Truss Spar Platform Design

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Abstract

The Happy Cat prospect is located in Green Canyon Block 782 approximately 100 miles south of New Orleans, Louisiana in 5,100 feet of water. Two exploratory wells have been drilled to delineate the reserves in the area and expected recovery volumes are near 350 MMboe. The subsequent development will employ a combination wet and dry tree truss spar based floating production facility with an initial production capacity of 120,000 boed. The design will include a topside design similar to the Lucius project topside with oil production through two full production trains.
Existing spar platforms were reviewed in order to attain the initial sizing. This information was be input into the preliminary design model and revised through the design spiral, as necessary. Metocean conditions and forcing at the installation site were determined. Designs of platform components include the hard tank, soft tank, truss system, heave plates, helical strakes, mooring system, suction piles, and cathodic protection.

What is a Spar?

- A type of deepwater floating oil production platform currently in operation around the world. This type of platform is safe, cost effective, proven design.
  - **Topsides**
    - Above the waterline. Holds the production equipment and the crew quarters
  - **Hard Tank**
    - Provides buoyancy, space for variable ballast, storage, and supports topside facilities
  - **Truss System**
    - Connects hard tank to soft tank. Increases structure length, increasing stability
  - **Soft Tank**
    - Holds heavy fixed ballast, lowering the center of gravity and providing stability
- When compared to other platform designs:
  - A proven design with 13 currently operating in the Gulf of Mexico
  - Unconditionally stable – very safe
  - Functional and adaptable to different production methods
  - Scalable to a variety of production requirements

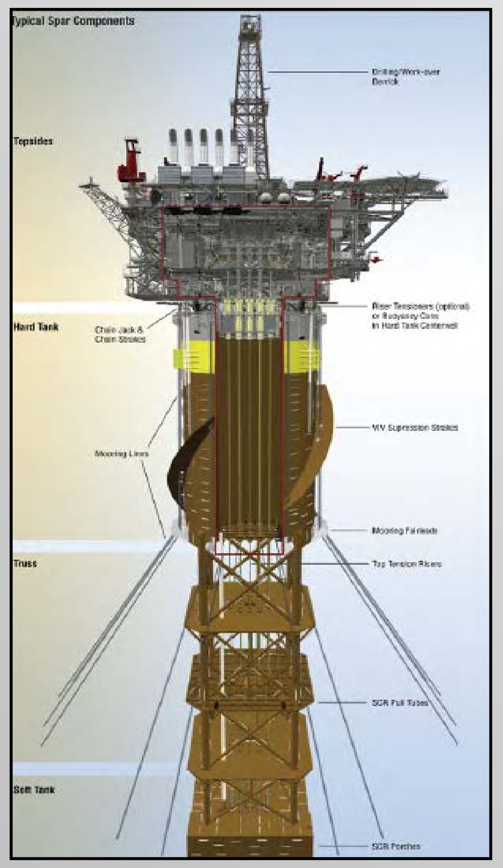
Figure I. Truss Spar Layout (SPE)

Project Location

- 100 miles south of New Orleans, Louisiana in Green Canyon Block 782
- Upper Continental Shelf – north of the Sigsbee Escarpment

Figure 2. Platform Location in the Gulf of Mexico (Google)

Metocean Design Criteria

American Petroleum Institute (API) provides hurricane design parameters for the Gulf of Mexico. This specifies the wave, wind, and current conditions for which the platform must be designed. As the industry's knowledge of hurricanes becomes more developed, evidence is showing that there is a regional dependence for large wave-making storms in the Gulf of Mexico. The parameters and loading states developed by API are region specific and take into account HURDAT hurricane hindcast data from 1950-2015.

After looking at the API data, site specific metocean data was consulted. NOAA NDBC buoy #42041 near the platform installation site was selected. This buoy had 5.33 years of data consisting of data taken at 1 hour intervals. After looking through this data, several wave heights above the API recommended values were observed. At this point a waves analysis campaign was launched to determine a new design wave height for the installation location.

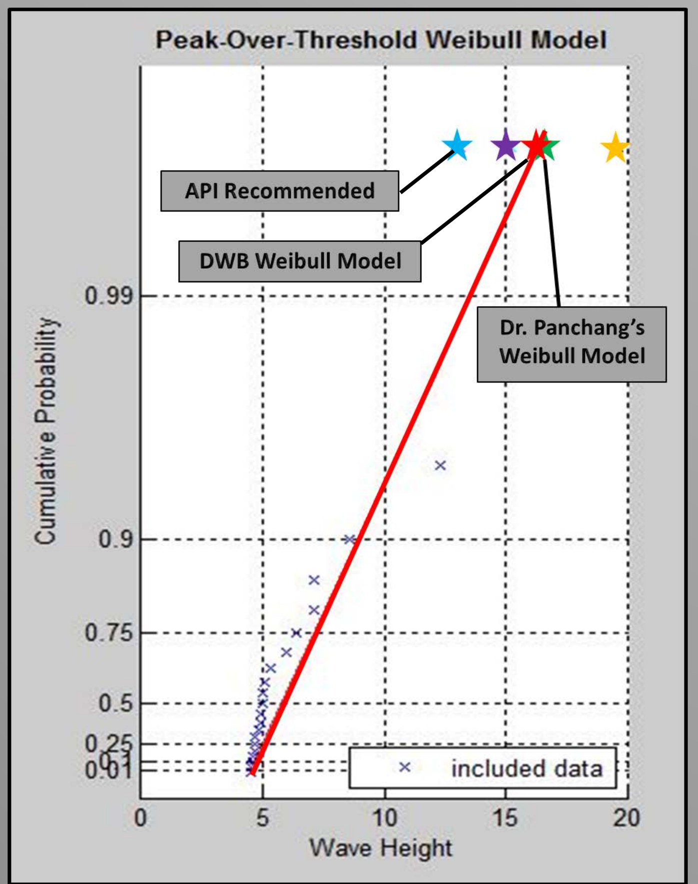

Figure 3. Weibull Model

A Three Parameter Weibull Distribution was used:
- Based on 5.33 years of buoy data
- Peak over threshold methodology
- Models created for weekly, daily, and hourly waves

Wave Height Comparison		
	$H_{s\,100}$ (m)	$H_{MAX\,100}$ (m)
Weibull Model	16.4	26.3
API Recommended	13.1	20.9

Table 1. Wave Height Comparison

Hydrodynamics

The hydrodynamic analysis was done in Sesam HydroD. A WADAM analysis was done to generate forcing on the structure and displacement RAOs. WADAM analysis performs a frequency domain radiation and diffraction analysis on panels combined with Morison forces on Morison elements.

The resulting maximum force was found to be in the pitch direction at 23 million pounds. The dominant wave period of the spectrum is 13.2 seconds or 0.475 rad/s. At 0.475 rad per second the Heave RAO is approximately 0.038. The Pitch RAO at the same frequency is 0.013. The responses due to these RAOs for the 100 year storm is 2.03 ft in heave and 4.12 degree is in pitch. The responses in Heave and Pitch are below the set design criteria of 7 ft in Heave and 5 degrees in Pitch.

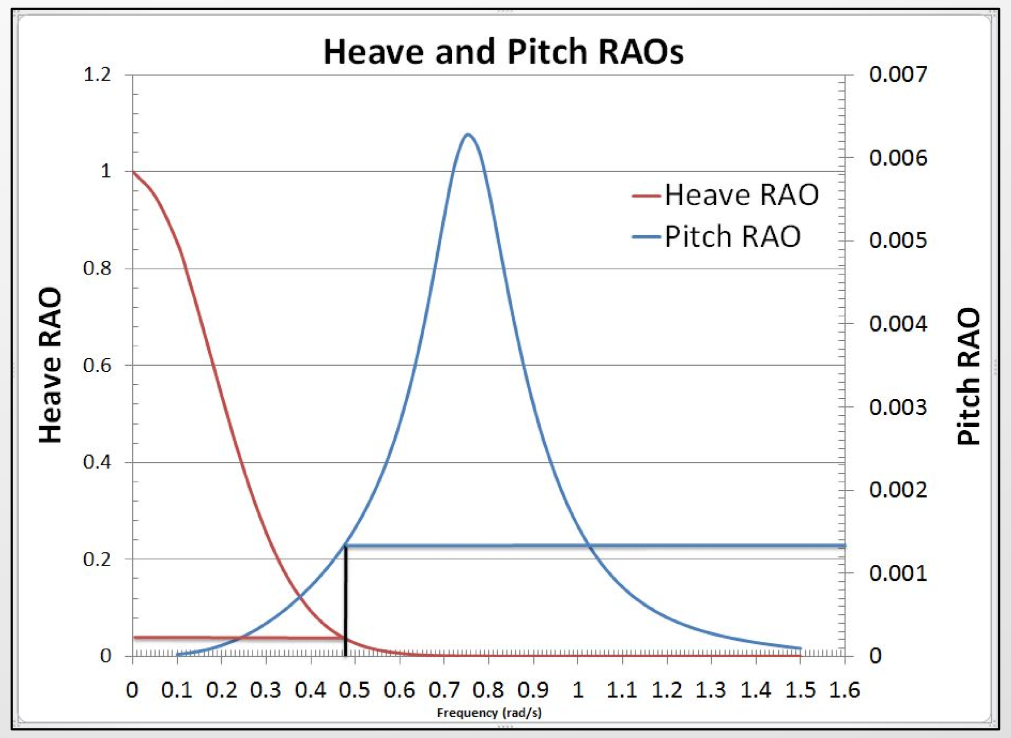

Figure 4. Heave and Pitch RAOs

Hull Design

Hard Tank

The hard tank was designed as a cylindrical flat plate shell according to API BULL 2U. This code designs plate thickness and stiffening members based on axial compression and external pressure in local, bay and general buckling. The structural reinforcement in the hard tank includes L-shaped longitudinal and ring stiffeners in addition to webs and watertight bulkheads. The hard tank will be assembled in 7 40' tall ring sections for a total height of 285'. The ring assembly methodology is shown in Figure 6 to the right.

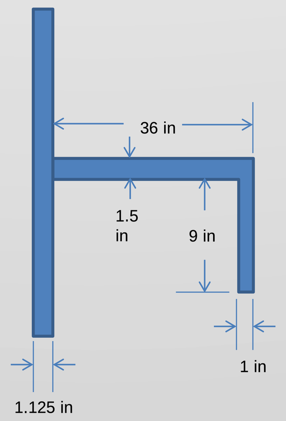
Figure 6. L-Shape Stiffener

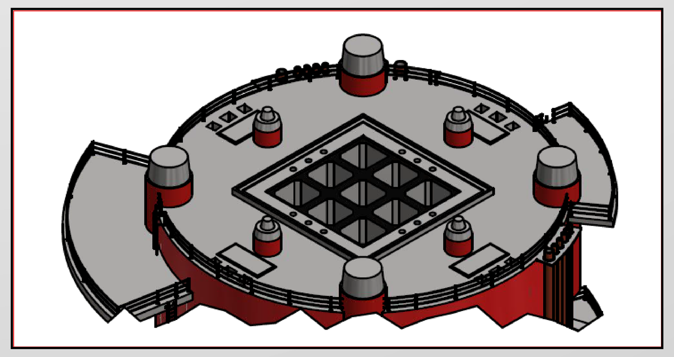
Figure 5. Topside Support Nodes on Hard Tank

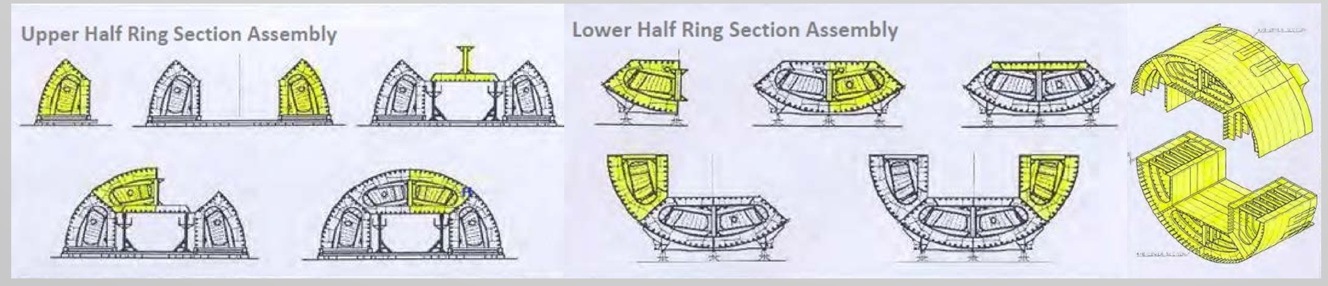

Figure 7. Hard Tank Mating Methodology (SPE)

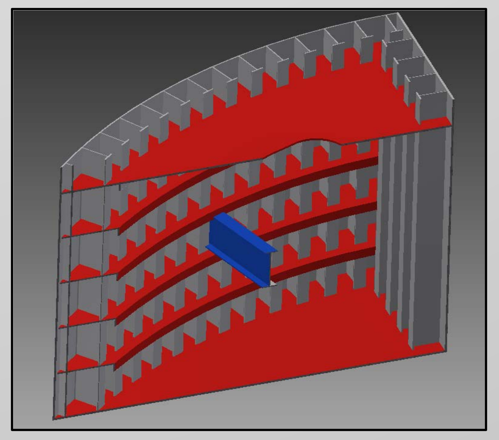
Figure 8. Hard Tank Section Design

Truss System

On a truss spar, the midsection of the hull is constructed of a space frame truss system similar to a fixed jacket structure. This serves as the structural link between the hard tank and the soft tank. It also provides lateral support to the top-tensioned risers, steel catenary risers, and umbilicals. It consists of vertical main legs (chords), horizontal braces, X-braces, and heave plates.
The design practice for the truss system is based on the API RP 2A WSD allowable stress design for cylindrical members. This analysis considers axial tension & compression, buckling, bending, shear, hydrostatic pressure. Combined stresses are also considered for this analysis. The heave plates increase damping in the structure by increasing the added mass, a stress analysis had to be done in order to verify the strength.

Soft Tank

The structural design of the soft tank began by estimating the supports using a tank boundary formula found in ABS Rules for Building and Classing Floating Production Installations 2013. After this initial estimation, a stress analysis was done using API Bulletin 2V – the design for flat plat shells.

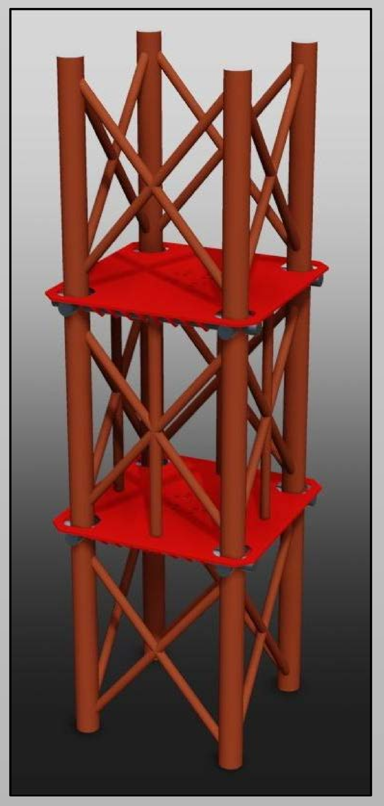
Figure 9. Truss System


Figure 10. Heave Plate and Soft Tank

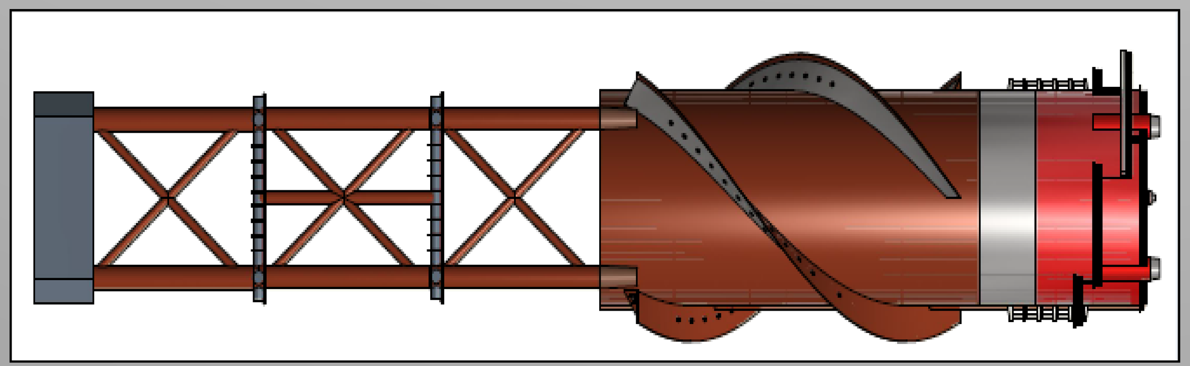
Figure 12. Assembled Spar Platform Components

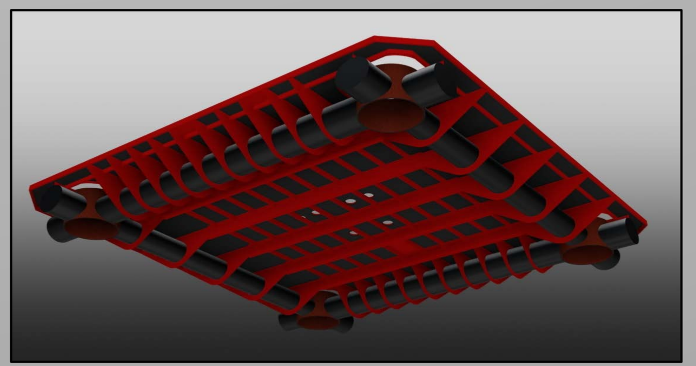
Figure 11. Heave Plate Stiffener Arrangement

Cathodic Protection

Designed according to DNV-RP-B401. The code sates different performance criteria for different climatic regions. The spar's location is classified as Tropical. A Tropical region is defined by the code as a region with surface water temperatures greater than 20° Celsius. To design the cathodic protection there are three main perimeters that determine the required protection, sea water temperature, salinity, and surface area to protect. The total weight of anodes needed for the spar is approximately 300,000 lbs. The anode type selected are Aluminum based log slender standoff anode. The design requires there to be 628 anodes. Each anode is 108i"x 8"x 8i"and will weighs approximately 540 lbs.

Helical Strakes

Spar floating production platforms use helical strakes to reduce the effects of current induced vortex induced motions (VIMs) (Truss Spar Vortex Induced Motions). These strakes work to alter the longitudinal flow separation angle and reduce the intensity of the vortices shedding off of the hull (Performance Comparisons of Helical Strakes for VIV Suppression of Risers and Tendons). Because the technology is still relatively new and there are little known numerical solutions to evaluate the performance of the strakes, so model tests are required to evaluate strake performance.
In order to reduce the effect of vortex induced motions, the natural period of the structure must be as far from the period of the vortex motion as possible. Computational fluid dynamics modeling was done for comparing a model with and without strakes

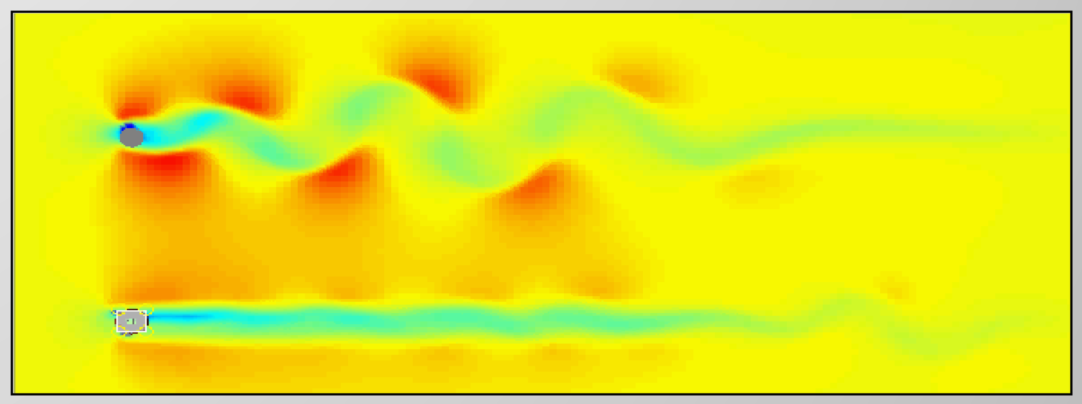
Figure 14. VIM Comparison With and Without Strakes

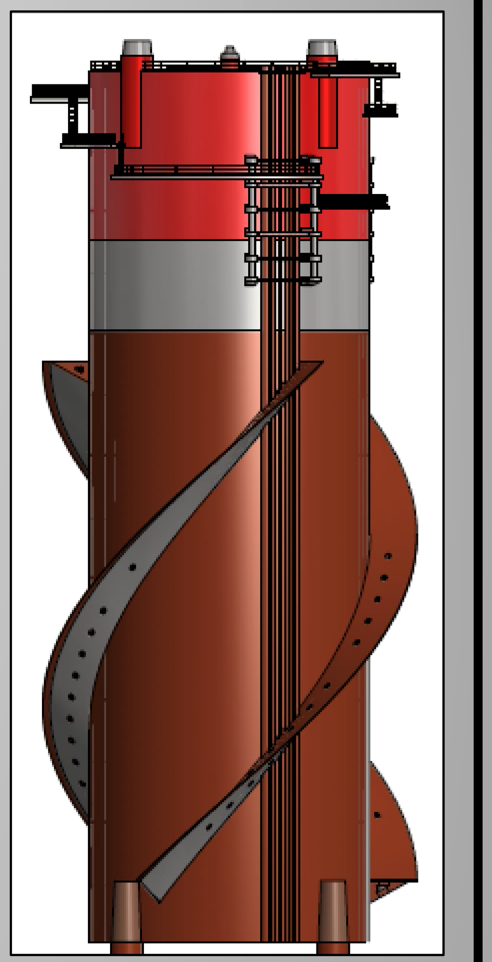
Figure 15. Strake Design

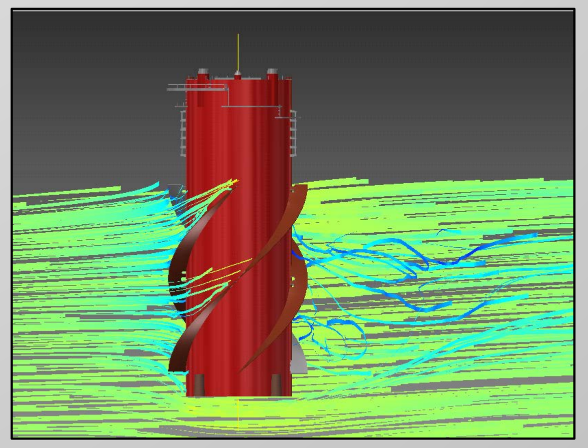
Figure 16. Modeling of Strake Effectiveness

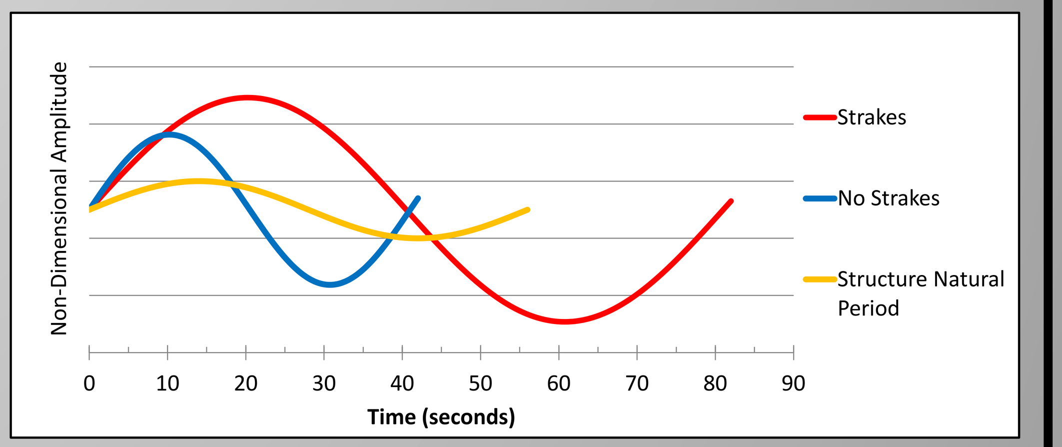

Figure 17. Plot of Natural Period of Spar, VIM Motion with Strakes, and w/out Strakes

Mooring System

The station keeping system for the platform was designed to last the life of the structure. This system is a permanent catenary spread mooring using nine mooring lines placed in a 3x3 pattern. These lines consist of a chain-polyester-chain configuration with an overall length of 10050 feet, 8050 feet of Bexco DeepRope and 2000 feet of Studlink chain ABS Grade R3.
A quasi-static and dynamic analysis was performed to verify the strength and environmental loads of 100 year peak wind, wave, and current were calculated. The tensions in the lines came out to be 1291 kips (Thousand lbs) in the intact configuration and 1543 kips for the damaged configuration with one mooring line broken. These stresses are less than the max breaking strength with safety factors.
Suction anchors were also designed for the station keeping system. These anchors are embedded into the sea floor and must resist an pull-out force equivalent to the maximum breaking strength of the mooring lines. These anchors were designed according to API RP 2A WSD and API RP 2SK.

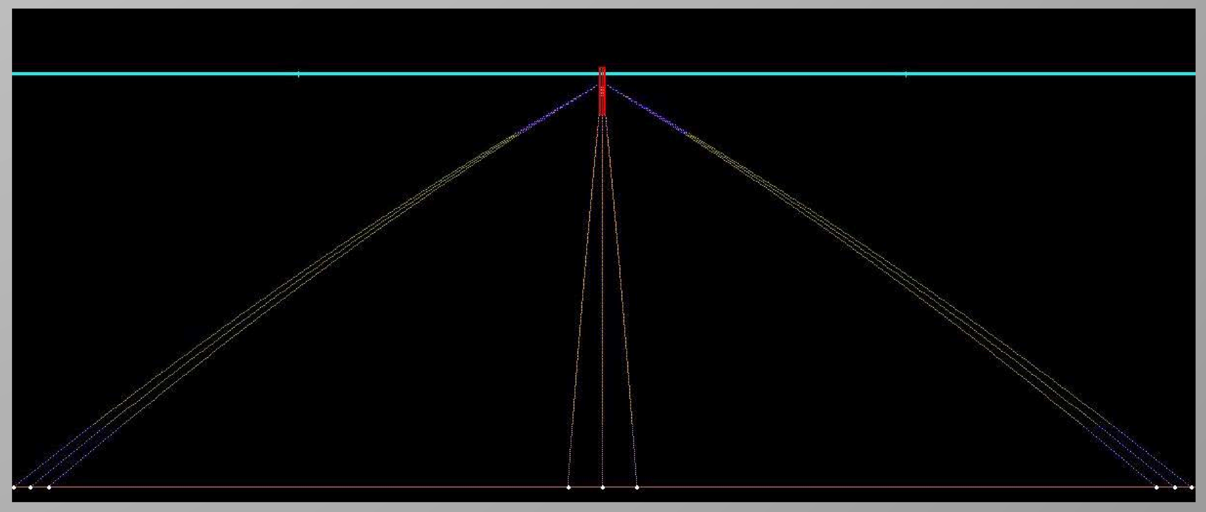
Figure 18. Mooring Line Layout

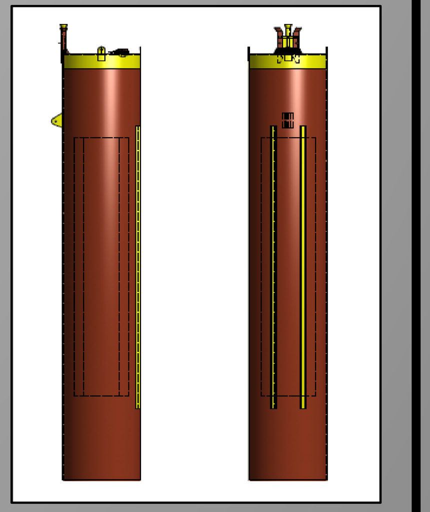
Figure 19. Suction Anchors

Conclusion

The preliminary design of a truss spar platform has been completed. As current sources of oil and natural gas in the Gulf of Mexico are consumed, new sources must be developed in order to maintain a steady oil supply given the current demand. The truss spar has proven to be a feasible design, both technically and economically, to develop subsea oil deposits into production.

References

SPE. Expanding Facilities Knowledge Workshop – Offshore Concept Selection. An Overview of Offshore Concepts. FloaTEC.
Truss Spar Vortex Induced Motions. 2006. 25th International Conference on Offshore Mechanics and Artic Engineering. OMAE2006-92673. Print.
Performance Comparisons of Helical Strakes for VIV Suppression of Risers and Tendons. 2004. Shell Global Solutions. Conference Paper. Offshore Technology Conference. Print.

Reference Codes

API RP 2A WSD – Recommended Practice for Fixed Offshore Platforms – Working Stress Design
API Bull 2U – Design of Cylindrical Plate Shells
API Bull 2V – Design of Flat Plat Shells
API RP 2SK – Design and Analysis of Stationkeeping Systems for Floating Structures