INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH & DEVELOPMENT

ISSN 2278 – 0211 (Online)

Feasibility Studies on Offshore Triceratops as Future Offshore Structure Using FMEA Approach

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Abstract:
As future drilling and exploration moves towards ultra-deeper waters, the interplay between offshore structures and the sea environment as well as lessons learnt from previous offshore accidents have been challenging for oil and gas professionals whose cravings for crude oil remains persistence in spite of all these challenges. These has necessitated the need for durable and reliable offshore structure(s) that will mitigate this challenges without compromising the potentials of exiting offshore structures as water depth varies from location to location. Comparing the characteristics of various offshore structures in this study, offshore triceratops is a recent innovation that combines the major characteristics of TLPs and Spars for ultra-deep water oil exploration. It is composed of deck structure that seats on three buoyant leg structures (BLS) linked together by ball joints. These joints make the structure a stable and heave restrained system where pitch and roll motion is absent with minimal level of surge and sway during operation. The three BLS structures are anchored to the seabed via mooring lines. Using FMEA methodology to assess the durability and reliability of the functional parts of offshore Triceratops in this study, the result shows that ball joint has the highest risk priority number of 70 due to effects of fatigue, corrosion, and bending and axial compression on the ball joints. Thus, the possibility of failure is high if strict design attention is not focused on the ball joint.

Keywords: *Offshore Structures, Materials, Failure, Durability and Reliability, Oil and Gas, Drilling.*

1. Introduction

The wellbeing of the world economy is highly dependent on the availability of cheap fossil fuel (non-renewable energy) as source of energy such as Coal, Crude oil and natural gas. This is because the cost per kilowatt hour of utilising renewable energy is expensive compared to fossil fuel [9]. The era of cheap fossil fuel is almost coming to an end as a result of the global energy needs which has increased rapidly in the last 200 years due to both industrial and human population growth [3]. However, the search for fossil fuel as source of energy has gone beyond shallow water depth to ultra-deep water locations (Gulf of Mexico, West Africa etc.) where the environment is very harsh and unpredictable for exploration. The trends in exploration and drilling operations have change simultaneously in this direction, with structural properties of offshore materials which their durability and reliability depends mainly on certain factors such as the nature of environment and water depth. For example, Zahodiakin [22] reported that ultra-deep water drilling is the last frontiers for most multinational companies because having explored the shallow water locations is believed that larger reserves are deposited in the ultra-deep water regions as majority are still unexplored. In addition, Anderson [2] suggested that although crude oil deposit in the ultra-deep waters is considerably substantial in quantity, diverting the interest of future offshore oil and gas production towards ultra-deep water location will probably necessitate the development of new offshore structures for drilling and extraction of oil and gas in the ultra-deep-waters The offshore environment is characterised by salty water, tidal wave, extremely cold temperature, high wind, minimal visibility etc. which have raised technical design challenges such as, fatigue, corrosion, stresses, vibration, cracks and upheaval buckling etc. of the structure and its materials [11]. Durability and reliability of these offshore materials becomes less efficient as some materials known for its resilience and longer life span in shallow and deep waters exhibit elements of deficiency and failure in ultra-deep waters. This has necessitated exploration skills as experience on oil exploration specifically in the ultra-deep area requires expertise because, continuous exposure of the offshore materials to this extreme region can shorten the life span of the materials as well as undermining the durability and reliability of this materials which results to failure over time.

Development of oil rigs involves the fabrication of platforms at a common point which serves as collection and control centre for wells located many kilometres away [12]. Since the offshore structures are made up of welded joints and complex frameworks, specific attention must be given to welding, structural design standards, cyclic loading, fatigue, corrosion, manufacturing defects and material selection for optimum performance and prevention of failure on offshore structures in these regions. Thus, the significance of durability and reliability of offshore structures in this research work will focus primarily on potential future offshore structures. As mentioned earlier, offshore structures are composed of materials assembled together through processes such as welding or riveting, and the ability of these structures to withstand the loads acting on them depends mainly on the material properties that make up the offshore structures. Wang et al. [20] classified these loads as structural loads and accidental loads, where the authors further classify structural loads as dead loads, live loads and environmental loads. Further to the discussion on loads acting on offshore structures, Dutta [10] added that offshore structures operate under the influence of dead, live and environmental loads. According to Billingham et al. [4], fixed offshore structures are traditionally fabricated with structural steels of medium grades with yield strength of about 350MPa, but now there is a call for very high strength steels with yield strength of 500MPa-800MPa because high strength steel provides various advantage over conventional steel usually because of the high strength to weight ratio. This has now been used predominantly in offshore structural application in which production jack-ups, semi-submersibles, tension leg platforms (TLPs) etc. are fabricated. Steel with typical yield strength of this range can be applicable in the fabrication of legs, spud cans and rack and pinions to enhance drilling operations. However, effective performance of offshore structures depends mainly on factors such as structural performance of the material (which are determined by the alloying elements and properties that constitute the materials), statistical distribution of service loading, environmental conditions, human and operational errors. The need to explore energy offshore in the most cost effective and sustainable manner has been prioritized by government, environmentalists and energy industries in recent times [19]. As oil exploration extends towards deep waters, design of offshore platform changes in both specification and functionality. In terms of fixed offshore structures which are composed of frame works of different geometries with broad base and slant jacket enhancing stability as a result of bottom density. Reverse is the case for floating platforms where tendons (mooring lines) are used to anchor the structures to the ground. The floating systems are composed of hulls (columns and pontoons) of adequate buoyancy to enable the floating of structures. The floating structures operate on the principles of buoyancy and dynamic positioning, in which the centre of buoyancy is designed to be higher than the centre of gravity for stability. However, the fabrication of jackets is changing over time. Nallayarasu [15] noted that the capability of machineries, technologies and availability of equipment was a challenge in the 1960s and 1970s unlike today where there is great improvement in these areas as computer aided engineering (CAE) simulations such as hyper-works and Acusolve etc. have been the current trends used in solving these challenges. Comparatively, mobile platforms have emerged as the most widely used platforms due to a number of advantages it has over fixed platforms. For example, Natural Gas Regulation [14] described mobile platforms as a function of its versatility in terms of exploration into 10000ft and above of water depth in diverse location with minimal cost requirement for the installation and operation processes unlike fixed platforms. These platforms contain large diesel engines, making them self-sustaining in terms of electricity supply. According toAbdullah et al. [1], oil rigs has an engine room accommodating four diesel engines for electricity generation. Fixed structures are usually constructed with steel or concrete foundation where the legs or piles are projected from the seabed to a certain height above the sea where the jacket seats in order to support the decks.The advantage of fixed platforms lies in the weight, strength and stability of these structures against hydrostatic force and tidal wave. These platforms are designed for long term operation and are characterised by their immobility. Depending on the type and design, location of some fixed offshore platforms in deeper water depths can be necessitated. This implies that water depths for fixed structures vary because; location of some offshore platforms such as steel jacket/tower in higher water depths can be highly expensive, gigantic and as well difficulty during installation [14].Example of Fixed offshore platforms can be classified as steel jackets/towers, concrete gravity based structures, jack-ups, compliant towers, and Tension Leg Structures (TLPs). Some platforms are commonly known for its mobility which can facilitate drilling operation in various locations. Although some mobile platforms such as the mobile offshore drilling units lack the facilities to process the raw material into finished product, Shell in Alaska [18]noted that floating production storage and offloading (FPSOs) despite its disadvantage (in areas with limited piping systems) to convey crude oil to shore can still perform the processing operation effectively. Natural Gas Regulation [14] reported that moveable rigs are usually applicable to exploration operations because they are less expensive to use than fixed offshore platforms. Also, uniqueness in the design and geometry of the mobile structures in deeper waters makes them more effective compared to the fixed platforms. Mobile platforms in this context can be classified as Semi-submersibles, Submersibles, Spars, Drill ships, Floating production storage and offloading (FPSOs), offshore Triceratops. Comparing the characteristics of both fixed and mobile offshore structures, mobile structures have more potential to thrive in ultra-deep waters than fixed structure. Semi-submersible rig and drillship are widely used as the prospective future offshore structures due to the trends in drilling operation towards ultra-deep waters, though the two distinctive structures possess almost similar potential in terms of operation and relevance for future drilling operations. In recent times in the offshore and marine sectors, cravings by researchers, experts, stakeholders etc. for more effective offshore structure has been directed towards innovative geometric shape, durable and reliable as well as cost effective platforms for motion properties in deep and ultra-deep water depths. For minimal challenges and greater success in the oil and gas industries, this endless desire has led to the newest development of an offshore structure known as TRICERATOPS FLOATING PLATFORM [8]. Triceratops is a gigantic platform composed primarily of a cylindricalbuoyant leg structures (BLS) which includes deck, ball joints between deck BLS's, tethers for restoring and suction on gravity piles relative to foundation. The ball joints play a vital role in the safety of this structure because it specifically transfers lateral displacement without rotating about any given point or axis which improves the effectiveness of the structure against unwanted yaw, roll or heave motion, as a result of aerodynamic loading [6]. In addition, Chandrasekaranet al. [5] supported that the presence of ball joints makes Triceratops a stable and heave restrained structure with no pitch and roll properties as well as minimal rate of surge and sway. In other words, Triceratops is a floating structure that is essential for deep and ultra-deep water applications in a depth of about 14000 feet and above. The BLS can be categorised as few or numerous number of water piercing cylindrical shapes that extremely high level of buoyancy and anchored to the seabed with the help of tethers. Even when the tethers are removed, this structure can still maintain a high degree of stability which is one of the major factors that enhances the survivability as well as the operational conditions of the structure [7].According to White, Copple and Capanoglu [21], design, construction, operations and safety measures of Triceratops is in accordance with the effective and efficient functionality requirements in conventional offshore performance in terms of minimal risk and efficiency which may result in lifecycle cost savings. This is because ineffectiveness of a poorly designed component will likely lead to more problems and inefficiency of such component may require improvement in order to fulfil the purpose of its design. However, whatever action taken to either correct a particular problem or improve the component will require capital and Triceratops plays a very important role in guaranteeing cost effectiveness as well as safety of employees and meeting targets when required. Chandrasekaran [8] stated that Triceratops is a floating structure that comprises one of the most distinctive feature that is peculiar to other offshore structures and this feature is known as re-gasification unit as shown in Figure 1. The re-gasification unit is applicable in the conversion of Natural gas into Liquefy Natural Gas (LNG) for storage in membrane tank and transported to onshore where treatment procedures required for processing the LNG to regulatory standard and end user requirement is carried out [13].Major exploration and production ships including the highly prospective semi-submersible rigs and drill ships only separate the water that accompanies crude oil during drilling and send the water back to the sea while the crude oil is transported onshore in the liquid state and the gas processed separately.

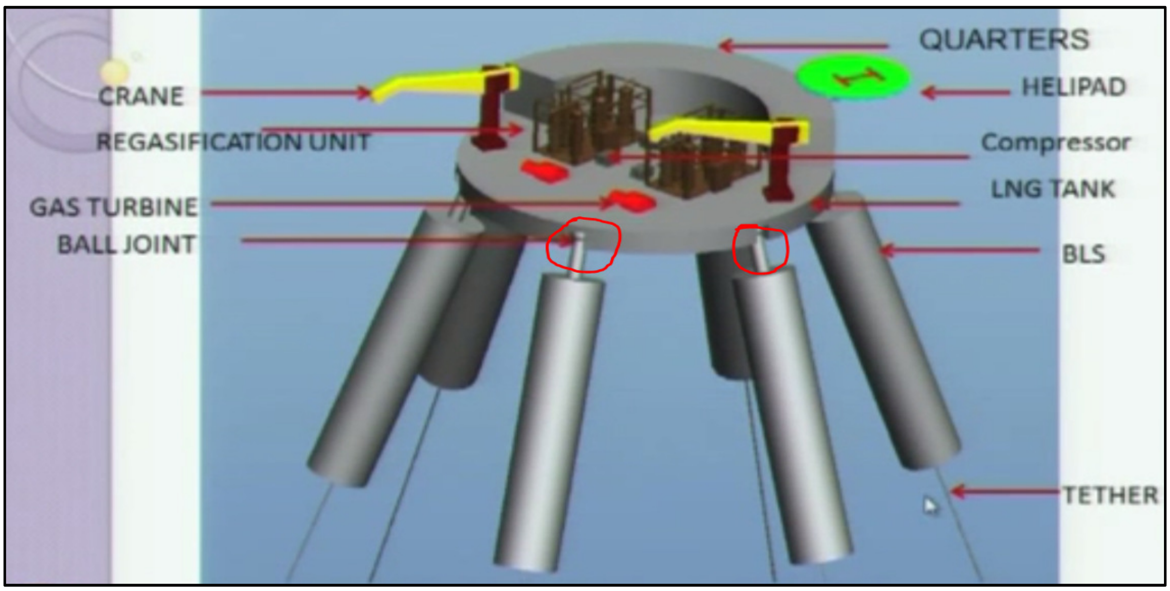

Figure 1: Offshore Triceratops with Floating Structure Regasification Unit (FSRU) on Board [8]

As shown in Figure 1, a typical Triceratops is made up of various parts that make up the entire structure and each of the parts plays a different role relative to the purpose by which the structure is meant for. Similarly, in Figure 1, it can be observed that in all these parts that Triceratops is consist of, there is one element that carries the entire weight of the deck and any malfunctioning in this element as a result of corrosion, fatigue, fabrication defect etc. can likely result in the collapse of this structure. In this context, the ball joint has been identified as that element which supports the weight of the deck and equally suspense the buoyant leg structures (BLS) which houses the umbilical (tethers) are used in anchoring them to the seabed. Moreover, this has raised a major concern as per how reliable is the ball joint to support the entire weight of the deck without failure, knowing that any defect on each of the ball joint will impose more load on other supporting ball joints on the structure which may eventually result in the entire structure collapsing. Having highlighted some properties that constitutes the Triceratops, the advantages and disadvantages of this structure with regards to its operations and functionality can be summarised as shown in Table 1.

Advantages of Offshore Triceratops	Disadvantages of Offshore Triceratops
❖ Easy to Install and decommission (Installation can be part by part or as a whole structure) ❖ Reusable in multiple operations ❖ Highly stable ❖ Relatively low cost ❖ Better motion characteristics against unwanted yaw, roll or heave motion ❖ Suitable for deep water operations of about 14,000 feet ❖ Improved dynamics in comparison to other offshore structures ❖ Simple station keeping ❖ Laterally support wells within protected environment ❖ Minimal rate of surge and sway motion due of the circular geometry ❖ Comprises re-gasification unit to process LNG back to NG	❖ Requires umbilical to keep the structure in tension during drilling operation ❖ Requires external vessel for mobility ❖ Requires a wide area for operation due to the wide spreading BLS

Table 1: Advantages and Disadvantages of Offshore Triceratops

Some innovations are produced as a miniature or as a test model to observe the performance during operation in order to decide the areas that require improvement. However, Triceratops though regarded as a new invention is no longer a test model due to a number of information that asserts the potentials of this structure. Nevertheless, Design Failure Mode and Effects Analysis (DFMEA) will be carried out on various features that make up the Triceratops including the ball joint in order to determine the possible failures attributed to each components and justification will be made as per how reliable and durable are these features, having achieved the DFMEA approach which will be specified clearly in the methodology.

2. Methodology

As mentioned earlier in previous sections of this study, Failure Mode Effects and Analysis (FMEA) is a reliability assessment tool that has been adopted effectively and successfully by many engineering practitioners in determining the reliability of current offshore structures in terms of parts prone to failure as well as predicting the future of such structures if proactive actions are not taken to prevent the occurrence of such failure. Although FMEA and other reliability assessment tools are considered as probabilistic approaches, it is worth mentioning that reasonable result can be obtained depending on how correctly the tools are applied. However, the reality behind the use of FMEA and any other reliability tool is that 100% accuracy cannot be achieve as no structure developed by man is 100% perfect and effective in terms of defects and failure occurrences irrespective of the design consideration, specifications, and standard procedures observed. Due to the innovative nature of Triceratops, limited literatures have been developed on the reliability of this structure but available information gathered on this subject indicates that characteristics of Triceratops outweighs that of semi-submersible rigs and drill ships. In this context FMEA has been adopted as the methodology to be used in evaluating the reliability of offshore Triceratops. However, FMEA can either be Design FMEA or Process FMEA of which DFMEA does the following;

1. Examining function(s) of the components, structures or substructures
2. Identification of significant failure as a result of unsuitable material or inappropriate standards
3. Examining the process used in producing a given component
4. Identification of significant failures. For example, incorrect assembly of parts etc.

2.1. Steps to be Adopted in the Methodology

1. Define the principles of structure/system to be evaluated
2. Identify the functional parts of the structure
3. Identify the functional relationships between components/parts of the structure
4. Identify all failure modes, causes and effects on the structure
5. Determine the Risk Priority Number (RPN)
6. Suggest actions for prevention and improvement

Having highlighted the steps to be taken in carrying out an effective FMEA in this study, the schematics can be presented as shown in Figure 2;

2.2. Working Principles of Each Functional Component in Relation to Each Other

When the switch board is activated and all the facilities on the deck are engaged, the drill bit is deployed into the seabed and the functional components come into play. It can be observed in Figure 1, that Ball joint is one of the most important parts of the offshore Triceratops as failure of any of the joint can result in a catastrophic collapse of the entire structure as mentioned earlier in offshore accident recorded for Alexander Keland. The relationship of the functional components with each other can be stated as follows;

1. Derrick holds or suspends the Riser during drilling (Riser houses the Drill string).
2. The Riser passes through the Deck structure (which accommodates and supports all surface drilling units) to the seabed. Hence, the hydrocarbon drilled from the ground passes through the Drill string to the LNG tank (storage tank for storing LNG product) located at the Deck surface.
3. Tethers also known as Umbilical or Tendons are anchored to the seabed to keep the platform in tension (constantly fixed position) during operation.
4. BLS which houses Tethers provides high level of buoyancy to the offshore Triceratops against unwanted heave, yaw and roll motion.
5. The Ball joint which is found between the Deck and BLS supports the entire weight of the Deck as well as suspending or holding the BLS. The Ball joint translates lateral displacement to the structure without rotating about a fixed point or axis and thus, improving the effectiveness of the structure against heaves and yaw motion.

Following the aforementioned steps highlighted earlier in this section, potential failure modes related to functional components in a typical offshore Triceratops can be identified as shown in Figure 2.

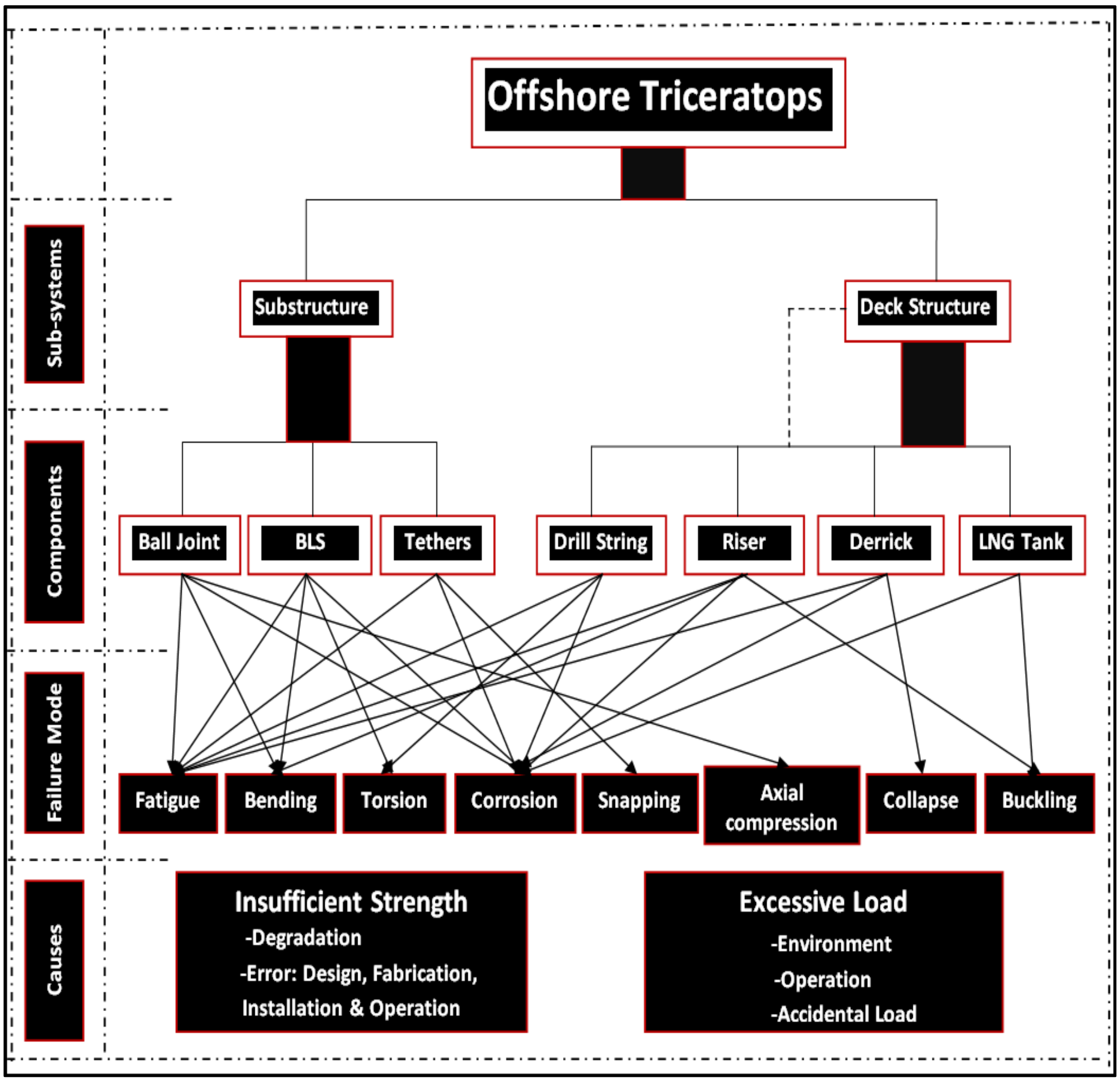

Figure 2: Identification of Potential Failure Modes with respect to each Component

There are some major considerations that must not be left out in order to reach optimal performance without compromising the integrity of the structure. For example, high density may likely affect the performance and floating tendency of the structure which therefore requires lightweight materials. However, bending is a major failure mode associated with the shaft connected to the ball joint and can be calculated from the generic beam bending equation;

$$\frac{M}{I}=\frac{\sigma}{y} \quad (1)$$

Where:
σ is the stress at distance y from neutral axis of beam;
M is the bending moment of the shaft connected to the ball joint;
y is the distance from the neutral axis; and
I is the second moment of area.
Comparatively, axial loads are usually very small at critical locations where bending and torsion dominates, so they will not be included in the following equations representing the fluctuating stresses due to bending and torsion;

$$\sigma_a = k_f \frac{M_a y}{I} \text{or} \sigma_m = k_f \frac{M_m y}{I} \quad (2)$$

$$\tau_a = k_{fs} \frac{T_a y}{J} \text{or} \tau_m = k_{fs} \frac{T_m y}{J} \quad (3)$$

Where
M_m and M_a are the midrange and alternating bending moments
T_m and T_a are the midrange and alternating torques
k_f and k_{fs} are the fatigue stress concentration factors for bending and torsion
J is the polar second moment of area

For fatigue resistance, it is desired that the Fatigue strength endurance limit σ_e be as high as possible. Therefore,

$$\frac{wl}{A} \leq \sigma_e \quad (4)$$

Where
wl is the total load on the shaft connected to the ball joint
A is the cross sectional area

$$A \geq \frac{wl}{\sigma_e} \quad (5)$$

Following the proposed methodology of the study, causes, possible effects, and preventive/mitigating actions of failure modes in relation to each functional component in an offshore Triceratops can be indicated as shown in Table 2.

S/N	Components	Failure Mode	Failure Effect	Causes/Sources	Recommended Actions
1	Ball Joint	Fatigue, Corrosion, Bending, Axial Compression.	Cracks, Misalignment, Collapse of the entire structure, Fatality.	Faulty Design, Manufacturing defect, Biological, Environmental factors, Improper lubrication.	-Rigorous Testing Required -Proper Lubrication Required -Proper Material Selection
2	BLS	Bending, Torsion, Corrosion, Fatigue.	Instability, Overturning, Submerging, Fatality	Environment factors, Design and Installation errors.	-Proper Inspection Required -Ultrasonic Welding required to avoid welding flaws
3	Tethers (Umbilical)	Fatigue, Corrosion, Snapping.	Instability	Manufacturing defects, Environmental factors, Accident.	-Installation of sensors to send signals to approaching objects -Proper Material Selection -Proper Manufacturing Skills
4	Drill String	Fatigue, Torsion, Corrosion.	Oil Spillage, Consume more energy.	Operational errors, substandard materials.	-Adherence to Safety Standards -Routine Checks Required for failure detection -Proper Material Selection Method
5	Risers	Fatigue, Corrosion, Bending, Buckling.	Oil spillage, affects operation.	Environmental factors, operation effect	-Proper Material Selection Method -Adherence to Safety standards -Routine checks to detect failure initiation
6	Derrick	Fatigue, Corrosion, Collapse.	Closure of entire operation, Fatality	Environmental factors, Poor material selection, faulty Design.	-Adherence to Manufacturing Standards -Proper Inspection to detect failure initiation -Anti-Corrosion Coating Required
7	LNG Tank	Buckling, Corrosion.	Leakage, Explosion, Fatality	Poor material selection	-Proper Material Selection Required -Proper Coating against Corrosion

Table 2: Causes, Possible effects and preventive/mitigating actions of associated failure modes of offshore Triceratops

Considering the failure modes, causes of the failure, effects/consequences as well as preventive/mitigating actions needed to be taken; FMEA of offshore Triceratops can be developed following certain steps and methods highlighted in this section, taking the FMEA variables and parameters into consideration.

2.3. Rating of Failure Mode

Just like failure occurrence (O), severity (S) of failure in FMEA is rated according to the number assigned to each part or component in a set of functional components which the FMEA is performed on and the number is rated on a scale of 1-10. This implies that the part or component with the highest number is the part with the most likelihood of failure. In other words, if the severity of failure mode is designated number 1, there is no probability of failure of such component [16]. Also, if the severity of failure mode is designated number 5, the probability of failure is moderate on a scale of 10 and if the severity of failure mode is designated 7 and 8, this indicates that the severity of failure is critical while 9 and 10 indicates that the probability of failure occurring in such component or part is extremely high or hazardous. This implies that the higher the number of severity of failure, the higher the likelihood of the component failing and failure of one single component in a structure can consequently result in failure of the entire structure.

2.4. FMEA Variables

Detection of failure mode correlates with the possibility that a method of detection or conventional controls will identify potential failure mode prior to releasing the component for production or for process prior to the component leaving production facility. In this case, the rating is determined on a scale of 1-10, number 1 has a degree of failure detection, while number 3 number has a good failure detection level, number 5 may likely detect failure, whereas number 7 has fair detectability of failure and number 9 or 10 will most likely not detect any failure [16].

2.5. Risk Priority Number (RPN)

RPN identifies major areas of concern in a structure. It evaluates the following;

1. Severity ratings
2. Occurrence ratings
3. Detection ratings for a significant failure mode

The RPN is derived by multiplying the following factors;

RPN = Severity rating * Occurrence rating * Detection rating.

If the severity is 9 or 10, it implies that corrective actions are required. Similarly, if severity ratings of occurrence are high, corrective actions are also required. The RPN indicates the importance for making decision and the higher the RPN, the more important it is to take action on the corresponding failure identified [16,17]. Having highlighted the necessary steps and procedures required for effective FMEA in this section, FMEA of offshore Triceratops will be carried out adopting the outlined procedures shown in Table 3;

Prepared by: Owunna Ikechukwu Bismarck								Design responsibility: XXX company				
FMEA No: 01								Date: 20/12/2014				
Component	Function	Failure Mode (s)	Effects	Sev (S)	Occ (O)	Failure Causes		Controls	Dt	SxO	RPN	Recommended Actions
						Potential Reasons	Occ					
Ball Joint (s)	Support Deck weight, connects deck to BLS	Fatigue Corrosion Bending and Axial compression	Cracks, Misalignment, Collapse of the entire structure, Fatality.	7	2	Faulty Design, Manufacturing defect, Biological, Environmental factors, Improper lubrication.	3	Routine checks and adoption of proper standards	5	14	70	-Rigorous Testing Required -Proper Lubrication Required -Proper Material Selection
BLS	Provides Buoyancy	Bending Torsion Corrosion Fatigue	Instability, Overturning, Submerging, Fatality	6	2	Environment factors, Design and Installation errors.	3	Check BLS design and buoyancy properties	5	12	60	-Proper Inspection Required -Ultrasonic Welding required to avoid welding flaws
Risers	Houses drill string and holds drill bit	Fatigue Corrosion Bending Buckling	Oil spillage, affects operation.	5	2	Direct exposure to the sea, operation effect, hydrodynamic loading.	6	Routine checks and maintenance before each operation	4	10	40	-Proper Material Selection Method -Adherence to Safety standards -Routine checks to detect failure initiation
Tether (s)	Provides Tension	Fatigue Corrosion Snapping	Instability	3	3	Manufacturing defects, Environmental factors, Accident.	3	Check weaving uniformity & material properties	4	9	36	-Installation of sensors to send signals to approaching objects -Proper Material Selection -Proper Manufacturing Skills
Drill String	Suction of Hydrocarbon	Fatigue Torsion Corrosion	Oil Spillage, Consume more energy.	5	2	Operational errors, substandard materials.	6	Proper lubrication and proper checks	3	10	30	-Adherence to Safety Standards -Routine Checks Required for failure detection
Derrick	Holds riser during drilling	Fatigue Corrosion Collapse	Collapse, Closure of entire operation, and Fatality	7	2	Environmental factors, Poor material selection, faulty Design.	2	Routine checks and maintenance	2	14	28	-Adherence to Manufacturing Standards -Proper Inspection to detect failure initiation -Anti-Corrosion Coating Required
LNG Tank	Stores Hydrocarbon	Buckling Corrosion	Leakage, Explosion,	6	2	Poor material selection Pressure gauge failure	2	Proper gauge installation	2	12	24	-Proper Material Selection -Proper Coating against Corrosion

Table 3: Failure Mode and Effects Analysis (FMEA) of Offshore Triceratops

3. Discussion

As shown in Table 3, the Risk Priority Number (RPN) is obtained from the product of occurrence (O), severity (S) and detection. The value assigned for each component is based on the likelihood of their outcome which can eventually amount to failure. The following colours represent the order in which failure can be categorised as presented in Figure 3.

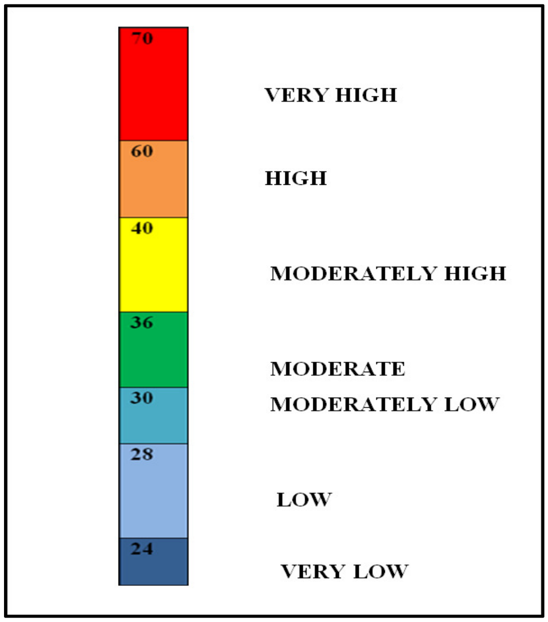

Figure 3: A Key Signifying the Failure Rating of Offshore Triceratops Using FMEA

Due to the effects of variable loads such as wind, wave, hydrostatic and hydrodynamic factors etc. acting on offshore structures, the effective performance of these structures tends to lessen overtime. However, research undergone in this project reveals that the trend of future offshore structure is towards ultra-deep waters. Offshore Triceratops as a new innovation has good characteristics in terms of operating depth of 14000 feet, relatively low cost, excellent buoyancy and stability characteristics except for transit speed compared to drill ships. Due to the uncertainty involve in determining the durability and reliability of offshore Triceratops, FMEA was carried out on each functional parts. The Result shows the highest risk priority number (RPN) as 70, assigned to the ball joint followed by BLS assigned as 60 with the RPN ranked as high. The riser is assigned number 40 with the RPN ranked as moderately high and RPN for tethers assigned number 36 with the likelihood of failure ranked as moderate, implying that the probability of failure occurrence in this component is may not be often. This is followed by drill string and derrick as shown in Table 3 above. However, the least RPN assigned is 24 and this designates LNG tank. This implies that the ball joint has the highest likelihood of failure followed by BLS, while LNG tank has the least possible tendency of failure as shown in table 3 (but the ball joint can hardly fail in strict design application). Following the FMEA methodology in this study, the higher the RPN the more likelihood of failure and RPN of 70 in this case is critical enough to subject the entire offshore Triceratops to failure if the performance is compromised by design considerations, the harsh environment or abandonment due to lack of routine checks.

4. Conclusion

Offshore Triceratops when compared to conventional drill ships and semi-submersibles in this work has been identified as future offshore structure with huge potentials to thrive in ultra-deep waters for a number of reasons such as better motion characteristics (than even the highly rated semi-submersibles and drill ships), low cost and the re-gasification unit which are the major factors differentiating it from every other conventional offshore structures. Furthermore, FMEA which was the model adopted for assessing the functional parts of the offshore triceratops reveals that the ball joint which is connected to a shaft is more likely to fail if routine checks are not carried out, and failure of the ball joint (which the entire weight and support of the structure is depended upon) may likely result in accident such as collapse of the structure due to the harsh sea environment which is accompanied by intense tidal wave, corrosion, fatigue etc. Hence, frequent maintenance and checks of the functional elements of the structure must in no account be ignored in order to ascertain the longevity, integrity, and performance of the structure.

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