Computer Aided Design of a Deepwater Floater

by

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Dissertation submitted in partial fulfilment of

the requirements for the

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CERTIFICATION OF APPROVAL

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A project dissertation submitted to the
Mechanical Engineering Programme
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BACHELOR OF ENGINEERING (Hons)
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Approved by,

____

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

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

May 2013

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.

AFDZAL ZULLAH BIN MAHAMED SALLEH

ABSTRACT

Recently the deepwater floater has become an encouraging option as a wet-tree floating platform supporting steel catenary risers and mainly due to its capability of quayside topside integration and cost-effectiveness. However, it is still a challenge for a conventional semisubmersible to support steel catenary riser, particularly large ones, in harsh environment and relatively shallow water due to its large heave motion. In PETRONAS, the design library of offshore floaters thus extensive iterative process is typically engage to the concept design and selection work. Determination of specific parameters with respect to scaled model testing and calibration is not always straightforward and involved cross referencing between numerical analysis and experimental testing. Furthermore, the objective of the project is to develop a semi-submersible's hull section by concentrate on the concept design and selection work and to evaluate the stability and natural period of semi-submersible model at operating condition at same water depth. The project focus on developing the hull section of two pontoon which supported by four columns as well as top side section of semi-submersible model by using CATIA V5R18. The chosen parameter based on the design specification without neglecting the importance of stability and natural period of semi-submersible. In conclusion, the CAD model of four cylindrical columns rig pontoons of semi-submersible and the analysis are the fundamental initiator for the semi-submersible's design library. With concentrated on design selection work, natural period of semi-submersible and also analyze the increment of stability angle to determine the maximum degree of inclination as well as considered about load weight on the top side of semi-submersible.

ACKNOWLEDGEMENT

Alhamdulillah, praise to Allah s.w.t after two semester working on this project and finally it has been successfully completed. I would like to take the opportunity to express my gratitude and acknowledge all the people involve directly and indirectly with this project.

First of all, I would like to thank you to my supervisor, Assoc. Prof. Dr. Fakhruldin Bin Mohd Hashim who offered to take this challenge to do this project tittle proposed. The guidance and advice were appreciated.

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1.1 Introduction

The world crude oil demands will rapid increase in 2013 which expended the consumption of oil 840,000 barrel per day this year [1]. This scenario has forced the expertise to explore more oil reservoir to cater all demands as well as enhance the deepwater technology that can be operated at any situations of environment. In addition, it forced the expertise to in-depth study about the technology of deepwater structure which is able to explore more oil in any type condition of deepwater. Semi-submersible platform has recently become more popular to operate at deepwater oilfield exploration programs. It is also being more practical to replace conventional fixed oil platform structure to enhance the oilfield production. However, in-depth study to figure out some solutions about certain problems must be made even though the outcome still good uniformity.

1.2 Problem Statement

The critical stage in the design of floaters is to determine the conceptual design and feasibility study which is part of the Front End Engineering Design (FEED). Such an exercise is based on a structure approached to meet specific requirement and criterion. With unavailability of design library of offshore floaters in PETRONAS is the reason that extensive iterative process is typically being engaged in this exercise.

1.3 Objectives

The objectives of this project are:

I. To develop a computer based model of Semi-submersible by introducing a semi-submersible CAD model to eliminate some repetition in concept design and selection.

II. To analyze the capabilities, performance and natural period of Semi-Submersible with respect to stability studies and expected load condition during working operation.

1.4 Scope of Study

The project will focus on:

1. Developing of the vessel's hull constrains a deck section with four columns and supported by two pontoons semi-submersible production platform model by using computer based software CATIA V5R18

2. The design parameters of semi-submersible based on previous standard design based on [2].

3. The stability and natural period of semi-submersible will be analyzed by using varied parameters of metacentric height (GM) and the weight to be loaded on the topside for quick analysis to determine the degree of inclination as well as assuming no external environmental effect such as wave and wind forces.

1.4.1 Deepwater Study

The definition of deepwater field deept is yet to be established because the boundary differentiating deepwater and shallow water keep evolving as more and more technologies being developed. The Bureau of Ocean Energy Management, Regulation and Enforcement formerly of The United States Mineral Management Services (MMS) defines deepwater field depth from 300m to 1520m (1000feet – 5000feet) and any depth beyond 1520m (5000feet) is considered as ultra-deepwater field [3].

However in Malaysia, the society of Petroleum Engineer (SPE 138647) classified the depth of the field as deepwater range from 200m to 1200m and beyond that is considered as ultra-deepwater. As for the rest of the areas, the boundary for the deepwater ranges from 200m to 1600m as describe on the table below [1].

Table 1: Deepwater Classification [4]

Country/ Area/ region	Deepwater	Ultradeepwater
Malaysia	200m – 1200m	>1200m
Philippines	>200m	-
Indonesia	>200m	>1372m
Brunei	>1000m	-
Gulf of Mexico – Industry Convention	>500	>1600m
India	>400m	-
Brazil	>400m	>1000m

1.4.2 The Malaysian Deepwater Development

This project will focus in Malaysian Deepwater. The deepwater field development in the last few years has shown significant upward trend in the reserve growth worldwide. The breakthrough for Malaysia deepwater area started with the achievement of the first project first oil in August 2007, 5 years after the first discovery of oil in the field [1].

The discoveries in the deepwater have prompted a shift in focus towards deepwater and positioned Malaysia through PETRONAS as the highly potential deepwater hub in the region [1].

1.4.3 Semi-submersible Operating Location

Malaysian has recently installed its first spar at Kikeh field near Sabah in 2007 [5]. It is the first Spar in Malaysia located in more than 1000m water depth offshore Sabah and is also the one ever installed outside the Gulf of Mexico [5]. The Semi-submersible, Ocean Rover has tendered assist rig and will be mobilized to batch set location to finish the drilling and completion operation [6].

The scope of this project will focus at Kikeh or Block K which located 75 nautical miles off the west coast of Sabah, Malaysia in the South China Sea [6].

Figure 1: Kikeh Field Location [6]

Table 2: List of deepwater fields that are in operation in Sabah seawater [6].

No	Field name	Waterdepth (m)	Operator
1	Kikeh	1300	Murphy oil
2	Gumusut/Kakap	1220	Shell
3	Kebabangan	>200	Conoco P.
4	Jangas	>1000	Murphy oil
5	Ubah Crest	>1000	Shell

In this study the semi-submersible will be used at Malaysian sea water and the water depth choosen at Kikeh location with 1300m and the significant wave height is considered as 6m and wave period equals 14 s. Thus, another element in geometrical properties such as sea bed size is 8000 x 8000 m^2. Below is the table of Metocean data:

Table 3: Metocean Data (Malaysia) [4]

Location	**Malaysia**	
Condition	**Max Operating**	**Design Extreme**
Environmental Component	**10 Year**	**100 Year**
Wind:		
Wind Spectrum	API RP 2A	API RP 2A
Speed, V_w (1 hour mean at 10 m)	31.1 knots	36.9 knots
Sea Waves:		
Wave Spectrum	JONSWAP[3]	JONSWAP[3]
Significant Wave Height, H_s	16.1 ft.	20.7 ft.
Maximum Wave Height, H_{max}	30.8 ft.	39.4 ft.
Peak Period, T_p	12.7 sec.	13.1 sec.
Peakedness Parameter, γ	1.7	1.9
Surface Speed, V_c	2.3 knots	2.5 knots

CHAPTER 2

LITERATURE REVIEW

2.1 Computer aided design (CAD)

Computer Aided Design (CAD) CATIA V5R18 is software to design and draft in a short time without used conventional method for modeling and architectural design. CATIA V5R18 has consisted of Two Dimensional - 2D and Three Dimensional - 3D modeling and designing program. The 2D program commonly used for basic drafting, drawing and designing 2D layout according to the specific dimensional has been decided. However the CATIA V5R18 also allowed the engineer view in 3D modeling design proposed the actual products will come out in future [7].

Hence the CATIA V5R18 software has some advantages which is able to design in solid modeling which created a digital geometric data base as well as be able to decrease the cost when production begin [7].

Based on previous project [8], the project focuses on tension leg platform which consists of four cross sectional area of pontoon with supported by four columns for topside section. The project also focus on mechanical design, part design and assembly design as well as analyze vertical center of gravity and draft, where the final hull design was a square ring pontoon with outer lengths of 270ft, height of 40ft and width of 55ft [8].

2.2 Types of Deepwater Floater

The deepwater floater's structure can be defined in two interdependent parameters, which namely their function and configuration. A Mobile Offshore Drilling Unit (MODU) configuration is commonly determined by its variable deck payload and transit speed requirements [9].

The floating structure has various degrees of compliancy. The buoyant forced such as semi-submersibles is dynamically unrestrained and allowed to have six degree freedom (heave, surge, sway, pitch, roll and yaw). Positively buoyant Tower (TBTs) or Buoyant Leg Structures (BLS) are tethered to the seabed and are heave-restrained. All of these structures with global compliancy are structurally rigid. Compliancy is achieved with the mooring system. The sizing of floating structure is dominated by considerations of buoyancy and stability [9].

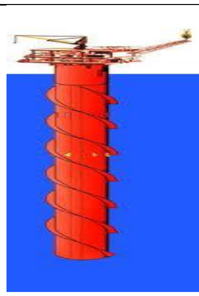
A very high demand for oil and gas has forced people to explore new oil reservoir either on the land or inside the sea. However it needs a very expensive investment to cater all demand to the people. It starts from the land which used portable oil platform, derrick and so on until very sophisticated equipment for exploring new oil reservoir [9].

Therefore, the engineers have to in-depth study about deepwater engineering facilities to meet people demanded. Deep-water floaters are the most suitable technology which is able to operate at ultra-deepwater oceans [9].

Below is the table constrains several types of deepwater floaters:

Table 4: Types of Deepwater Floater

Deepwater floaters	Description
Tension Leg Platform  Figure 2: TLP [10]	- The structure have columns and pontoons - It looks like submersible platform - The unique feature is the mooring system (consist of tendons/tethers)
Extended Tension Leg Platform  Figure 3: ETLP [10]	- It is vertical mooring platform commonly used for oil and gas production.

 Figure 4: Spar [10]	- It used vertical cylindrical mooring platform for oil and gas production.
 Figure 5: Semi-Submersible [10]	- It has twin pontoon and several column as a hull section.
FPSO  Figure 6: FPSO [10]	- It is a ship that can be a drill ship, production, storage and offloading the crude oil

2.3 Semi-submersible

The Project will narrow down to focus only on Semi-submersible floaters. The structure of semi-submersible platform consists of a deck, multiple columns and pontoons. The purpose of “columns” are for stabilizing the platform, it means that the center of gravity is above of the columns. In the contrary, it a little bit different design with spar platform, which achieves stability by placing the center of gravity below the center of buoyancy and the TLP which have stability from tendons [11].

The structure design of semi-submersibles depends on the principle of consideration which generic the floater concepts:

- Weights and CG’s (Center of Gravity)
- Hydrostatics and tank capacities
- Intact and damaged stability
- Wind force (Stability and mooring loads)
- Current forces (mooring loads)
- Ballast system performance
- Motions (sea keeping, drift and low frequency mooring loads)
- Global Strength
- Fatigue

Before initiating the design, the designer must consider several parts such as drilling, production, quarters, the systems and equipment list. On the other hand some constraints might be included such as maximum lightship draft for quayside outfitting, maximum beam for canal transit or dry transportations and maximum lightship weight and VCG (vertical center of gravity) envelope for dry transport [11].

2.3.1 General Arrangement and Hull Design.

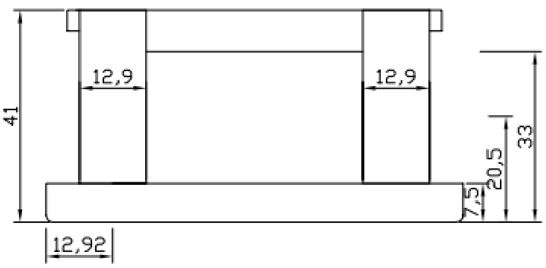
The semi-submersible design not only for drilling purposes, it is also accommodate several equipment such as heavy lift machinery, crew's accommodations, operational support constrains surface and subsea and even space launch [11].

Therefore the semi-submersible must consider:

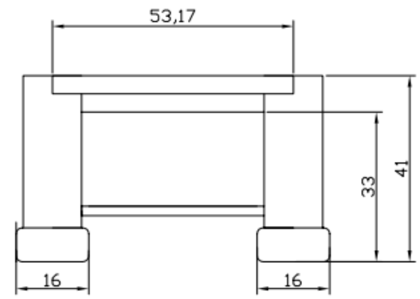
i. Stable support a payload above the highest waves.
ii. Minimize respond upon to the waves.

2.3.2 Design Selection of Semi-submersible platform

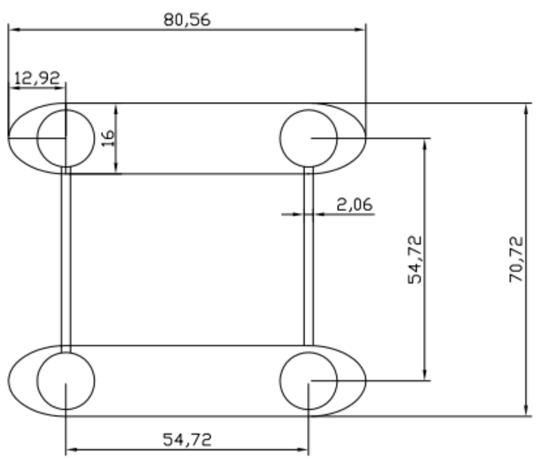
This project will refer standard dimensions of semi-submersible from thesis of Master engineering [2] to design and analyses the semi-submersible stability, buoyancy force and improve some necessary strength to resist hydrodynamic force via a combined support system.



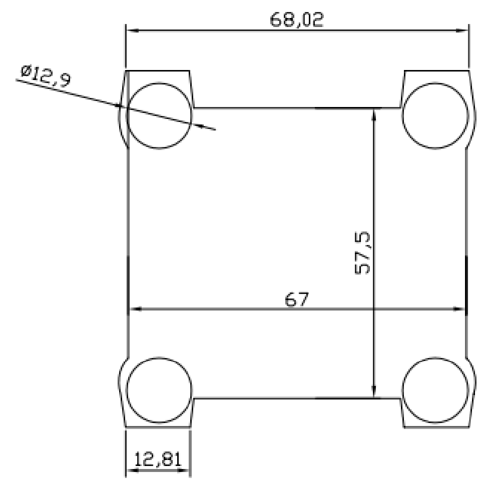
Side View



Front View



Section A-A – Pontoons



Topside view

Figure 7: General Arrangement Semi-Submersible [2]

2.3.3 Buoyancy force

Draft is the height of semi-submersible form the bottom of pontoon until to the water level which shown at figure 6. Draft also can be calculated by using Buoyancy force formula with respect to the principal of Archimedes. The buoyancy force exerted on the body of a vessel is equal to the weight of water displacement [12].

$$\text{Buoyancy force} = \text{Water displacement}$$

In order to calculate the Buoyancy force of vessel, determine the water plane area of column, draft, cross sectional area of pontoon, length of pontoon in each part of semi-submersible respectively and the density of seawater. Below is the formula of Buoyancy force [8].

$$\text{Buoyancy} = [(4 \times \text{water plane area of columns} \times \text{draft}) + (2 \times \text{cross sectional area of pontoon} \times \text{length of pontoon})] \times \text{seawater density}$$

2.3.4 Vertical center of gravity

Vertical Center of gravity is found using the centroid formula [13].

y' = Vertical Center of Gravity

Then,

$$y' = \frac{y_1 * A_1 + y_2 * A_2 + y_3 * A_3 + y_4 * A_4}{A_1 + A_2 + A_3 + A_4}$$

$$x' = \frac{x_1 * A_1 + x_2 * A_2 + x_3 * A_3 + x_4 * A_4}{A_1 + A_2 + A_3 + A_4}$$

2.3.5 Stability

Semisubmersible are used for a wide in oil and gas industries which loads some heavy machinery and accommodate facilities for drilling and some crews to operate the semisubmersible. Stability considerations are critical when conducting transportation and other marine operations safely [14].

Stability is the tendency to return the previous condition when troubled. When the semi-submersible rolls or pitches, the center of buoyancy shifts. It will determine that the semi-submersible is stable or unstable. This project will narrow down to focus on evaluating stability which considered two parameters are chosen for the faster analysis. The formulas are to find the parameters will be included in the parameters and formula function [14].

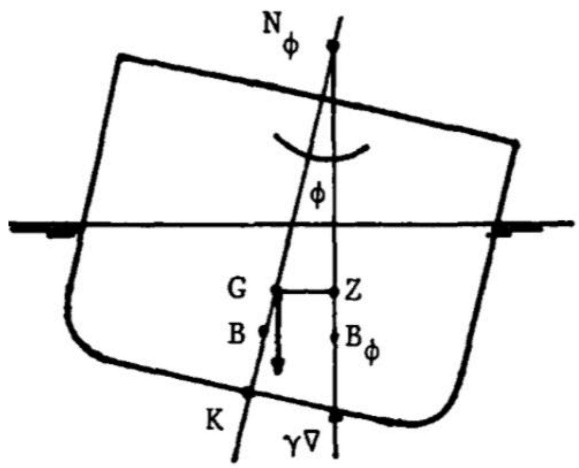


Figure 8: Schematic Diagram of Ship Stability [14]

K	Keel
G	Center of gravity
B	Center of buoyancy (center of the underwater displacement volume)
M	Metacenter
GM	Metacentric Height
GZ	Righting of Overturning lever

2.3.6 Six degree of freedom formula

The six degree of freedom consist of heave, yaw, roll, surge, sway and pitch. In this project only focus on Heave and Roll motion. These two formula were suited in this project to determine both motion accurately. Below are the formulas of natural period Heave, Pitch and Roll [4]:

$$T_{Heave} = 2\Pi\sqrt{\frac{2m}{\rho g A_{wp}}}$$

Where:

m = mass

rho,ῤ = desity

g = gravity

A_{wp} = water plane area

$$T_{Roll} = 2\Pi\sqrt{\frac{I}{A_{wp}\,gGM}}$$

Where:

I = Second Moment if Inertia with respect to waterplane.

GM = distance from the center of gravity to metacenter.

$$T_{pitch} = 2\pi\sqrt{\frac{Iyy}{\Delta GM}}$$

Where:

I = Second Moment if Inertia with respect to waterplane.

GM = distance from the center of gravity to metacenter.

Below is the diagram of natural period which consist of heave, pitch and roll.

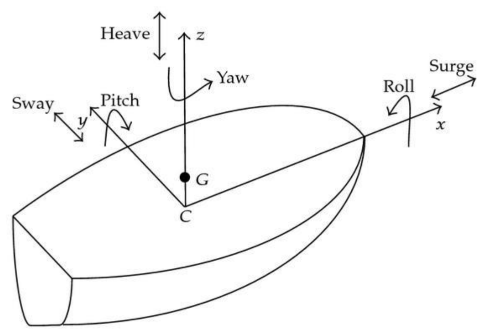


Figure 9: Schematic Diagram the Six Degree of Freedom [15].

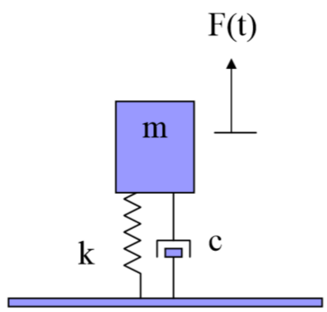


Figure 10: Simplified example of heave motion [4].

RAO (Response Amplitude Operator) data was found using a hull of similar dimensions. RAO is defined as response amplitude of the structure per unit wave height or wave amplitude.

CHAPTER 3

METHODOLOGY

3.1 Introduction

In this chapter, this project will focus on methodology of this project. This project was covered several topic in chapter one such as introduction, problem statements and scope of studies. Thus, the chapter two covered the formulas of Stability, Buoyancy, Six degree of Motions, and Vertical center of gravity.

In addition, this chapter three will focus detail on the CAD development by using CATIA V5R18 software. The project will focus on the hull section of semi-submersible. It also concentrate on the simple parametric model need only represent pontoon, columns and topside.

Lastly, this chapter also concentrates on the design and development where the semisubmersible typically will be studied under three conditions, namely tow out or loading, operating and survival condition. To narrow down of survival condition part, this project will study in depth at operating condition only. For the overall project management schedule, refer to appendix G for Gantt chart.

3.2 Flow chart explanation

The project started from preliminary research work to gather the information about semi-submersible which consist of Conceptual Design [4], Vertical Center of Gravity (VCG), Buoyancy, Stability and Natural Period. The information will be used to determine the design specification, criteria as well as parameters of semi-submersible on this project.

When the decision to select the specific criteria has done, first the project must determine the specific formula and calculation of Vertical Center of Gravity, Buoyancy and Stability which suited to the semi-submersible. However on the next semester this project will focus on the formula and calculation of natural period (Heave, Pitch and Roll) of semi-submersible.

Hence the project also focus on the CAD design of semi-submersible's stability to enhance the understanding of this project as well as to ensure the project is clear according to the objective. The design used CATIA V5R18 as a computer based software to design the pontoons, columns and topside. The design focuses on two pontoon which supported by 4 columns without having embrace support and the top side of the vessel to accommodate the equipment, facilities and crews.

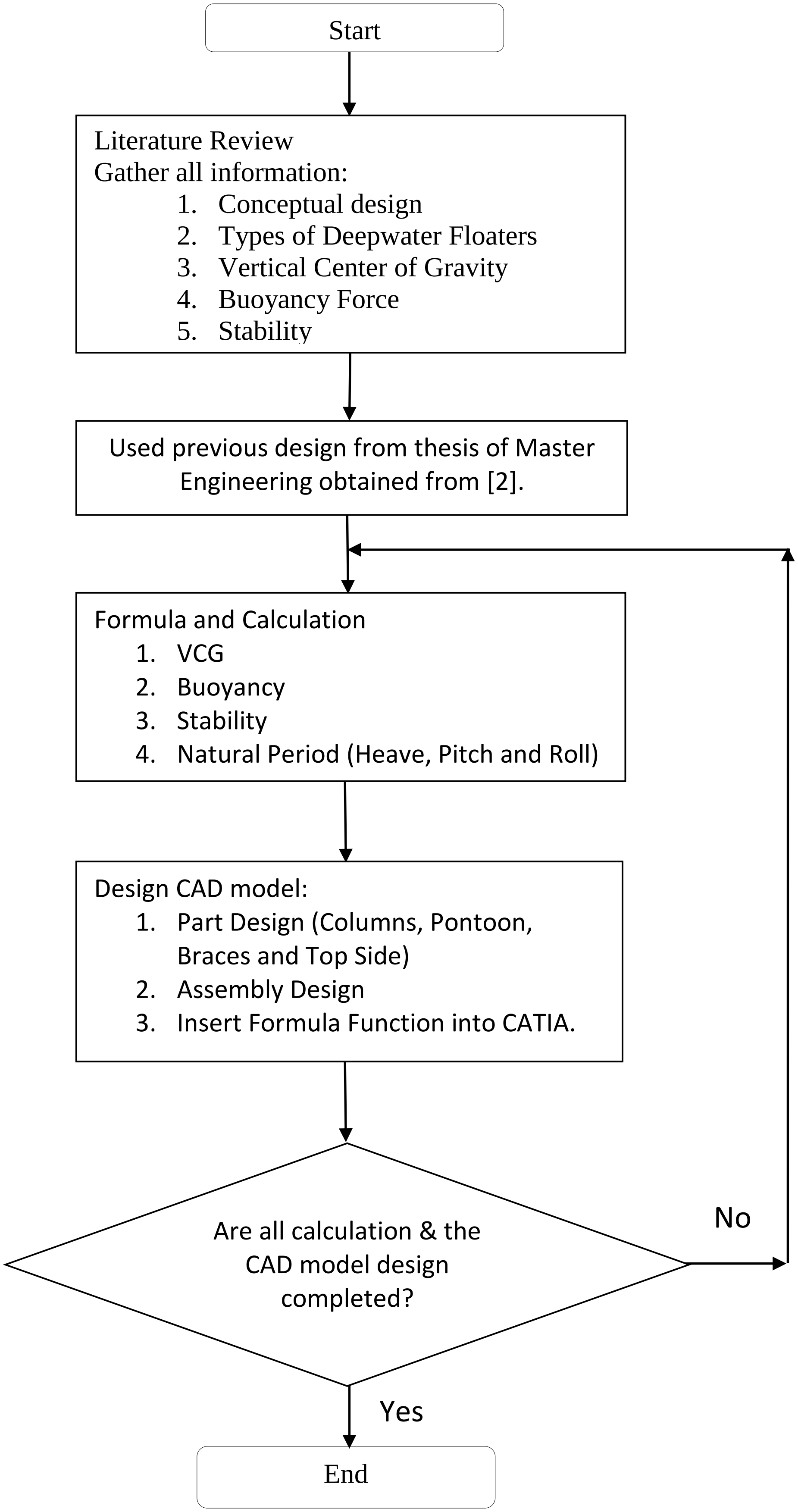


Figure 11: Flow chart

Table 5: Milestones

		FYP1					FYP2				Remarks
		J	F	M	A	M	J	J	A	S	
i	FYP Title Selection	◆									Completion of the title selection
ii	Submission of FYP title proposal	◆									Completion of the title proposal
iii	Submission of Extended Proposal		◆								Completion of the Extended Proposal
iv	Submission of Draft Report				◆						Completion of draft report
v	Submission of Interim Report				◆						Completion of Interim report
vi	AutoCAD model of Initial semi-submersible design					◆					AutoCAD model of the semi-submersible
vii	Calculation of VCG, Buoyancy and Stability					◆					Result for VCG, Buoyancy and Stability
viii	Calculation of Natural Period					◆					Result for heave, pitch and roll
ix	CAD Model for Semi-Submersible Design						◆				CATIA model of the semi-submersible
x	Submission of Progress Report						◆				Completion of Progress Report
xi	SEDEX							◆			Completion of SEDEX
xii	Submission of Draft Report							◆			Completion of Draft Report
xiii	Submission of Technical Paper								◆		Completion of Technical Paper
xiv	Submission of Final Report									◆	Completion of Final Report

3.3 The scope of project.

The project will concentrate on the semi-submersible's hull section. The parametric model need only represent the pontoons, columns and cross bracing as a prismatic section [11]. The semi-submersible typically will test under three conditions, tow out or loading, operating and survival condition but this study is conducted at operating and survival condition.

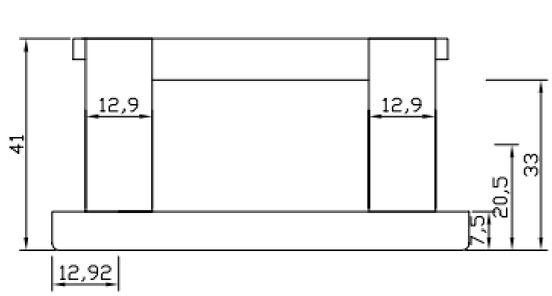
The most important input is in sizing a semi-submersible to ensure it has stable support a payload above the highest waves and to minimize the semi-submersible's dynamic responds. Therefore, to reduced responds to waves, the size shape and depth of submerge structure, pontoon and columns relatively to its waterplane area and the spacing of the pontoons and columns are the key factors to look into.

Hence the hydrodynamic responses must have a minimum natural heave and pitch/roll period of 20 sec based on standards of API codes for optimum operation of topside separation tanks and risers [11].

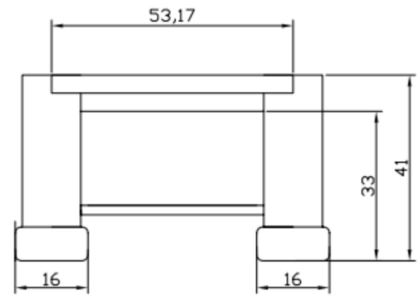
The model design used the parameter have been provided at (table 6) which obtained from thesis an experimental study of motion response in regular waves of a semi-submersible under damage conditions.

Table 6: The Parameter of Semi-submersible [2]

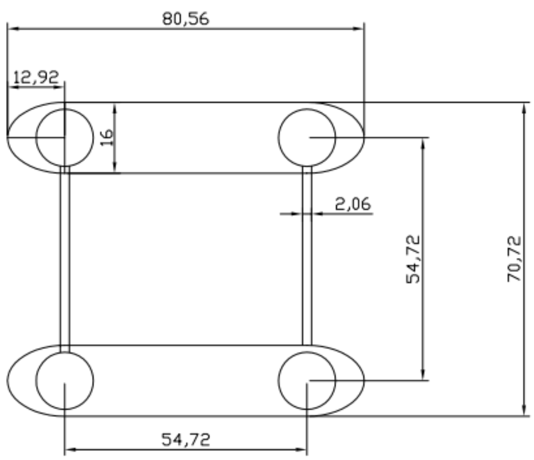
Details	Meter
Pontoons	
Length	80.56
Width	16.00
Height	7.50
Bilge Radius	1.35
Columns	
Diameter	12.90
Transverse/Longitudinal Spacing, C-C	54.72
Height above keel	33.00
Brace	
Diameter	2.06
Height C above keel	11.20
Top side	
Length	67.00
Beam	57.50
Height	
Keel to Topside	41.00
Plate Thickness	0.0508 mm
Draught (Operational)	20.50 m
Volume (Operational)	50964.88 m^3
CG From Keel	20.05 m
GM	2.40 m
Number of Columns	4
Number of Pontoons	2
Number of Topside	1



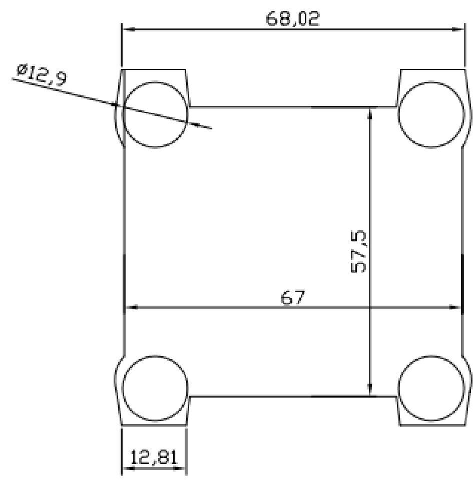
Side View



Front View



Section A-A - Pontoons



Topside view

Figure 12: General Arrangement of Semi-submersible

3.4 Intact Stability Formula and Calculation

Semi-submersible stability can be defined in simple terms as its characteristics or tendency to return to its original state or upright state, when an external forces is applied on or removed form the semi-submersible.

A semisubmersible is at equilibrium where the weight of the semi-submersible acting down through center of gravity is equal to the up thrust force of water acting through center of buoyancy and when both of these force are in same vertical line. To determine the stability of Semi-submersible must have three vital points which are G (Center of Gravity), M (Metacentric) and Z (Inline distance from G). According to the table 6, CG is located at 20.05 m from the keel and GM is at 2.4 m above CG. Hence the VCB (Center of Buoyancy) centered at 10.45 m and the Draught at 20.50 m above the keel respectively.

The project also concentrated on the stability regulations which is relating to damage stability and loss of buoyancy would be most affected by vessel motion [2].

I. Maximum inclination of angle is 15^o after define damage.
II. Maximum inclination angle of 35^o with minimum freeboard to down flooding of 0.6m and minimum righting arm (GZ) of 1.0m after completely loss of buoyancy at the column.

Based on [9] the appropriate formula is:

$$GZ = GM \text{ Sin } Ø$$

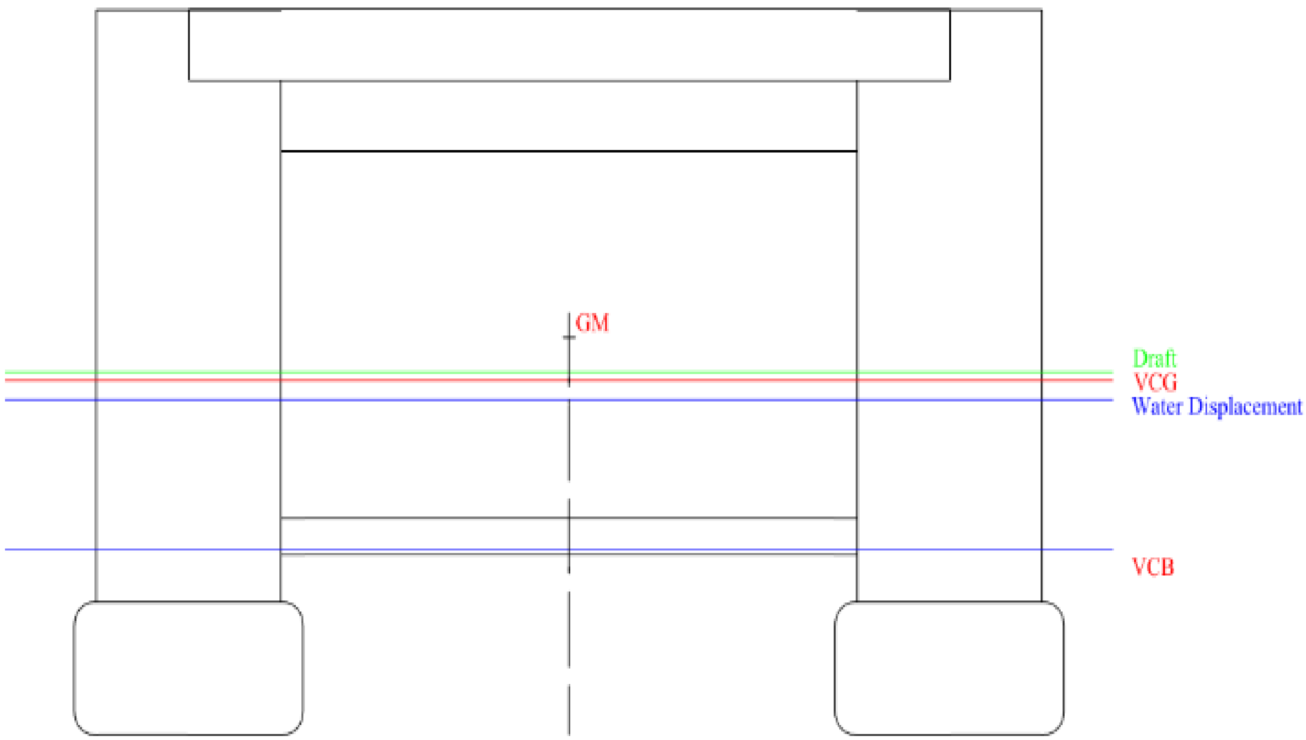


Figure 13: Front View of Semi-submersible

All the calculation stated at appendix B.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Configuration

This project begin from preliminary research work which consists of conceptual design, vertical center of gravity, buoyancy force, stability and natural period of s semi-submersible. Hence, the project also considered about the formula that must be used and applicable to the semi-submersible according to the objective of this project. After determine the suitable formula to be applied at submersible, this project will determine the design specification as well. However this project used previous design and parameters that obtained form [2] .

Hence, this project concentrated on CAD model design which consists of step in developing formula function and CAD model (part design and assembly design) by using CATIA. After the design of CAD model finished, the vertical center of gravity VCG can be generated by using CATIA as well. Furthermore, in this project also concentrated on stability and natural period of semi-submersible by referred to the design parameter that already decided in section 2.

4.2 CAD model design

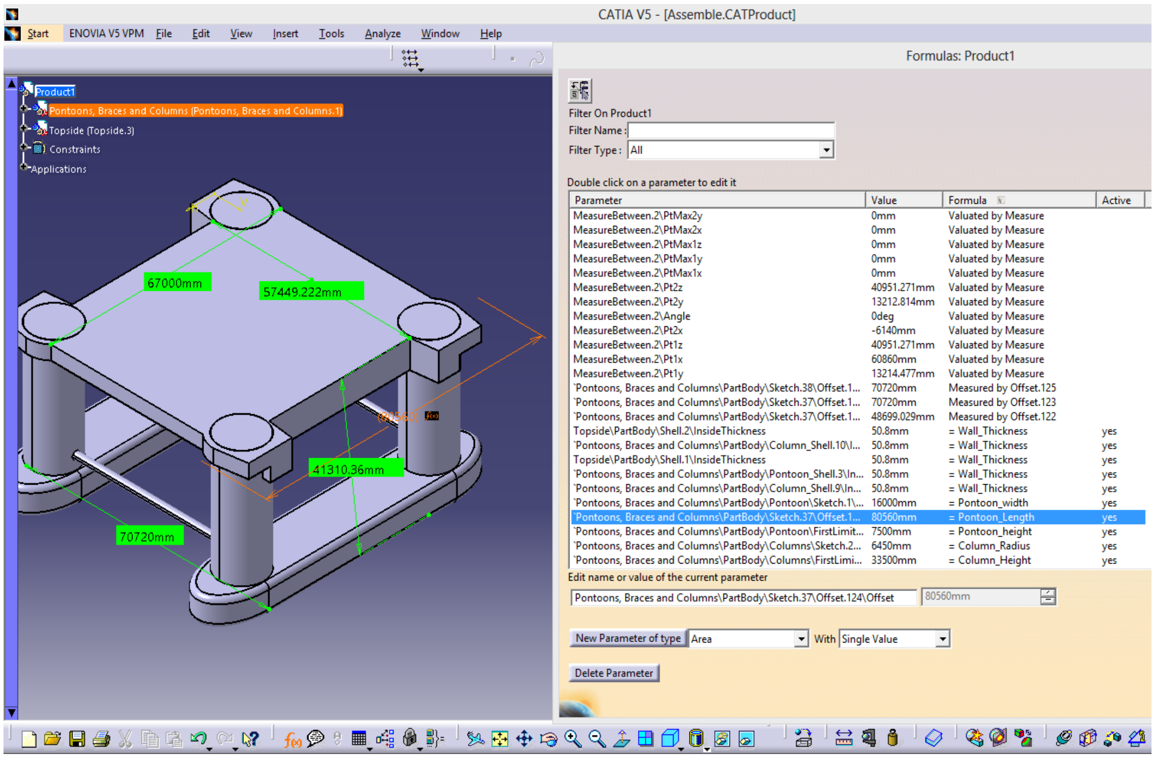


Figure 14: CAD model design and formula function

In figure 14, Started form part design and assembled at assembly design module, the step arrangement of development the hull section consist of two pontoons, four columns and one topside are based on the connection of the part each other. The lowest part were pontoons which were connected with four columns. The columns also has supported two braces between port and starboard side of semi-submersible's aft and front section. The topside is the upper part of the hull section and was supported by four cylindrical columns. Hence, the parts also developed concurrently with the formula function in CATIA V5R18. All the parameters of specified dimension were inserted into the formula function at CATIA V5R18. With this function, the water plane area to every part pontoons, braces and columns were calculated simultaneously when the dimension is changed. Hence, this model also can be used for simulation of easily understanding on the semi-submersible's condition and effect by having it virtually on screen. The result can be a basic assumption for semi-submersible's design calculation for stability and natural period analysis.

4.3 Stability

In stability section, this project focused in two difference parameters of GM where the project firstly must determine the GZ (righting arm) at specific angle of inclination with fix height of metacenter (GM) 2.4 m and 1.5 m.

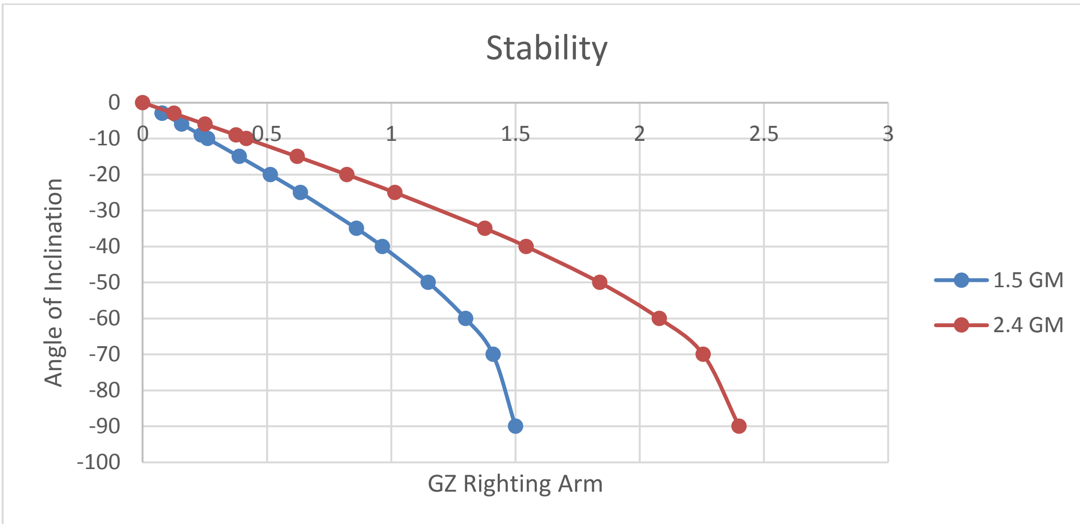


Figure 15: Intact Stability Graft

In figure 15, the angle of inclination against righting arm of semi-submersible's stability shows that as the Metacenter (GM) of semi-submersible increase the righting arm (GZ) increase as well at same angle of inclination. The intact stability has been determine by formula GZ = GM Sin Ø which were using the draft of Semi-submersible is 20.50meter during operation [2]. Based on the data gathered, when the GM is assume to reduce the distance from 2.4m to 1.5m the result seems different where the GZ (righting arm) of semi-submersible at 1.5m (GM) become less than before. It means the structure seems unstable or easy to topple during rough operation condition if the GM is lower than 2.4m.

4.4 Natural Period

Furthermore, the natural period of Semi-submersible's heave, roll and pitch which were the using the data collected from such as the value of Mass, Area of waterplane, Moment of inertia I_{xx} and I_{yy}. All the information will be using at the formula of Heave, Roll and Pitch to determine the motion period of semi-submersible in free floating without considered moored.

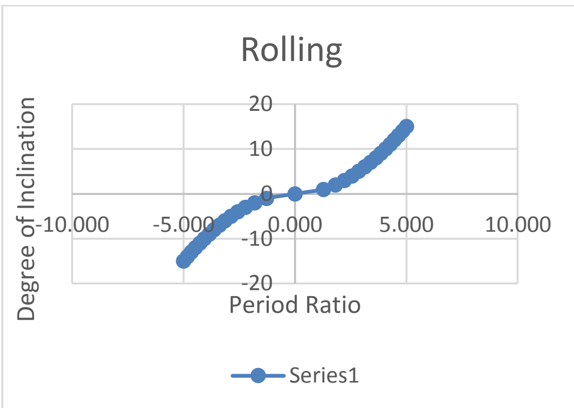


Figure 16: Rolling Period

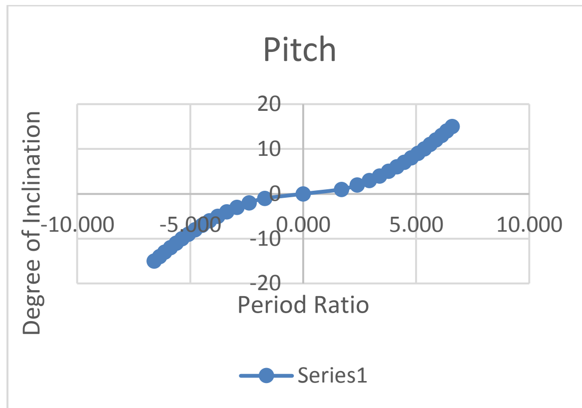


Figure 17: Pitch Graph

In figure 17 and 18, the graph of pitch and roll provided which were the degree of inclination against period determined by excel graph. The period ratio ($T'/T_{\varnothing}$) determined by formula which were using k (radius of gyration) as well as moment of inertia and semi-submersible displacement. The original period (s) obtained from formula of period, $T_{roll,}$ $T_{pitch,}$ and T_{heave} . According to the result, this project get to determine the natural period of semisubmersible during wavy or rough condition at the sea.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

A CAD-based model of a semi-submersible was developed to eliminate some repetition in the concept design and selection. The reduction value of semi-submersible’s metacenter (GM) from 2.4m to 1.5m resulted in a difference in the value of righting arm (GZ). Based on the results, if GM is less than 2.4m, the semi-submersible has the tendency to topple under rough conditions.

Furthermore, this project has succeeded in analyzing the capabilities, performance and natural period of semi-submersible with respect to stability studies and expected load condition during working operation. The natural period of semi-submersible’s heave, roll and pitch which uses the data collected from the values of semi-submersible’s mass, area of waterplane, as well as moment of inertia I_{xx} and $I_{yy.}$ Using specific formulas these data were then used to determine the motion period of semi-submersible which was considered without being moored (free floating). This project only focused on a simple type of semi-submersible with two pontoon and four columns, assuming no external any environmental impacts such as wind force and wave force.

5.2 Recommendation

For future works, it is recommended to develop the same parameter of semi-submersible with two pontoon, two braces and one top side with supported by four columns to meet the maritime classification requirement. Additional recommended parameters for analysis is the damage stability calculation to determine the safest degree of inclination of semi-submersible taking into effect. The environmental conditions such as wave and wind forces.

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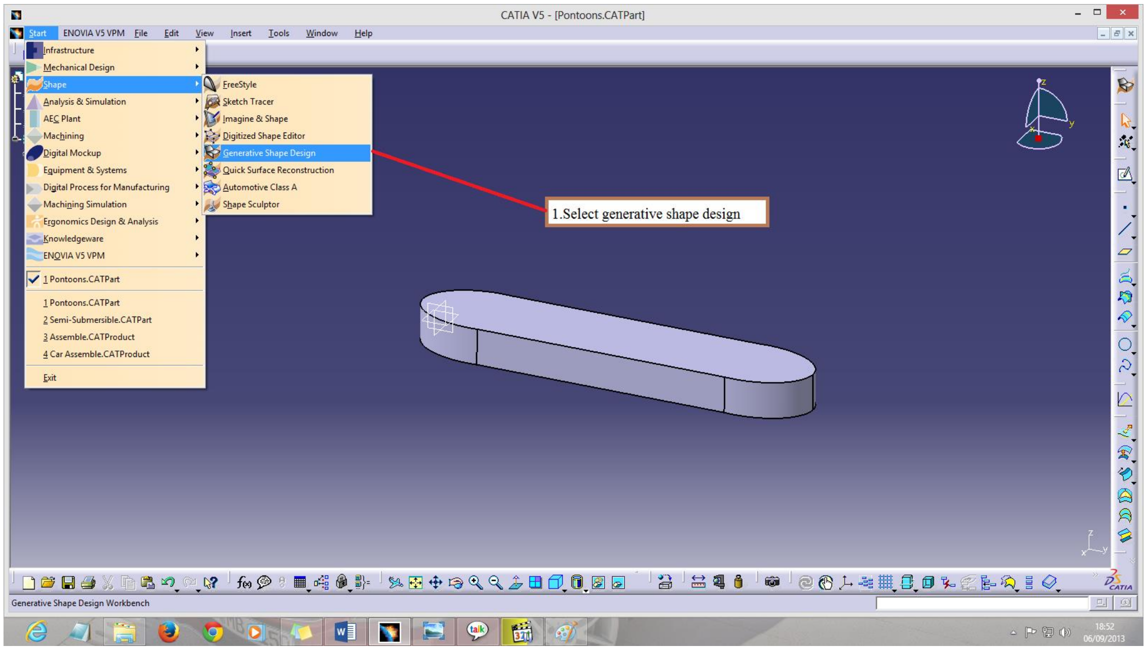
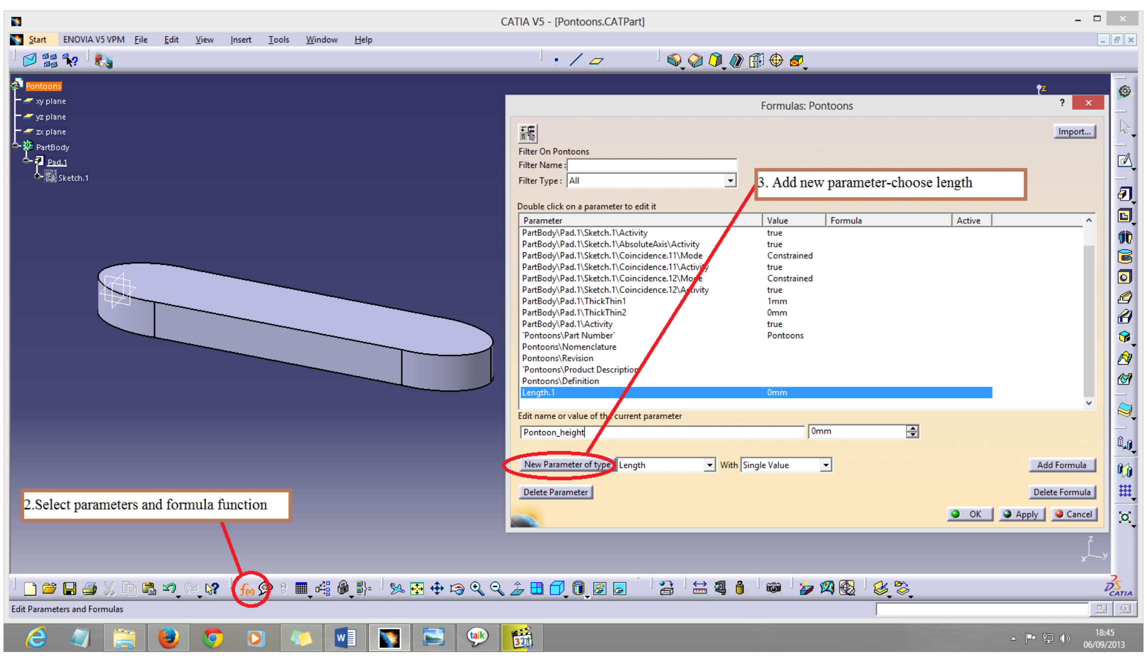
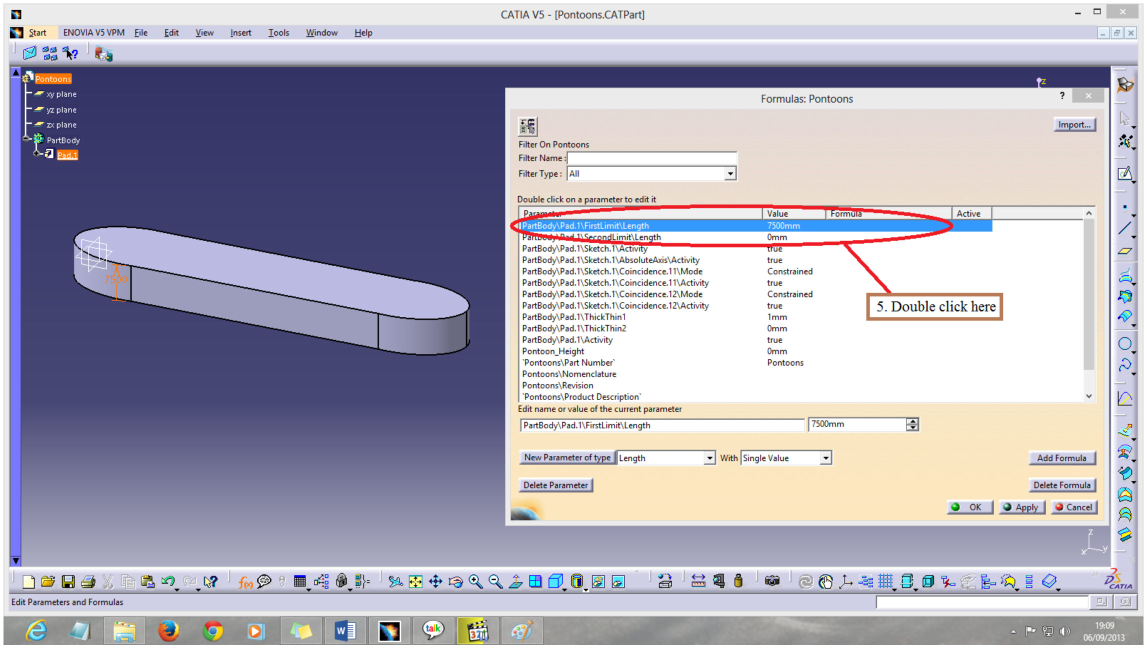
Step in Developing Formula Function.



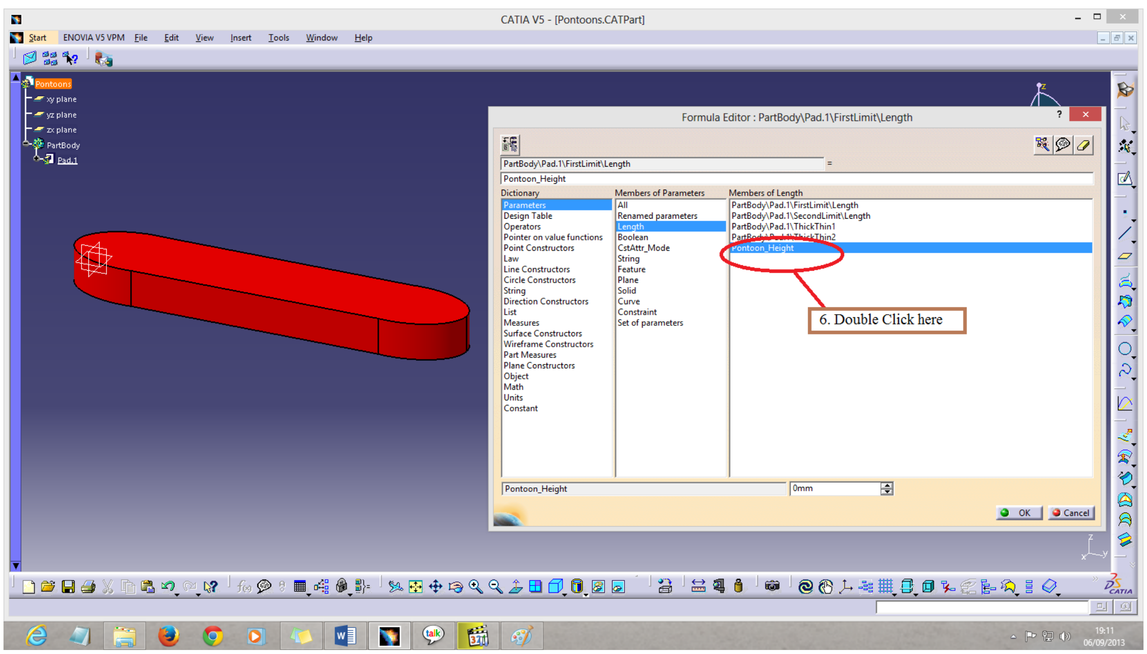
A1: Step 1



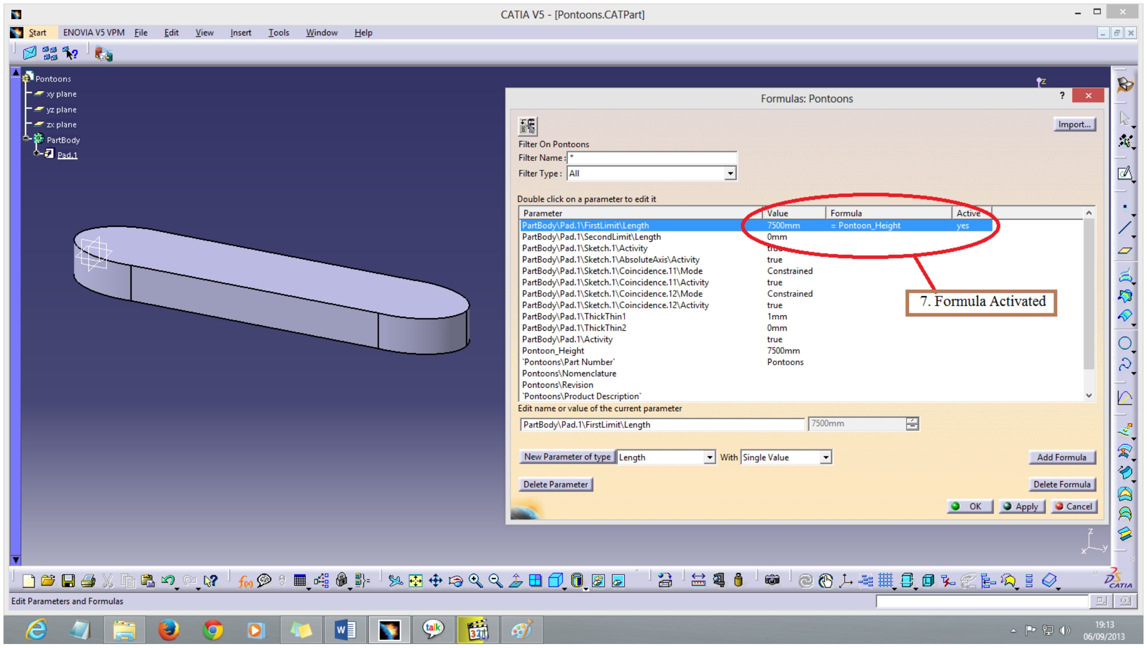
A2: Step 2



A3: Step 3



A4: Step 4



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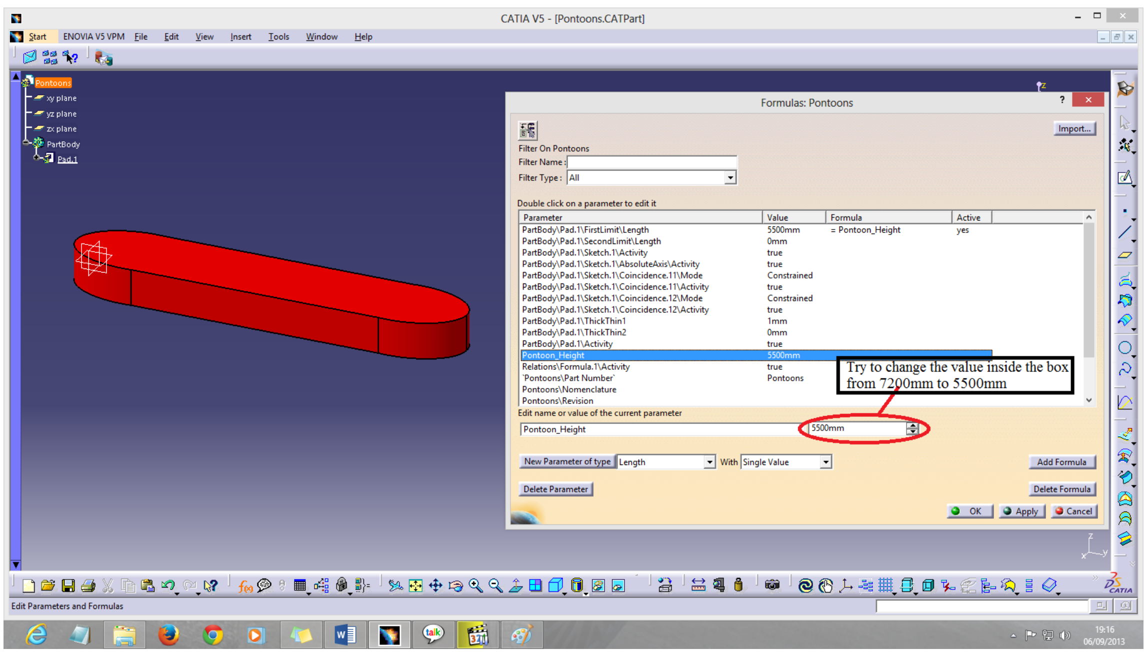
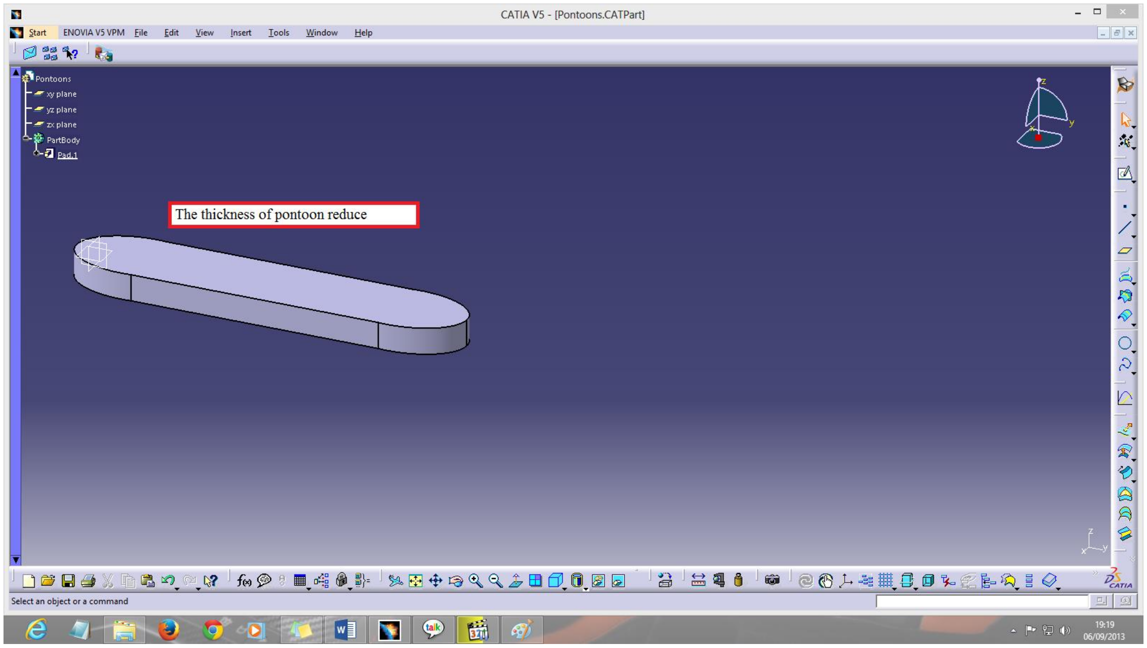
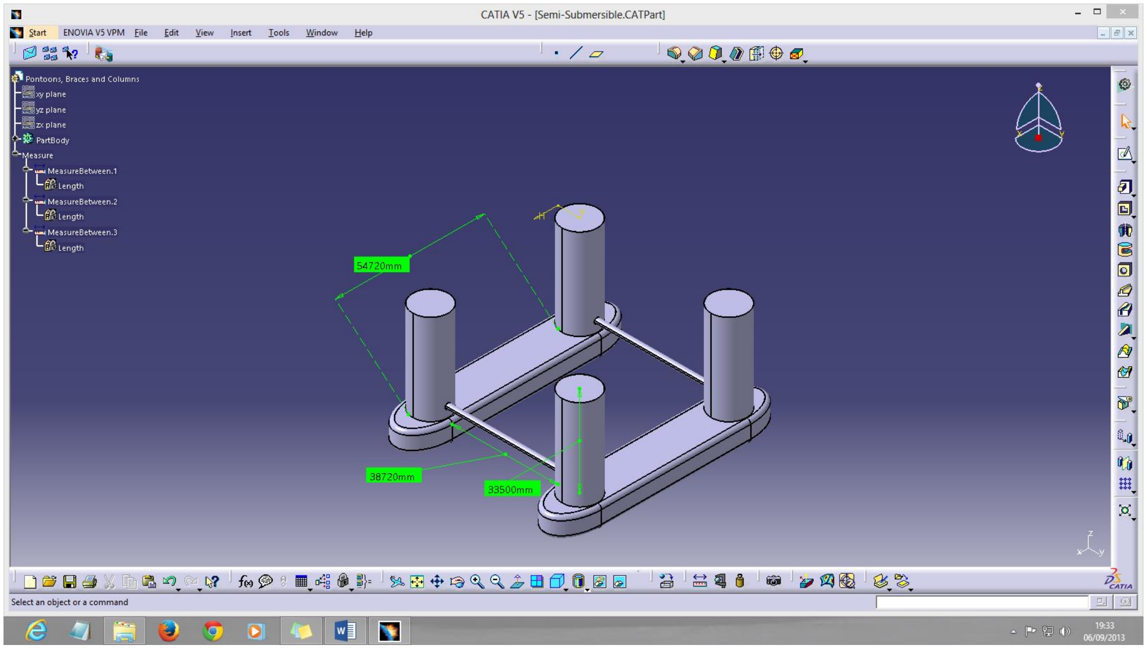


A6: Step 6

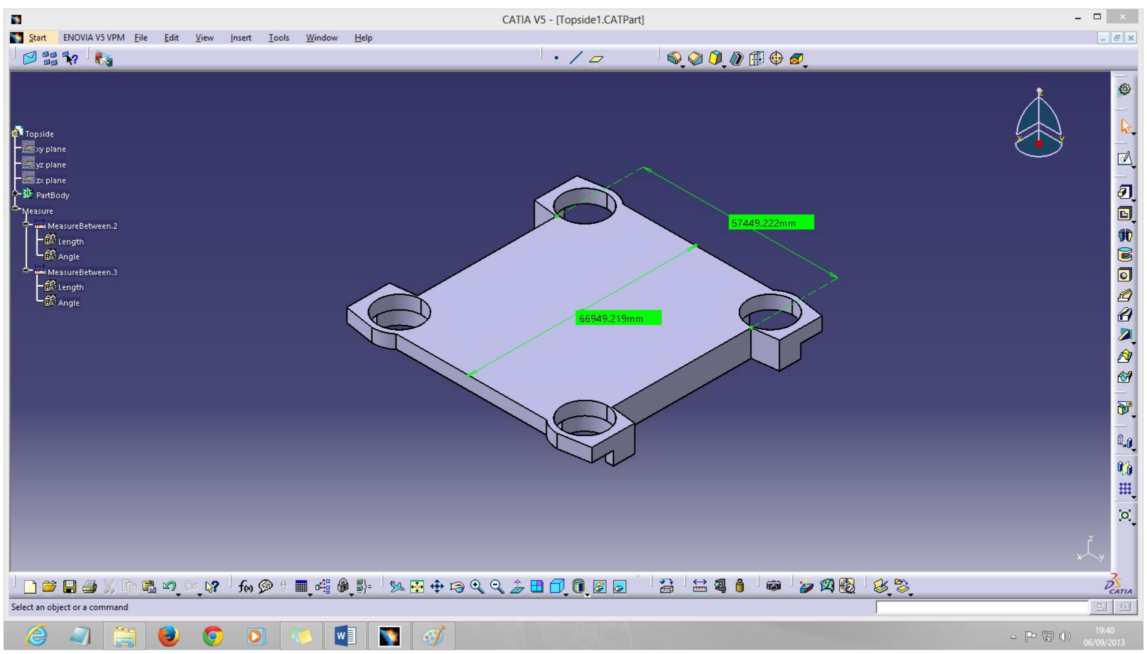

CATIA V5 - [Pontoons.CATPart]
Start
ENOVIA V5 VPM
File
Edit
View
Insert
Tools
Window
Help
Pontoons
xy plane
yz plane
zx plane
PartBody
Pad.1
The thickness of pontoon reduce
Select an object or a command

A7: Step 7

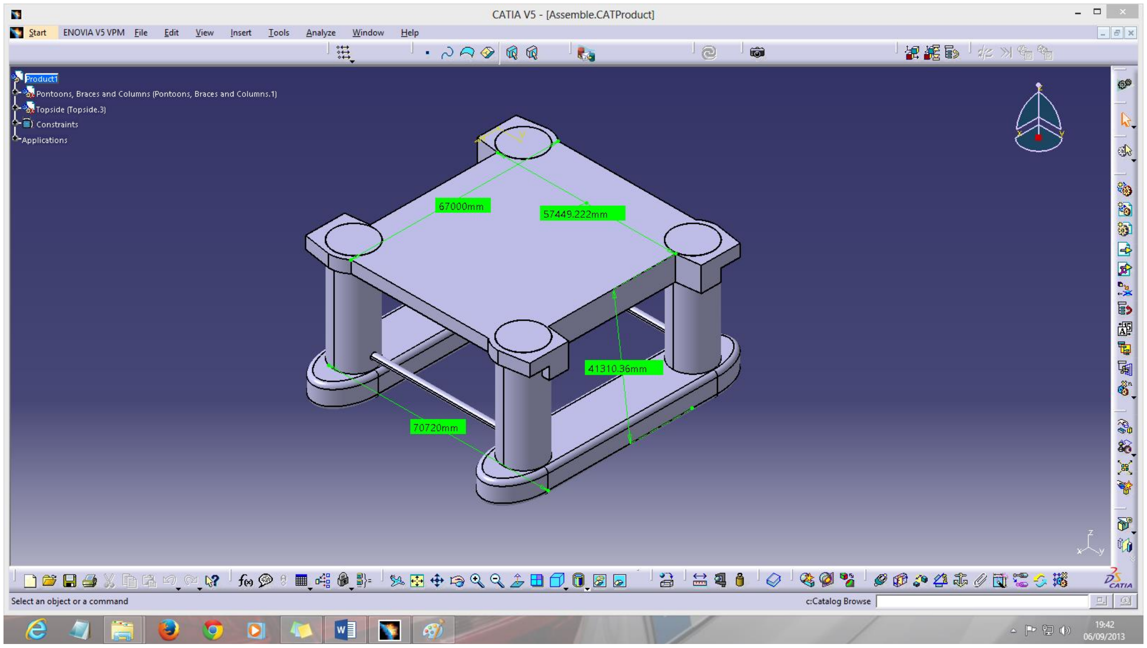
Step in Developing Semi-Submersible CAD Model



A8: Pontoons and Columns Part Design

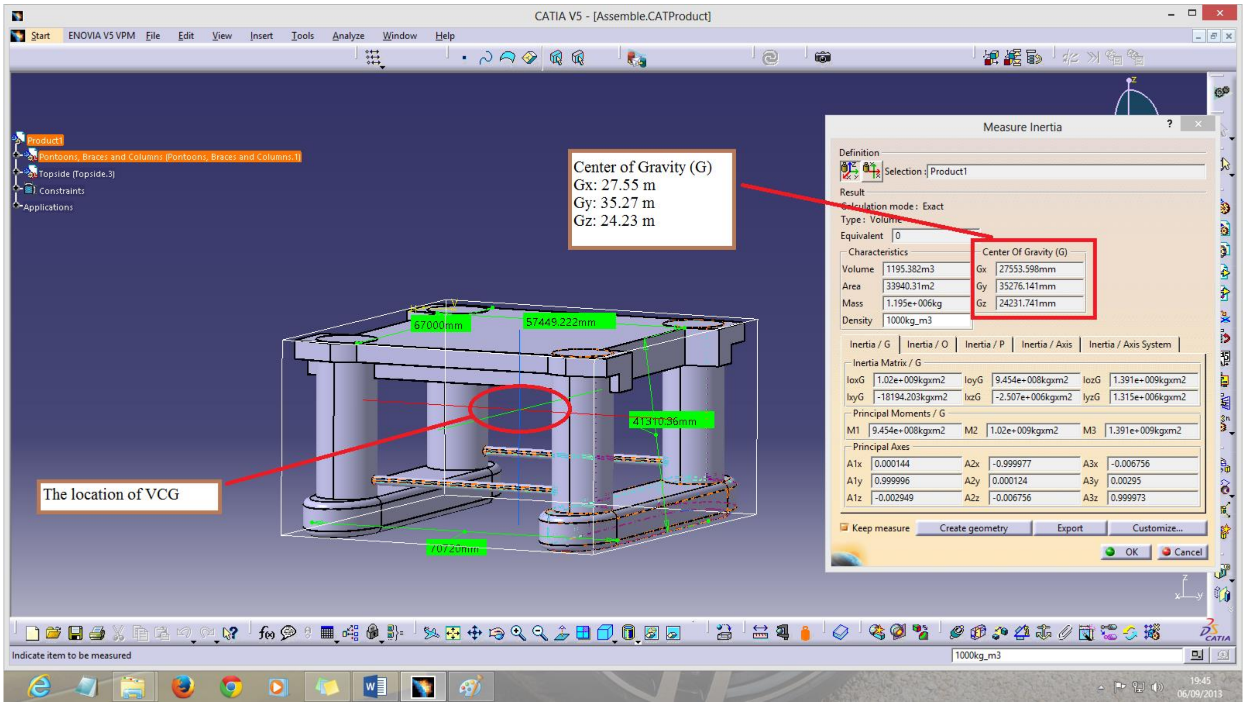


A9: Topside Part Design



A10: Assembly Design

Vertical Center of Gravity generated by CATIA



A11: Vertical Center of Gravity

APPENDIX B

Calculation of Intact Stability

Semi-submersible Stability:

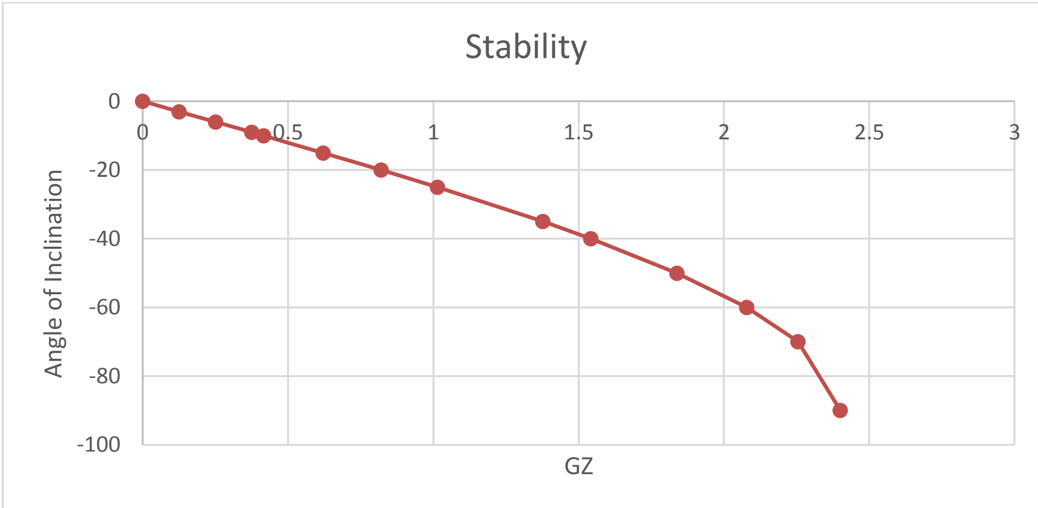
GZ = GM Sin Ø

i. GM value obtained from [2] :

G = 20.05 m above the keel

M = 2.4 m above from G

GM	GZ (righting arm)	Angle	Condition
2.4	0	0	Safe
2.4	0.125606295	-3	Safe
2.4	0.250868312	-6	Safe
2.4	0.375442716	-9	Safe
2.4	0.416755626	-10	Moderate
2.4	0.621165708	-15	Maximum
2.4	0.820848343	-20	Toppled
2.4	1.014283827	-25	Toppled
2.4	1.376583446	-35	Toppled
2.4	1.542690262	-40	Toppled
2.4	1.838506662	-50	Toppled
2.4	2.078460968	-60	Toppled
2.4	2.255262289	-70	Toppled
2.4	2.4	-90	Toppled



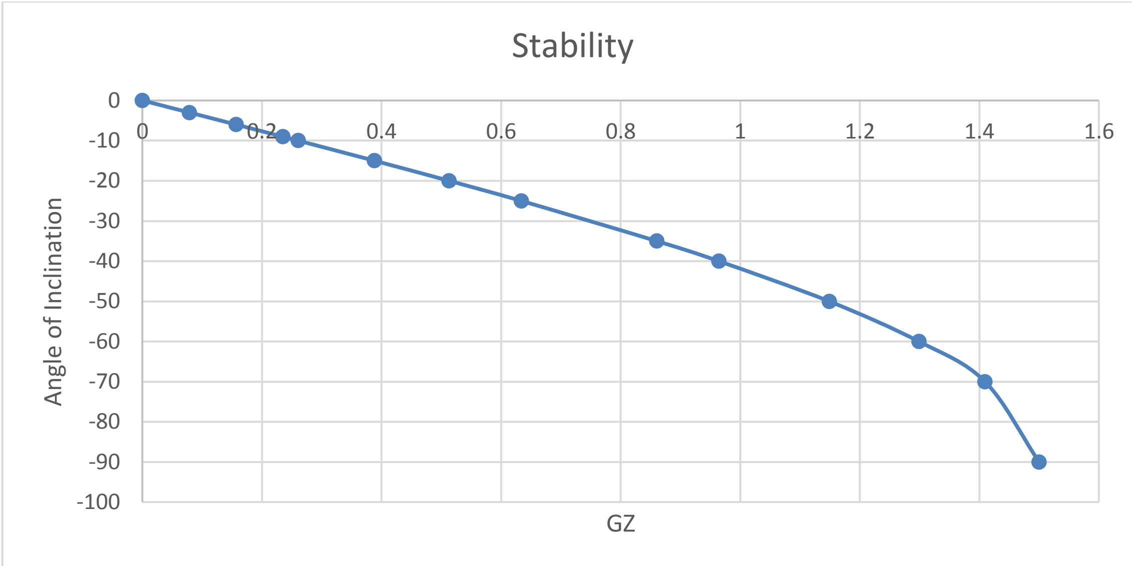
Stability Graft for 2.4 GM

ii. GM value reduced to 1.5m:

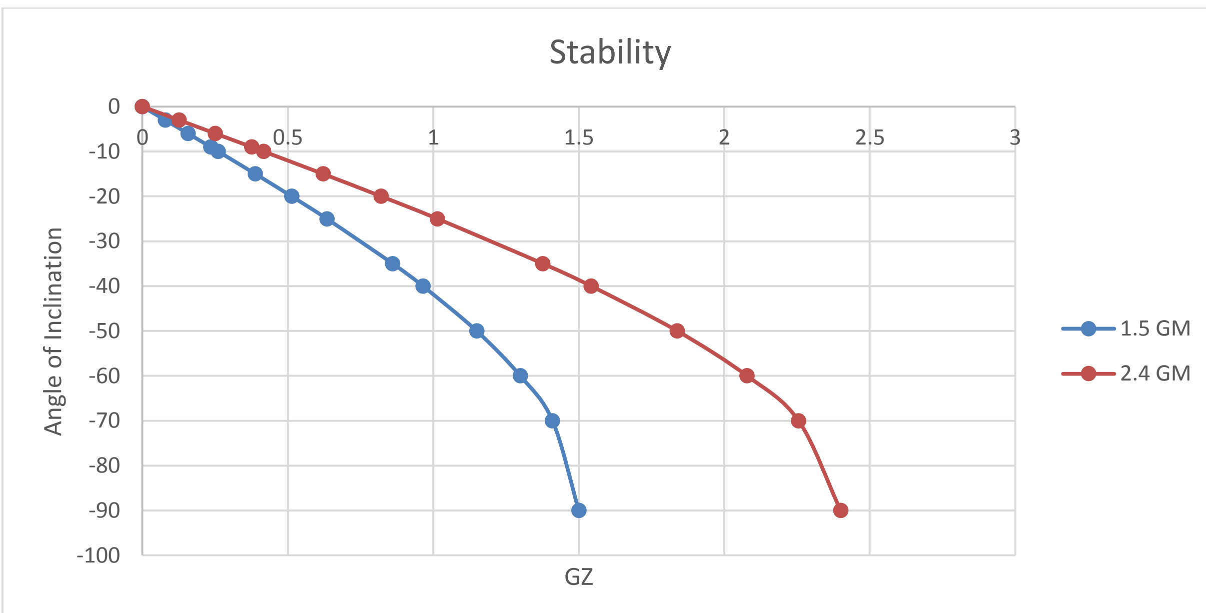
G = 20.05 m above the keel

M = 1.5 m above from G

GM	GZ (righting arm)	Angle	Condition
1.5	0	0	Safe
1.5	0.078503934	-3	Safe
1.5	0.156792695	-6	Safe
1.5	0.234651697	-9	Safe
1.5	0.260472266	-10	Moderate
1.5	0.388228567	-15	Maximum
1.5	0.513030214	-20	Toppled
1.5	0.633927392	-25	Toppled
1.5	0.860364654	-35	Toppled
1.5	0.964181414	-40	Toppled
1.5	1.149066664	-50	Toppled
1.5	1.299038105	-60	Toppled
1.5	1.40953893	-70	Toppled
1.5	1.5	-90	Toppled

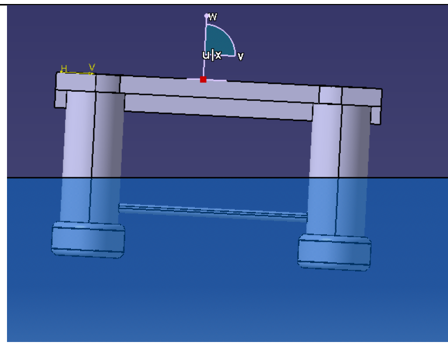
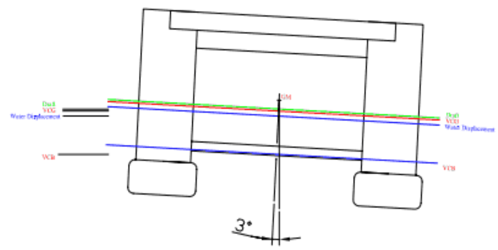
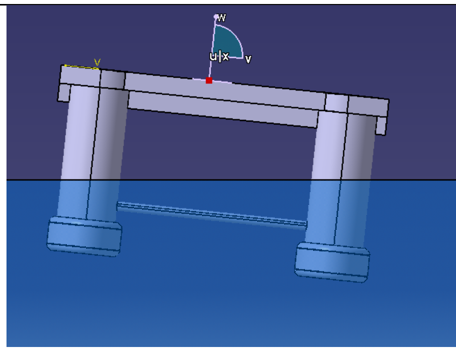
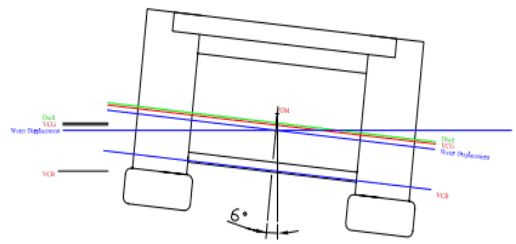
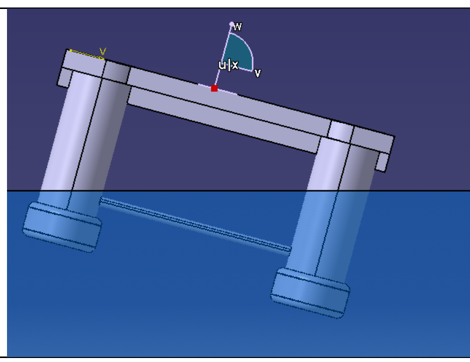
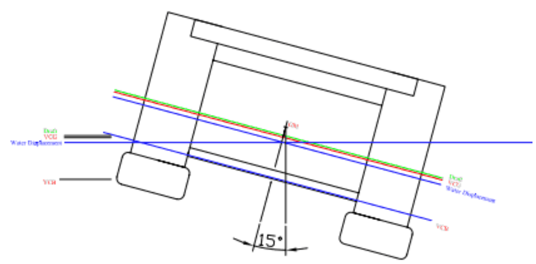
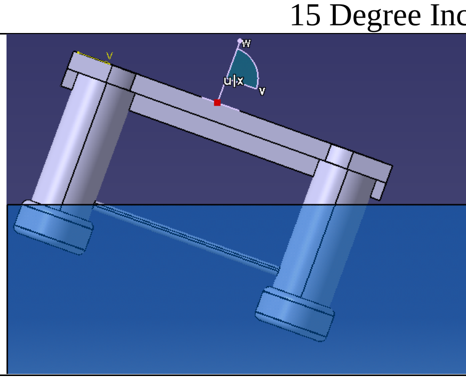
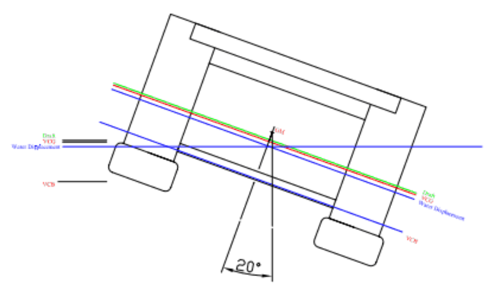


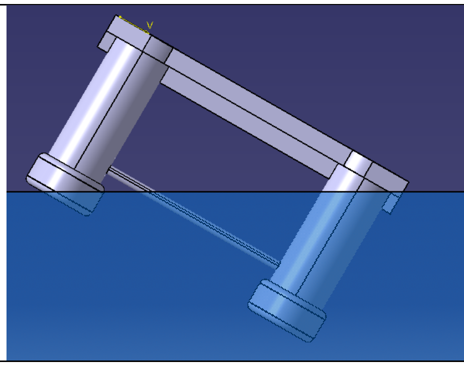
Stability graft for 1.5 GM

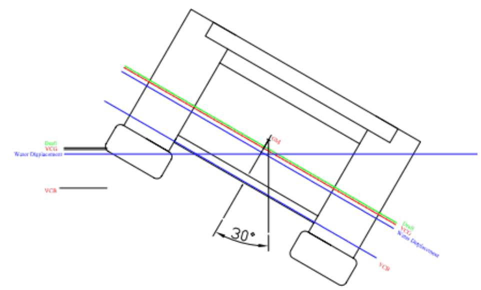


Comparison 2.4 GM & 1.5 GM

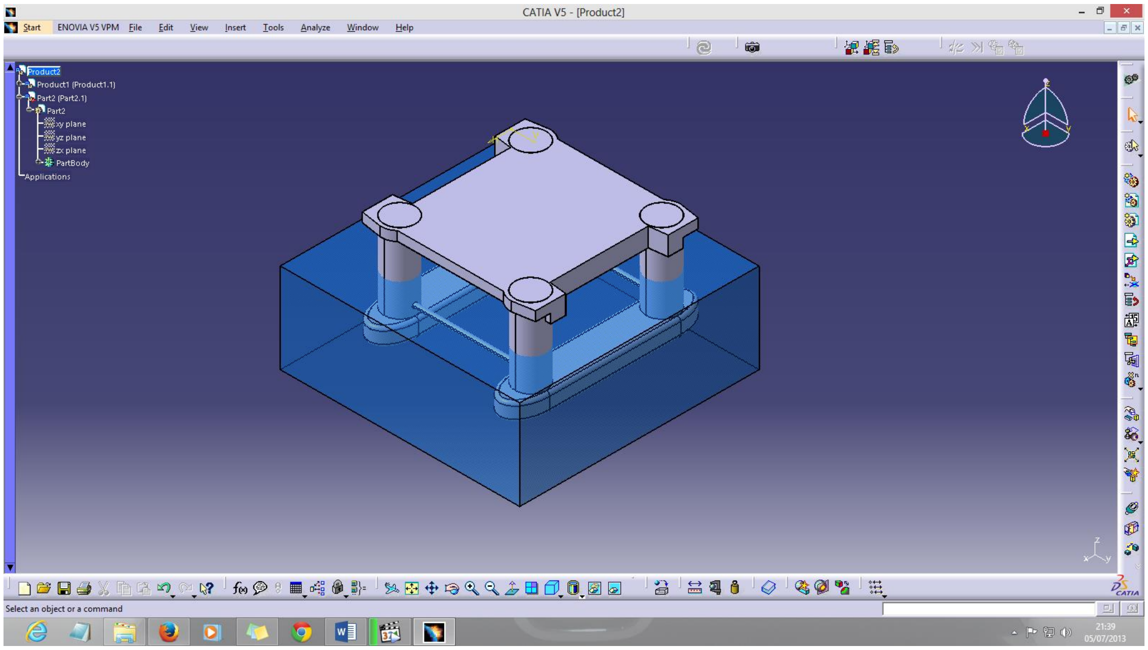
Table 7: Semi-submersible intact stability

Catia 3D Views	Autocad 2D Views
	
3 Degree Incline	
	
6 Degree Incline	
	
15 Degree Incline (Maximum Incline)	
	
20 Degree Incline (Unsafe)	

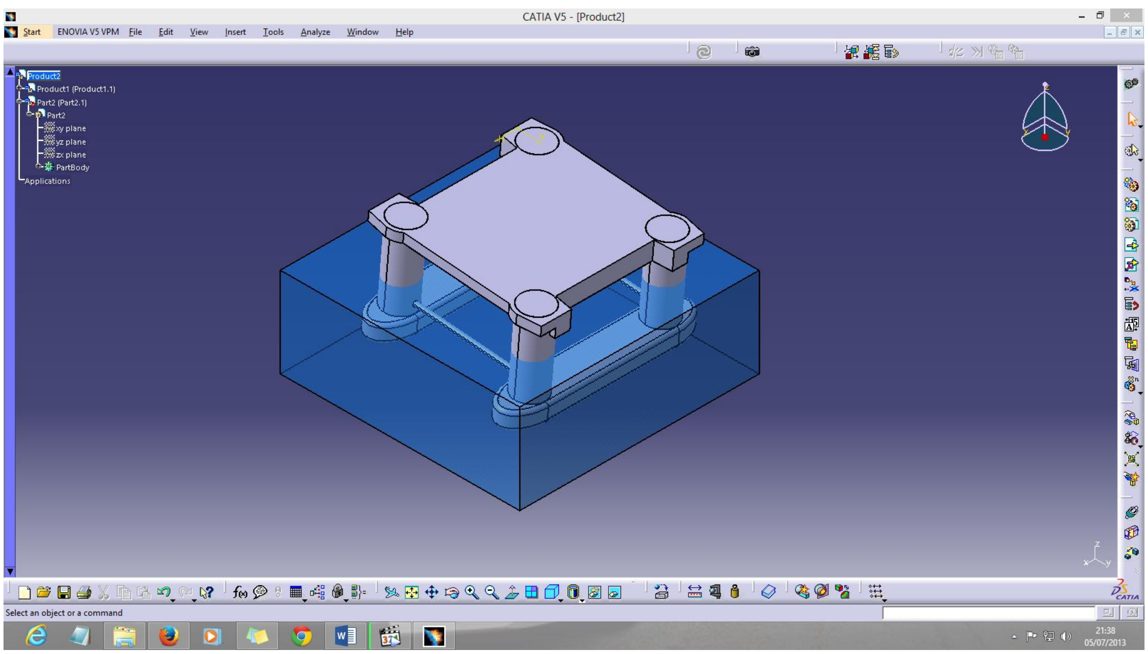




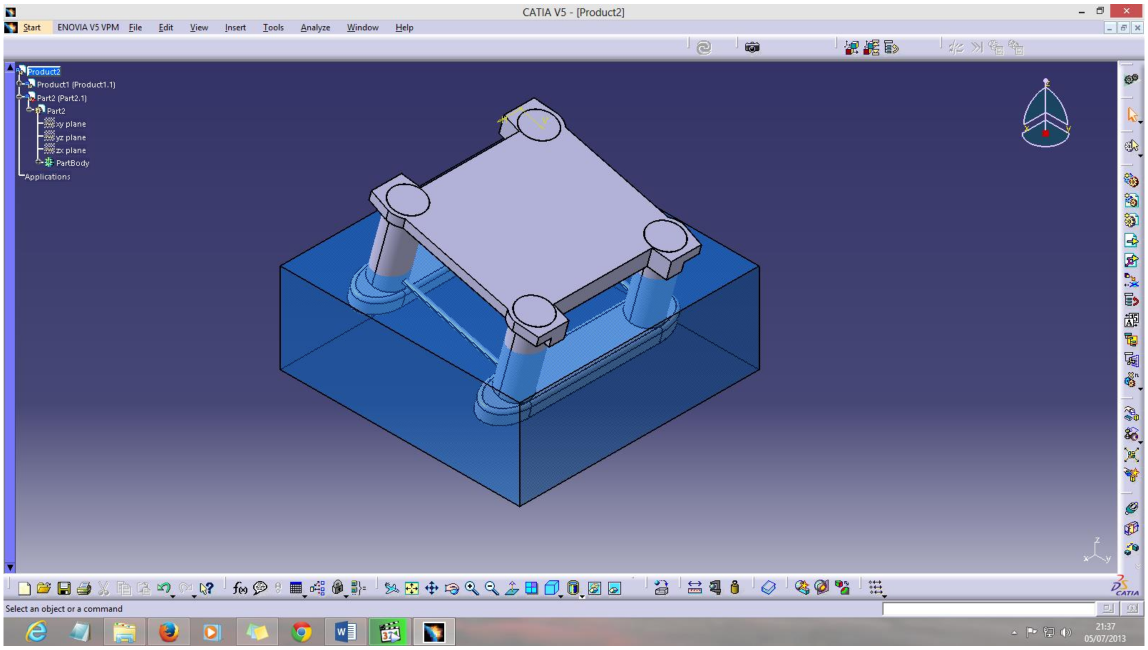
30 Degree Incline (Unsafe)



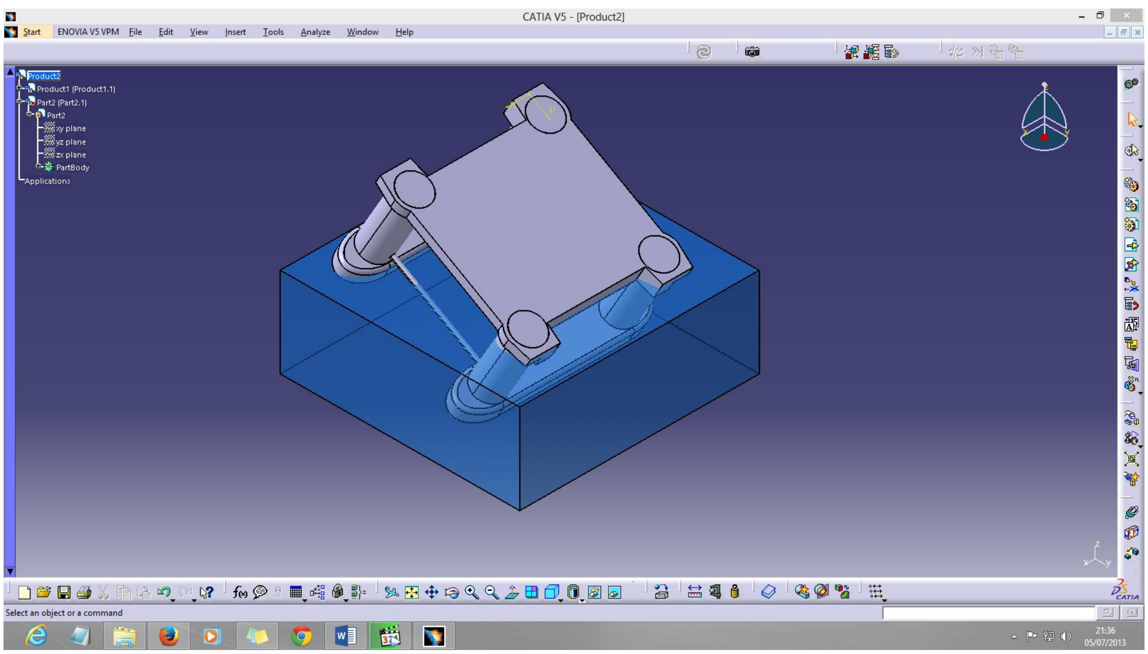
0 Degree Floating Safe



5 Degree Tilted to Starboard

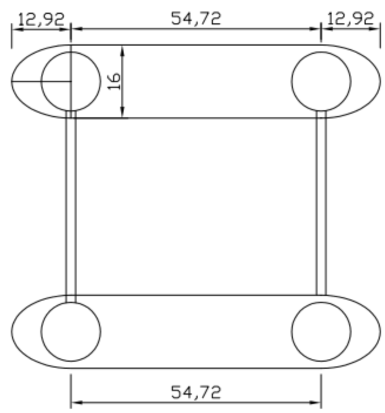


15 Degree Tilted to Starboard (Maximum)



30 Degree Tilted to Starboard (Unsafe/Highly Damaged)

Calculation of Semi-submersible Waterplane Area



Surface area of pontoon consist of ellipse and rectangle shape.

$$A_{wp} = \left(\frac{\pi ab}{4}\right) + (b \times l)$$

Ellipse waterplane area

$$A_{wp} = \frac{\pi(25.84)(16)}{4}$$

$$= 324.71 \text{ m}^2$$

Rectangle waterplane area

$$A_{wp} = B \times L$$

$$= 54.72 \times 16 = 875.52 \text{ m}^2$$

Total Pontoon waterplane area for port side.

$$A_{wp} = 875.52 + 324.71 = 1200.23 \text{ m}^2$$

Brace waterplane area for front section.

$$A_{wp} = 2\pi r^2 + 2\pi rh$$

$$= 6.6658 + 284.75 = 291.42 \text{ m}^2$$

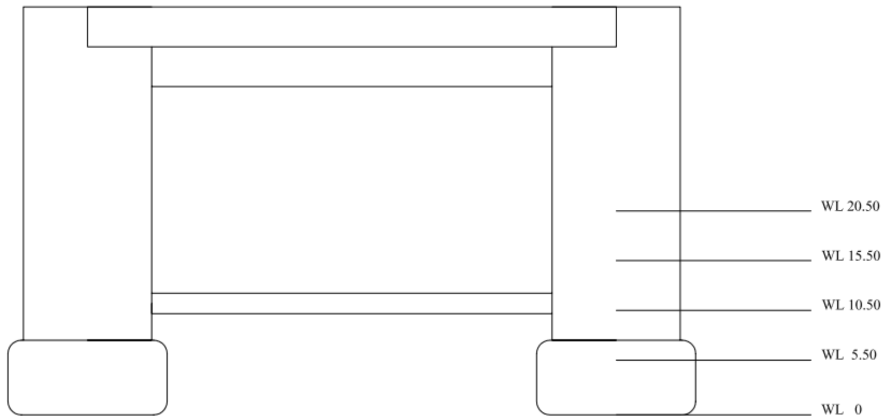
Total waterplane area of Semi-submersible

$$A_{wp} = (2 \times \text{Pontoons}) + (2 \times \text{Braces})$$

$$= (2 \times 1200.23) + (2 \times 291.42) = 2983.31 \text{ m}^2$$

APPENDIX D

Calculation of VCB



WL	A_{wp}	SM	A_{wp} x SM	Z	A_{wp} x SM x Z
0	2983.31	0.50	1491.655	0.00	0.00
5.5	2983.31	1.00	2983.31	5.5	16408.21
10.5	2983.31	2.00	5966.62	10.5	62649.51
15.5	2983.31	1.00	2983.31	15.5	46241.31
20.5	2983.31	0.50	1491.655	20.5	30578.93
		Total	14916.55	Total	155877.95

$$h = \frac{\text{draught height}}{2} = \frac{20.50}{2} = 10.25 \text{ m}$$

$$\text{Volumetric, } \Delta = \frac{h \times \sum Awp \times SM}{3} = 50964.88 \text{ m}^3$$

$$VCB = \frac{\sum Awp \times SM \times Z}{\sum Awp \times SM} = 10.45 \text{ m}$$

Explaination:

1. The maximum waterline of semisubmersible, WL obtained form [2].
2. The waterplane area, A_{wp} obtained from appendix C.
3. SM is simpson's rule obtained from [16].

APPENDIX E

Calculation of Buoyancy Force

Below is the formula of buoyancy force from [17]:

[(4 x WPA of Columns x Draft) + (2 x CSA of Pontoons x Length of Pontoons)] x SW density

[(4*130.69*20.5)+(2*1288.96*7.5)] x 1029 = 30,924,572.5 N

WPA : Waterplane Area

CSA : Cross Sectional Area

SW : Sea water (1029 kg/m^3) [4]

Calculation of Natural Period (Heave, Pitch and Roll)

Below are the formulas of Heave and Roll motion from [4]:

Unit	Value
Mass	1195000 kg
Density of Seawater, ṗ	1020 kg/m3
Area of Water plane, A_{wp}	2983.31
Gravity, g	9.81 N/kg
Moment of inertia, I_{xx}*	1.02e+009 kg.m^2
Moment of Inertia, I_{yy}*	9.454e+008 kg.m^2

*The moment of Inertia I_{xx} and I_{yy} were generated from CATIA V5R18

$$T_{Heave} = 2\Pi\sqrt{\frac{2m}{\rho g A_{wp}}}$$ = 0.3250 s

$$T_{Roll} = 2\Pi\sqrt{\frac{I}{A_{wp} g GM}}$$ = 757.26 s

$$T_{pitch} = 2\pi\sqrt{\frac{Iyy}{\Delta GM}}$$ = 552.40 s

Pitch Natural Period.

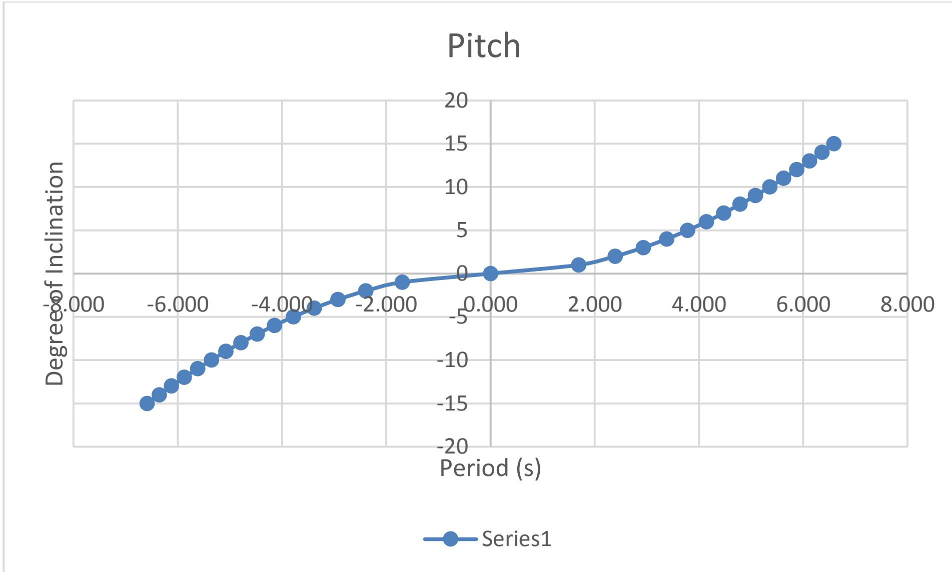
KM =	22.45	m	**T,pitch=**	552.400	original
Displacemet =	1034.49	Ton	**Ixx=**	945400000.000	Moment of inertia
Weight =	28	Ton	**k=**	2994.189	radius of gyration
distante d =	26.59	m			

Section	**Healing Angle**	**GM**	k (m)	I	I'	k'	T'	TØ	T/TØ (s)
Port	-15	-2.69	-197.52	4114309.89	4144890.93	198.26	760.08	3806.757	-5.008
	-14	-2.89	-204.77	4421589.23	4452170.27	205.47	759.89	3672.100	-4.832
	-13	-3.12	-212.80	4775131.67	4805712.71	213.48	759.69	3533.548	-4.651
	-12	-3.39	-221.77	5186506.61	5217087.65	222.43	759.50	3390.519	-4.464
	-11	-3.70	-231.91	5671490.16	5702071.20	232.53	759.31	3242.314	-4.270
	-10	-4.08	-243.49	6252168.60	6282749.64	244.09	759.12	3088.079	-4.068
	-9	-4.54	-256.92	6960443.90	6991024.94	257.48	758.93	2926.747	-3.856
	-8	-5.12	-272.74	7844168.66	7874749.70	273.27	758.75	2756.958	-3.634
	-7	-5.86	-291.79	8978539.35	9009120.39	292.29	758.56	2576.919	-3.397
	-6	-6.85	-315.38	10488882.86	10519463.90	315.84	758.38	2384.180	-3.144
	-5	-8.23	-345.68	12600786.97	12631368.01	346.10	758.19	2175.228	-2.869
	-4	-10.29	-386.66	15765426.46	15796007.50	387.03	758.01	1944.692	-2.566
	-3	-13.73	-446.63	21035541.41	21066122.45	446.95	757.82	1683.553	-2.222
	-2	-20.61	-547.15	31569350.49	31599931.53	547.41	757.64	1374.266	-1.814
	-1	-41.23	-773.90	63157943.90	63188524.94	774.09	757.46	971.605	-1.283
Even	0	42.00	781.08	64335202.22	64365783.26	781.27	757.45	962.674	0.000
Starboard	1	41.23	773.90	63157943.90	63188524.94	774.09	757.46	971.605	1.283
	2	20.61	547.15	31569350.49	31599931.53	547.41	757.64	1374.266	1.814
	3	13.73	446.63	21035541.41	21066122.45	446.95	757.82	1683.553	2.222
	4	10.29	386.66	15765426.46	15796007.50	387.03	758.01	1944.692	2.566
	5	8.23	345.68	12600786.97	12631368.01	346.10	758.19	2175.228	2.869
	6	6.85	315.38	10488882.86	10519463.90	315.84	758.38	2384.180	3.144
	7	5.86	291.79	8978539.35	9009120.39	292.29	758.56	2576.919	3.397
	8	5.12	272.74	7844168.66	7874749.70	273.27	758.75	2756.958	3.634
	9	4.54	256.92	6960443.90	6991024.94	257.48	758.93	2926.747	3.856
	10	4.08	243.49	6252168.60	6282749.64	244.09	759.12	3088.079	4.068
	11	3.70	231.91	5671490.16	5702071.20	232.53	759.31	3242.314	4.270
	12	3.39	221.77	5186506.61	5217087.65	222.43	759.50	3390.519	4.464
	13	3.12	212.80	4775131.67	4805712.71	213.48	759.69	3533.548	4.651
	14	2.89	204.77	4421589.23	4452170.27	205.47	759.89	3672.100	4.832
	15	2.69	197.52	4114309.89	4144890.93	198.26	760.08	3806.757	5.008

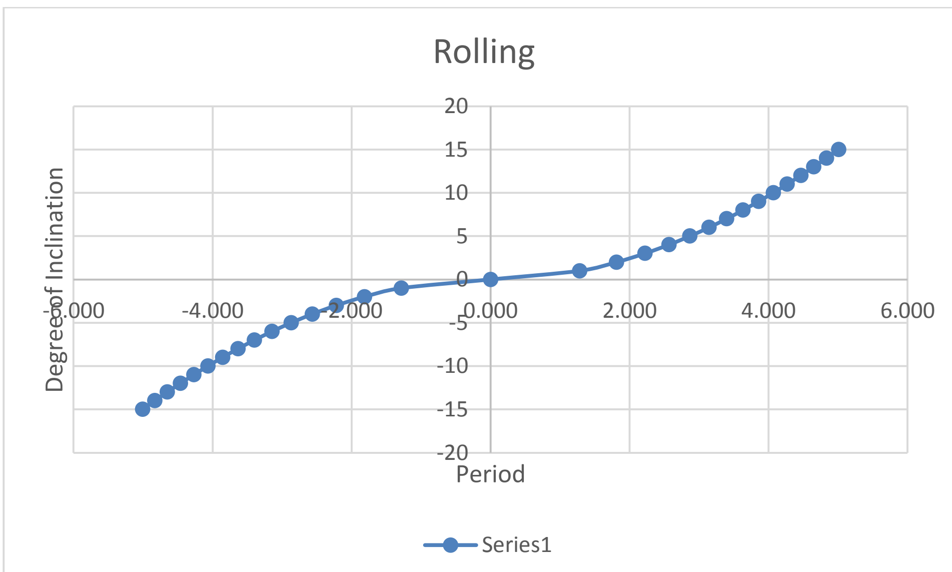
Roll Natural Period

KM =	22.45	m	T,rool=	757.260	original
Displacemet =	1034.49	Ton	Ixx=	1020000000.000	moment of inertia
Weight =	28	Ton	k=	3110.079	radius of gyration
distante d =	26.59	m			

Section	Healing Angle	GM	k (m)	I	I'	k'	T'	TØ	T/TØ (s)
Port	-15	-2.69	-144.09	2189345.51	2219926.55	145.09	556.25	3664.907	-6.589
	-14	-2.89	-149.37	2352857.90	2383438.94	150.34	555.99	3535.267	-6.359
	-13	-3.12	-155.23	2540988.25	2571569.29	156.16	555.72	3401.878	-6.122
	-12	-3.39	-161.78	2759892.98	2790474.02	162.67	555.46	3264.179	-5.877
	-11	-3.70	-169.17	3017967.02	3048548.06	170.03	555.20	3121.496	-5.622
	-10	-4.08	-177.62	3326963.12	3357544.16	178.44	554.94	2973.008	-5.357
	-9	-4.54	-187.41	3703857.27	3734438.31	188.18	554.68	2817.688	-5.080
	-8	-5.12	-198.95	4174113.26	4204694.30	199.68	554.43	2654.226	-4.787
	-7	-5.86	-212.85	4777745.32	4808326.36	213.53	554.17	2480.896	-4.477
	-6	-6.85	-230.06	5581443.60	5612024.64	230.69	553.92	2295.339	-4.144
	-5	-8.23	-252.16	6705250.00	6735831.04	252.74	553.67	2094.173	-3.782
	-4	-10.29	-282.05	8389247.92	8419828.96	282.57	553.41	1872.227	-3.383
	-3	-13.73	-325.80	11193631.35	11224212.39	326.25	553.16	1620.819	-2.930
	-2	-20.61	-399.13	16798981.52	16829562.56	399.49	552.91	1323.057	-2.393
	-1	-41.23	-564.54	33608202.77	33638783.81	564.80	552.66	935.400	-1.693
Even	0	42.00	569.78	34234656.60	34265237.64	570.03	552.66	926.802	0.000
Starboard	1	41.23	564.54	33608202.77	33638783.81	564.80	552.66	935.400	1.693
	2	20.61	399.13	16798981.52	16829562.56	399.49	552.91	1323.057	2.393
	3	13.73	325.80	11193631.35	11224212.39	326.25	553.16	1620.819	2.930
	4	10.29	282.05	8389247.92	8419828.96	282.57	553.41	1872.227	3.383
	5	8.23	252.16	6705250.00	6735831.04	252.74	553.67	2094.173	3.782
	6	6.85	230.06	5581443.60	5612024.64	230.69	553.92	2295.339	4.144
	7	5.86	212.85	4777745.32	4808326.36	213.53	554.17	2480.896	4.477
	8	5.12	198.95	4174113.26	4204694.30	199.68	554.43	2654.226	4.787
	9	4.54	187.41	3703857.27	3734438.31	188.18	554.68	2817.688	5.080
	10	4.08	177.62	3326963.12	3357544.16	178.44	554.94	2973.008	5.357
	11	3.70	169.17	3017967.02	3048548.06	170.03	555.20	3121.496	5.622
	12	3.39	161.78	2759892.98	2790474.02	162.67	555.46	3264.179	5.877
	13	3.12	155.23	2540988.25	2571569.29	156.16	555.72	3401.878	6.122
	14	2.89	149.37	2352857.90	2383438.94	150.34	555.99	3535.267	6.359
	15	2.69	144.09	2189345.51	2219926.55	145.09	556.25	3664.907	6.589



F1: Pitch Natural Period



F2: Rolling Natural Period

APPENDIX G

Gantt chart

No	Details	Week (FYP1)													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Project Topic Selection														
2	Preliminary Research Work														
	- Conceptual design, VCG, Buoyancy, Stability, Motion Behavior.														
3	Design Specification														
4	Formulation and Calculation														
	- VCG, Buoyancy and Stability														

No	Details	Week (FYP2)													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
6	Formula and Calculation														
	- Motion Behavior (Heave and Roll)														
7	CATIA Design														
8	Completed														