Computer Aided Design of FPSO Vessel for Deepwater Operations

by

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CERTIFICATION OF APPROVAL

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Approved by,

(Assoc. Prof. Dr. Fakhruldin B M Hashim)

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

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CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

AMIR ZHAFRI BIN ELLIZA

ABSTRACT

Due to the unavailability of Floating, Production System and Offloading (FPSO) design library in PETRONAS, extensive iterative process is typically being implemented in concept design and selection process. Such exercises are based on a structured approach to meet specific criterion. Determination of specific parameters with respect to scaled model testing is not always simple and straightforward as it involves experimental testing as well as cross referencing between numerical analysis. For this project, the objective is to develop a computer aided design (CAD) model of an FPSO vessel by initiating an FPSO CAD model library in order to eliminate some of the iteration in concept design and selection. Besides that, this project aims to analyze the motion behaviour of an FPSO vessel for the expected operational load condition. The focuses of this project are on acquiring details of an FPSO vessel and producing a model of the vessel using CATIA V5R12. Included in the scope of work is; conducting motion analysis of the FPSO vessel. The design library is expected to be achieved through literature review, calculation, part design and assembly design for CAD model development, and analysis and data generation. The result of this project is likely to give an instant value for engineers to review the dimension chosen for the FPSO as well as the motion behaviour of the vessel. In addition, it is expected that the results to be a basic assumption for the FPSO's design calculation for weight and stability analysis.

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

For many years, floating productions systems have been operated in inaccessible offshore areas without a pipeline infrastructure. However, they have become even more essential with the push by the offshore industry into ever deeper waters. Floating Production, Storage, and Offloading (FPSO) systems have now become one of most commercially practical concepts for remote or deep-water oilfield developments. It is becoming one of the most attractive alternatives to conventional fixed platform field development. However, problems are still arising even though their abilities are showing good consistency. To overcome those problems, new ideas about FPSO systems have been in focus as projects started working in aptly FPSO design direction.

1.2 Problem Statement

Front End Engineering Design (FEED) is performed after conceptual design or feasibility study has been conducted. In designing offshore floaters, concept design and selection is a critical stage in FEED. Such an exercise is based on a structured approach to meet specific requirement or criterion. In PETRONAS, the unavailability of offshore floaters design library is the reason that extensive iterative process is typically being engaged in such in exercise. For this project, specific parameters will be determined with respect to scaled model testing besides developing the offshore floater design.

1.3 Objectives

The objectives of this project are:

1. To develop a CAD model of an FPSO vessel by initiating an FPSO CAD model library for future design selection work in order to eliminate some of the iteration in concept design and selection.

2. To analyze the motion behavior of an FPSO vessel for the expected operational load condition.

1.4 Scope of Study

In this project, the focuses are on

1. Acquiring details of an FPSO vessel and produce a model of the vessel using CATIA V5R12.

   CATIA V5 is chosen as it represents the modern CAD tool available regarding programming concepts and data structures [1].

2. The chosen parameter that will be varied is the cargo loading condition.

3. The stability will also be analyzed by draft values, weights and centre of gravity.

   It will be a quick stability analysis for the FPSO model.

CHAPTER 2

LITERATURE REVIEW

2.1 Computer Aided Design (CAD)

Computer-Aided Design (CAD) is the use of computer software and systems to draft, model, and edit architectural or engineering designs. Tedious manual drafting process is replaced with an automated process by using the CAD programs. There are two types of CAD software that are widely used by engineers and designers; Two-dimensional CAD software and Three-dimensional CAD software. Two-dimensional CAD software is used for basic drafting and drawing applications while designers are able to apply multiple light sources such as rotating objects in three dimensions, and viewing designs in rendered form from any angle with the Three-dimensional CAD software [2].

According to Haresh Khemani, implementing CAD systems increases the productivity of the designer as they assist designers in visualizing the final product that is to be made. Designers are also able to synthesize, analyze and carry out documentations of the design. Besides that, using the CAD software improves the quality of the design as the numerous offered tools helps designers in executing engineering analysis of the proposed design. Another advantage of using CAD software is that the documentation of designing can be created conveniently. Apart from that, designing data can be saved easily with CAD software for future reference. This reduces the usage of time and money as certain components do not have to be redesigned [3].

Several industries and practices have been revolutionized with the help of knowledge sharing through the online communities. Other than the CAD library of products and services offered by industrial suppliers, support is also available from professionals who can offer advice. The field of knowledge and capabilities of the computer drafting environment has expanded by the Internet's collaborative nature. On the whole, almost every engineering discipline such as Civil Engineering, Mechanical Engineering, Electrical Engineering, Electronics, Engineering, Architectural Engineering, Aerospace, Automobile, Manufacturing, Production, Plumbing, Piping, and HVAC find CAD drawings and a CAD library essential [4].

2.2 Floating Offshore Structures

Humankind has been able to efficiently extract petroleum from beneath the seas only in the last 40 years. The search is not only difficult and extremely expensive, but it is often unproductive. However, it is crucial to the nation's economic future. In the beginning, a derrick is simply fitted to a barge before it is being towed to the site. Nowadays, there are various types of floating offshore structures that are used to drill wildcat or exploration wells as well as to process oil and gas before exporting the products to shore [5].

Table 1: Characteristics of Floating Offshore Structures

Floating Offshore Structure	Characteristics
Semi-Submersible  [Picture taken from www.energyindustryphotos.com]	- Obtains buoyancy from ballasted, watertight pontoons located below the ocean surface and wave action. - Less affected by wave loadings than a normal ship - Sensitive to load changes, and therefore must be carefully trimmed to maintain stability. - Able to transform from a deep to a shallow draft by removing ballast water from the hull [6].
Tension Leg Platform (TLP)  [Picture taken from www.oceanexplorer.noaa.gov]	- A buoyant platform held in place by a mooring system. - Vertical movement is restricted by the tension leg. - High axial stiffness (low elasticity), such that all vertical motion of the platform is virtually eliminated.

Drillship  [Picture taken from www.blog.energytomorrow.org]	- Ordinary ships that have a derrick on top which drills through a hole in the hull. - Either anchored or positioned with computer-controlled propellers along the hull which continually correct the ships drift. - Often used to drill wildcat wells in deep waters.
FPSO  [Picture taken from www.bumiarmada.com]	- Typically ship-shaped - Stores crude oil in tanks located in the hull of the vessel - Can easily be relocated to another field at less cost

These floaters have commons elements although they come in different sizes and shapes as well as have different functions [7]. Those elements include:

- Hull – steel enclosure that provides water displacement. The hulls come in various shapes such as; ship shapes, pontoons and caissons, or a large tubular structure called a spar.
- Topsides – the deck which consist all the production equipment used to treat the incoming well streams. Pumps and compressors needed to transfer oil and gas to next destinations. The export lines are connected to the deck. Usually, topsides include living accommodations for the crew.
- Mooring – the connection to the seabed that keeps the floaters in position. Some combine steel wire or synthetic rope with chain and some use steel tendons. In some cases a huge footprint is installed on the seabed floor.
- Risers – steel tubes that rise from the sea floor to the hull. A riser transports the well production from the sea floor up to the deck.

2.2.1 Floating Production, Storage and Offloading (FPSO)

According to Yoshihide Shimamura [8], offshore oilfield developments have been moving toward deeper water and more distant areas. Nowadays, there are even oilfields that are located in water depths of over 5000 feet. Furthermore, the development of the smaller oil field is required as the rate of discovery of new huge fields is vastly decreasing. The Floating Production, Storage and Offloading (FPSO) system has the ability to reduce the minimum economic field size, as well as develop these small or remote oil fields in deeper water.

FPSOs are used for processing and storage of oil and gas prior to either offloading it to a tanker, or being transported through a pipeline. The fluid from the undersea oil reservoir is received by the FPSO system via flexible risers through a turret-mounted swivel before it is separated to oil, gas, and water by the process equipment. They are then packaged into modules and secured on the deck of the vessel. The tanks of the vessel are where the separated oil is stored for periodic offloading to a shuttle tanker using a floating hose arrangement. The production facilities of the FPSO vessel are located on deck while large storage tanks are in the hull. Apart from that, the FPSO system has other functional components to ensure safety of the unit during offshore operations. Components such as the mooring system and turret are required to keep the unit in a stationary position. Besides that, the riser system and swivel are required in order to receive the fluid. Safety and utility systems are also essential to maintain continuous offshore operations [8].

There are two main types of FPSOs; the converted oil tanker option and the purpose built FPSO. The converted oil tanker is where a super tanker is converted into an FPSO by installing all the required production and storage facilities on board, while the purpose built FPSO is a vessel originally built with oil and gas production and storage facilities on it. It is known that the conversion of an existing tanker into an

FPSO is more economical and takes less time than a newbuilding. Tanker Conversion requires various multifaceted structural modifications to be made to the hull and structure of the ship. Model tests and Finite Element calculations are performed by the engineers as preparations for all structural and naval aspects of a tanker conversion. As the vessels are positioned in sites with a benign environment, they will still have sufficient strength for a long operational life [9].

According to Rupert Herbert-Burns [10], FPSOs are complex in nature as they are a fusion of vessel and petroleum production function. The main features of the system include;

- the accommodation and helideck superstructure
- production systems located on the upper deck (oil/water/gas separation units)
- storage tanks located in the hull
- mooring system
- off-loading pumping systems
- gas flare tower or boom
- mooring turret (internal or external)

Apart from anchoring the vessel, the turret structures are designed to allow weather vaning of the FPSO in order to accommodate changing wind and wave direction and conditions. They also enable the continuous flow of oil and production fluids from vessel to undersea field wellheads. In the event of an emergency, external turrets facilitate quick disconnection of the main facility [10].

2.3 Deepwater Operations

Deepwater is one of the most important areas of exploration for the oil and gas industry. There are potential reserves exceeding 100 billion bbl of oil underneath the primary deepwater basins such as US Gulf of Mexico, West Africa, and Asia-Pacific. As estimated by industry experts, more than 2,500 wells would have to be drilled during the next three decades to access those hydrocarbons alone [11].

Drilling in the deep water represents challenges far beyond those experienced by energy companies in shallower waters. Drilling platforms with rigid frames attached to the seafloor are cost prohibitive because of the extreme water depths. Operations in deep water must accommodate tremendously high pressures in the cold and dark recesses of the ocean bottom. Energy companies have made huge investments in new technologies to counter these challenges. 3-Dimensional and 4-Dimensional seismic information and advanced computer interpretations are implemented for deep water operations in order to better define drilling targets which then reduces the need to drill costly and unnecessary wells [12].

2.4 Front End Engineering Design (FEED)

Front End Engineering Design (FEED) is a study used to analyze a variety of technical options for new developments with the objective to identify the facilities required [13].

According to Mohammed Samad [14], FEED, also known as Conceptual Design, is the preliminary phase of the engineering project. The purpose of the FEED is to identify the:

- Feasibility of the project
- Costing of the project
- Major equipment required for the project
- Major issues that can arise during the project
- Major deliverables of the project

In general, most of the Oil and Gas engineering projects undergo phases such as Pre-FEED, FEED, Detail Design, Procurement, Construction and Testing and Commissioning. The deliverables of the FEED are used as the stating documents for Detail Design of the project.

The FEED phase consists of two basic elements; a technical aspect and a work process aspect. From the technical aspect, working in cooperation with the plant owner and process designers, the engineering company's organization utilizes its unique combination of technical expertise and product knowledge from its own portfolio of products and that of alternative suppliers. This is to provide the best technical concept definition, project standards, common functional design criteria as well as generic equipment specifications. As for the work process aspect, the FEED phase is also the period when the management systems and specific project plans to be employed during project execution are defined and developed into documented processes [15].

2.5 Freedom of Motion

Offshore Magazine [16] stated that a free-floating ship consists six degrees of freedom of motion; three rotations and three displacements. The rotations, also known as angular movements, are pitch, roll, and yaw. The displacements, also called linear movements, are surge, sway, and heave. It is necessary to consider movements in all these modes to completely define the ship motion as illustrated in Figure 1.

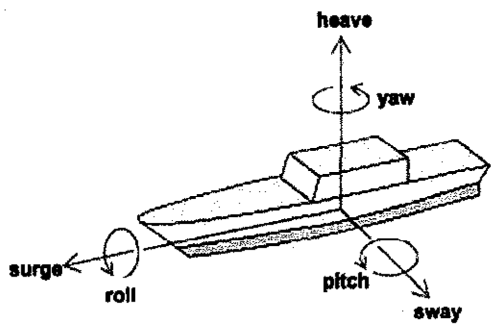

Figure 1: Ship Motion Degrees Of Freedom

However, some of these degrees of freedom can be either eliminated or neglected if the ship is moored. This mooring arrangement consists of only pitch and roll with some heave as surge, sway, and yaw are eliminated. FPSO vessels usually weathervane on a turret located at the bow [16].

Table 2 lists the description of the degrees of freedom [17].

Table 2: Degrees of Freedom

Degrees of Freedom of Motion	Description
Pitching	• Swaying along the lateral Y-axis. • Motion about the vessel's transverse axis. • Stability in the motion of pitch must be acquired to have a constant trim (trim being the difference of the forward and after drafts). • Governing stability – Longitudinal stability
Heaving	• The yawing along the vertical Z-axis. • The vertical bodily motion of the vessel. • To keep the vessel on the surface at a relatively constant mean draft, stability in heave is necessary. • Governing stability – Positional motion stability
Surge	• Rolling along the longitudinal X-axis. • Longitudinal bodily motion. • There is a desire for a vessel to maintain a constant speed; this would require that the vessel have stability along the surge axis. • Governing stability – Stability in motion ahead & astern
Rolling	• Motion about the vessel's longitudinal axis. • Rolling is sometimes a direct cause of speed reduction but more often a change in course, which in turn, may result in speed reduction. • It is a concern to keep the vessel from capsizing, stability in rolling motion must be sufficient. • Governing stability – Transverse stability
Yawing	• Motion about the vessel's vertical axis. • Rotation of a ship about a vertical axis approximately through its center of gravity. • This is undesirable because its correction requires the use of a rudder with increase in resistance to propulsion and because it produces yaw-heel. • Governing stability – Directional stability
Sway	• Bodily transfer of the ship in a lateral direction due to orbital motion of the water in a wave. • Lateral, side to side, bodily motion. • It is important to minimize a vessel's sideways or lateral motion. • This requires a high degree of stability in sway. • Governing stability – Lateral motion stability

CHAPTER 3

METHODOLOGY

3.1 Methodology

The chart below shows the steps taken throughout the course of this project:

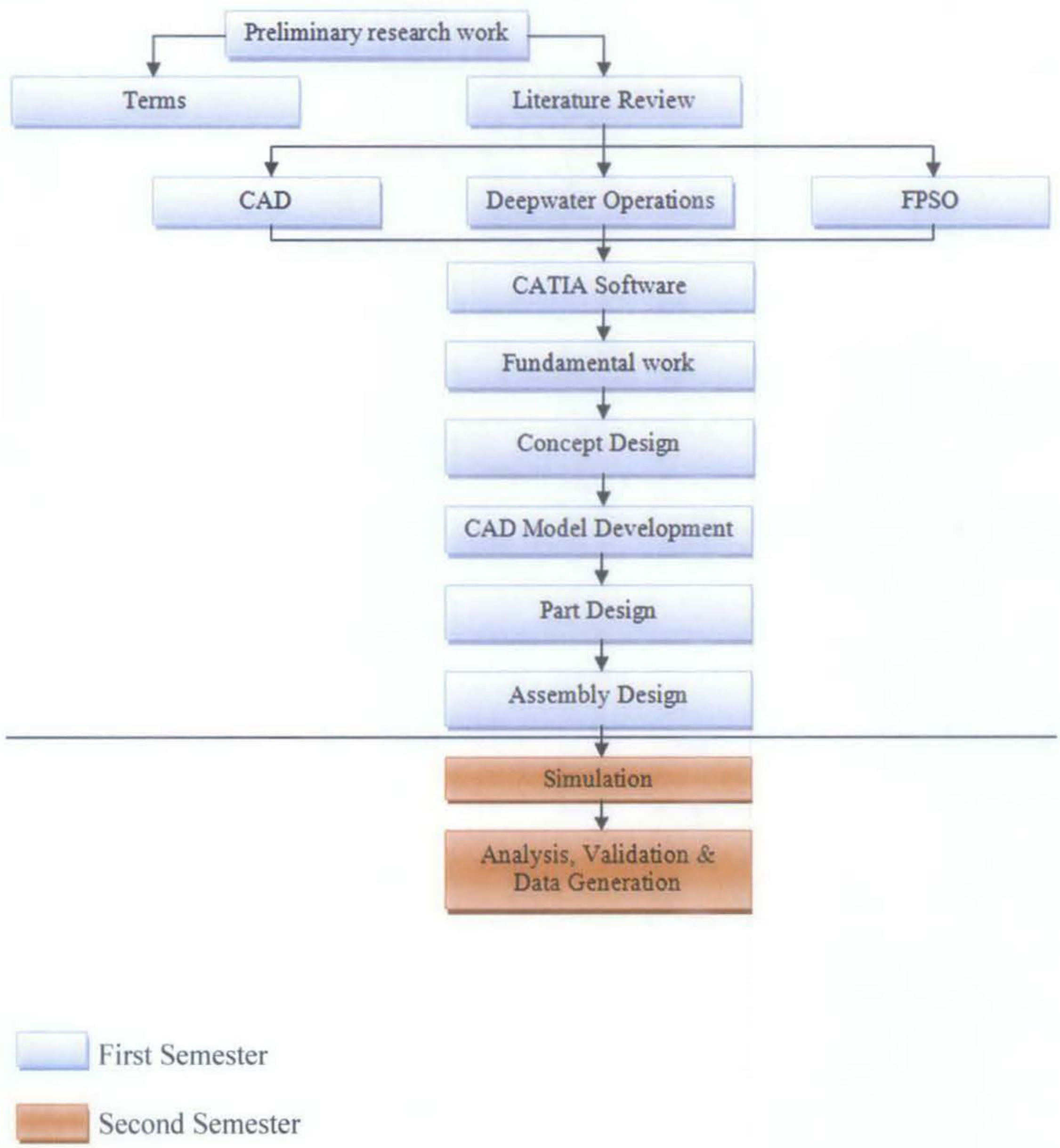

Figure 2: Methodology

The charts below illustrate the schedule of this project:

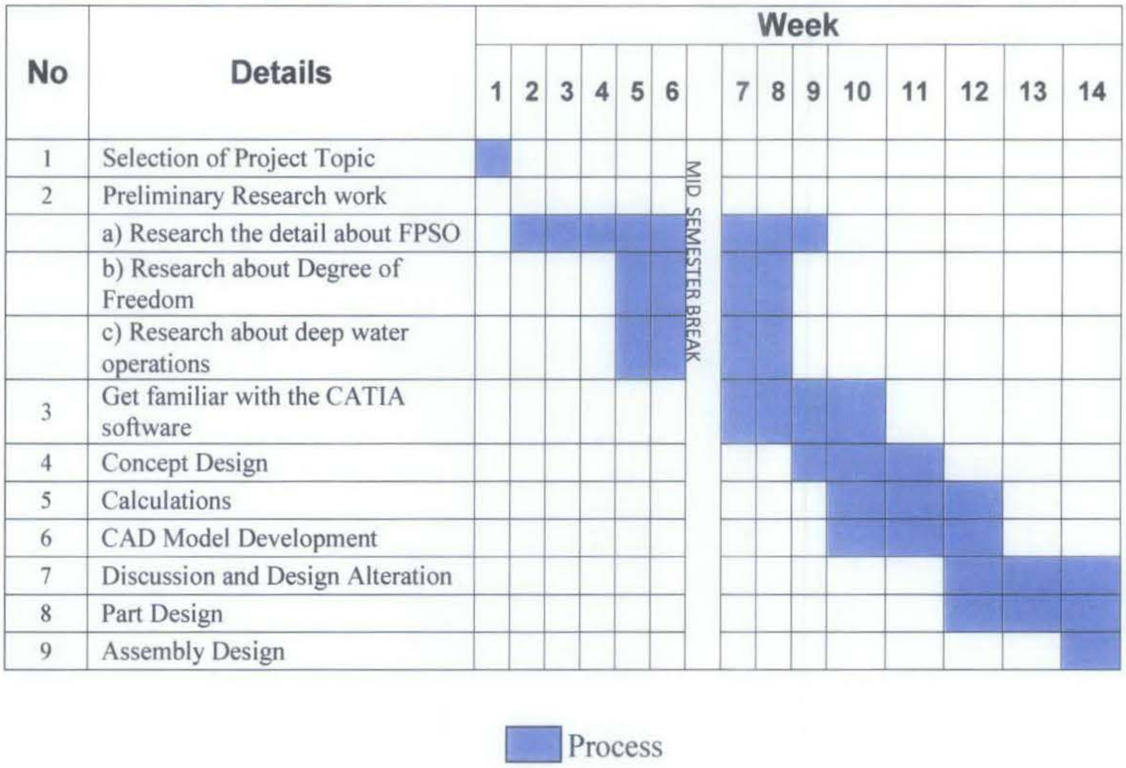

Figure 3: Gantt Chart for First Semester

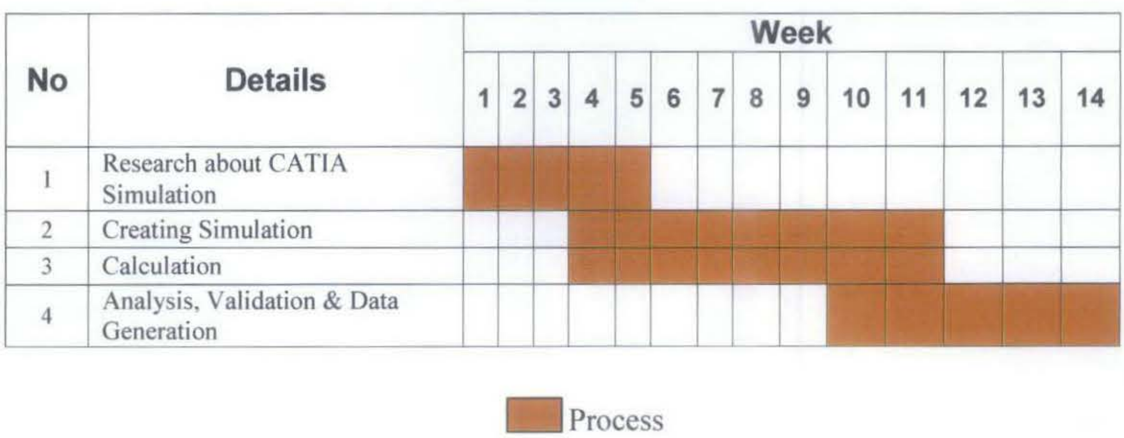

Figure 4: Gantt Chart for Second Semester

3.2 FPSO's Scope

The focus of the project is on the draft of the FPSO which is the depth of the water to which the vessel sinks according to its load. For this project, the FPSO is expected to be tested under various load conditions which are; lightship weight, 50% cargo load and full load.

Lightship weight refers to the actual weight of the vessel with no fuel, cargo oil, water, etc. on board. 50% cargo load means the weight of half-filled cargo tank is added to the FPSO actual weight along with water and fuel on board. Lastly, full load condition is when the actual weight is totaled up with the weight of fully filled cargo oil tank, fuel and water.

Based on the data obtained through research, below is the constraint for the FPSO vessel in order to prevent it from being flooded:

- Maximum value of 16 meters for draft.

3.3 CAD Model Development

Figure 5 shows the hull section and the topside of the FPSO vessel will be designed using Part Design in CATIA.

Figure 5: Hull Section and Topside of FPSO [20]

During the course of the project, the assumptions made are the dimensions of the parts as well as the weights of the topside modules, hull, and the liquids.

The topside consists of various modules or 'pancakes'. For this project, the shape of most modules is assumed to be in solid cuboids with its own dimension and weight based on the existing ones taken through literature review.

By using Part Design, the hull was the first part that was designed. The outline of the hull was sketched by using Sketcher before it was panned. The hull was then made hollow by using the shell function. Inside the hull are the cargo oil tank and the engine room. The cargo oil tank is also hollow in order to be able to insert oil representation later on during analysis. The engine room is assumed to be in shape of a cuboid.

Topside modules are added using the same method. The modules are in different colours to represent the types of modules.

Figure 6 shows the FPSO design as the assembly design that is created throughout the first part of the project during the first semester.

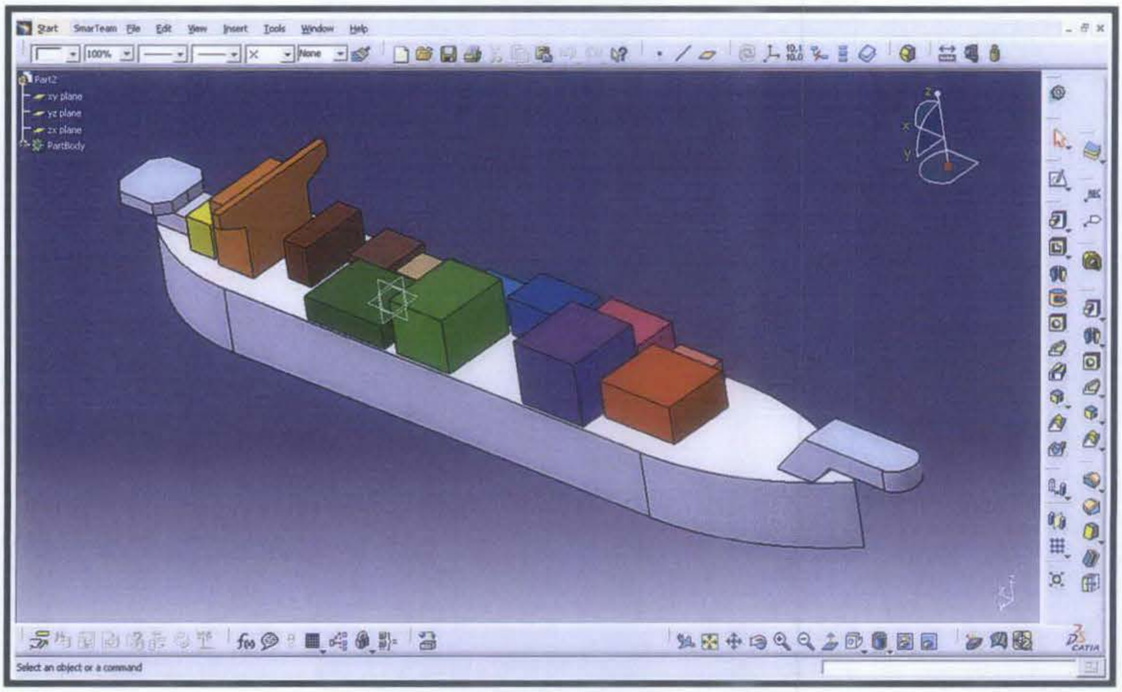

Figure 6: Design of FPSO Vessel

Design specifications of the FPSO are shown in the table below:

Table 3: FPSO Vessel Specifications

Overall Length	295.097 m
Breadth	46 m
Depth	23 m
Maximum Draft	16 m
Volume	200383.7 m^3
Mass	34465650 kg
Cargo Load Capacity	620000 bbls

3.4 Formula and Calculation

The stability of a ship normally refers to the ability of a floating vessel to resist the overturning forces encountered in the course of its operations. For this stability evaluation, 3 parameters are chosen which are; draft, displacement and centre of gravity.

3.4.1 Draft

Draft is known as the vertical distance between a ship's waterline and the lowest point of its keel. The value of draft at a given load can be determined by deriving the buoyancy equation shown below;

$$
\begin{aligned}
Buoyancy &= Displaced\ Fluid\ Weight \\
&= L \times B \times d \times \rho \times C_b
\end{aligned}
$$

L = *Length*

B = *Breadth*

d = *Depth*

ρ = *Water Density*

C_b is known as block coefficient which represents the ratio of the underwater volume of a ship to a rectangular block having the same length, breadth and depth. Figure 7 shows the representation of the block coefficient.

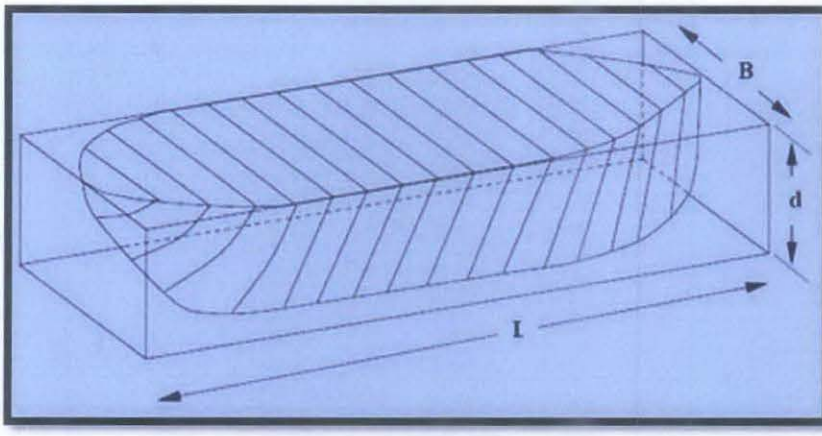

Figure 7: Block Coefficient

By performing calculations, the C_b of the FPSO model has the value of 0.625 (C_b = 0.642). The value is acceptable as the range of real FPSO vessels' C_b is from 0.6 to 0.8.

Thus, the derivation from above equation yields the draft equation used in this project:

$$Draft,\ T = d = \frac{Displaced\ Fluid\ Weight}{L \times B \times \rho \times C_b}$$

For this project, the displaced fluid weight, also known as displacement, which will be the variable used to determine the draft value. The values of length, breadth, water density and block coefficient are set to be constants.

3.4.2 Displacement

Displacement can be defined as the mass of the volume of water that a ship displaces. In this case, the mass is equal to the mass of the FPSO vessel. The variable used in this project is known as the Loaded Displacement which is the total of the lightship displacement and deadweight of the vessel. Lightship displacement refers to mass of the vessel in light condition. Deadweight is the mass that the vessel can carry which represents the cargo oil, diesel and water. The equation below expresses the relationship among the three:

$$\boxed{Loaded\ Displacement = Lightship\ Displacement + Deadweight}$$

3.4.3 Centre of Gravity

According to Narciki Naval Architecture, the centre of gravity (COG) is the location of the centroid of mass of a vessel [21]. For this project; longitudinal, transverse and vertical COG are defined in order to analyze the stability of the FPSO. The values of COG for the modules and tank are determined by using the 'Measure Between' tool in CATIA. The longitudinal centre of gravity (LCG) is the position along the length of the vessel of the COG. LCG for each module or tank is measured from the apt perpendicular (AP) point to the average location of its physical dimension. Transverse centre of gravity (TCG) is the lateral location of the COG which is measured from the center line of the vessel to the average location of the physical dimensions of the modules. Values of TCG can be either positive or negative. Positive value shows the module is located at the Starboard Side of the vessel while negative value shows that it is located at the Port Side of the vessel. The vertical centre of gravity (VCG) is known as the height above the baseline of the COG. It is measured from the baseline of the FPSO to the module's average location of its physical dimension. These COGs graphic representations can be shown below in Figure 8.

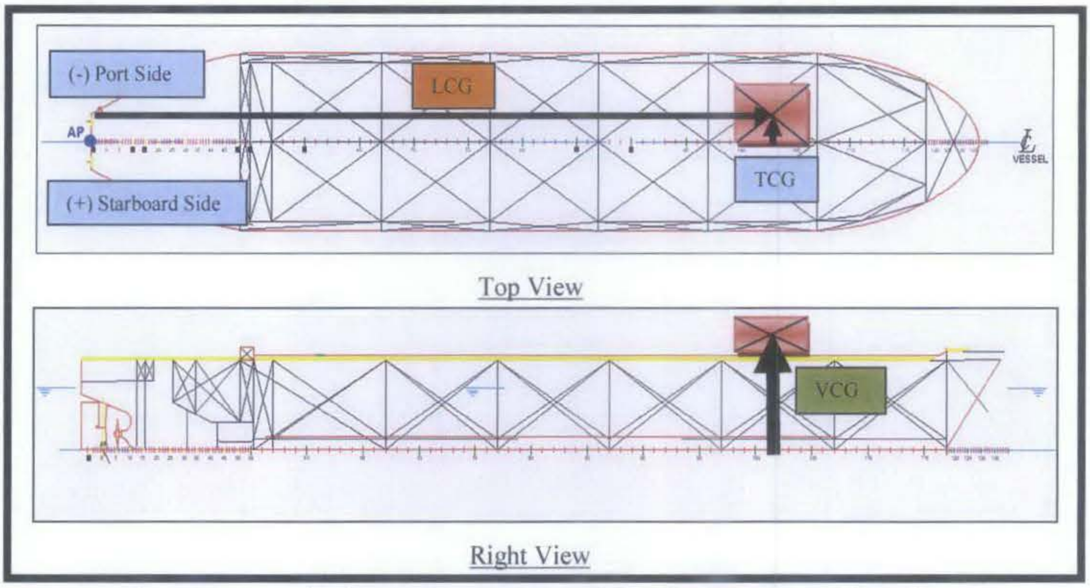

Figure 8: Longitudinal, Transverse and Vertical Centre of Gravity

The sum of moments of the weights about the mid-ship are calculated to evaluate the pitch movement of the FPSO vessel. Forward direction (from mid-ship to Forward Perpendicular) is assigned as positive, while aftward direction (from mid-ship to Aft Perpendicular) is assigned as negative. If the sum of moment is positive, it means that the weights are concentrated to the forward of the ship; thus, implying that it is trimming by bow. Bow refers to the forward part of the vessel. The vessel is said to be trimming by stern if the sum of moment is negative. Stern is defined as the rear or aft-most part of the vessel. Figure below shows the graphical representations of stern, bow and mid-ship:

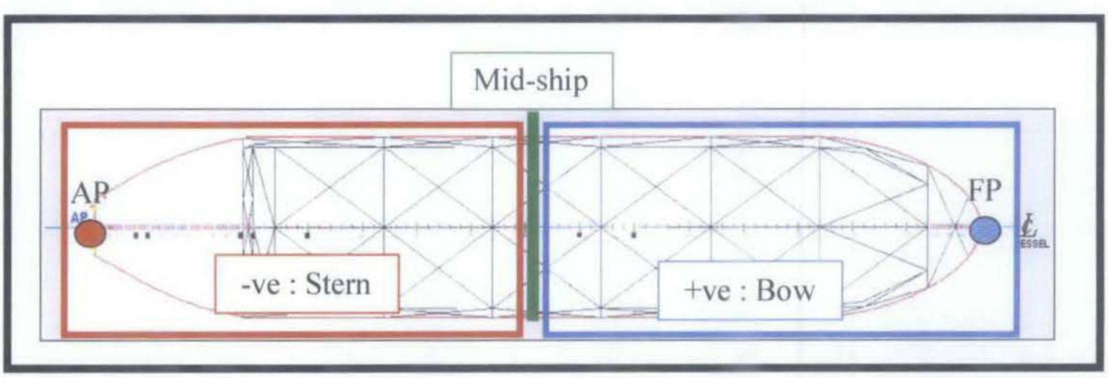

Figure 9: Stern, Bow and Mid-Ship

For roll movement of the vessel, the sum of moment of the weights about the centerline is calculated. This time, starboard direction (from centerline to the right side of vessel) is assigned as positive, and port direction (from centerline to the left side of vessel) is assigned as negative. Figure below shows the graphical representations of starboard side, port side and centerline:

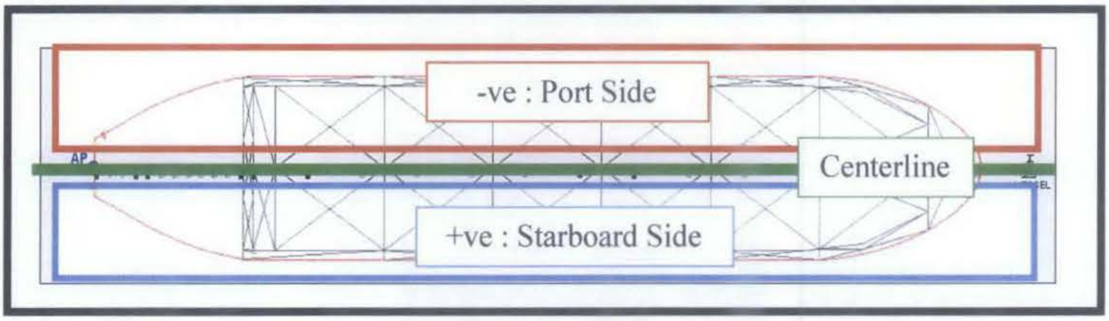

Figure 10: Starboard Side, Port Side and Centerline

3.5 Parameters and Formula Function

An additional feature to compute parameters automatically is added to the design library. The additional feature is the parameters and formula function which is used to insert formula and correlated the formula to the developed CAD model. This feature is capable to automatically compute parameter such as the draft when the cargo loading are changed to accommodate the respective project requirements. These parameters are useful for quick stability analysis on the input load.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Results

The end results of this project are:

- The hull section and topside as the 2 sections of FPSO Vessel CAD model that are designed using CATIA.
- An analysis on the behavior of the vessel in different loads.

Two sections of the vessel as mentioned above are designed using CATIA V5R12. The topside consists of many facilities and equipments such as the accommodation, laydown area, helideck, 'pancakes' and others. Dimensions of parts are estimated through literature reviews. The outcome is as shown below;

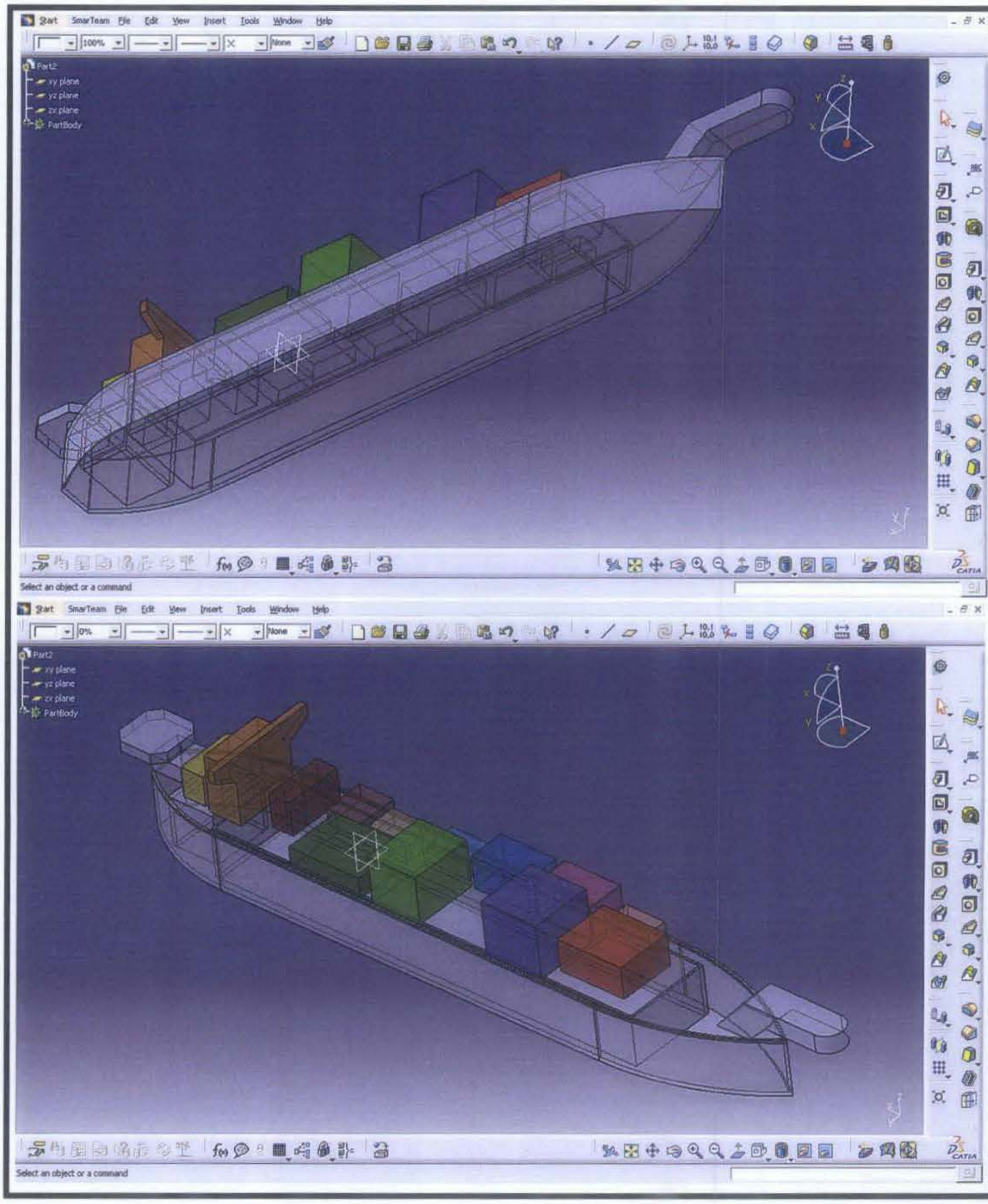

Figure 11: FPSO Vessel Model

Appendix B shows the steps in developing FPSO vessel model.

An analysis on the heave movement of the vessel was conducted on the Assembly Design module on CATIA. Three parts are assembled to represent the FPSO vessel in its operating condition. The parts are the FPSO vessel, seawater and cargo oil representation. For this analysis, the seawater is assumed to be under static condition, without any wave action. The seawater is represented by a large blue cuboid. Inside the cargo tank of the FPSO vessel is a yellow cuboid that represents the cargo oil. New parameters and formula functions are added in order to compute parameters automatically is added to the design library. For the analysis, the focus is on the 2 parameters which are draft and cargo load. By using the formula function, the value of draft can be determined for a specific loading as the loading value is set as the input. The assembly will then simulate accordingly to the determined values. Appendix B shows the steps in developing the formula function. As mentioned before, the analysis is focused on the movement of the FPSO vessel under 3 conditions; lightship weight, 50% cargo load and full load. The weights of the topside modules are assumed to be uniformly distributed along vessel's length.

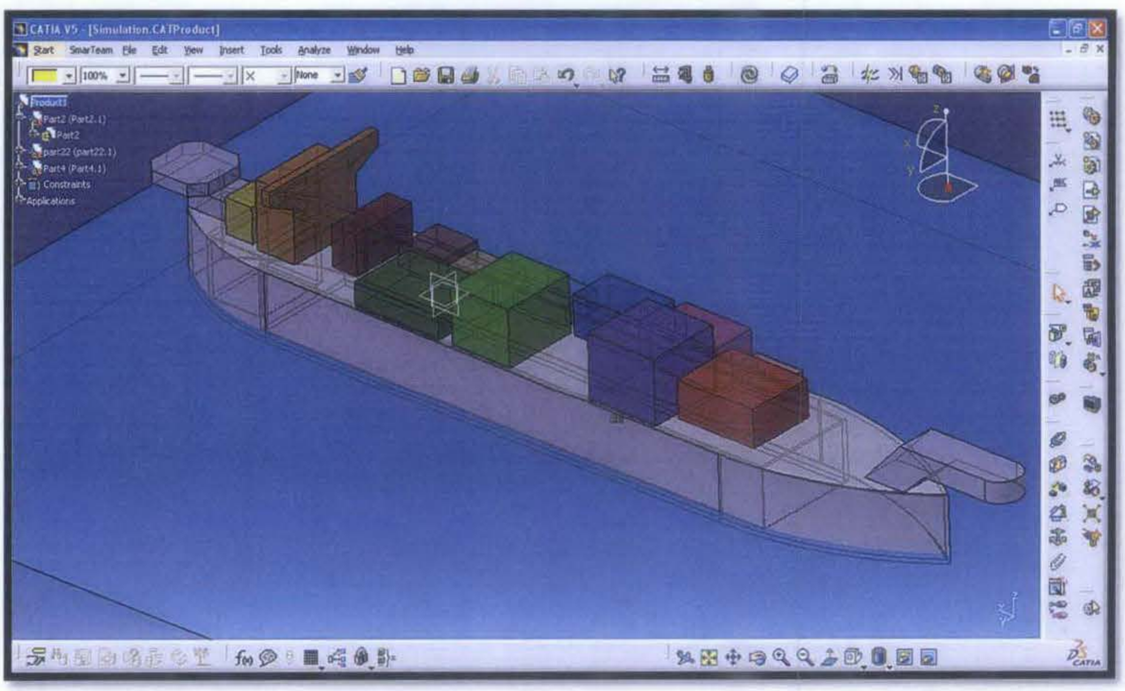

Figure 12: FPSO Vessel at Lightship Weight

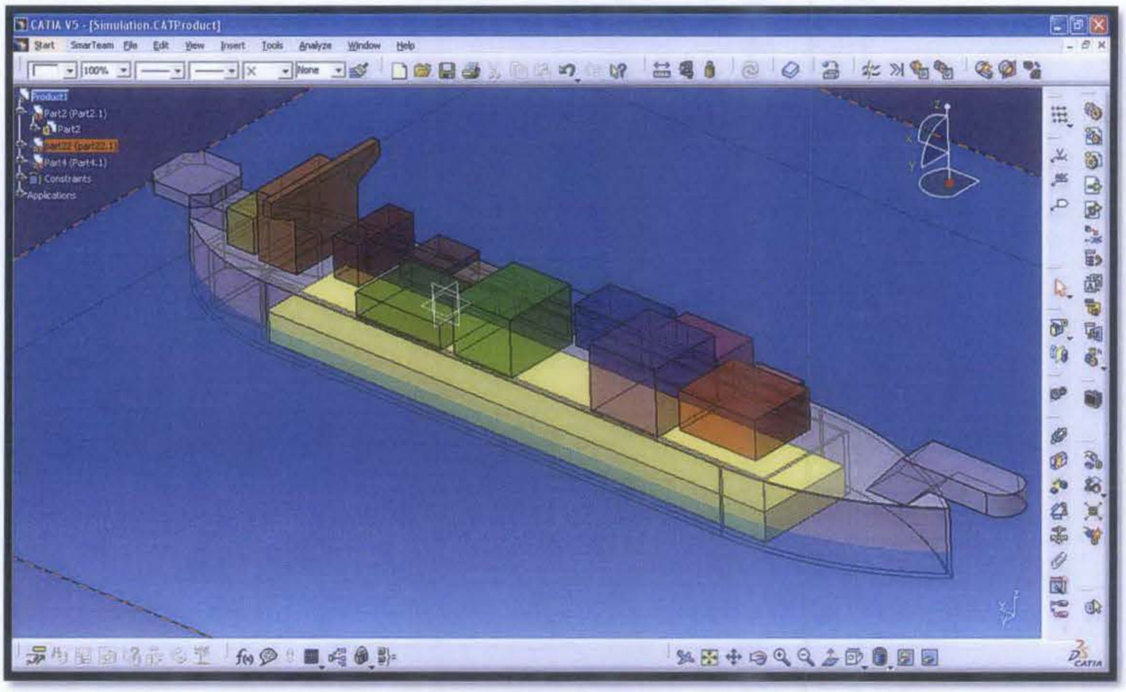

Figure 13: FPSO Vessel at 50% Cargo Load

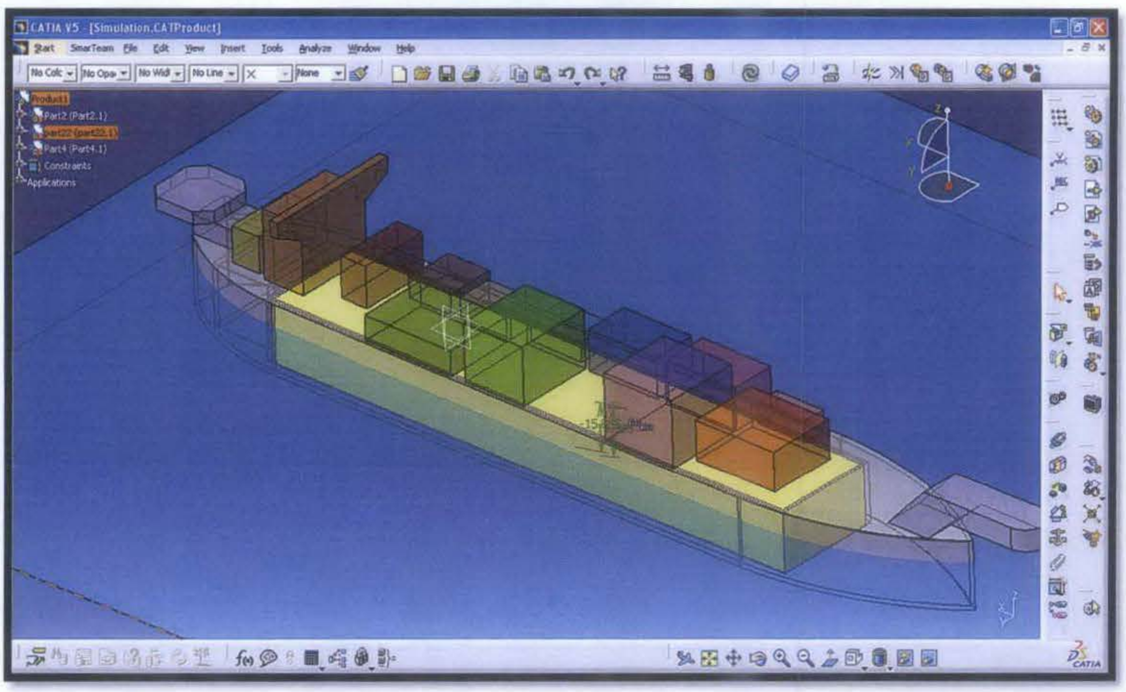

Figure 14: FPSO Vessel at Full Load

The parameters and formula function is used to compute the draft and the height of the cargo oil automatically. The figure below shows the functions created with the model in CATIA V5R12.

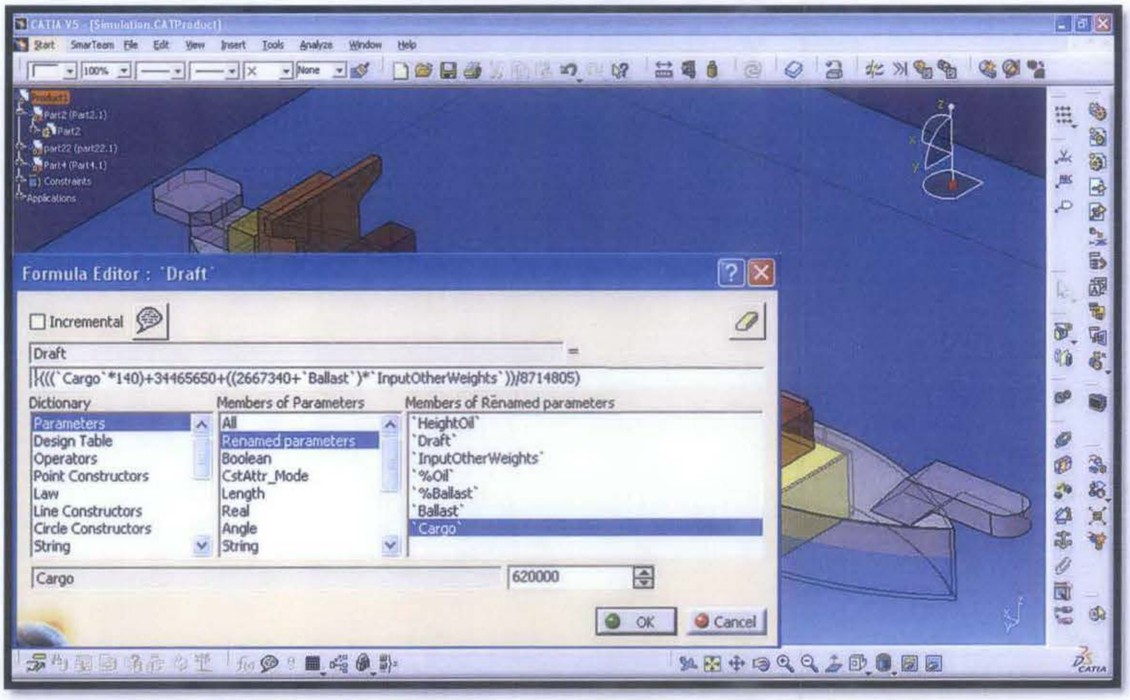

Figure 15: Parameters and Formula Function Used to Compute the Draft and Cargo Oil Height

The displacements and drafts of the FPSO vessel for various cargo load conditions are shown in the table below;

Table 4: Displacement and Draft Values

Load Conditions	Lightship	50% Cargo Load (310000 bbls)	Full Load (620000 bbls)
Displacement	34456.65 mt	109532.99 mt	138432.99 mt
Draft	3.955 m	12.569 m	15.884 m

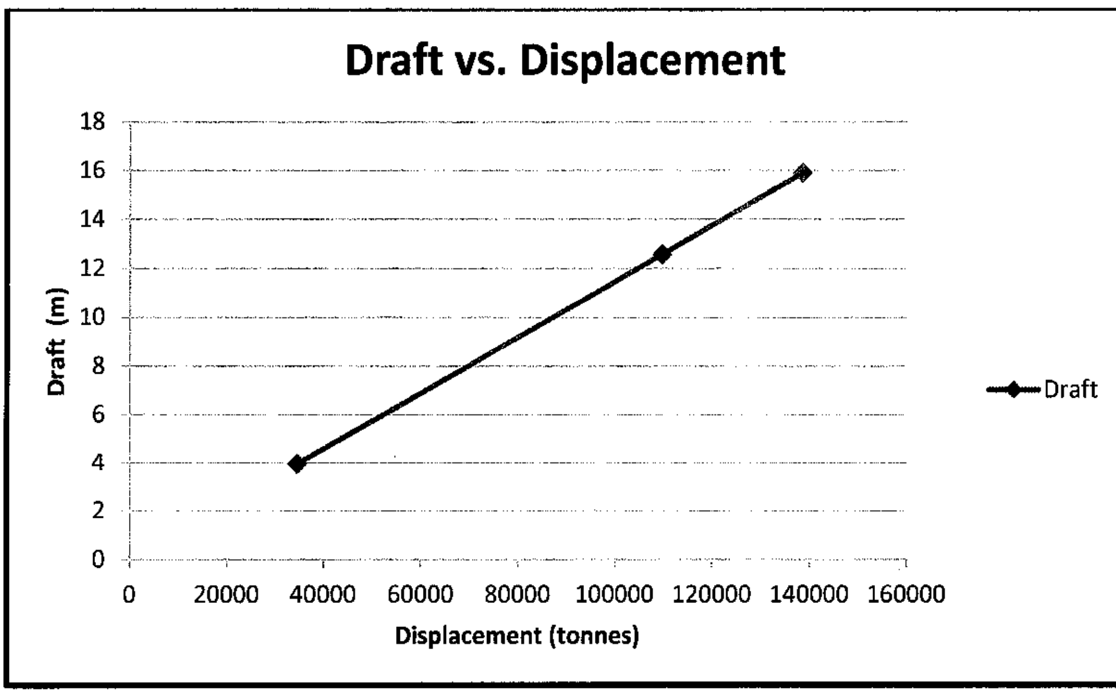

Figure 16: Draft against Displacement

As mentioned before, the weights are obtained through literature review and the centre of gravity values were determined by using the 'Measure Between' tool on CATIA V5R12. The table below provides information on the weights as well as the centre of gravity of the modules and other equipments. This table is used to predict the pitch and roll movement of the FPSO vessel.

Table 5: FPSO Weight Distribution

ITEM	COLOUR	MASS (T)	LCG (m)	TCG (m)	VCG (m)	AFT LIMIT (m)	FWD LIMIT (m)
Accommodation		483.00	41.04	0.00	34.50	33.54	48.54
Module 1		151.15	64.41	-4.45	29.85	58.29	68.29
Module 2		349.22	83.71	-12.97	26.30	73.66	89.76
Module 3		113.93	102.83	-10.99	26.40	93.13	112.53
Module 4		589.85	96.05	9.66	27.05	79.57	112.60
Module 5		240.82	127.56	-14.40	26.25	117.86	137.26
Module 6		560.60	129.20	8.00	32.50	117.85	140.55
Module 7		386.15	155.41	-13.23	29.65	142.36	168.46
Module 8		541.40	185.25	-13.9	29.85	172.20	198.30
Module 9		1448.31	185.34	8.40	34.00	172.29	212.96
Module 10		104.55	209.69	-17.32	26.40	200.74	218.64
Module 11		1040.00	215.60	1.76	29.50	200.60	230.60
TSS		1869.00	295.86	0.00	30.50	268.31	323.41
Helideck		140.00	-3.09	0.00	31.40	-14.57	8.41
Helideck (Pancake + Alum. Support)		45.00	7.50	0.00	26.15	0.00	15.00
Engine Room		1824.00	23.74	0.00	10.00	13.09	34.39
Cargo Oil		86841.37 (FULL) [620K bbls]	138.30	0.00	10.00	39.46	237.14

Table 6: Moment of Weight and Pitch Movement

Cargo Load Condition	Moment of Weight	Pitch Movement
Lightship	417297963.4 Nm	Trimming by bow
50% Cargo Load (310000 bbls)	-3520926537.0 Nm	Trimming by stern
Full Load (620000 bbls)	-7459151037.0 Nm	Trimming by stern

Table 7: Moment of Weight and Roll Movement

Cargo Load Condition	Moment of Weight	Roll Movement
Lightship	-1844035.731 Nm	Heel to port
50% Cargo Load (310000 bbls)	-1844035.731 Nm	Heel to port
Full Load (620000 bbls)	-1844035.731 Nm	Heel to port

4.2 Discussion

Results show that parts of FPSO Vessel CAD model are developed using CATIA V5R12. The parts are created from sketcher to part design. Creating the model starts from modeling the hull and placing the tank and the engine room inside the hull. It is followed by creating the topside by placing modules on top of the hull. The dimensions are taken from previous FPSO projects in order to build a model that is close to a real existing one.

For the heave movement, the parameters and formula function are used to create formulas that will enable automatic calculation to obtain values of the parameters. With this function, draft and height of cargo oil in tank formulas are calculated simultaneously when the specified cargo loading is changed as input. The parts which are developed concurrently with the formula function will simulate accordingly to the values obtained. For example, when cargo load is changed from Lightweight (cargo load = 0 bbls and deadweight = 0 tonnes) to 50% cargo load (cargo load = 310000 bbls and deadweight = 75067.34 tonnes), the value of draft will also change from 3.955 m to 12.569 m.

The analysis on pitch and roll movements are only done through theory although the values were obtained by measuring using this library. Further analysis need to be done in order to obtain more accurate results.

Based on the majority of current findings, limited works are done on the existing modeling of FPSO vessels. In some cases, engineers are inaccessible to work on the design of the FPSO as design libraries have high confidentiality to some sub-contractor companies. The benefit of this idea is expected to give an instant value for engineers of PETRONAS to review the dimensions chosen for the FPSO vessel and to proceed with subsequent steps. The final result is expected to be a basic assumption for the FPSO's design calculation for weight and stability analysis.

The Draft against Displacement graph in Figure 14 shows that the draft increases as the displacement increases. This shows that the more load is added on the vessel, the more water the vessel displaces. This means that the vessel sinks more as the displacement increases. This is very important for stability analysis because a vessel has its own draft limit to prevent itself from flooding. For this FPSO vessel model, the maximum draft is 16 m. The values of drafts based on specific loading are determined by using the formula function. Manual calculations were done to compare with the values computed by the function. The calculations can be seen in Appendix C.

The Moment of Weight and Pitch Movement in Table 6 show that various load conditions affect the pitch movement of the vessel. The weights and locations of the modules and cargo oil tank have to be taken into account as they affect the stability of the vessel. Appendix C shows the calculations used to obtain the values in the table.

CHAPTER 5

CONCLUSION

5.1 Conclusion

Based on the objectives, the FPSO vessel CAD model and the analysis on its motion behavior are the initiator for the offshore floaters design library which eliminates some of the iteration in concept design stage for future design selection work.

The increment of cargo loading increases the draft of the FPSO vessel. Hence, it increases the possibility of the FPSO vessel to be flooded. The modules and cargo oil tank have their affects on the stability of the vessel. Locating the modules is essential to ensure the weight is properly distributed in order to prevent flooding.

As mentioned before, an extensive iterative process in concept design and selection stage is being implemented in PETRONAS due the unavailability of design library of offshore floaters in the company. Thus, the success of this project will be an opening for PETRONAS to further improve its selection approach in meeting specific requirements or criterion. The results obtained increases the decision reliability and narrow down the scope of FPSO vessel dimension. This model library is user-friendly and it decreases working time. However, the analysis is only focused on only one degree of freedom and also without any environment effect such as wave action.

5.2 Recommendation

Further enhancement on the design library should be made in order to analyze the motion behavior of the vessel efficiently. It is recommended that formulas related to pitch and roll movement calculations to be added into the parameter and formula function in order to obtain more accurate results. Environmental effects such as wave and wind forces should also be added to this library.

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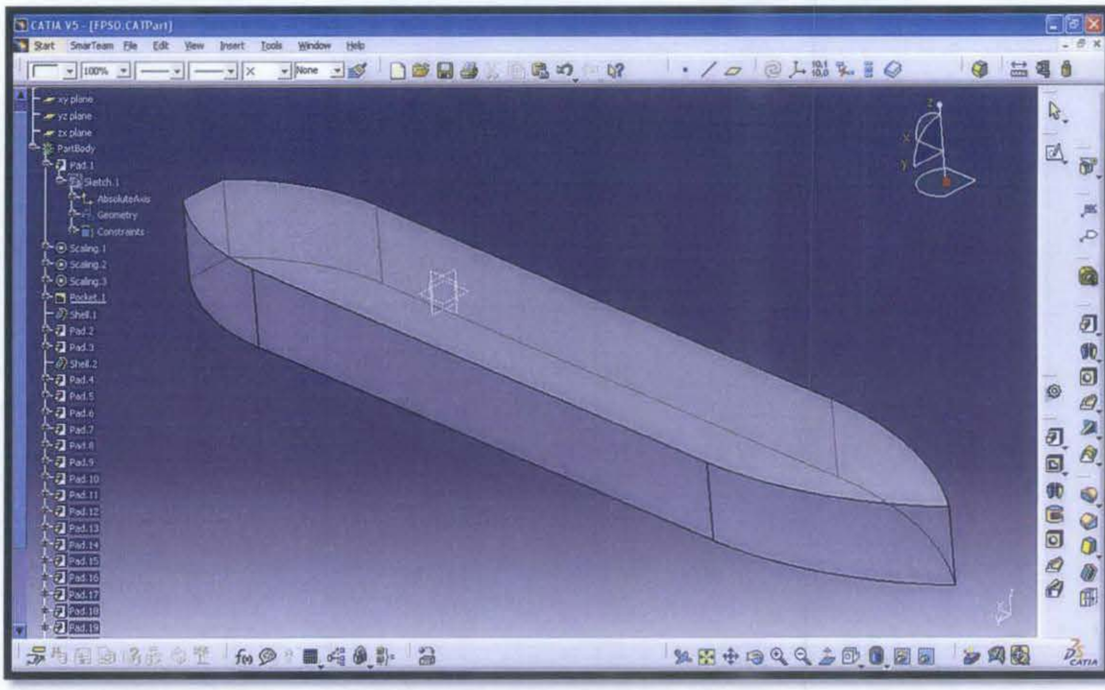
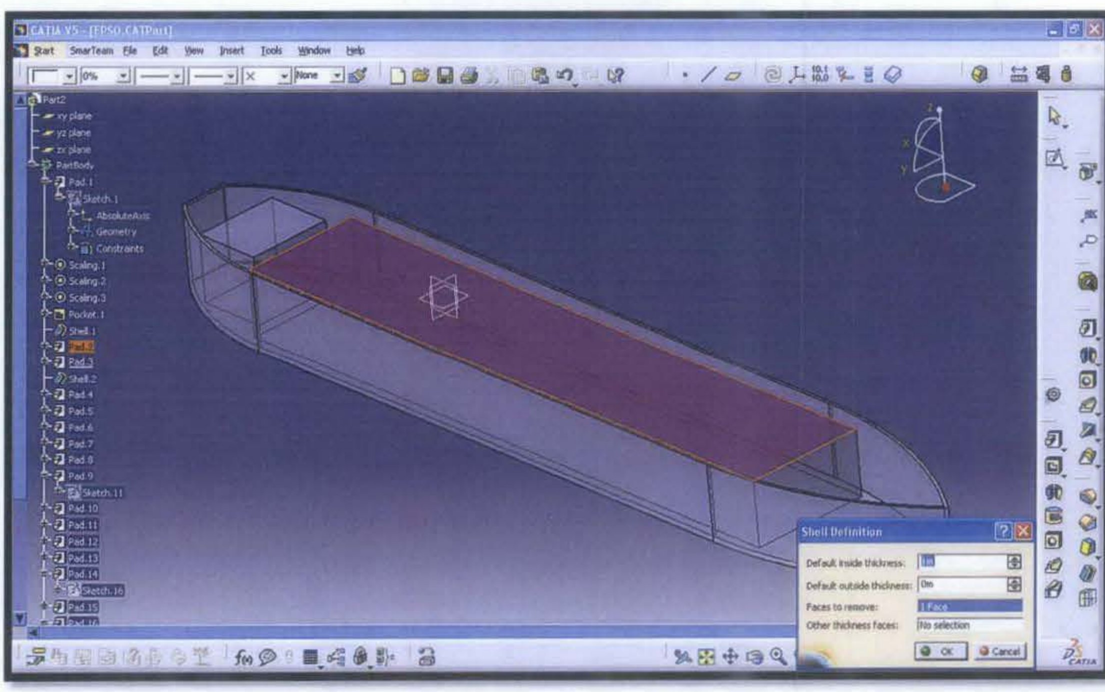
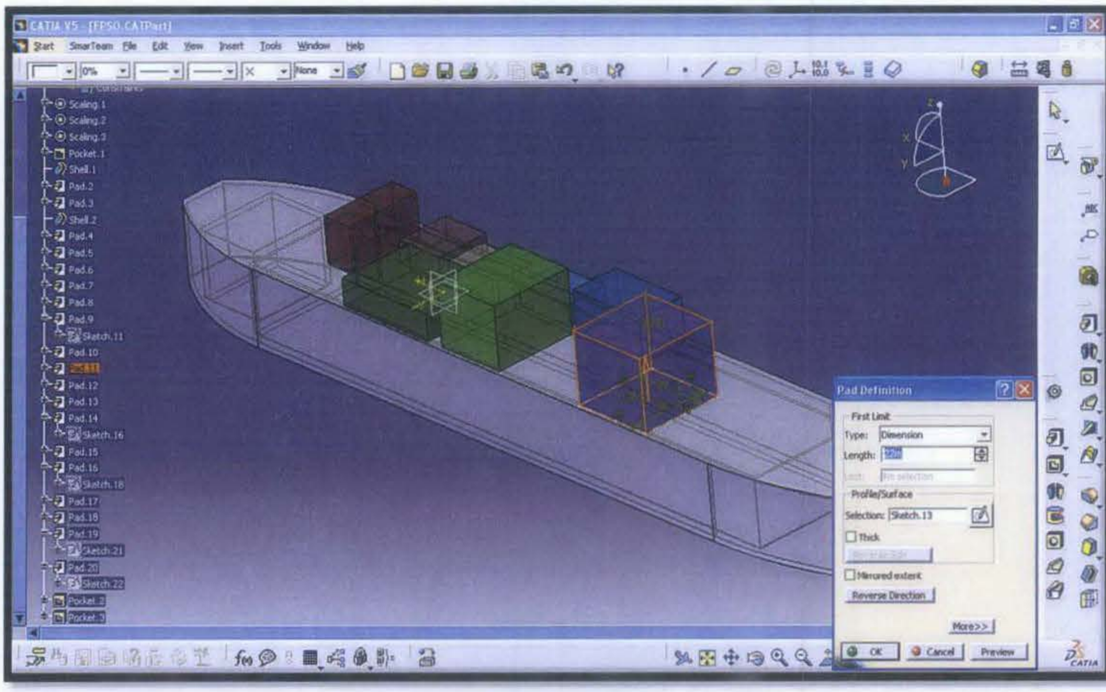
STEPS IN DEVELOPING THE FPSO VESSEL CAD MODEL



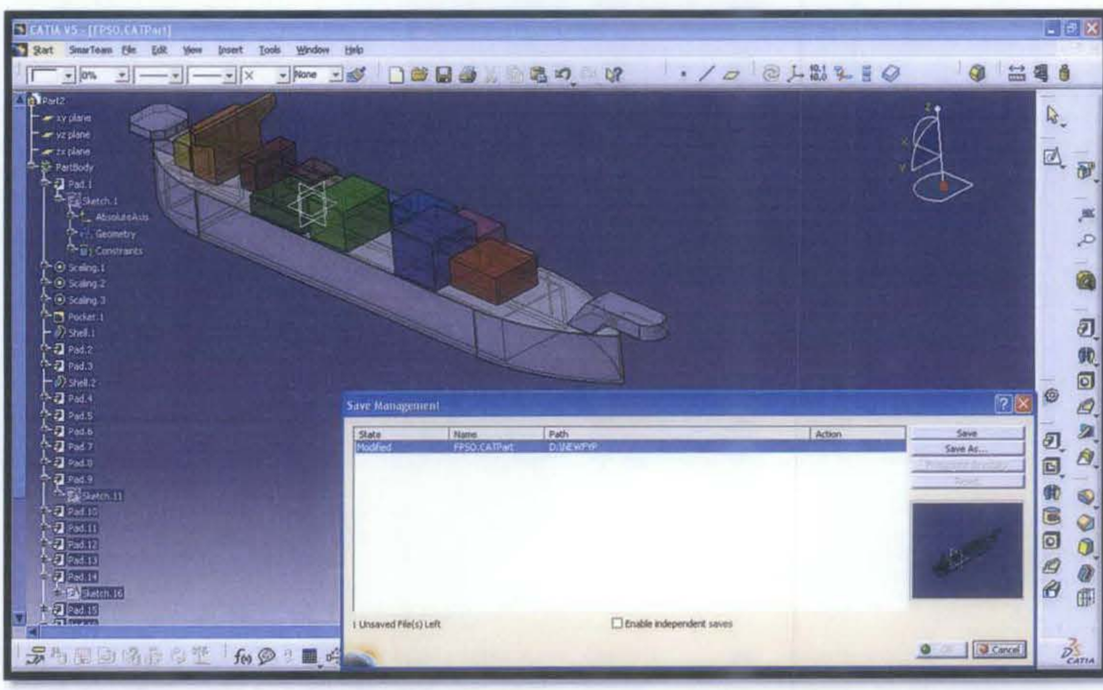
A1: Hull Part Design



A2: Cargo Tank Part Design

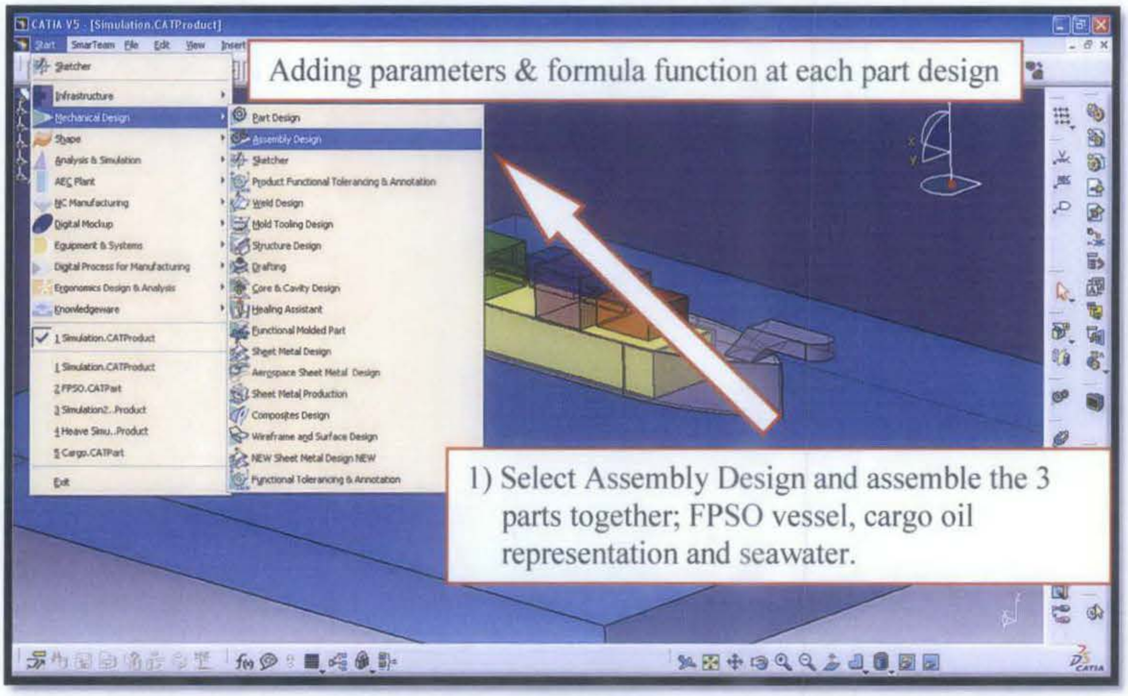


A3: Topside Modules Part Design

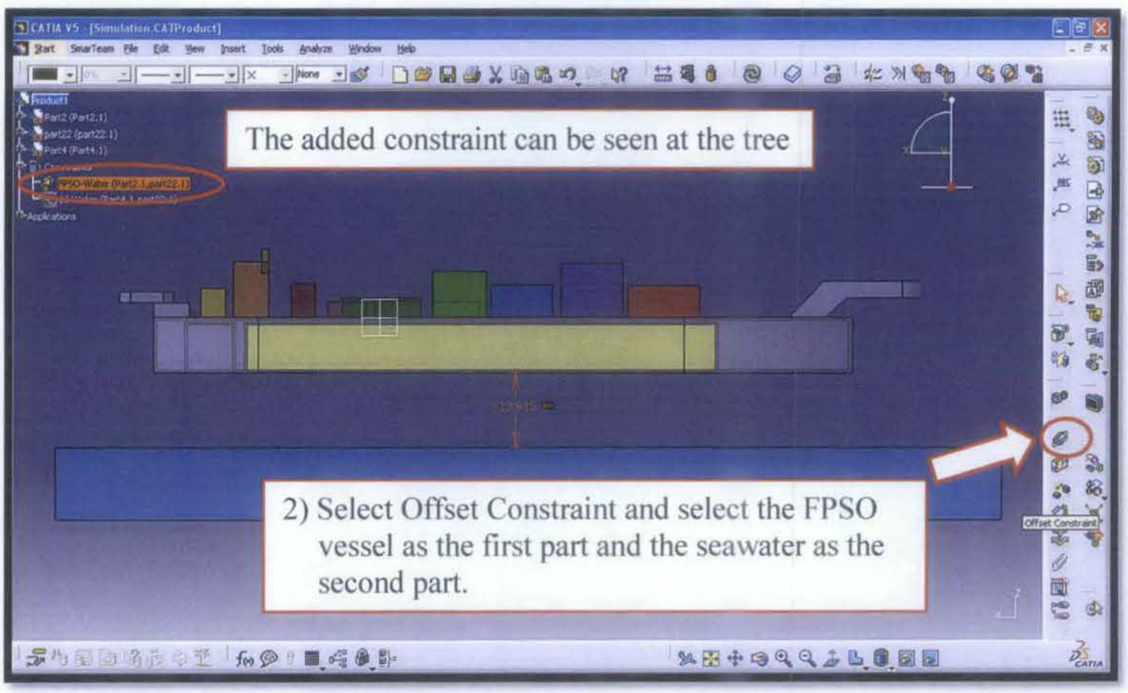


A4: Save Management Function in Part Design

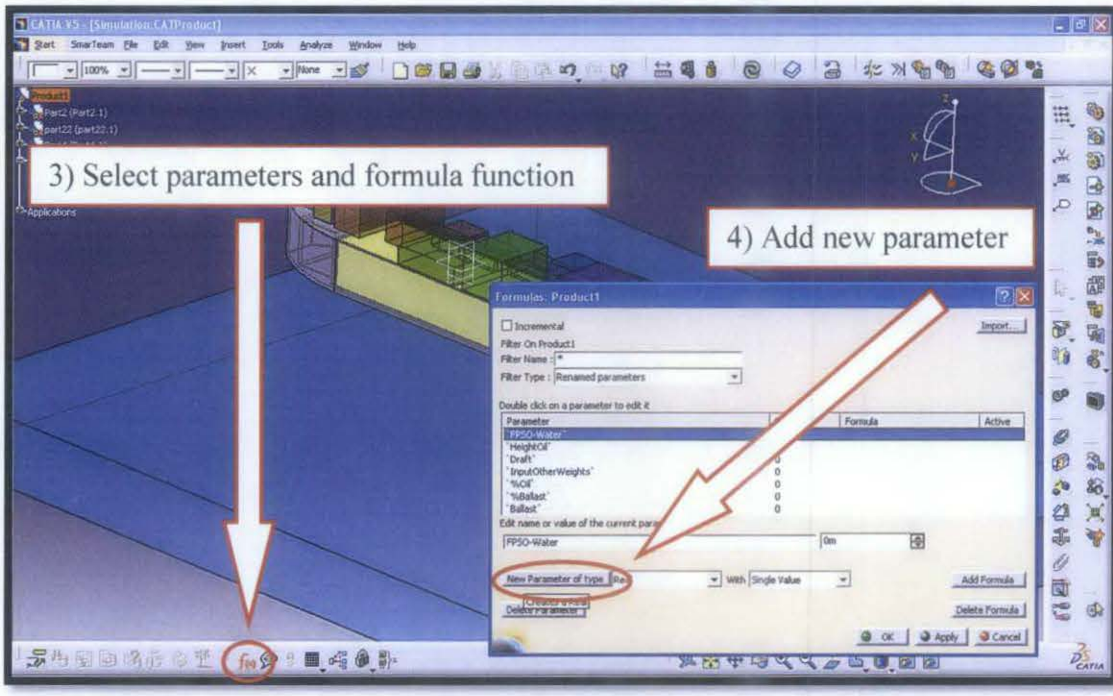
STEPS IN DEVELOPING THE FORMULA FUNCTION



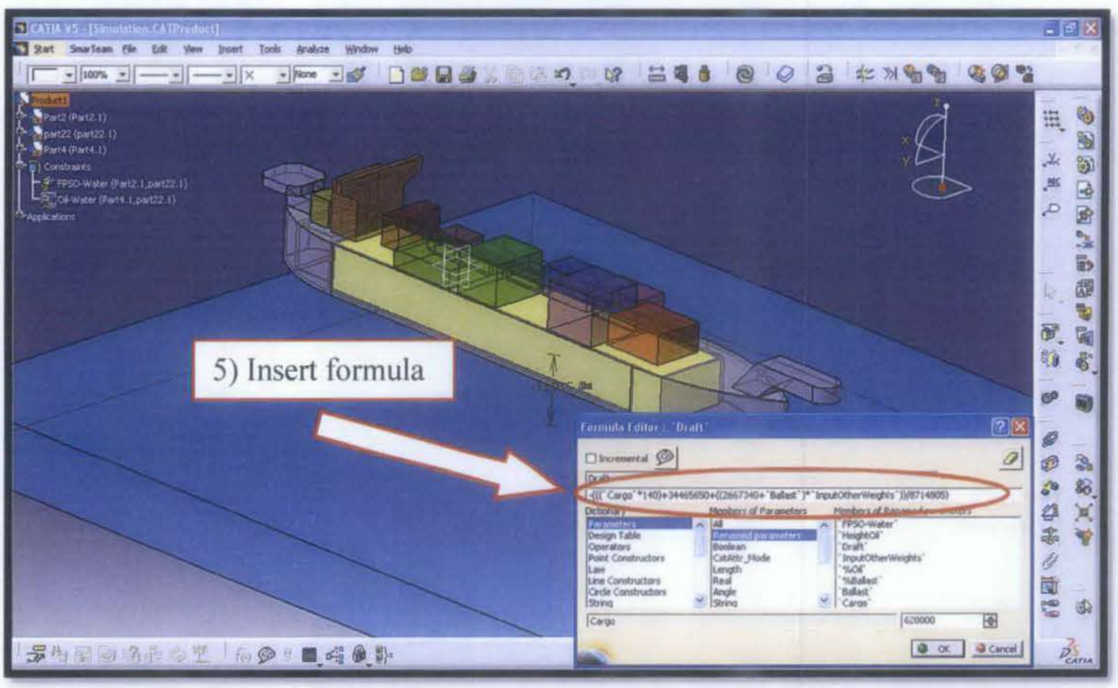
B1: Step 1



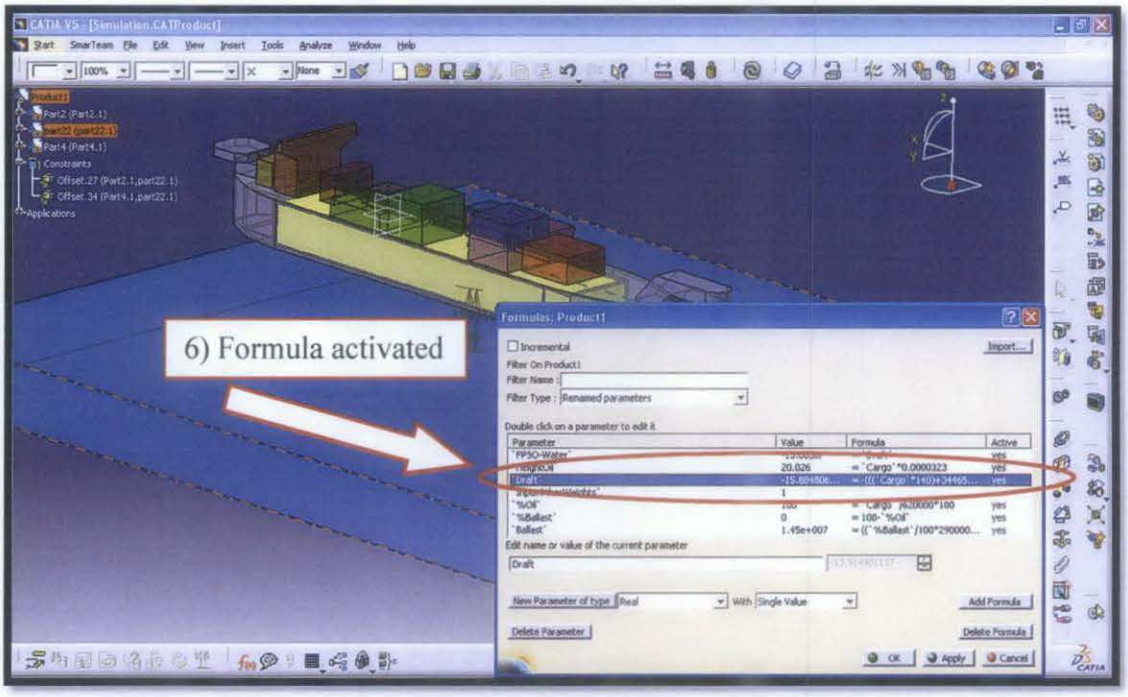
B2: Step 2



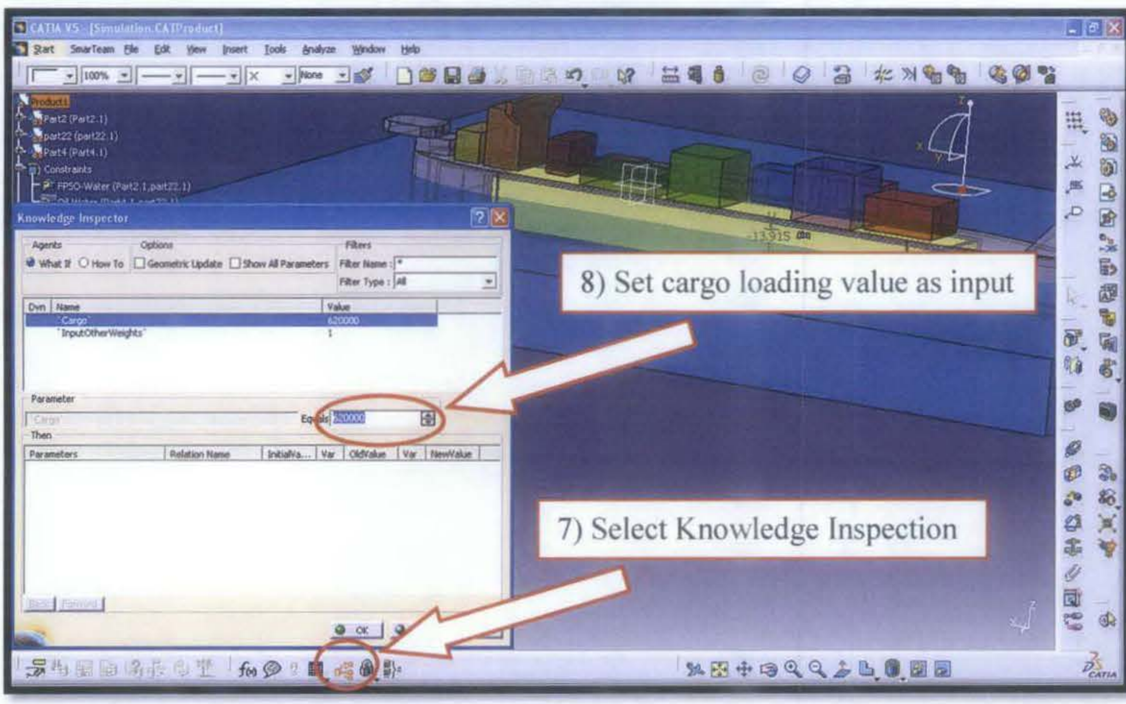
B3: Step 3



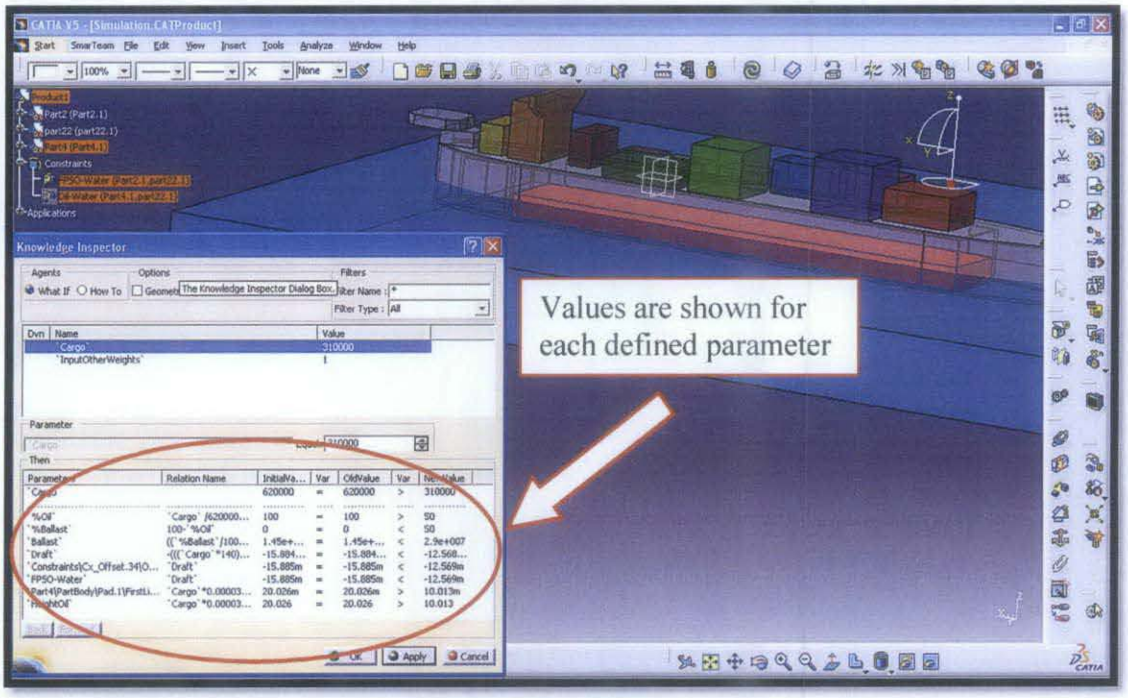
B4: Step 4



B5: Step 5



B6: Step 6



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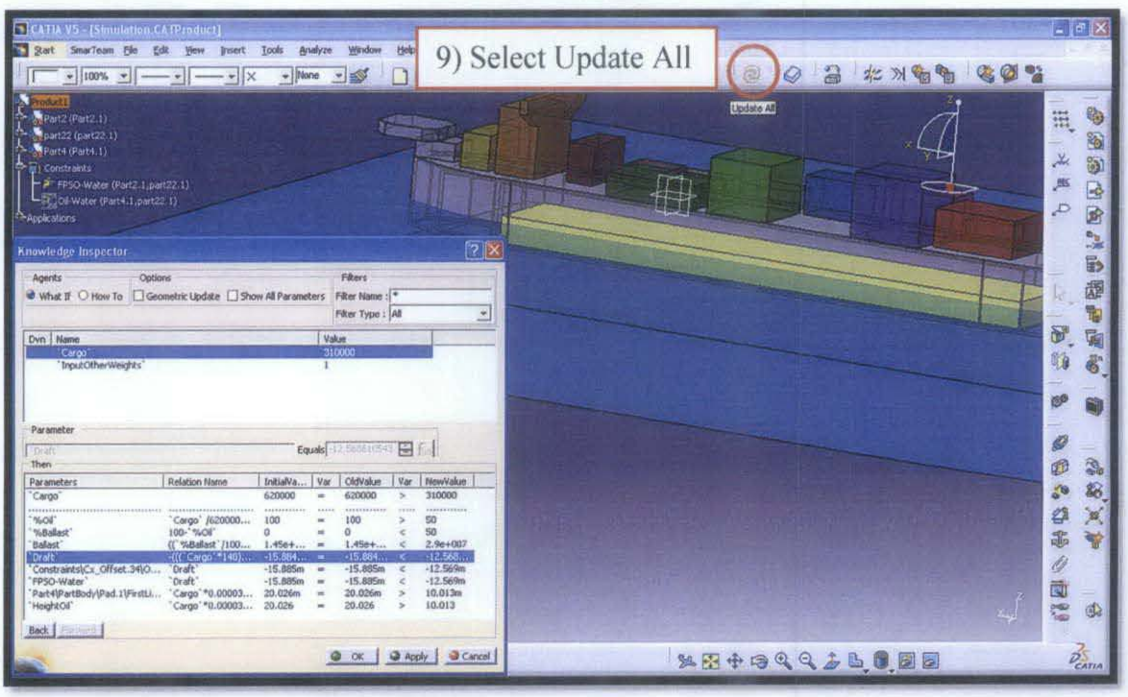

B8: Step 8

APPENDIX C

FORMULAS AND CALCULATIONS

Specifications of FPSO Vessel

Overall Length, L	295.097 m
Breadth, B	46 m
Depth, D	23 m
Maximum Draft, t	16 m
Volume, V	200383.7 m^3
Mass, m	34465650 kg
Cargo Load Capacity	620000 bbls
Cargo Tank Volume, V_{tank}	151760 m^3

$$\text{Block Coefficient, } C_B = \frac{V}{L \times B \times d}$$

$$= \frac{200383.7\ m^3}{295.097\ m\ \times\ 46\ m\ \times\ 23\ m}$$

$$= \mathbf{0.642}$$

1 bbls : 3.23 x 10^{-5} m Oil in Tank

Assumptions:

Tonnage values for items on the FPSO vessel are assumed according to literature review.

Deadweight tonnage table:

Items	Tonnage
Diesel Oil	2240.43 t
Fresh Water	426.91 t
Water Ballast*	Vary

* Water ballast is needed to keep the vessel upright. It is affected by the cargo loadings.

The formula used to determine the tonnage for the water ballast is assumed as:

$$\text{Water ballast tonnage} = \left(\frac{100\% - \left(\frac{\text{Cargo Load}}{\text{Total Cargo Load}} \text{ x } 100\%\right)}{100}\ x\ 29000\right) + 14500$$

1. Heave Movement Calculations

a. Cargo Load Condition: Lightship Weight

Lightship Displacement = 34465.65 t

Deadweight = 0 t

Loaded Displacement = Lightship Displacement – Deadweight

= 34465.65 t + 0 t

= **34465.65 t**

$$\text{Draft} = \frac{(\text{Loaded Displacement x 1000) kg}}{\text{L x B x } \rho \text{ x } C_B}$$

$$= \frac{(34465.65 \text{ t x 1000) kg}}{295.097 \text{ m x 46 m x 1000 } \frac{\text{kg}}{\text{m}^3} \text{ x 0.642}}$$

= **3.955 m**

b. Cargo Load Condition: 50% Cargo Load

Lightship Displacement = 34465.65 t

Cargo Load = 310000 bbls

1 bbls = 0.140 t

Cargo Oil = (310000 bbls x 0.140) t

= **43400 t**

$$\text{Water ballast} = \left(\frac{100\% - \left(\frac{\text{Cargo Load}}{\text{Total Cargo Load}} \text{ x } 100\% \right)}{100} \; x \; 29000 \right) + 14500$$

$$= \left(\frac{100\% - \left(\frac{310000}{620000} \text{ x } 100\% \right)}{100} \; x \; 29000 \right) + 14500$$

= **29000 t**

Deadweight = Cargo Oil + Water Ballast + Diesel Oil + Fresh Water

= 43400 t + 29000 t + 2240.43 t + 426.91 t

= **75067.14 t**

Loaded Displacement = Lightship Displacement + Deadweight

= 34465.65 t + 75067.14 t

= **109532.79 t**

$$\text{Draft} = \frac{(\text{Loaded Displacement x 1000) kg}}{\text{L x B x } \rho \text{ x } C_B}$$

$$= \frac{(109532.79 \text{ t x } 1000) \text{ kg}}{295.097 \text{ m x } 46 \text{ m x } 1000 \frac{\text{kg}}{\text{m}^3} \text{ x } 0.642}$$

= **<u>12.569 m</u>**

Height of Oil in Tank = (310000 bbls x 3.23 x 10^{-5}) m

= **<u>10.013 m</u>**

c. Cargo Load Condition: Full Load

Lightship Displacement = 34465.65 t

Cargo Load = 620000 bbls

1 bbls = 0.140 t

Cargo Oil = (620000 bbls x 0.140) t

= **86800 t**

$$\text{Water ballast} = \left(\frac{100\% - \left(\frac{\text{Cargo Load}}{\text{Total Cargo Load}} \text{ x } 100\% \right)}{100} \; x \; 29000 \right) + 14500$$

$$= \left(\frac{100\% - \left(\frac{620000}{620000} \text{ x } 100\% \right)}{100} \; x \; 29000 \right) + 14500$$

= **14500 t**

Deadweight = Cargo Oil + Water Ballast + Diesel Oil + Fresh Water

= 86800 t + 14500 t + 2240.43 t + 426.91 t

= **103967.34 t**

Loaded Displacement = Lightship Displacement + Deadweight

= 34465.65 t + 103967.34 t

= **138432.99 t**

$$\text{Draft} = \frac{(\text{Loaded Displacement x 1000) kg}}{\text{L x B x } \rho \text{ x } C_B}$$

$$= \frac{(138432.99 \text{ t x } 1000) \text{ kg}}{295.097 \text{ m x } 46 \text{ m x } 1000 \frac{\text{kg}}{\text{m}^3} \text{ x } 0.642}$$

= **15.884m**

Height of Oil in Tank = (620000 bbls x 3.23 x 10^{-5}) m

= **20.013 m**

2. Pitch Movement Calculations

ITEM	COLOUR	MASS (T)	LCG (m)	MOMENT OF WEIGHT (Nm)
Accomodation		483.00	41.04	-504668877.30
Module 1		151.15	64.41	-123278453.90
Module 2		349.22	83.71	-218706149.10
Module 3		113.93	102.83	-49981455.58
Module 4		589.85	96.05	-298001067.80
Module 5		240.82	127.56	-47225259.56
Module 6		560.60	129.20	-100915568.10
Module 7		386.15	155.41	29774713.59
Module 8		541.40	185.25	200229751.80
Module 9		1448.31	185.34	536917338.40
Module 10		104.55	209.69	63732989.97
Module 11		1040.00	215.60	694273320.00
TSS		1869.00	295.86	2719247536.00
Helideck		140.00	-3.09	-206888976.00
Helideck (Pancake + Alum. Suppo		45.00	7.50	-61825072.50
Engine Room		1824.00	23.74	-2215386806.00
TOTAL TOPSIDE MOMENT OF WEIGHTS				417297963.40

a. Cargo Load Condition: Lightship Weight

Cargo Load = 0 bbls

Cargo Oil Moment of Weight = 0 Nm

Σ Moment of Weight = Total Topside M.O.W + Cargo Oil M.O.W

= 417297963.40 Nm + 0 Nm

= **417297963.40 Nm**

b. Cargo Load Condition: 50% Cargo Load

Cargo Load = 310000 bbls

d_{cargo} = - 9.25 m

Cargo Oil Moment of Weight = F x d_{cargo}

= [(Cargo Load x 140) kg x g] x (-9.25 m)

= [(310000 bbls x 140)kg x 9.81 m/s^2] x (-9.25 m)

= 425754000 N x (-9.25 m)

= -3938224500 Nm

Σ Moment of Weight = Total Topside M.O.W + Cargo Oil M.O.W

= 417297963.40 Nm + (-3938224500 Nm)

= **-3520926537.00 Nm**

c. Cargo Load Condition: 100% Cargo Load

Cargo Load = 620000 bbls

d_{cargo} = - 9.25 m

Cargo Oil Moment of Weight = F x d_{cargo}

= [(Cargo Load x 140) kg x g] x (-9.25 m)

= [(620000 bbls x 140)kg x 9.81 m/s^2] x (-9.25 m)

= 851508000 N x (-9.25 m)

= -7876449000 Nm

Σ Moment of Weight = Total Topside M.O.W + Cargo Oil M.O.W

= 417297963.40 Nm + (-7876449000 Nm)

= **-7459151037.00 Nm**

3. Roll Movement Calculations

ITEM	COLOUR	MASS (T)	TCG (m)	MOMENT OF WEIGHT (Nm)
Accomodation		483.00	0	0.00
Module 1		151.15	-4.45	-6598377.67
Module 2		349.22	-12.97	-44433251.15
Module 3		113.93	-10.99	-12283009.77
Module 4		589.85	9.66	55896899.31
Module 5		240.82	-14.4	-34019196.48
Module 6		560.60	8	43995888.00
Module 7		386.15	-13.23	-50116979.75
Module 8		541.40	-13.9	-73824762.60
Module 9		1448.31	8.4	119346537.20
Module 10		104.55	-17.32	-17764006.86
Module 11		1040.00	1.76	17956224.00
TSS		1869.00	0.00	0.00
Helideck		140.00	0.00	0.00
Helideck (Pancake + Alum. Suppo		45.00	0.00	0.00
Engine Room		1824.00	0.00	0.00
TOTAL TOPSIDE MOMENT OF WEIGHTS				-1844035.731

a. Cargo Load Condition: Lightship Weight

Cargo Load = 0 bbls

Cargo Oil Moment of Weight = 0 Nm

Σ Moment of Weight = Total Topside M.O.W + Cargo Oil M.O.W

= -1844035.731 Nm + 0 Nm

= **-1844035.731 Nm**

b. Cargo Load Condition: 50% Cargo Load

Cargo Load = 310000 bbls

d_{cargo} = 0 m

Cargo Oil Moment of Weight = F x d_{cargo}

= [(Cargo Load x 140) kg x g] x 0 m

= [(310000 bbls x 140)kg x 9.81 m/s^2] x 0 m

= 0 Nm

Σ Moment of Weight = Total Topside M.O.W + Cargo Oil M.O.W

= -1844035.731 Nm + 0 Nm

= **-1844035.731 Nm**

c. Cargo Load Condition: 100% Cargo Load

Cargo Load = 620000 bbls

d_{cargo} = 0 m

Cargo Oil Moment of Weight = F x d_{cargo}

= [(Cargo Load x 140) kg x g] x 0 m

= [(310000 bbls x 140)kg x 9.81 m/s^2] x 0 m

= 0 Nm

Σ Moment of Weight = Total Topside M.O.W + Cargo Oil M.O.W

= -1844035.731 Nm + 0 Nm

= **-1844035.731 Nm**