Fatigue Analysis Result

CASE 1: 4x3 Spread mooring system

The fatigue analysis results performed on (line 1) of the 4x3 mooring composition shows the fatigue expectancy at the TDP and fairlead (hang-off) locations separately for simulations using the JONSWAP wave spectrum. The results are as follows;

Fatigue life at fairlead (hang-off) location (line 1): 867 years.
Damage over total exposure at hang-off (line 1): 0.1841
Fatigue life at TDP (line 1): 3232 years.
Damage over total exposure at TDP (line 1): 0.0495

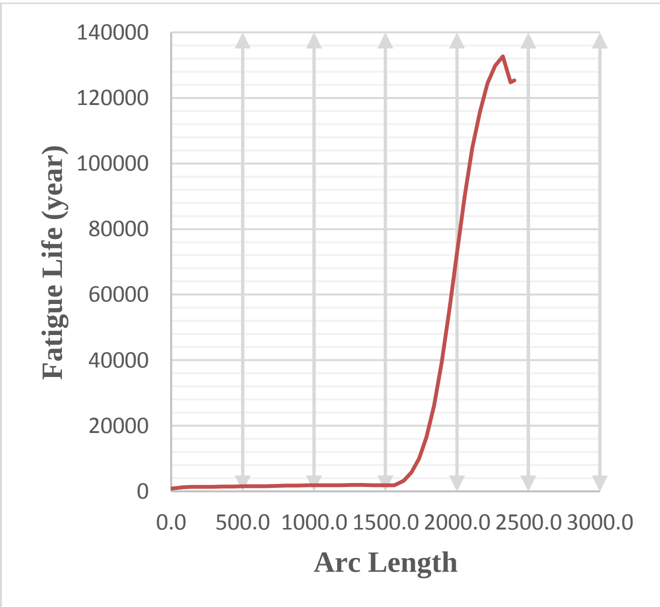


Figure 4: Fatigue life versus Arc Length for entire Length

International Research Journal of Advanced Engineering and Science
ISSN (Online): 2455-9024

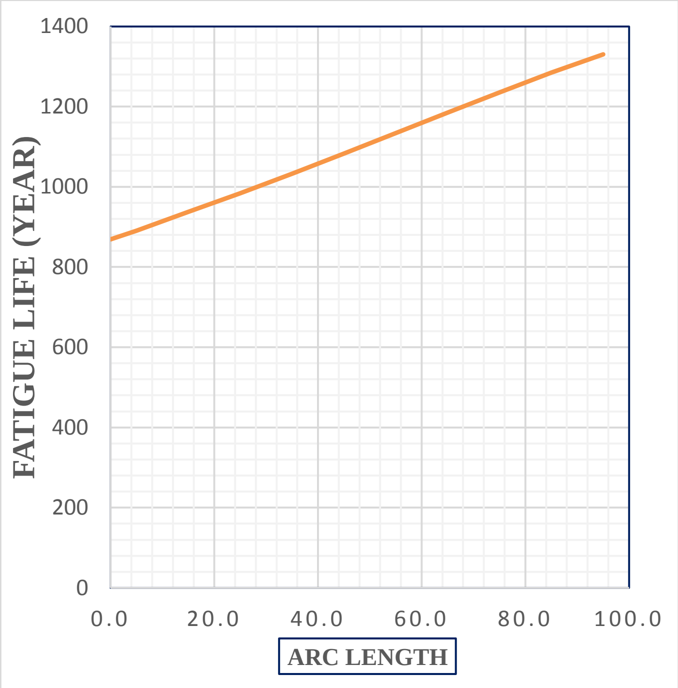


Figure 5: Fatigue life at Fairlead point (Hang-off)

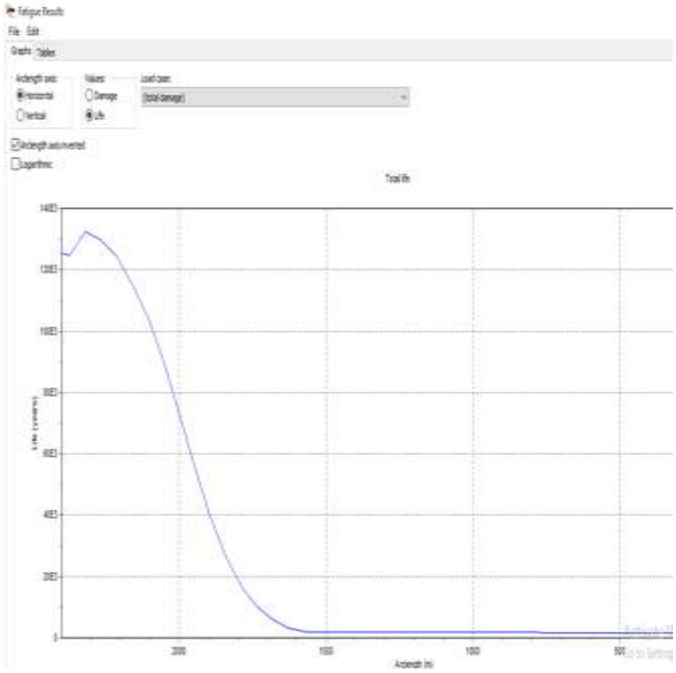
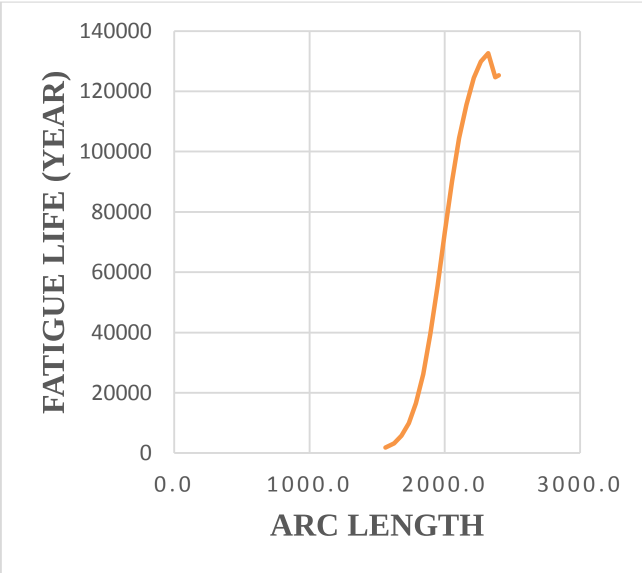


Figure 6: Fatigue Life Vs Arc Length at TDP



The fatigue life of the 4x3 system for the two critical locations meets the minimum tolerable fatigue life of 200 years. However, the results have shown very high fatigue life which will give it a high score in the selection decision making process for this system in terms of fatigue and environment applicability. The various graphical fatigue simulation results depicts an increasing trend along the arc of the fatigue life expectancy as it passes from the more active zone in terms of hydrodynamic and environmental forces (Hang-off point) to a calm sea bottom where the TDP is located. Thereafter a small sharp increase is observe close to the anchor point due to an applied pre laid tension as shown below in figures 4, 5, 6 and 7.

Figure 7: Orcaflex fatigue life Vs Arc Length

CASE 2: 4x2 Spread mooring system

The results of the Fatigue analysis performed on line 1 of 4x2 mooring composition give the same trend as that of 4x3.However, the results are not of same value but meets the minimum tolerable fatigue life of 200 years at the hang-off and TDP as stipulated by API RP 2SK.

Fatigue life at hang-off location (line 1): 349 years
Damage over total exposure at hang-off: 0.4587
Fatigue life at TDP (line 1): 975 years
Damage over total life at TDP: 0.164

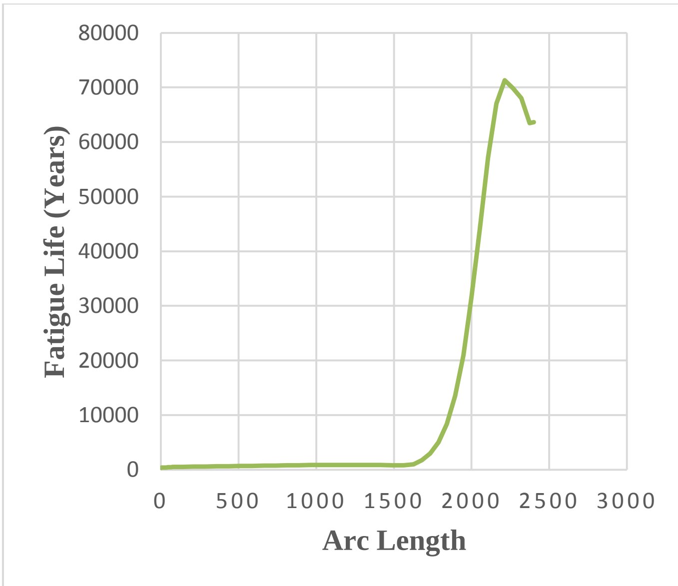


Figure 8: Fatigue versus Arc Length for entire Length

Figures 8, 9 and 10 show the fatigue life expectancy at a particular arc length of the ML's below. However from the graphs, the fatigue life expectancy shows increase along the hang-off point gradually to the TDP and produces a sharp decrease close to the anchor point due to the applied pre laid Tension.

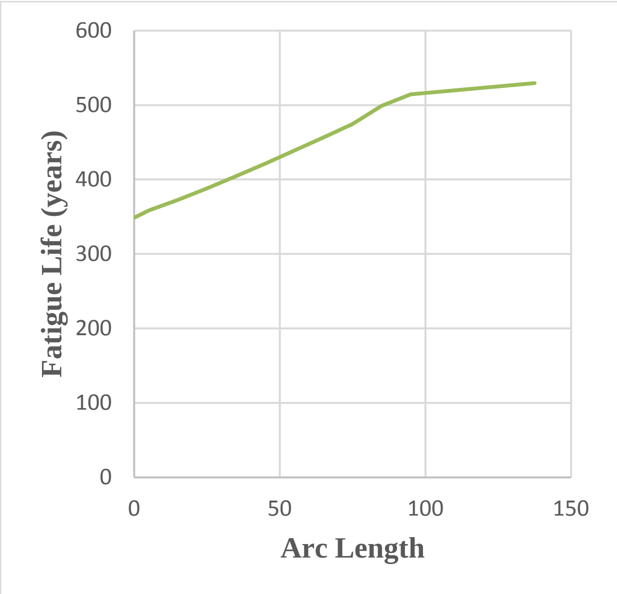


Figure 9: Fatigue life at Fairlead point (Hang-off)

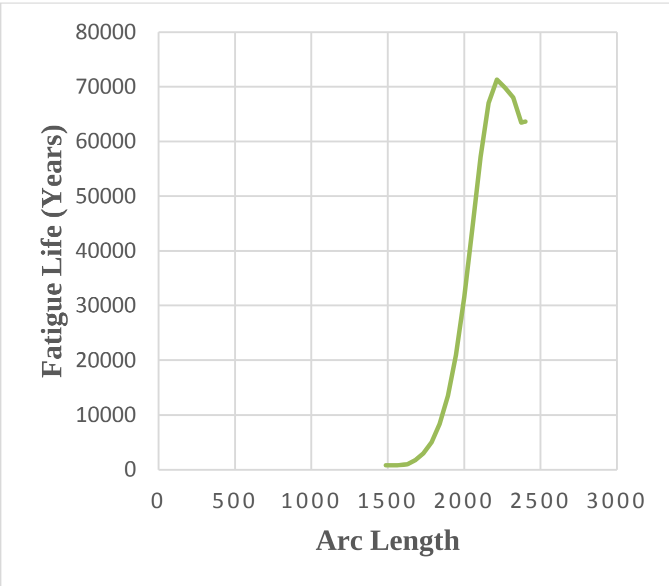


Figure 10: Fatigue Life Vs Arc Length at TDP Results of Weighted Objective Model.

The weighted objective model results use for the final selection analysis as shown in table 7 confirms that the 4x3 composition has the highest total score compared to the 4x2 composition after considering specific performance indicators as objectives needed to perform a selection process. The results demonstrations that 4x3 composition scored 4.3 and the 4x2 scored 4.1. Therefore, the high scoring composition would be selected for offshore Nigeria.

TABLE 7. Weighted objective Score card

S/N	OBJECTIVE	MOORING TYPE	
		4x3 SPREAD MOORED	**4x2 SPREAD MOORED**
		SCORE	SCORE
A	Fatigue Life	1	0.8
B	Environmental Applicability	0.5	0.5
C	Restoring characteristic	0.4	0.3
D	Manufacturing and Installation	0.1	0.2
E	Loads on Mooring Line	0.5	0.5
F	Maintenance ease	0.1	0.15
G	Redundancy	0.25	0.2
H	Tandem Offloading	0.15	0.15
I	Length of Mooring Line	0.3	0.3
J	Cost	1	1
	TOTAL	**4.3**	**4.1**

This criteria are highlighted below in bar chart formats as cases 1 and 2.

CASE 1: 4x3 Spread Mooring Composition
Total score: 4.3

The score results are presented in bar chart format as shown in Figure 11, it is clear from this bar chart representation, fatigue life and cost are considered higher than all other objective criteria, therefore justifying the need for a fatigue analysis before selection of a particular spread mooring system for offshore Nigeria.

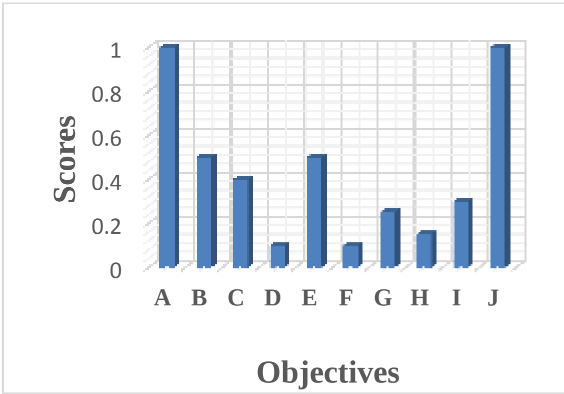


Figure 11: 4x3 Objective weighted bar chart

CASE 2: 4x2 Spread Mooring Composition
Total score: 4.1

The score results are presented in bar chart format as shown in Fig 12, it is clear from this representations, cost is scored higher than all other objective criteria including fatigue, in a 1-1 scale with the 4x3 system though it justifies the need for a fatigue analysis before selection of a particular spread mooring system for offshore Nigeria.

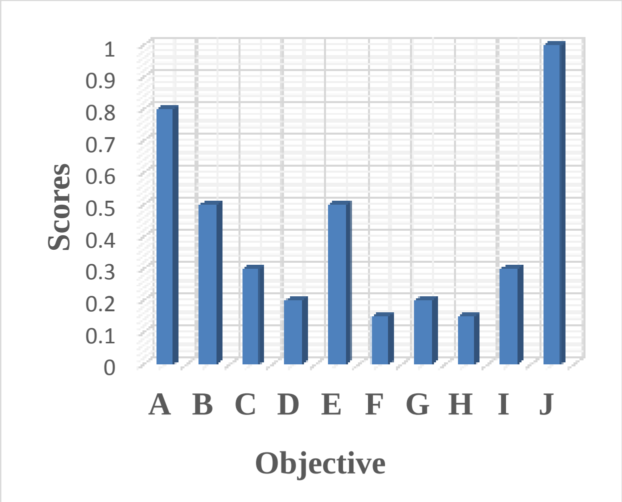


Figure 12: 4x2 Objective weighted bar

IV. CONCLUSION

The conceptual design stage of an FPSO spread mooring system, poses a selection challenge of which system is suitable for offshore Nigeria as the case may be. Fatigue analysis is recommended to be performed before the installation of the ML due to notable failure cases of mooring structures observed recently. There are several FPSO spread mooring compositions known to the industry, some of which are the 4x4, 4x3 and the unpopular 4x2 compositions. Selection of the most efficient composition from the view point of fatigue life, the importance of a credible fatigue analysis and other selection objectives like cost, restoring characteristic, length of mooring line, manufacturing/installation, maintenance ease, Tandem offloading and environmental applicability were considered in this study to create an efficient and reliable performance based selection analysis.

The fatigue life is considered in this research due to the quantitative and qualitative methods involved in obtaining fatigue results, Also API RP 2SK (2005) states that, 20 years expected exposure time (design life) multiplied by a fatigue factor of 10, confirming the minimum acceptable fatigue life of a mooring line in deep waters to be 200 years. To this end, the fatigue life of the 4x3 composition for JONSWAP wave spectrum at the hang-off and TDP respectively are 867 and 3232 years which is far above the API stipulated 200 years. Furthermore, the 4x2 composition was observed to also have fatigue life well above 200 years up to 349 and 975 years respectively at the hang-off and TDP.

The final process of selection using objective weighted model favored the spread mooring systems with higher fatigue life. However, the major conclusions from this study are stated below:

i. The performance of fatigue analysis on mooring lines is a practicable solution to the selection problem of an efficient and reliable mooring composition in offshore Nigeria.
ii. Selection should be done with multiple criteria with different important factors and applicability for qualitative decision making.
iii. The unpopular 4x2 composition having a fatigue life above the minimum value of 200 years is an indication of its applicability in the Gulf Guinea (offshore Nigeria) if trade- offs are considered .
iv. In the application of weighted objective model, the system with highest score should be selected

REFERENCE

[1] API RP 2SK. (2005). Design and analysis of station keeping systems for floating structures.
[2] Brown (2010) Phase 2 Mooring integrity JIP – summary of findings. OTC-20613, Houston, Texas.
[3] Chanhoe, K.Changhyun, L.Seock-Hoe, J and Yeong-Tae, O. (2016) Fatigue analysis of spread mooring lines. International Journal of Geological and Environmental Engineering 10(5).504-510.
[4] DNV (2010)
[5] Fontaine et al. 2012. Investigation of severe corrosion of mooring chain in West African waters. Proceedings of the Twenty-second International Offshore and Polar Engineering Conference, Rhodes, Greece, pp. 389-394
[6] Larsen, K. (2014). Lecture note on Mooring and station keeping of floating structures (TMR4500 specialization project).
[7] Mohammad Hasan Saide (2015) Fatigue Analysis and design of mooring systems. Assessment and comparison of different analysis method.
[8] Srinivasan Chandrasekaren (2015) Dynamic analysis and design of offshore structures (Ocean engineering and oceanography. Volume 5.)

International Research Journal of Advanced Engineering and Science
ISSN (Online): 2455-9024

APPENDICES

APPENDIX A-1 (WAVE SCATTER TABLE)

No.	Inc1	Hs1	Tp1	Inc2	Hs2	Tp2	Inc3	Hs3	Tp3	Occ	No.	Inc1	Hs1	Tp1	Inc2	Hs2	Tp2	Inc3	Hs3	Tp3	Occ
1	225	1.3	13	203	0.8	9	180	0.3	7	230	43	225	0.3	11	203	0.8	9	203	0.3	5	46
2	203	1.3	13	203	0.8	9	203	0.3	5	228	44	225	1.3	15	203	1.3	9	203	0.8	7	46
3	203	0.8	11	203	0.8	7	180	0.3	5	218	45	203	1.3	15	203	1.3	11	180	0.8	9	44
4	203	1.3	11	0	0.0	0	0	0.0	0	198	46	203	0.8	9	203	0.8	7	203	0.8	5	43
5	225	0.8	13	203	0.3	9	180	0.3	5	184	47	203	0.3	11	203	0.3	9	180	0.3	5	42
6	225	0.8	13	203	0.8	9	180	0.3	5	184	48	225	1.8	15	203	0.8	9	203	0.3	9	42
7	225	1.3	13	203	0.3	7	158	0.8	5	179	49	203	0.3	17	203	0.8	11	180	0.3	9	40
8	203	0.8	11	203	0.3	7	338	0.8	5	146	50	225	0.3	17	225	0.8	11	180	0.3	5	40
9	225	0.3	15	203	0.8	11	203	0.3	5	146	51	203	1.3	13	180	0.3	7	180	0.3	7	39
10	203	1.3	9	0	0.0	0	0	0.0	0	141	52	203	2.3	15	0	0.0	0	0	0.0	0	39
11	203	0.8	13	203	0.8	9	180	0.3	7	131	53	225	0.8	15	225	0.8	11	203	0.8	7	39
12	203	1.3	13	0	0.0	0	0	0.0	0	126	54	203	0.3	13	203	0.3	9	203	0.3	5	38
13	203	1.3	11	203	0.8	7	180	0.3	5	102	55	225	0.3	15	225	0.3	11	203	0.3	7	38
14	225	0.3	13	203	0.8	9	203	0.3	5	102	56	203	1.3	13	180	0.8	9	180	0.3	5	36
15	203	1.3	13	203	0.3	7	180	0.3	5	91	57	225	0.3	13	203	1.3	9	180	0.3	7	36
16	225	0.8	11	203	0.8	7	135	0.8	5	90	58	225	1.8	13	0	0.0	0	0	0.0	0	36
17	203	0.8	13	203	0.3	9	203	0.3	5	88	59	203	1.8	13	203	0.8	9	203	0.3	7	35
18	203	1.3	11	203	0.3	5	225	0.3	5	88	60	225	1.3	15	203	0.3	9	180	0.3	9	35
19	203	1.3	13	203	1.3	9	180	0.3	9	85	61	203	0.8	11	180	0.3	7	180	0.3	5	34
20	225	0.8	15	203	0.8	9	180	0.3	9	85	62	203	1.3	11	225	0.3	5	203	0.3	5	34
21	225	1.3	15	203	0.8	9	203	0.3	9	85	63	225	0.8	13	203	1.3	9	225	0.3	5	34
22	203	1.8	13	0	0.0	0	0	0.0	0	84	64	225	1.3	13	180	0.8	7	203	0.8	5	34
23	225	0.3	15	225	0.8	11	203	0.3	5	83	65	225	2.3	15	0	0.0	0	0	0.0	0	34
24	225	0.3	15	203	1.3	11	203	1.3	9	79	66	203	2.3	13	0	0.0	0	0	0.0	0	33
25	203	0.8	9	203	0.3	7	203	0.3	3	77	67	225	1.3	13	180	0.3	7	203	0.3	5	33
26	225	1.3	13	203	1.3	9	90	0.8	5	75	68	203	0.8	9	0	0.0	0	0	0.0	0	31
27	225	0.8	11	203	0.3	7	180	0.3	5	74	69	203	0.8	11	0	0.0	0	0	0.0	0	31
28	225	1.3	13	0	0.0	0	0	0.0	0	73	70	203	1.3	11	180	0.3	7	225	0.3	5	30
29	203	0.8	13	203	1.3	9	203	0.3	7	70	71	203	0.8	11	225	0.3	7	180	0.3	7	29
30	203	0.3	15	203	0.8	11	203	0.3	7	67	72	203	1.8	15	0	0.0	0	0	0.0	0	29
31	203	1.3	15	203	0.8	9	203	0.8	9	58	73	203	0.3	15	203	0.3	11	203	0.3	7	28
32	225	0.3	17	203	0.8	11	180	0.3	7	58	74	225	0.8	15	203	1.3	9	180	0.8	7	27
33	225	0.3	13	203	0.3	9	203	0.3	5	56	75	225	1.3	11	203	0.3	7	90	0.8	5	27
34	225	1.8	15	0	0.0	0	0	0.0	0	56	76	225	1.8	13	203	0.8	7	225	0.3	7	27
35	225	0.8	15	203	0.3	9	203	0.3	7	53	77	203	0.8	15	203	1.3	9	180	0.8	9	26
36	203	0.8	15	203	0.8	11	203	0.8	7	51	78	203	2.3	11	0	0.0	0	0	0.0	0	26
37	203	0.3	13	203	1.3	9	203	0.3	7	48	79	203	1.8	15	203	1.3	9	0	0.0	0	25
38	203	0.3	15	203	1.3	11	203	0.3	9	48	80	225	0.3	17	203	1.3	11	203	0.8	9	25
39	203	0.3	11	203	0.8	7	180	0.3	5	47	81	225	1.3	17	225	0.8	13	180	0.8	9	24
40	203	0.3	13	203	0.8	9	180	0.3	7	47	82	203	1.8	15	203	0.8	7	203	0.8	9	23
41	203	1.8	11	0	0.0	0	0	0.0	0	47	83	225	0.8	15	225	0.3	11	203	0.3	7	23
42	225	0.3	15	203	0.3	11	203	0.3	7	47	84	203	0.3	15	225	0.8	11	203	0.3	7	22

Source: International Science Index, Geological and Environmental Engineering V0l: 10, 5, 2016 Waste.org/Publication/10004227
Inc= wave heading,
Hs= significant wave height,
Tp peak period,
Occ= Occurrence

Ubani, Chikwendu and Ikpaisong, Ubong, "Selection of FPSO Spread Mooring Systems in (Deep Water) Offshore Nigeria," *International Research Journal of Advanced Engineering and Science*, Volume 5, Issue 1, pp. 149-156, 2020.