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Design, Fabrication and Installation of Spar Platforms for Ultra Deepwater

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1. Introduction

A new compliant structure being designed and developed for deepwater offshore drilling and production is called a spar platform (Figure 1). The basic form of the spar consists of a deep-draft cylinder, vertically floating structure with a fully compartmented upper section (hard tank) that is buoyant and lower sections (soft tanks) that are flooded. The hull uses standard ship-type plate and stiffener construction and contains an open center well (moonpool) for drilling or production of oil and gas. Station keeping is provided by lateral, catenary anchor lines, which are attached to the hull near its center for low dynamic loadings. Because of the very favorable interaction of the spar hull and mooring system, a spar uses a taut catenary system of chain and wire. The taut mooring system is much shorter than conventional full catenary arrangements.

Using the normally flooded center section, a spar can be configured for oil storage. Since the size of the hull is usually proportional to the topside payload and the corresponding production throughput, the hull can store an 8 to 10-day supply of oil without increasing the diameter or draft for this purpose.

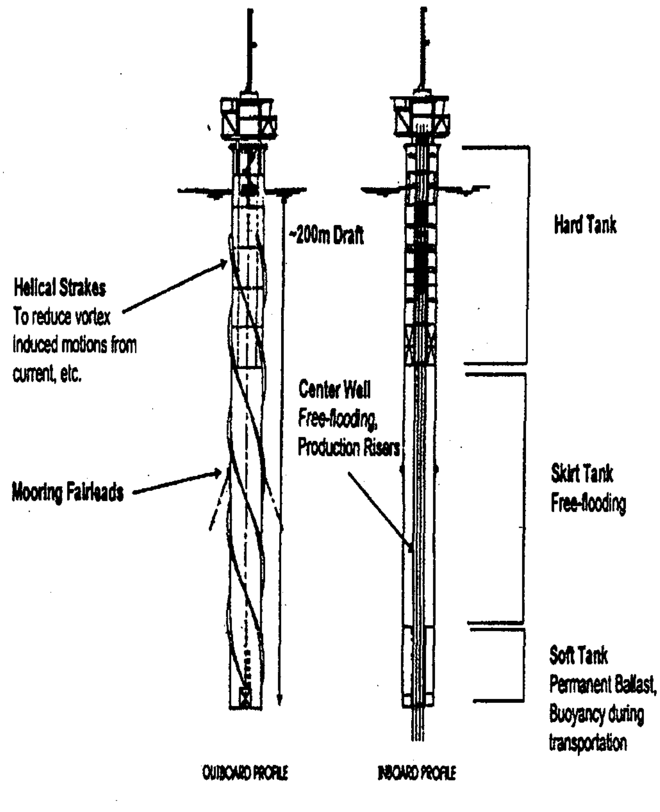

Fig.1 Typical caisson type spar platform

2. Characteristics of Spar

The spar platform has a unique shape compare to other type of offshore platform. Followings are summarized items of characteristics of spar platform.

- Floating production and drilling structure

• Application in water depth up to 500 m - 3,000m
• Production deck supported by a single deep draft caisson hull
• Center well for drilling and production riser
• Hull dimensions range in diameter from 22m to 50 m, length 240m with a draft of 200m

Advantages of the concept include the following item.

• Large payloads and flexibility for future facility enhancements
• Excellent motion properties due to deep draft and small water plane area Tn = 30–40 seconds
• Cost relatively insensitive to water depth
• Flexibility in mooring configurations
• Hard tank : Provide buoyancy to support the topside and provide space for variable ballast
• Heave plates and soft tank: reduce heave motions by increasing added mass and damping and support risers

3.0 Design Considerations of Spar

The following illustrates how design approach could be used in design. An important design parameter for a spar is the global system designs. The design steps involved are:

3.1 Design Planning

• Design spiral
• Operational requirements
• Environmental considerations
• Seafloor characteristics
• Global systems design
• Fabrication and installation
• Materials and welding
• Safety and reliability
• Codes, standards and regulations

3.2. Design Criteria

• Operational requirements for the drilling, production, and maintenance
• Stability requirements free-floating, in-place, intact, damaged
• Environmental load criteria
• Safety criteria and load types

3.3. Environmental Loads

• Wind loads
• Current loads
• Wave loads
• accidental loads

3.4 Global Design and Analysis

The global analysis is to get the motion, which are to be used in scantling and preliminary buckling calculations. The global stress levels of the spar structures are to be calculated based on the self-weight of the structure and global moment envelope. Section modulus of the each individual hard tank ring section is to be calculated by computer program.

• Extreme responses offset, yaw, min. and max. tension deck clearances etc.
• Response for fatigue analysis joint wave height/period statistics, frequent domain
• Hydrodynamic loads for hull design hydro-static, squeeze-pry racking, slamming towing
• Static and mean response analysis steady offset and set-down due to wave, wind and current
• Equations of motion and solutions six

degrees of freedom, surge, sway, heave, pitch, roll, yaw

• Random process statistics probabilistic design to provide rational methods for event

• Hydrodynamic model tests calibration and verification

3.5 Structure Design Method

The design steps involved are:

Step1: Input data required

• Basic data (overall dimensions, weight and cog. deck spacing)

• Environmental data (wave, wind, current)

• Mooring data (mooring arrangement, chin braking load, mooring load dist.)

• Riser data (riser arrangement and lodes)

• Topside data (mainframe arrangement, weight, inertia and cog. topside reactions)

• Ballast tank configuration

• Fixed ballast arrangement

• Caissons arrangement

• Upending sequence and loads

Step 2: Global strength calculation

Step 3: Classification drawings

Step 4: Calculation of scantling, buckling and Hydrodynamic loading

Step 5: Global finite element analysis (FEA)

Step 6: Final buckling analysis

Step 7: Local finite element analysis

• Topside leg connection to the hull

• Chain jack foundation structure

• Fairlead foundation structures

• Hard tank interfaces

• Splash zone area

• Riser/hull interfaces area

• Details risen up from global FEA

Step 8: Fatigue analysis

• Global fatigue analysis

• Local fatigue analysis

Step 9: Transportation analysis

3.6 Fatigue Damage Methodology

• Develop stress RAO's from global finite elements model and detailed submodels

• Submodel mesh near crack points

• Multiple wave directions

• Multiple frequencies - in and out-of-phase positions

• SCF's for misalignment or other factors

• S-N curves

• Spectral calculations with directional scatter data

• Safety factor = 10 for uninspectible area and safety factor = 3 for other area

3.7 Mooring System Design

The mooring system is designed with the capability to move the spar in any direction to a new drilling location, and to return back to its initial position, and than to hold the spar in position during design environmental conditions.

• General design procedure, sizing, stress analysis, fatigue, model test

• Design loading conditions load types, loading conditions (extreme, normal, etc.)

• Load analysis methods frequency/time domains hydrodynamic, seismic analysis

• Structural analysis methods stress analysis, fatigue analysis, inspection interval election

• Structural design criteria allowable stress, hydrostatic collapse, fatigue life, inspection

• Fabrication, installation procedures, operational procedures, corrosion protection, inspection and maintenance

• Traditional combination wire or chain

catenary and taut-leg systems

- Polyester rope is a developing alternative
- Number of lines vary from 6 to 20
- Moorings are preset prior to arrival of the platform.
- Anchoring by driven or suction piles
- Mooring lines typically terminated via chain jacks

4.0 Fabrication of Spars

During fabrication phase of the spars, the builder ensure that enhanced safety level, highest quality and effectiveness of schedule and focuses on the critical matters to be raised. The erection sequence, block lifting method and dimension control procedure to be provided by the builder.

4.1 Erection Sequence

The erection process and fabrication flow from plate cutting to the completion of the hull. The capabilities of shop production and yard construction the list of equipment to be used for such purpose is indicated under general description of the fabrication yard.

The erection sequence and block divisions are shown in the below for example:

- Spar block division and weight
- Hull fabrication and erection flow
- Sub-block fabrication and assembly in shop
- Block assembly at yard
- Hull erection sequence: hull tank
- Hull erection sequence: truss and soft tank

4.2 Block Lifting and Mating Method

To meet the dimension tolerance during the construction phase, the cranes can lift the weight up to approximate 3,000ton. For the block lifting exceeding 2,000ton weight, It will be mobilized a heavy lift system, that is mainly comprised of heavy lift towers.

The lift and hull mating procedure will contain the design criteria and operational considerations as follows ;

- Lift preparations
- Design aspects of lower part skidding, lift and & post-lift operation
- Organization & communications
- Operating procedure
- Lift system description
- Dimension monitoring and control
- Hazard plan
- Weather forecast

In addition to above, detailed data, calculations and manuals shall be prepared by the builder.

4.3 Dimensional & Tolerance Control

In order to obtain the high quality spar, builder will prepare the procedure to assure the dimensional tolerances of plate, rings, sub-block, block and the complete structures as specified in the drawings, during fabrication phase, specification of the clients and the ship class codes on a timely basis.

In addition, actual execution plan such as organization, process record sheets, check points, record forms and so forth will be contained in the further developed procedure.

4.4 Material and Welding Issue

- Design code
- Additional company specification
- Special materials may require proprietary welding procedure specification (WPS)
- WPS and procedure qualification record

(PQR) maps to provide to ensure scope of qualifications are completely met

- Material traceability system to put in place
- All materials except those not subjected to structural loading to be traceable to mill material certificates
- System will be audited periodically both by client and class representatives

4.5 Fit-up and Construction

- Early plate beveling of thick plate to avoid flame cutting at assembly stage
- Reduction of weld defect risk
- Special attention to fit-up inspections of large blocks
- Alignment
- Edge preparation
- Allowable fabrication tolerances contained in design and specification

4.6 High Stressed and Fatigue Sensitive Areas for Spars

Special attention for such area as followings:

- Anchor leg chain stopper structures foundation area
- Chain jack foundation structures
- Fairlead foundation structures
- Deck and spar body and column interface structures
- Truss and hard tank interface structures
- Anchor piles

5.0 Transportation and Installation

The analysis of spar, transportation vessel and process of the installation is made based on ship class requirement. After complete the spar, following items will be checked and confirmed by ship class and code requirements.

- Ship class is not warranty surveyor
- Spar can be transported by heavy lift ship in one piece (shorter overall length)
- Ship class reviews transportation for the peak loads and fatigue imposed on the structures under limiting sea slates
- Ship class will survey and tie-down to ensure no damage is sustained
- Load-out by skidding-precautions
- Skid foundations continuity and stability
- Transportation barge ballasting and deballasting to receive the structure load
- Tie-down points to be in accordance with approved design
- Welding of tie-down and inspection
- Transit damage surveys of anchor foundation equipment
- Position and orientation checks
- Pile monitoring and data gathering
- Paying out and mating of anchor legs
- Anchor leg proof load testing as required
- Conduct transit damage surveys prior to commencement of installation for spar
- Launching operations in accordance with approved procedures
- Up-righting in accordance with approved procedures
- Hook-up and tensioning of anchor legs
- Final position checks.
- Mating of deck with spar body
- Hook-up and commissioning item list

6.0 Conclusions

Through this paper the spar system that compared to other systems, has been excellent motion and cost relatively insensitive to ultra deepwater depth, when subjected to the offshore environment and be able to understand.

1.The spar platform will dominate over 1,000m water depth.

2.The spar strength is to be calculated and decided base on the weight of the caisson structure, global moment and environmental conditions.

3. For obtain the high quality of the spar, the erection sequence and dimension control procedure for construction to be provided and distribute to the production department. Its very important things for the work commence stage.

4. The welding of the high stressed and fatigue sensitive area shall paid attention specially and such areas inspection reports shall be controlled.

5. Taut mooring systems will be used to reduce movement, as water depth increases, external pressure, environmental forces, and longer lengths require thicker, heavier component to limit stresses, which result in larger spar to support the component loads.

6. As regards, the installation of spar, to take advantage of the lifting capacity of the barge, the topsides should be designed minimize the quantity of lifting blocks rather then as a series of four or more smaller modules. The reason for constructing the deck in this way is to minimize the number of lifts, the effort expended in offshore hook-up, and to allow for even weight distribution during the installation process.

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