BACHELOR THESIS & COLLOQUIUM – ME141502

# DESIGN OF MARINE POWER PLANT BASED ON LINEAR GENERATOR

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**SUPERVISOR APPROVAL SHEET**

# DESIGN OF MARINE POWER PLANT BASED ON LINEAR GENERATOR

**BACHELOR THESIS**

Submitted To Comply One Of The Requirements To Obtain A Bachelor Thesis Engineering Degree On

Laboratory of Marine Electrical and Automation System (MEAS)
Bachelor Program Departement of Marine Engineering
Faculty of Marine Technology
Institut Teknologi Sepuluh Nopember, Surabaya

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## DEPARTEMENT APPROVAL SHEET

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# Design of Marine Power Plant based on Linear Generator

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## ABSTRACT

Nowadays we hear about Innovative technologies. When the word innovative is heard we think of its simplicity and benefit from it towards one self. However, innovation is anything that makes the task easier, faster and convenient.

Here we will be talking about jacket platform using linear generator technology as a marine power plant. Basically, this type of platform will provide the shoreline/rural areas with electricity from wave energy to complete their daily needs / for emergency power supply as it’s a renewable energy.

It is generally a fixed platform with floatable buoy’s and a double acting cylinder which act as a linear generator to which the pressurized air from the pumping chamber is supplied and the whole system operates by wave forces from the sea / ocean.

**Keywords: Wave Energy by Air Compression System**

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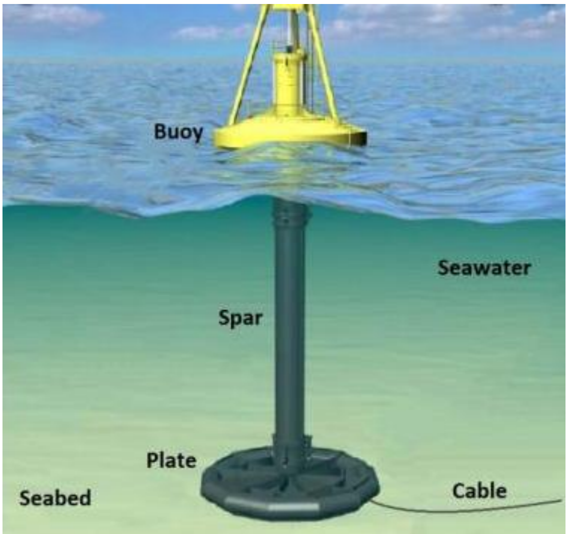
# CHAPTER 1
# INTRODUCTION

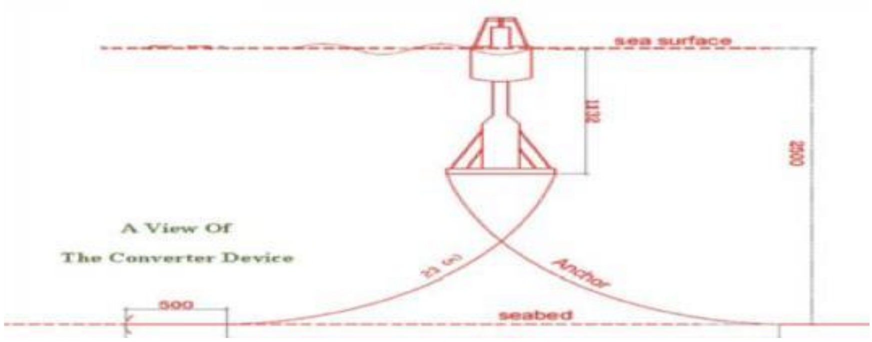
## 1.1 Background

### 1.1.1 Power Buoy Technology




Picture 1.1

This floating power buoy is connected with anchors in the sea bed. The buoy floats depends on waves condition as the linear generator oscillates up and down by the force of water. But as the whole buoy takes the same dynamic movement behaviour as wave velocity and height it generates around 50% of energy from the waves.

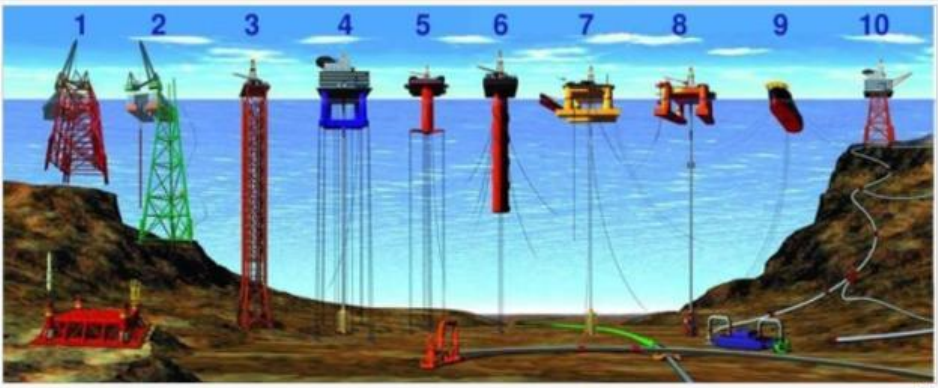



Picture 1.2

This is the 2D design of power buoy which shows how is it mounted with sea bed.

### 1.1.2 Jacket Platform Concept

The jacket platform fixes in the seabed using concrete piles (jacket leg) and includes parts like, jacket structure deck and ring. The platform has good adaptability, high safety and high reliability and has become the primary structure form in the development of shallow sea oil and gas fields.

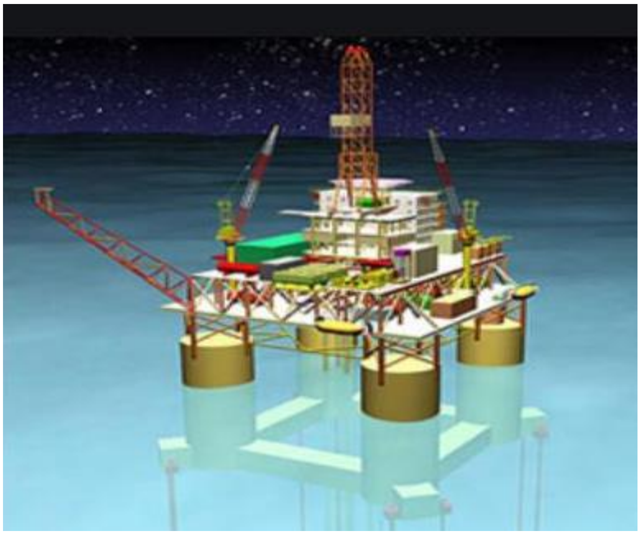



1, 2) conventional fixed platforms; 3) compliant tower; 4, 5) vertically moored tension leg and mini-tension leg platform; 6) spar; 7, 8) semi-submersibles; 9) floating production, storage, and offloading facility; 10) sub-sea completion and tie-back to host facility.[16]

Picture 1.3
Types of Jacket Platform

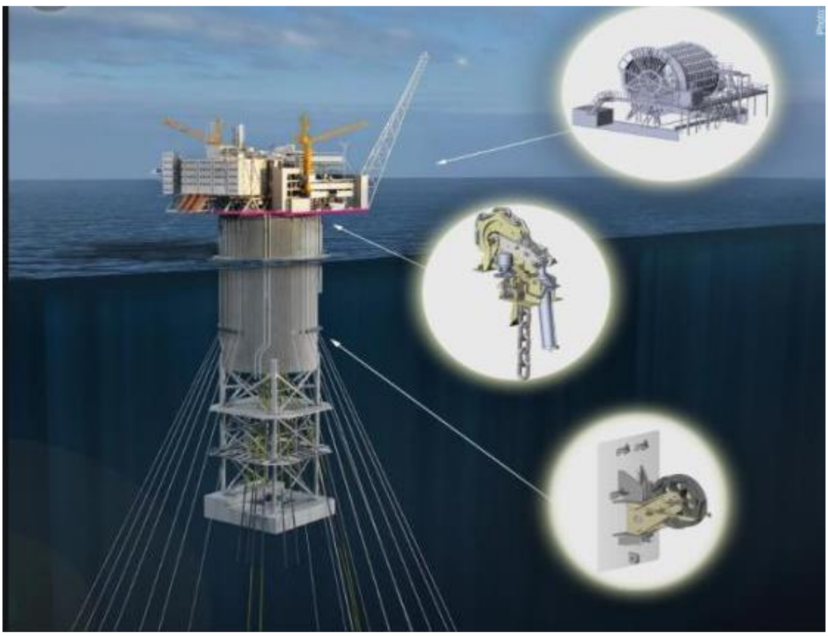
The efficiency and safe design of the platforms depend on structure of influence between the surrounding environment and resistance to different loading during the entire period. Fixed jacket platforms are huge steel framed structures used for the extraction of oil and gas from the earth's crust. Jacket type structures are appropriate for shallow water depth.

Jacket anticorrosion design covers the steel structure corrosion in all areas including atmospheric area, splashing area, sea water area and sea mud area. According to international standards and actual marine environment conditions and through reasonable external anticorrosive coating design and cathode protection design, prohibit steel structure corrosion, slow down wall thickness thinning and strength reduction, and ensure long-period safety of the structure.



Picture 1.4
Tension-leg platform (TLP)

A tension-leg platform (TLP) or extended tension leg platform (ETLP') is a vertically moored floating structure normally used for the offshore production of oil or gas, and is particularly suited for water depths greater than 300 metres (about 1000 ft) and less than 1500 metres



Picture 1.5
Spar Platform

A spar is a type of floating oil platform typically used in very deep waters, and is named for logs used as buoys in shipping that are moored in place vertically. Spar production platforms have been developed as an alternative to conventional platforms.

A spar platform consists of a large-diameter, single vertical cylinder supporting a deck. The cylinder is weighted at the bottom by a chamber filled with a material that is denser than water (to lower the center of gravity of the platform and provide stability). Additionally, the spar hull is encircled by helical strakes to mitigate the effects of vortex-induced motion. Spars are permanently anchored to the seabed by way of a spread mooring system composed of either a chain-wire-chain or chain-polyester-chain configuration.


Picture1.6
Parts of an Offshore Platform

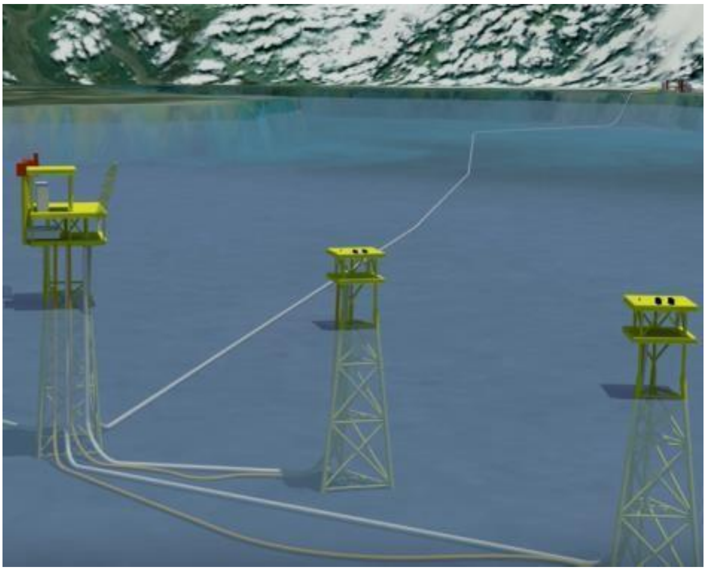
Offshore structures are designed for the open sea, lakes, etc., far away from seashore. These structures may be made of steel, reinforced concrete or a combination of both.

A fixed platform is a type of offshore platform used for the production of Petroleum oil or gas. These platforms are built on concrete and/or steel legs anchored directly onto the seabed, supporting a deck with space for drilling rigs, production facilities and crew quarters. Such platforms are, by virtue of their immobility, designed for very long-term use. Various types of structure are used, steel jacket, concrete caisson, floating steel and even floating concrete. Steel jackets are vertical sections made of tubular steel members, and are usually piled into the seabed.

While the platform jacket is temporarily resting on the seafloor prior to pile installation, seafloor support is provided by the soil resistance (skin friction and end bearing) on the jacket leg extensions and the bearing capacity of the soil supporting the lowest horizontal (mudline) bracing members and mud mats. Mud mats with skirted plates are design to sustain significant horizontal loading from the upper structures.

Fixed platforms are economically feasible for installation in water depths up to about 500 feet (150 m); for deeper depths a floating production system, or a subsea pipeline to land or to shallower water depths for processing, would usually be considered.

The jacket design technology is intended to determine the jacket structure form according to the general layout of oilfield blocks, technological process and natural environment conditions of the sea area, carry out calculation and analysis as required by specifications, provide advanced, reasonable, safe and economic schemes and meet the actual needs of various projects.



Picture 1.7
Shallow water Platform

The total number of offshore plat form in various bays and oceans of the world is increasing each year, most are fixed jacket-type platforms located in 100 ft (32 m) to 650 ft (200 m) depth for oil and gas exploration purposes.
The analysis, design and construction of offshore structures relating with the extreme offshore environmental conditions is a most challenging and creative task.

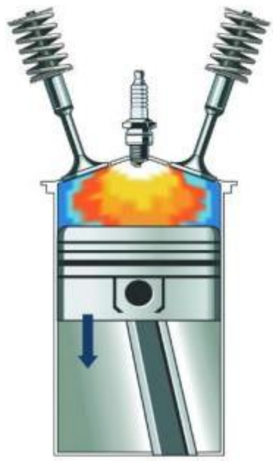
The jacket structure design includes on-bottom analysis and installation analysis. On-bottom analysis: after platform installation and emplacement, various loads on the jacket are analyzed in the whole life cycle of the platform, including dead weight load, equipment load, operation load, wind load, wave and current load, ice load, seismic load, accidental load, etc., for the purpose of ensuring the stress on 3D schematic of the jacket Schematic of aluminum alloy sacrificial anode structure for jacket Pile driving analysis schematic the structure meets the requirements of relevant standards and specifications.

### 1.1.3 Working principal of Engines Chamber

There are 2 or 4 strokes engines

1. Piston Move down by the force from ignition stroke.

2. Rotates the crankshaft with the help of piston rod.
3. Move up by the kinetic force made by ignition and pushes the combusted air out from the outlet.
4. A second stroke which pushes the combustion by the inlet of fuel or the fourth stroke in which the combusted air is removed after the pressure/force made by ignition.



Picture 1.8
Engines Chamber

The combustion process increases the internal energy of a gas, which translates into an increase in temperature, pressure, or volume depending on the configuration. In an enclosure, for example the cylinder of a reciprocating engine, the volume is controlled and the combustion creates an increase in pressure. In a continuous flow system, for example a jet engine combustor, the pressure is controlled and the combustion creates an increase in volume. This increase in pressure or volume can be used to do work, for example, to move a piston on a crankshaft or a turbine disc in a gas turbine. If the gas velocity changes, thrust is produced, such as in the nozzle of a rocket engine.

## 1.2 Problem Statement

1. How to Design the model?

## 1.3 Limitation

1. Simulation analysis is done in Ansys Workbench v.R19.0 which is a

learning software for students as it shows graphical analysis. There are some professional soft wares which shows a realistic live simulation for fluid flow. But due to the lack of facility we are suggested to use the student version software.

### 1.4 Objective

1. To redesign the power buoy and analyze the pressure / force created by waves

### 1.5 Benefit

1. Introducing a new efficient renewable energy as a challenge as Indonesia is widely surrounded by oceans.

# CHAPTER 2
# LITERATURE REVIEW

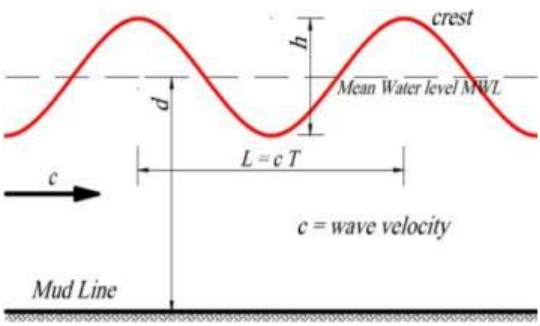
## 2.1 Basic Theory

### 2.1.1 Environmental effect

Force in ocean can be classified as forces due to waves and current. Wind blowing over the ocean's surface drags water along, thus forming current and generating waves. The forces induced by ocean waves on platform are dynamic in nature.

### 2.1.2 Waves Force

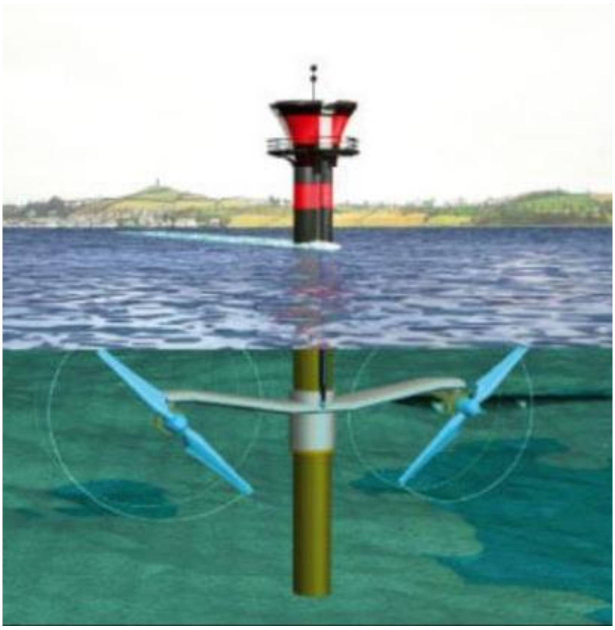
Wave forces calculation on fixed offshore structures are based on the three parameters water depth (d), wave height (h) and wave period (T) as obtained from wave measurements adapted to different statistical models, as shown below




Picture 2.1
Wave Coordinate system

The ocean is never still. Whether observing from the beach or a boat, we expect to see waves on the horizon. Waves are created by energy passing through water, causing it to move in a circular motion. However, water does not actually travel in waves. Waves transmit energy, not water, across the ocean and if not obstructed by anything, they have the potential to travel across an entire ocean basin.

Waves are most commonly caused by wind. Wind-driven waves, or surface waves, are created by the friction between wind and surface water. As wind blows across the surface of the ocean or a lake, the continual disturbance creates a wave crest. These types of waves are found globally across the open ocean and along the coast. a series of long waves that are created far from shore in deeper water and intensify as they move closer to land.  The gravitational pull of the sun and moon on the earth also causes waves.
These waves are tides or, in other words, tidal waves. It is a common misconception that a tidal wave is also a tsunami. The cause of tsunamis are not related to tide information at all but can occur in any tidal state.



Picture 2.2
Tidal Energy

### 2.1.3 Tidal Energy

Tidal power or tidal energy is the form of hydropower that converts the energy obtained from tides into useful forms of power, mainly electricity.

Although not yet widely used, tidal energy has potential for future electricity generation. Tides are more predictable than the wind and the sun.

Among sources of renewable energy, tidal energy has traditionally suffered from relatively high cost and limited availability of sites with sufficiently high tidal ranges or flow velocities, thus constricting its total availability. However, many recent technological developments and improvements, both in design (e.g. dynamic tidal power, tidal lagoons) and turbine technology (e.g. new axial turbines, cross flow turbines), indicate that the total availability of tidal power may be much higher than previously assumed, and that economic and environmental costs may be brought down to competitive levels.

### 2.1.4 Wind loads

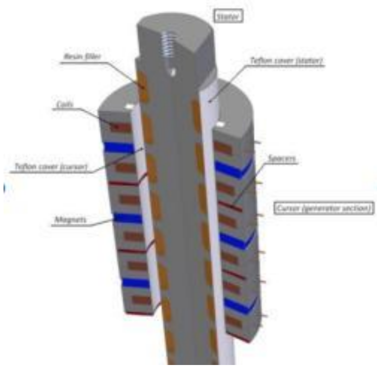
Wind is deflected from its path when a structure is placed in between the movement of air, then all or part of the kinetic energy is transformed into potential energy pressure. The obstruction to free flow of the wind caused by the differential pressure when the force of wind is applied on any structure.

Wind forces on offshore structures are discussed through both the steady and unsteady wind profiles and forces, and through spectral analysis. Other considerations include sections on: model tests and similarity laws and how various physical quantities can be scaled to prototype; both commercial and open-source Computational Fluid Dynamics (CFD) tools; and extreme response estimation.

When an offshore structure is 'large' (generally the dimensions of the structure andperhaps even of each member is not small compared with the wave length), the viscous effects are much smaller than the inertial effects as far as thewave loads are concerned.

### 2.1.5 Linear Generator System

A linear alternator is essentially a linear motor used as an electrical generator. An alternator is a type of alternating current electrical generator. The devices are often physically equivalent. The principal difference is in how they are used and which direction the energy flows.




Picture 2.3
Linear generator: oscillating mass carries coils and permanent magnets

When a magnet moves in relation to an electromagnetic coil, this changes the magnetic flux passing through the coil, and thus induces the flow of an electric current, which can be used to do work. A linear alternator is most commonly used to convert back-and-forth motion directly into electrical energy. This short-cut eliminates the need for a crank or linkage that would otherwise be required to convert a reciprocating motion to a rotary motion in order to be compatible with a rotary generator.

### 2.1.6 Basic Concept

An alternator converts mechanical energy to electrical energy, whereas a motor converts electrical energy to mechanical energy. Like most electric motors and electric generators, the linear alternator works by the principle of electromagnetic induction. However, most alternators work with rotary motion, whereas "linear" alternators work with "linear" motion (i.e. motion in a straight line).

The simplest type of linear alternator is the Faraday flashlight. This is a torch (UK) or flashlight (USA) which contains a coil and a permanent magnet. When the appliance is shaken back and forth, the magnet oscillates through the coil and induces an electric current. This current is used to charge a capacitor, thus storing energy for later use. The appliance can then produce light, usually from a light-emitting diode, until the capacitor is discharged. It can then be re-charged by further shaking. Other devices which use linear alternators to generate electricity include the free-piston linear generator, an internal combustion engine, and the free-piston Stirling engine, an external combustion engine.

### 2.1.6 Application / Uses of Generators

1. Backup power for house, Standby power for business, Temporary power on a construction site, Helping mains to supply the total power required.

2. Because of their ability of giving wide range of voltage output, they are generally used for testing purpose in the laboratories.

3. Separately excited generators operate in a stable condition with any variation in field excitation. Because of this property they are used as supply source of DC motors, whose speeds are to be controlled for various applications. Example- Ward Leonard Systems of speed control.

4. Applications of Separately Excited DC Generators. These types of DC generators are generally more expensive than self- excited DC generators because of their requirement of separate excitation source. Because of that their applications are restricted. They are generally used where the use of self- excited generators is unsatisfactory.

5. Applications of Shunt Wound DC Generators. The application of shunt generators are very much restricted for its dropping voltage characteristic. They are used to supply power to the apparatus situated very close to its position. These type of DC generators generally give constant terminal voltage for small distance

operation with the help of field regulators from no load to full load.

- They are used for general lighting.
- They are used to charge battery because they can be made to give constant output voltage.
- They are used for giving the excitation to the alternators.
- They are also used for small power supply

6. Applications of Series-Wound DC Generators. These types of generators are restricted for the use of power supply because of their increasing terminal voltage characteristic with the increase in load current from no load to full load. For this property they can be used as constant current source and employed for various applications.

    - They are used for supplying field excitation current in DC locomotives for regenerative breaking.
    - This type of generators is used as boosters to compensate the voltage drop in the feeder in various types of distribution systems such as railway service.
    - In series arc lightening this type of generators are mainly used.

7. Applications of Compound Wound DC Generators. Among various types of DC generators, the compound wound DC generators are most widely used because of its compensating property. We can get desired terminal voltage by compensating the drop due to armature reaction and ohmic drop in the in the line. Such generators have various applications.

    - Cumulative compound wound generators are generally used lighting, power supply purpose and for heavy power services because of their constant voltage property. They are mainly made over compounded.
    - Cumulative compound wound generators are also used for driving a motor.
    - For small distance operation, such as power supply for hotels, offices, homes and lodges, the flat compounded

generators are generally used.

- The differential compound wound generators, because of their large demagnetization armature reaction, are used

**Uses of Electric Generator**

- To supply power grid by using wave energy.
- Tubular type Linear generator for free piston engine.
- Smooth motion drives

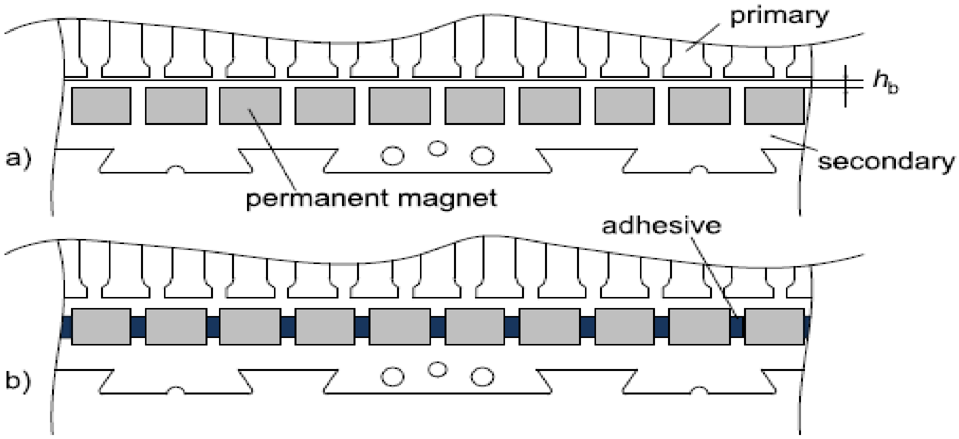
## 2.2 Problem faced during simulation and experiments

Method used by "*Miralem Had ziselimovi*" electric generators used in a Stirling engine and a novel concept of modular design of a linear oscillatory generator. (science direct: 26 April 2019)

The model contains various losses, such as friction losses caused by piston rings, bearings and seals

Because of the tubular form, soft magnetic composite (SMC) is usually chosen as ferromagnetic material, as it enables a more compact generator construction in comparison to conventional electrical steel, but leads to lower efficiency in the low-frequency area because of lower permeability of the SMC material.

A part of permanent magnets magnetic field is magnetic leakage to adjacent magnet poles, which results in a lower back-EMF and consequently lower electrical output power of the generator.
when air-gap width is too large this will result in the poor generator performance, while smaller air-gap width might result in increased eddy current losses in permanent magnets.



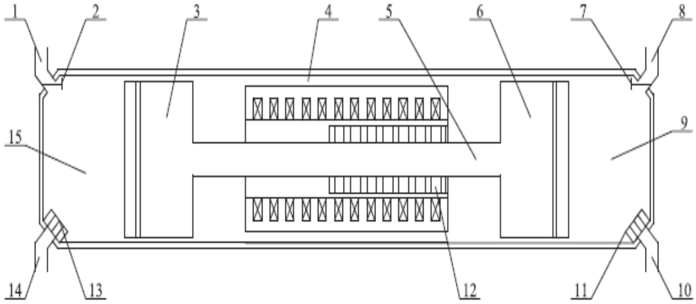

Picture 2.4 Different secondary part designs

Method by "*Yongming Xu"*- The system is composed of two cylinders and a permanent magnet linear generator. The power source is a peripheral air compressor which supplies compressed air to drive the FPLG and is controlled by a servo motor. (source: science direct, 23 June 2019)

Selection of the number of slots can weaken the cogging force using energy balance method, which can solve the problem of the cogging force in a cylindrical permanent magnet linear motor.

Problem of low power density due to the big air gap in the permanent magnet motors in a wave generation system.

Liu C proposed a new design which had an external permanent magnet for enhancing its power density and sinusoidal waveform. The results showed that the power density of the outer rotor permanent magnet linear generator (PMLG) is 6–8 times higher than that of the internal rotor permanent magnet linear generator in the same volume.




1 and 8-Air intake, 2 and 7-Intake valve, 3 and 6-Piston, 4- linear generator, 5-Connecting rod, 9 and 15- Cylinder, 10、14- Vent, 11 and 13- Exhaust valve, 12- Permanent magnet

Picture 2.5 Compressed air driven Free Piston Linear Generator

### 2.2.1 Main Problem faced during experiments

1. Magnetic leakage to adjacent magnet poles, which results in a lower back-EMF
2. When air-gap width is too large this will result in the poor generator performance.
3. The occurrence of cogging force

## 2.3 Advantages

1. Generates renewable energy
2. Structure and testing completed before installation
3. Maintenance free (depends on the material used to build)
4. Simple installation
5. Energy can be stored / use anywhere

**Disadvantages**

1. Need higher wave crest/lengths to get high pressure air
2. May take longer time to store pressurized air (depend on wave condition)

# CHAPTER 3

## RESEARCH METHODOLOGY

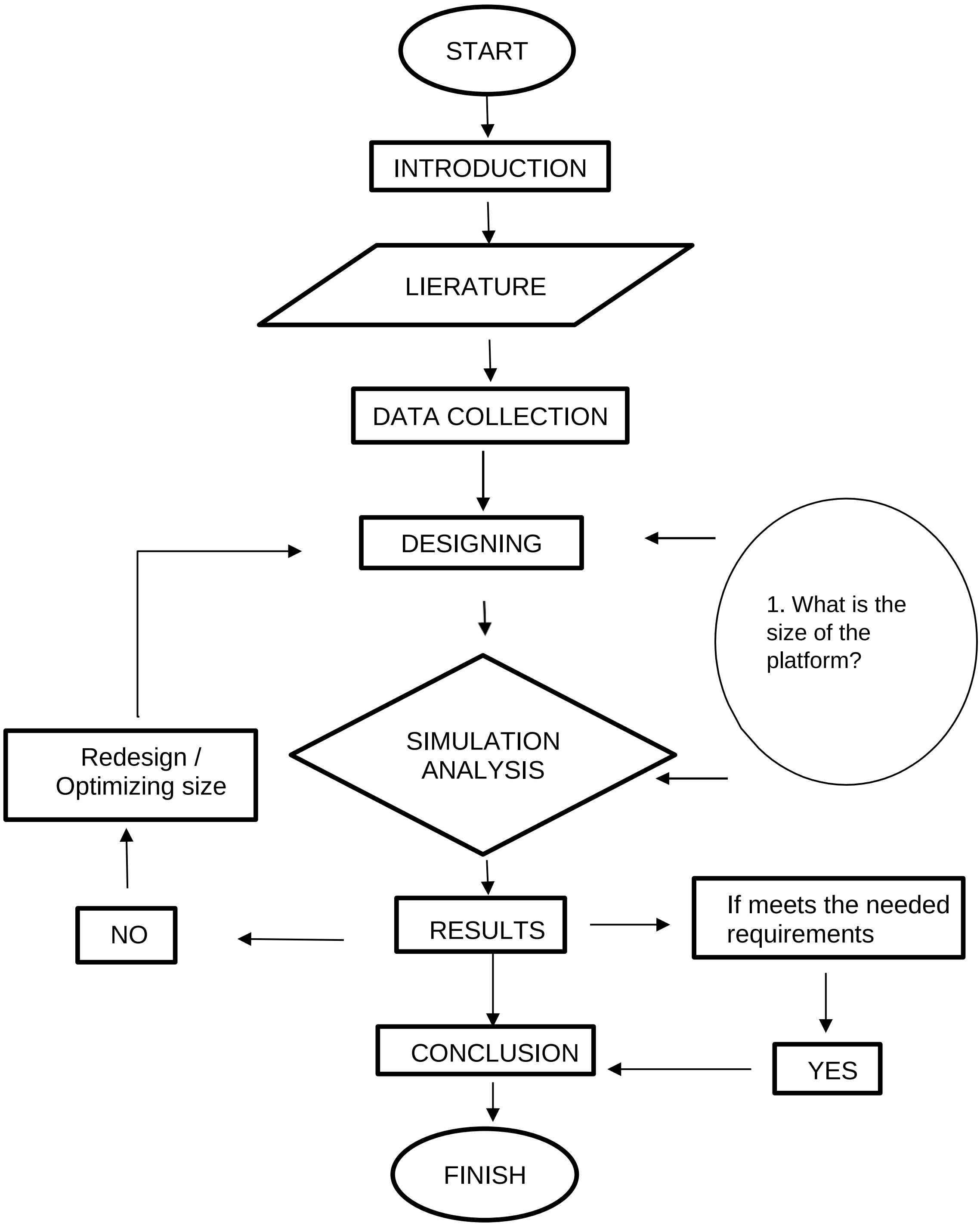


Fig 3.1 Research Methodology Flow chart

### 3.1 Literature Review

Here we initially learn about the basic ideology and steps required regarding the topic. In this research from which data analysis will be processed, deals with "renewable power generation plant" as wave energy

### 3.2 Data Collection

The data is collected from various sources related to the background study which is discussed earlier specifically for re-designing as to meet the requirements and also some real data from sea environment for further advanced designing.

### 3.3 Design

Combining idea of jacket platform, floating buoy, pressurized air and linear generator (as double acting cylinder) and designing with the parameters almost same size like power buoy and taking oceanic environmental data into account which is needed to determine the best variation of jacket platform.

### 3.4 Simulation Analysis

Simulating the model with the graphical wave analysis in ANSYS software by which we analyze the wave force on the floating buoy to know the amount of pressure build in the chamber which is then able to move the double acting cylinder.

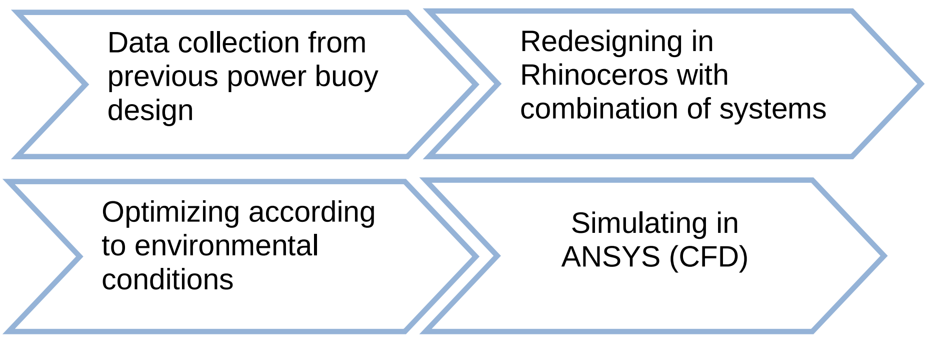
# CHAPTER 4
# DESIGN AND ANALYSIS

## 4.1 Introduction

First step to analyze is decided depending on how the model/device will work, the parameters in which the simulation process will take place. Further we will see how the simulation of the designed model works using cumulative fluid dynamics software (ANSYS) and so we will know that is the design able to fulfil the requirements in real life or not.

## 4.2 Designing Process

Combination of the backgrounds resulted in simple design by basic physics concept which named as Jacket buoy platform based on linear generator working principal in which whole system works by compressed air.



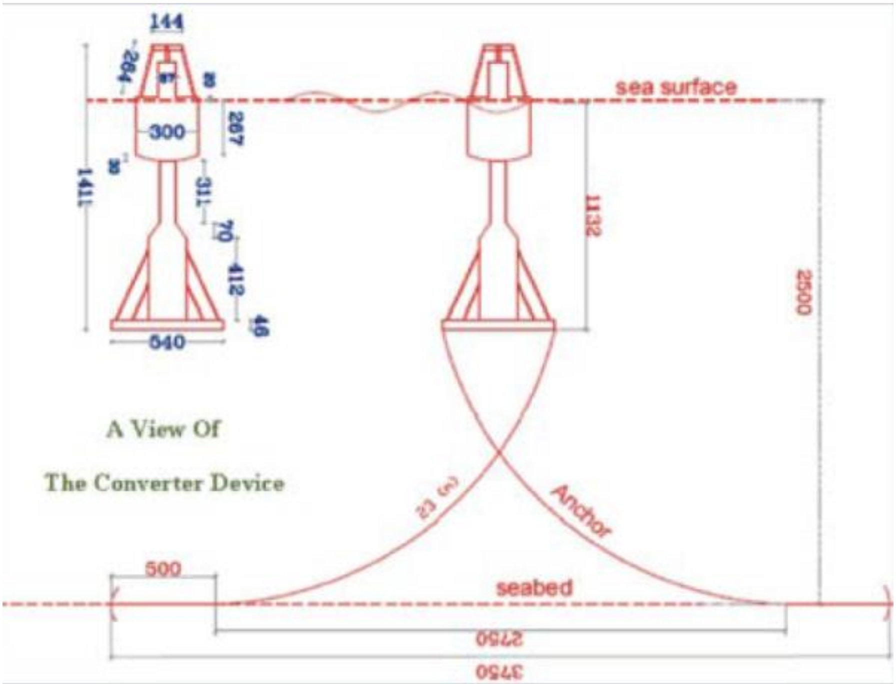

Picture 4.1.1 Design process overview

The stages are described below

- Data taken from the previous model as to connect / understand the basic of wave energy
- In Rhinoceros software re-designing the power buoy in the shape of fixed jacket platform with the basics of physics in which pressurized air in the chamber is made by the up and down movement of the floating balls by force of the waves. Then the pressure force is converted to mechanical by double acting cylinder (automation technology) and thus

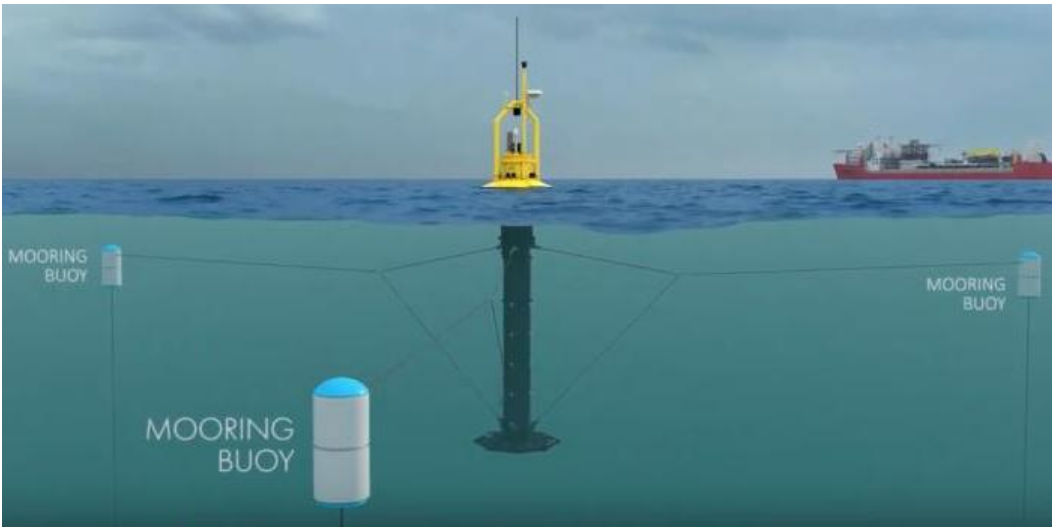
electricity is hopefully generated.

- Optimizing size based on the wave data from website (buoyweather.com) because during this project we could not get the original / accurate wave data.
- In Ansys software (wave simulator) I could simulate the model which can only show the wave force by graphical analysis and by color difference in which “Red” color means the point of maximum force and “Blue” color means minimum force from the wave.



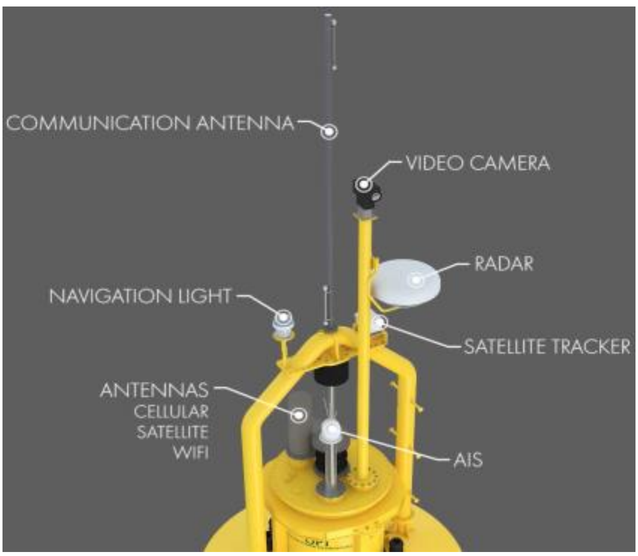

Picture 4.1.2

Design of previous Power buoy technology in which the floating assembly is below sea level to get the oscillating movement from waves so the linear generator which is connected with permanent magnets as it generates electromagnetic force (EMF) from which some amount of electrical energy is generated and then stored in battery packs which is fixed after the generator inside the power buoy between the floating assembly and the end plate where the strings are connected.




Picture 4.1.3

To stabilize the power buoy it is moored with the mooring buoy in the opposite direction like left side of power buoy is moored in the right side in sea bed and the right side of power buoy is moored in the left side in sea bed because of which when the power buoy will have the same dynamic movement like waves it will help the floating assembly to smoothly reciprocate the linear generator. The mooring buoys are connected with strings to the seabed.



Picture 4.1.4

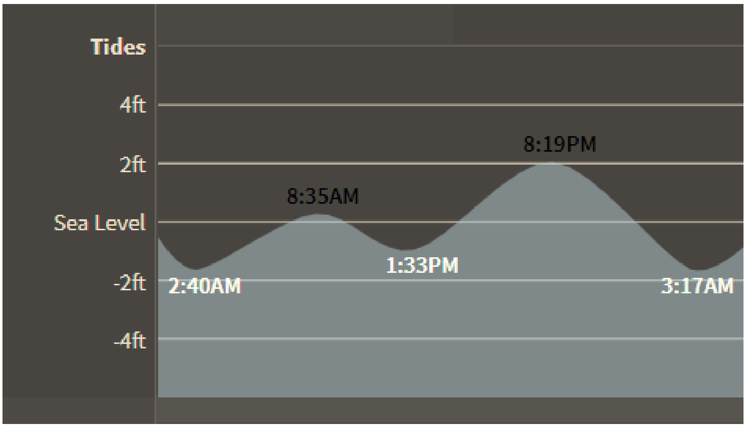
There are 7 different parts for analyzing the condition of powerbuoy

1. Communication antina: It functions for transmission and reception of electromagnetic radiation i.e. helps to collect data from electrical signals from a transmission line and converts them into radio waves.
2. Navigation light: It helps with site monitoring of ongoing ships.
3. Antennas cellular satellite wifi: It functions like satellite data transfer between the power buoy and control room.
4. Video camera: The camera shows the sea wave condition and also ship traffic data to help manage the system.
5. Radar: Helps to determine the range, angle, or velocity of objects like ships, spacecraft, etc.
6. Satellite tracker: Its like a Global navigation satellite system (GPS) which is tracking system that provides an information like exact location, speed, time and direction of an object.
7. AIS: Automatic Identification System is a reporting system used in identification of marine vessels nad its location.

| DIMENSIONS | ELECTRICAL |
|---|---|
| Height: 13.3 m | Continuous Average Power based on 8.4 kWh/Day (typical) (Annual Average: Site Dependent) |
| Draft: 9.28 m | Payload Peak Power: up to 3 kW peak power to load: 7.5 kW (custom) |
| Spar Diameter 1.0 m Float Diameter: 2.65 m | Nominal Battery Capacity (ESS): 50 kWh (approx.); Modular and Scalable to 100, 150 kWh (appx.) |
| Weight: 8,300 kg | Zero wave day capacity: 100 W load for 1+ weeks (50 kWh ESS) |
| **MOORING** | DC Output: 24 V and 300 V (standard) 5 V to 600 V (custom) |
| Type: Single point or 3 point | Power Generation Sea States: 1 - 5 |
| Point: Anchor or shackle | |
| Min Depth: 25 m | |
| Max Depth w/ standard design: 1,000 m* | *Other mooring designs available for deeper deployments |

Picture 4.1.5

The data of power buoy technology which shows an average of 8.4 kWh/Day of energy.




Picture 4.1.6

The wave condition data in Java Sea from (buoyweather.com)

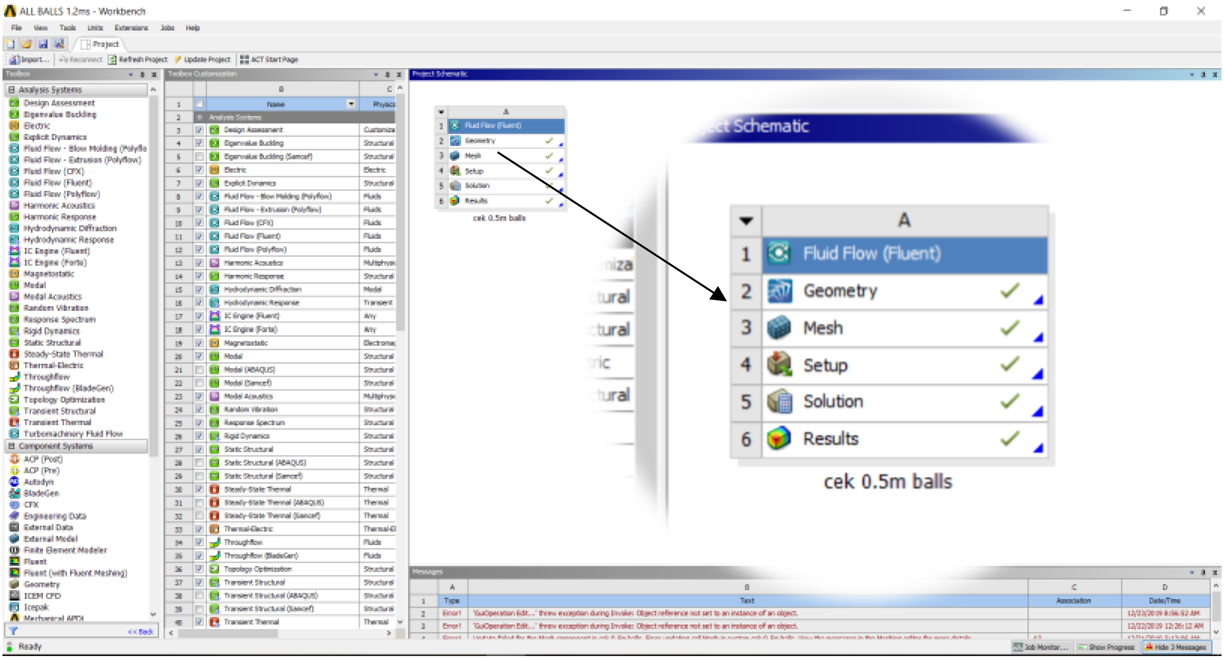
1. An average height of tides is o.1 m from sea level in the morning time.
2. The highest tides is 0.6 m at night above sea level


Picture 4.1.7

Wind speed and wave height condition in Java Sea

1. An highest wind speed at the sea surface is 6.6 m/s from noon until night.
2. An average wind speed at sea surface is 3.6 m/s from midnight until morning

3. The average wave height is 3.08 in timing of 8 seconds



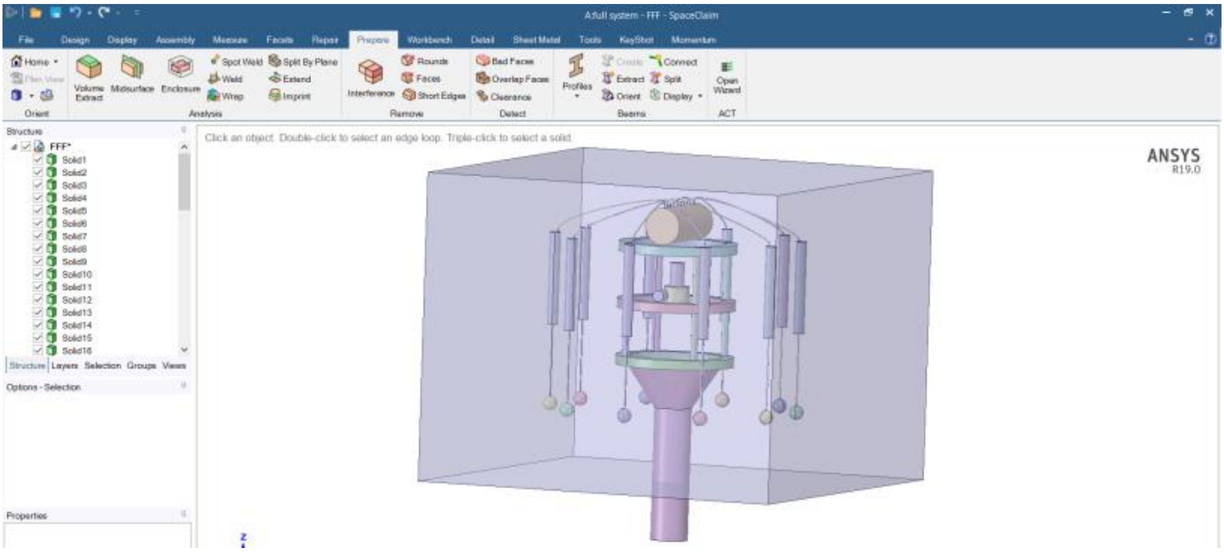

Picture 4.1.8

In this Ansys software there are many kinds of different analysis methods from which one of it is “Fluid Flow (Fluent)” where we can simulate like graphical wave analysis as shown below.

In this method there are 5 steps to analyze

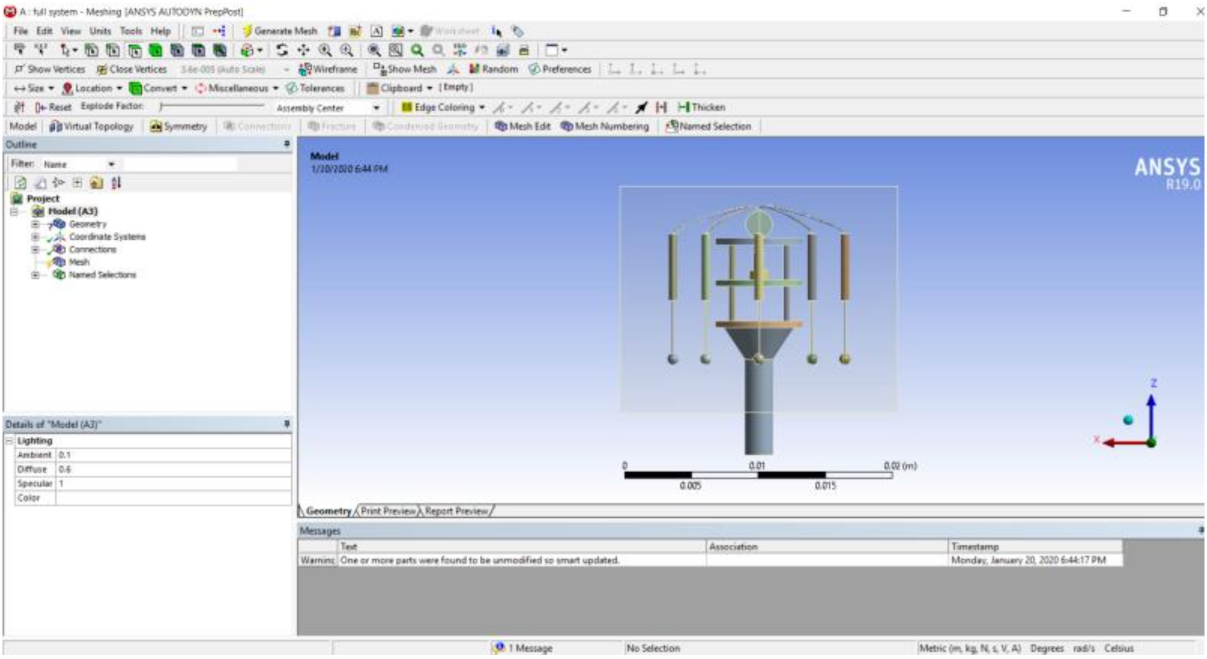
8. Geometry: In this we can import or design from Rhinoceros, Sketchup, Solid works and other possible formats. You have to create an imaginary box which functions as the Inlet and Outlet of fluid flow (wave).
9. Mesh: Here we resize the Imaginary box (meshing box) to get the fine mesh results and if the meshing is not done correctly then it will not show a green tick as shown above.
10. Setup: Here we can set the type of fluid, velocity, height and other required steps for internal calculation by the software.
11. Results: the results are shown in a colored graphics as “Red” means the highest fluid pressure / force and “Blue” means the lowest pressure / force as shown in picture 4.1.5.
12. The green tick means the analysis is successfully done

**(*Note: The time for analysis depends on how well you can use the software. The analysis for this design took about 7- 12 hours with many trail and fails)**




Picture 4.1.9

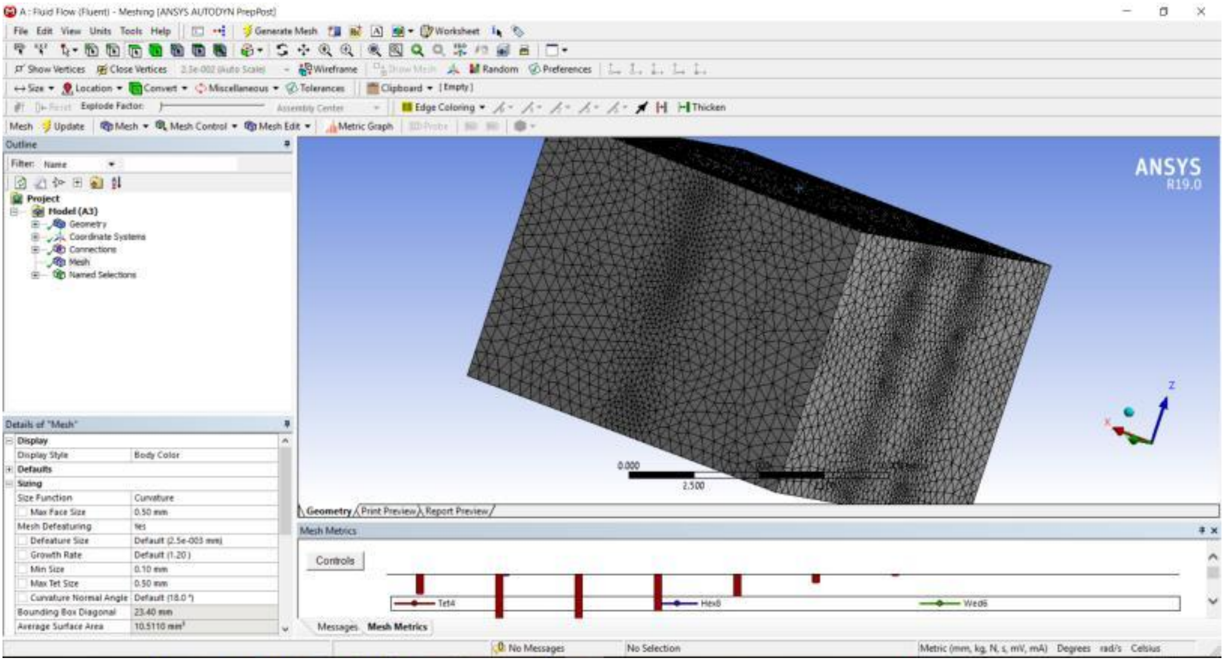
In first step in geometry we must create “Enclosure” which is an imaginary box for generating mesh and making an imaginary fluid flow condition in the enclosure box. We can adjust the size of this box according to the size of model / as we need the fluid inlet pressure. The size of this box is taken as 0.4m. As the box is closer to the model, the meshing will be faster.




Picture 4.10

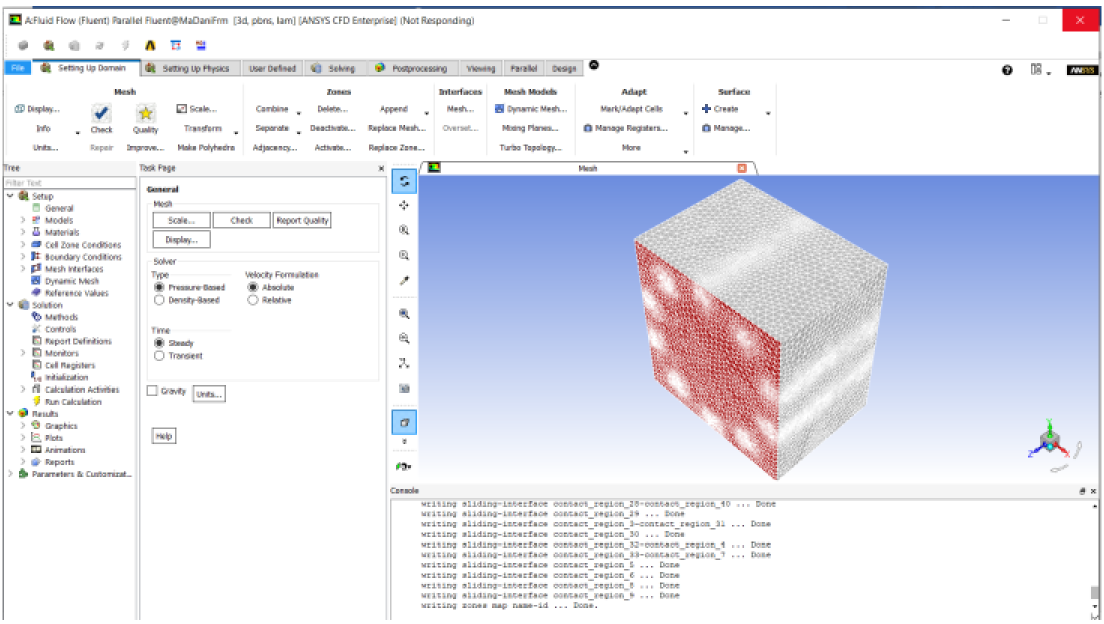
In second step picture 4.1.10 in “Mesh” there are 3 different sections of information

1. In the left side up “Project” section you can see “green tick mark” which means in that sub section of model the geometry system is correct, “question mark” means there is some problem with some parts of geometry or settings (because of some parts are not yet a solid structure) because of which the mesh cannot be created, and a “hazard mark” means the sizing or other setting like quality or inflation for meshing is bad / incorrectly set.
2. In left side down “Details of mesh” which includes setting options (display, default, sizing, inflation, quality, advanced, statistics). In here mainly we change the sizing of mesh box to mesh the model in minimum size like 0.5mm to process faster. And in quality we mainly check the smoothing of mesh of model as in this I take medium smoothing to check the sizing of mesh is clearly done or not.
3. Last section “Message” at the bottom which shows messages like reasons if meshing is not done at some parts of model (mostly because of bad sizing of mesh).




Picture 4.1.11

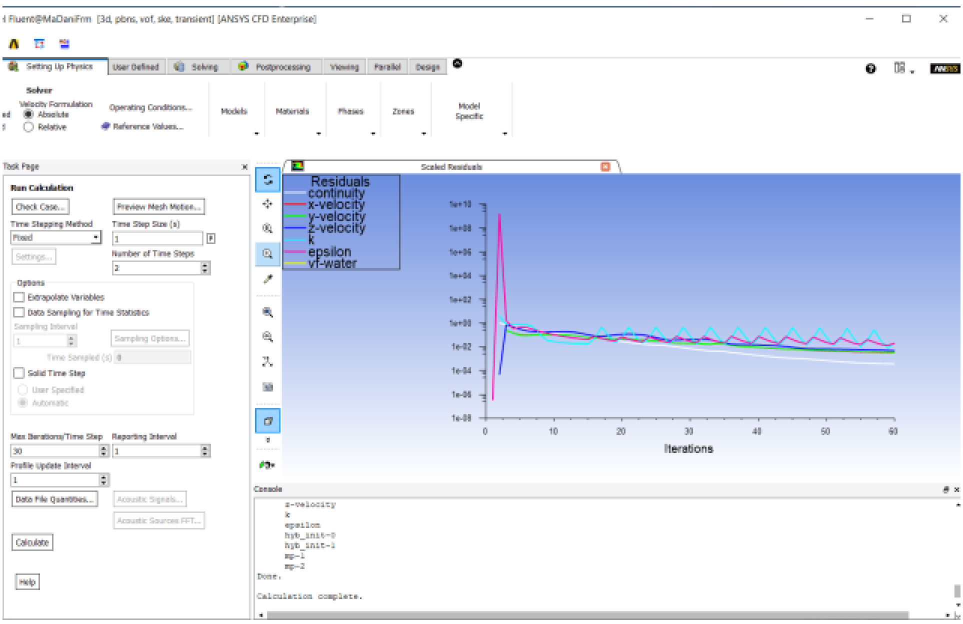
When the meshing is successfully done it shows a green tick in project section and as you can see the mesh looks like small triangle shaped which is small because of the size of mesh set before. (meshing basically means a set of finite elements for computational analysis or modeling).



Picture 4.1.12

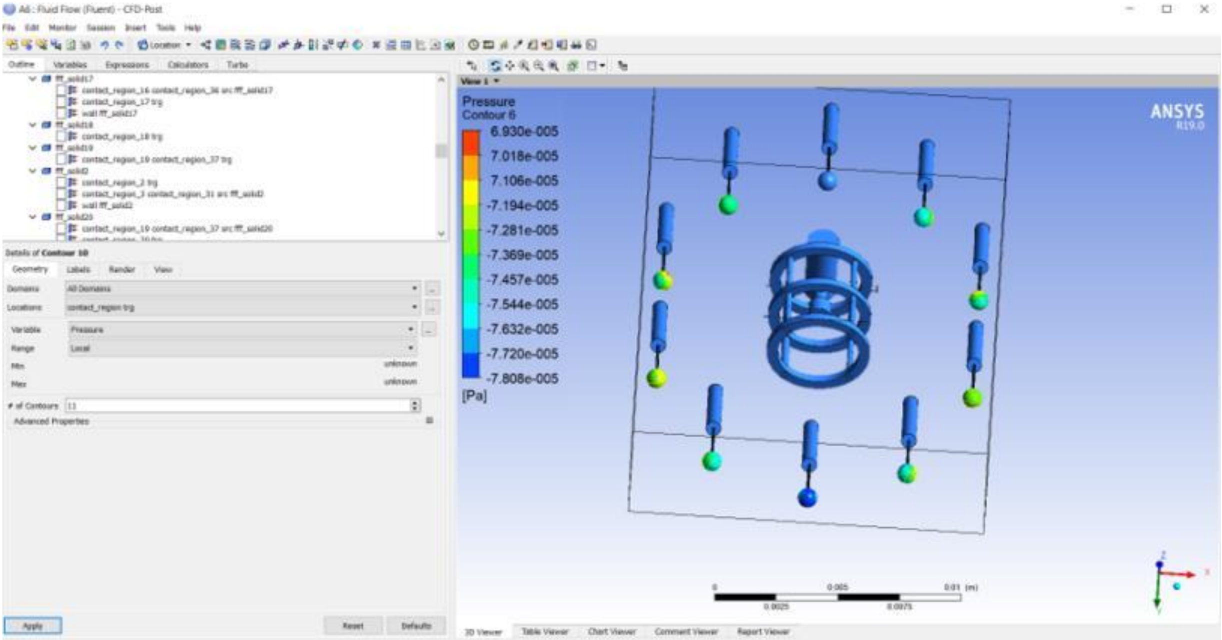
Next step in “Setup”, because your meshing was done this setup program will automatically show your meshed model and will check if there is any errors before doing the final setting for analysis.

1. The setting toolbar on the left side shows many options for analysis (pressure, force, gravity, materials to use for fluid analysis, boundary conditions, methods, controls, monitors)
2. In this we mainly change the (gravity force, materials like type of solid for model, boundary conditions for inlet of type of fluid).
3. There is an option called “hybrid initialization” which shortly checks the settings used for calculating the model. This step is used so there is no errors during calculation and the analysis runs smoothly.




Picture 4.1.13

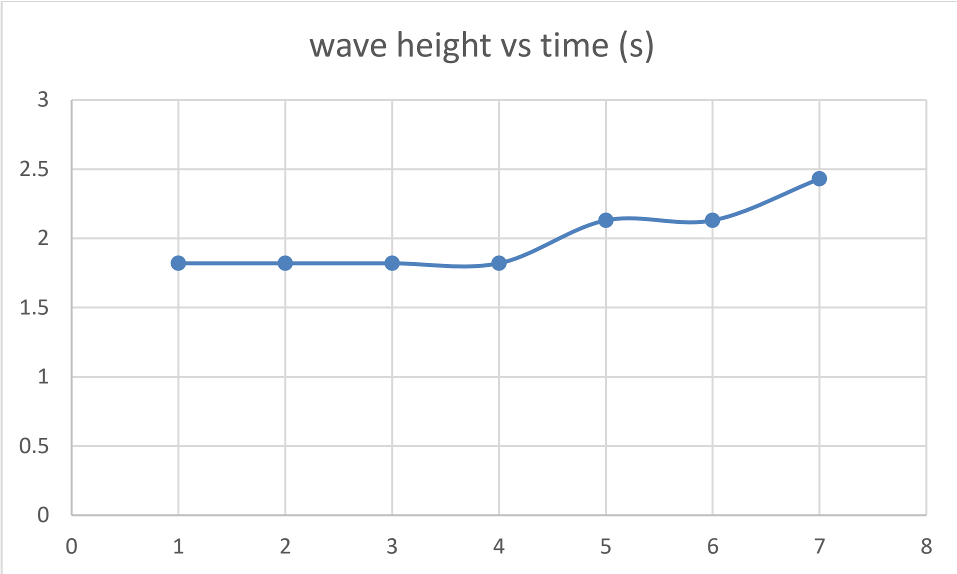
After the calculation is completed The graph shows a wave like lines in the middle of iterations and starting of smoother lines at the end which means it had some errors in the middle because of the wave force deflection due to the jacket structure which oppose the continuous wave flow.




Picture 4.1.14

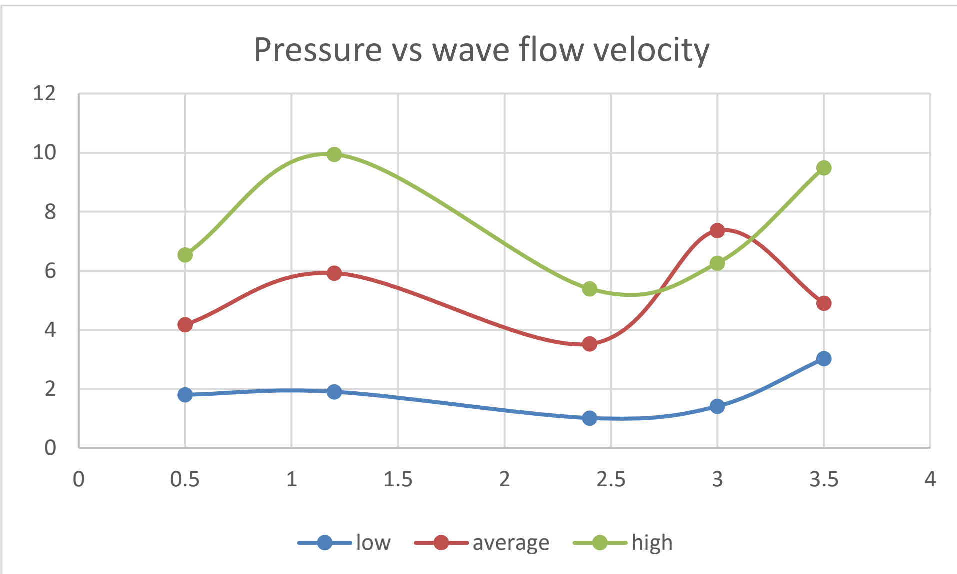
The results show the pressure on just 1 ball even if we analyze the whole system but the pressure on other floating buoy is different because the jacket structure oppose the motion of wave flow due to which the pressure is low on other side of jacket. The analysis does not show full model because of the fluid flow setting done in setup. As in this the inlet of fluid is from down to up.

(Note: the pressure from waves highly depends on the direction of wave flow because of wind direction and speed)




Graph 4.1

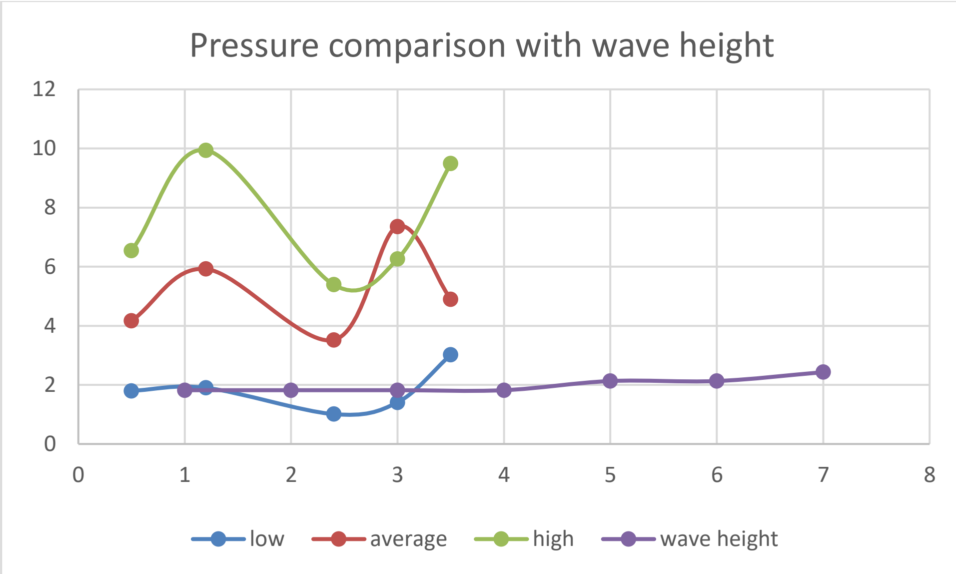
This wave height / tides graph is according to the data from picture 4.1.7. The (X-axis) is for seconds and (Y-axis) is for wave height. As we can see the wave height is constant until 4 seconds which is from midnight until morning. And the height increases from 5 until 7 seconds which is during afternoon until evening time.




Graph 4.2

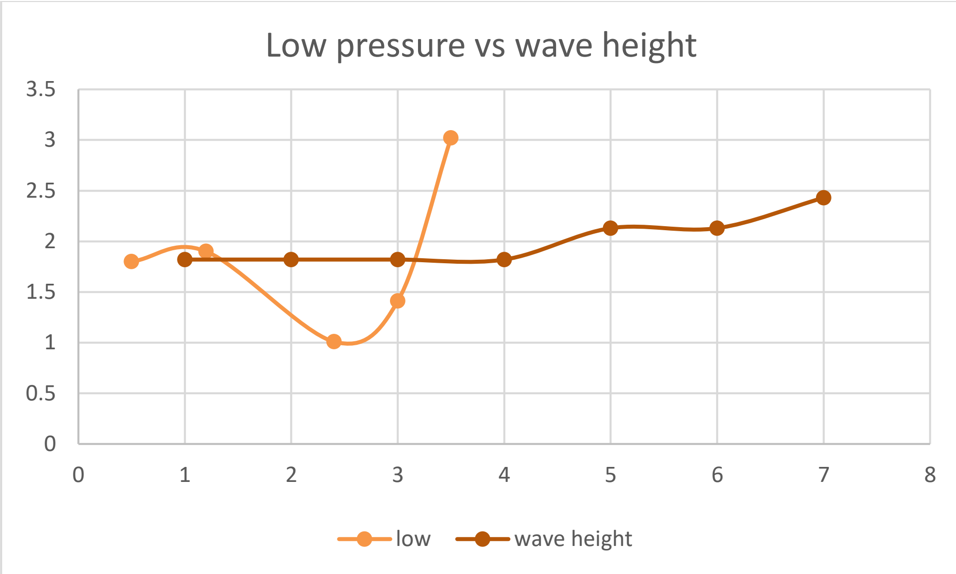
This graph is plotted based on real data taken from Ansys after simulating the model. It is a pressure vs wave flow velocity graph. The

X-axis shows wave flow velocity data based on picture 4.1.7. As shown in the graph the pressure is balanced (wave like lines) shows with low, average and high pressure differences. And Y-axis shows the pressure values from 0 to 12 psi.



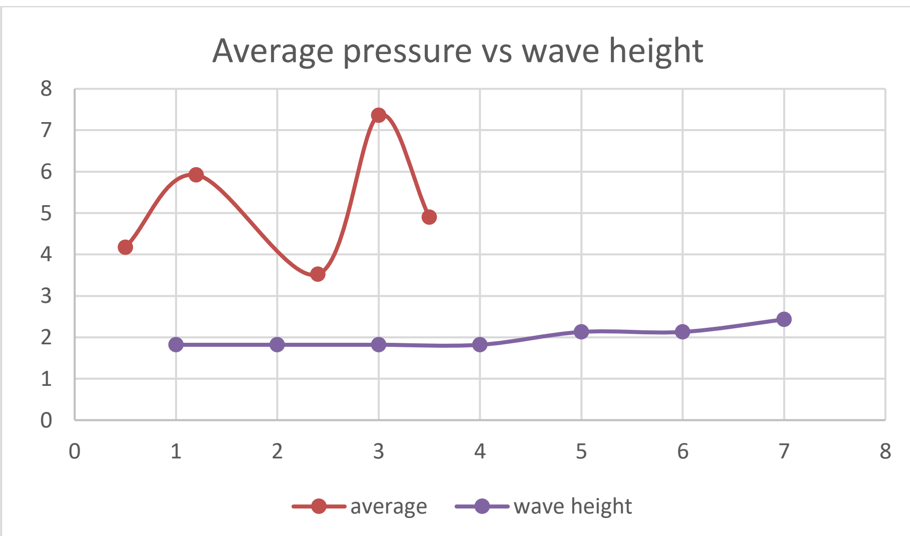

Graph 4.3

This graph is plotted based on real data taken from Ansys after simulating the model. It is a pressure vs wave velocity graph. The Y-axis shows the pressure and X-axis shows the wave velocity data from picture 4.1.7, so the values are from minimum until maximum velocities (0.5m/s, 1.2m/s, 2.4m/s, 3m/s, 3.5m/s).



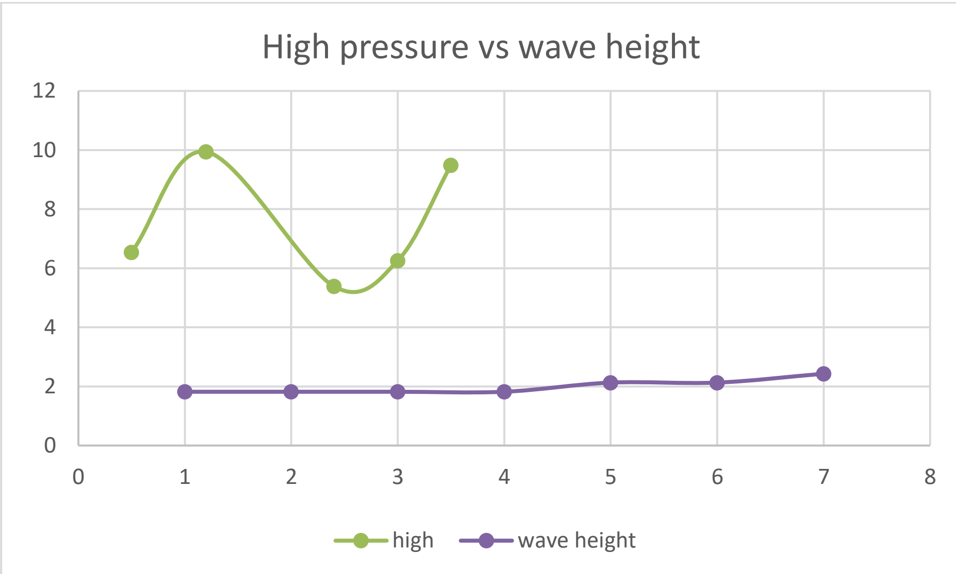

Graph 4.4

This graph shows the pressure on buoy made by wave with comparing the data of wave height. As the wave height is constant until 3 seconds the pressure is getting lower from 1.7psi to 1 psi from 0.5 m/s to 2.4 m/s and during the 4 second the pressure is increased until 3 psi at 3m/s. hence as the velocity of wave increases the pressure maybe constant or decrease and if the velocity of water decreases the wave height increase so the pressure on buoy also increase. This graph shows the lowest pressure condition with different velocities from 0.5 to 3.5 m/s.



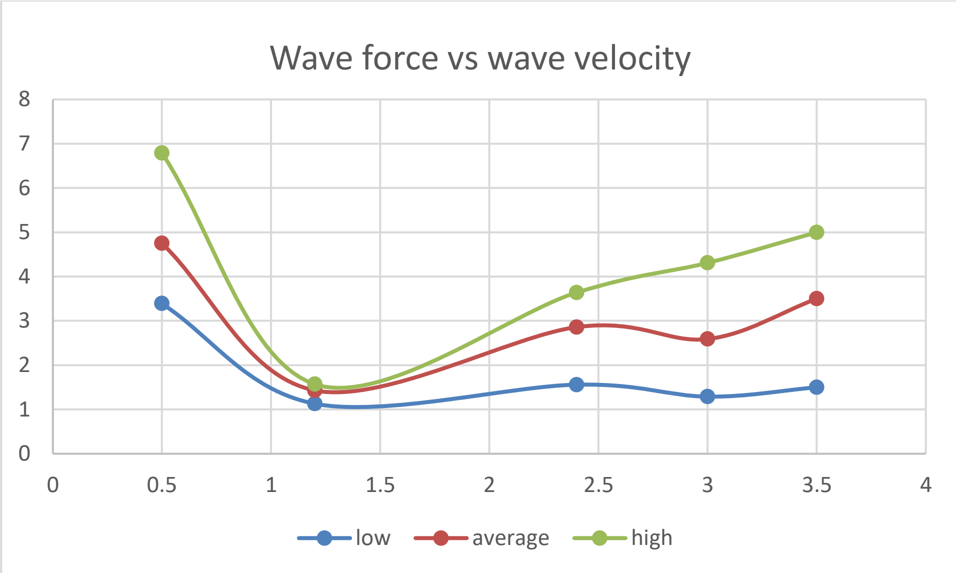

Graph 4.5

This graph shows an average pressure on buoy made by wave comparing the data of wave height. As the wave height is constant until 3 seconds the average pressure is balanced from (5.92 psi at 1.2 m/s, 3.52 psi at 2.4 m/s, 7.36 psi at 3 m/s). By this we can evaluate that based on the analysis the average pressure is balanced during certain velocities and can push up the floating buoy to create pressure.



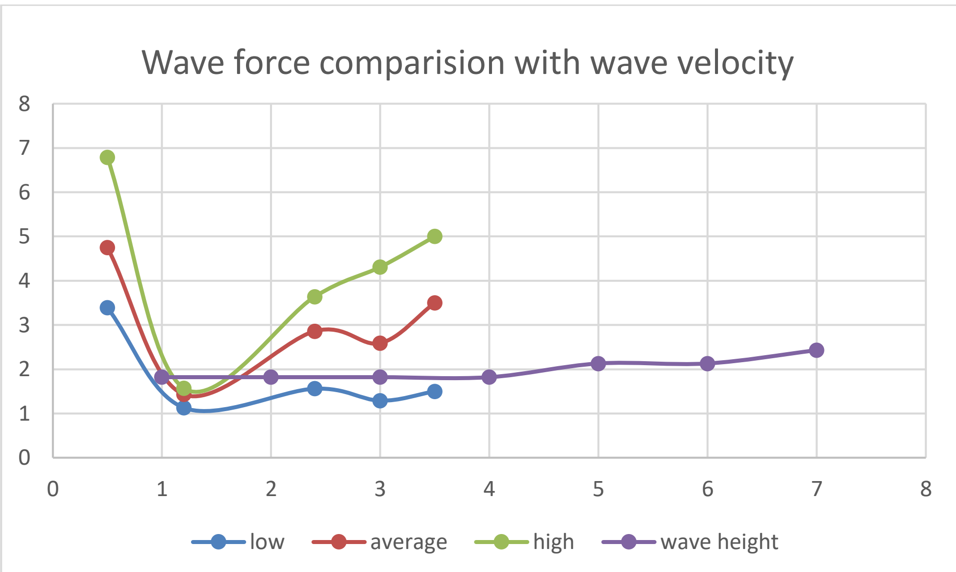

Graph 4.6

This graph shows the pressure on buoy made by wave with comparing the data of wave height. As the wave height is constant until 3 seconds the high pressure is balanced from (6.54 psi at 0.5 m/s, 9.94 psi at 1.2 m/s, 5.39 psi at 2.4 m/s, 6.26 psi at 3 m/s). By this we can evaluate that based on the analysis the high pressure is balanced during certain velocities and can push up the floating buoy to create pressure.



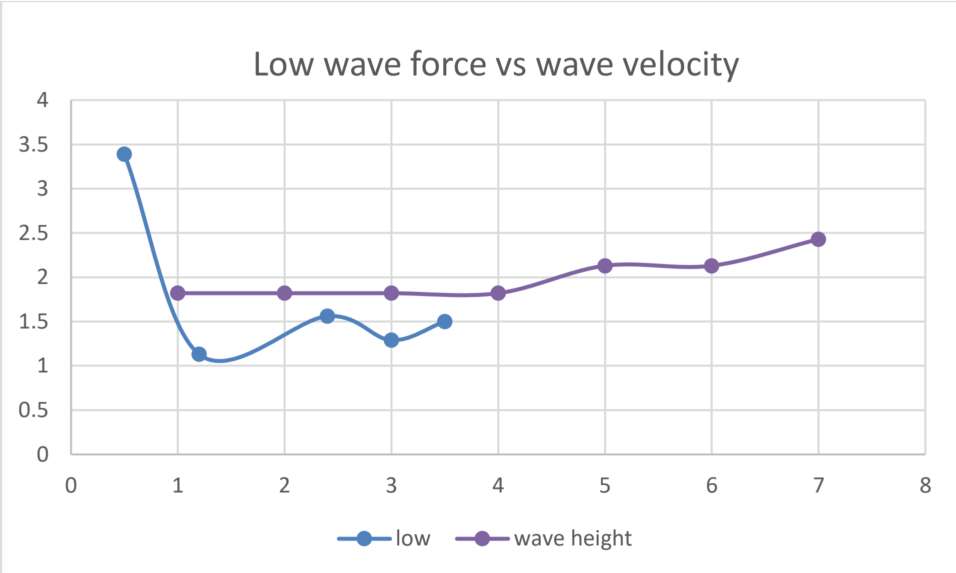

Graph 4.7

This graph is plotted based on real data taken from Ansys after simulating the model. It is a wave force vs wave flow velocity graph. The X-axis shows wave flow velocity data based on picture 4.1.7. Y-axis shows the force values from 0 to 8 m/s which is created from waves. If we compare this graph with graph in picture…its almost same but this graph is plotted with four values which is the wave flow data between 0.5 to 3.5 m/s.



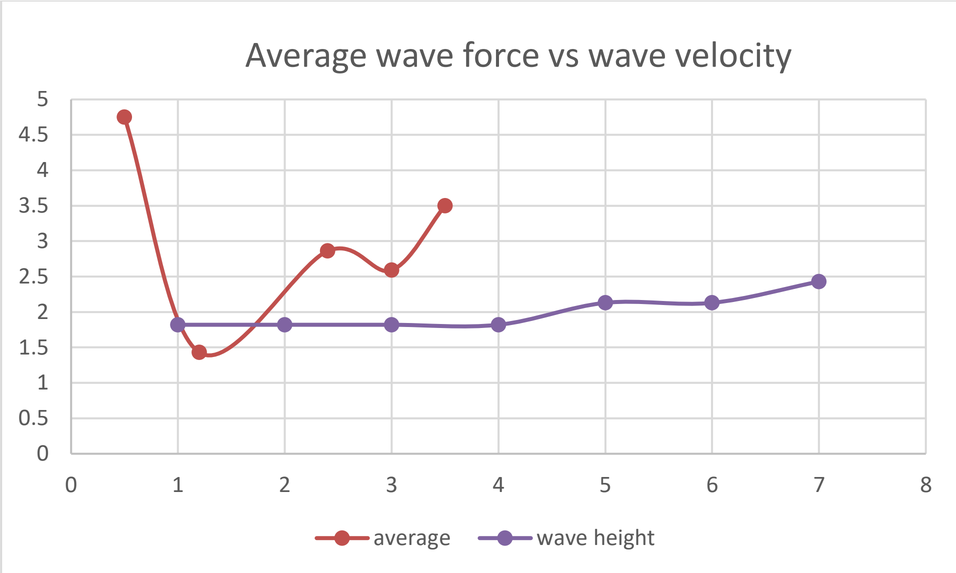

Graph 4.8

This graph is plotted based on real data taken from Ansys after simulating the model. It is a wave force on buoy vs wave flow velocity graph. The Y-axis shows the wave force and X-axis shows the wave velocity data from picture 4.1.7, so the values are from minimum until maximum velocities (0.5m/s, 1.2m/s, 2.4m/s, 3m/s, 3.5m/s).



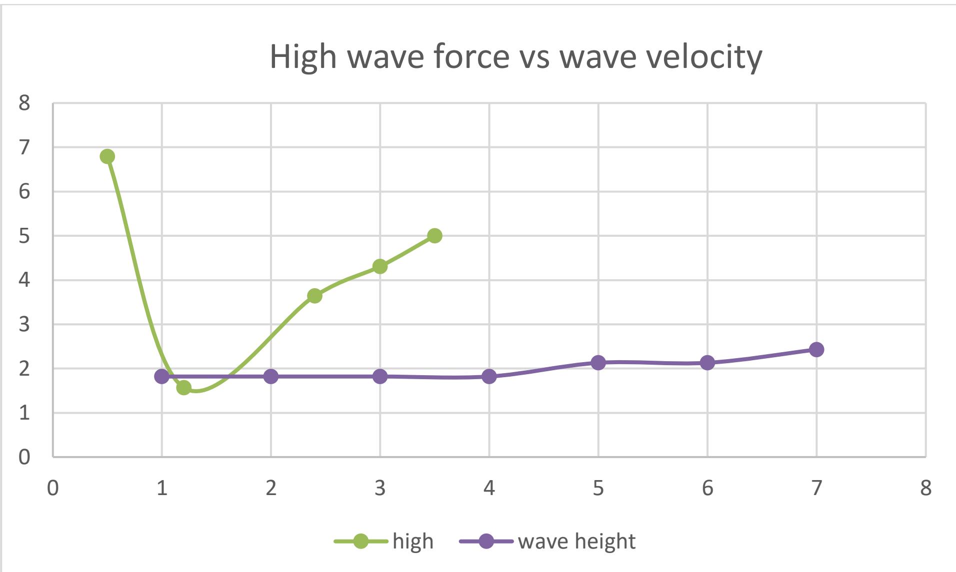

Graph 4.9

This graph shows the wave velocity force on buoy and comparing with the wave height. Based on analysis with velocities (0.5, 1.2, 2.4, 3, 3.5 m/s) evaluating low wave force data shows that even the wave flow is constant until 3 seconds but because of wind speed condition there is some small tides / wave crest due to which at low force the buoy has some floating movement.




Graph 4.10

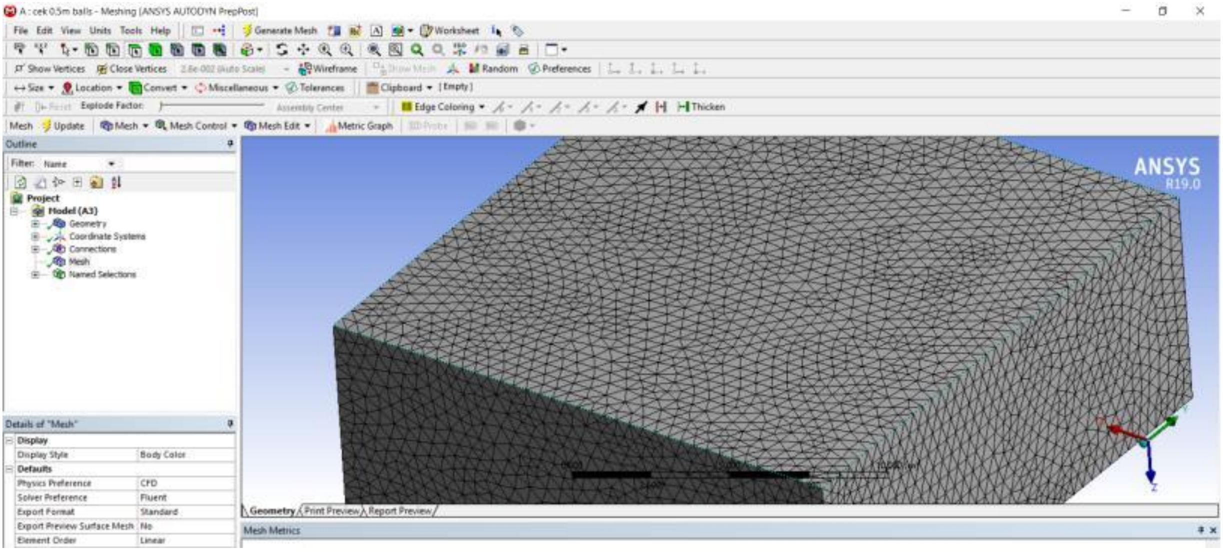
This graph shows the wave velocity force on buoy and comparing with the wave height. Based on analysis with velocities (0.5, 1.2, 2.4, 3, 3.5 m/s) evaluating average wave force data shows that in an average velocity force on buoy it can create pressure in chamber but in less amount as it depends on sea condition.




Graph 4.11

This graph shows the wave velocity force on buoy and comparing with the wave height. Based on analysis with velocities (0.5, 1.2, 2.4, 3, 3.5

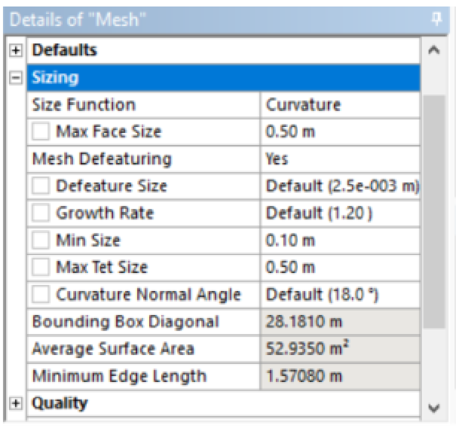
m/s) evaluating high wave force data shows that when wave flow is constant the highest force on buoy is (6.79 at 0.5 m/s, 3.64 at 2.4 m/s, 4.31 at 3 m/s, 5 at 3.5 m/s)




Picture 4.1.15

Meshing successfully done

1. We must select the type of material of the object which will be simulated.
2. There are many materials like type of metals, types of solids, etc.



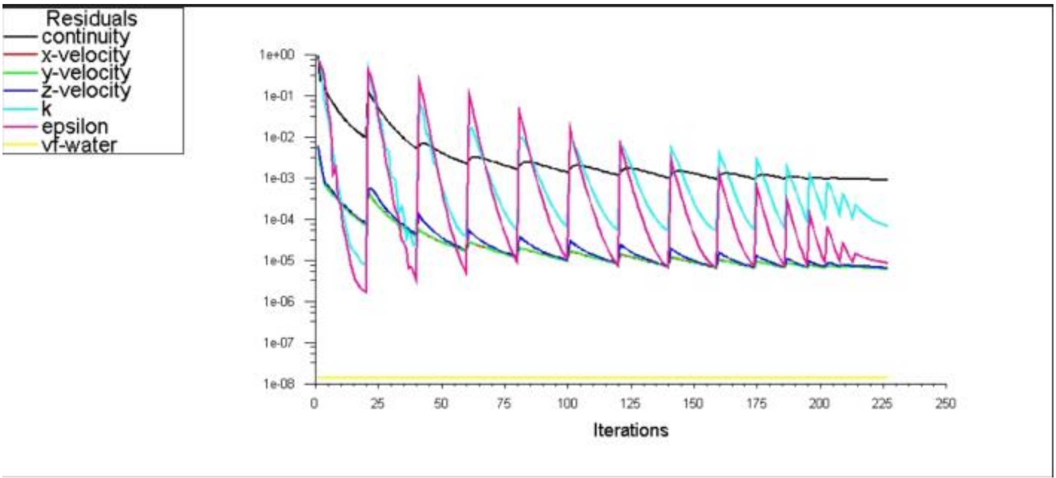
Details of "Mesh"

| | |
|---|---|
| **Defaults** | |
| **Sizing** | |
| Size Function | Curvature |
| Max Face Size | 0.50 m |
| Mesh Defeaturing | Yes |
| Defeature Size | Default (2.5e-003 m) |
| Growth Rate | Default (1.20 ) |
| Min Size | 0.10 m |
| Max Tet Size | 0.50 m |
| Curvature Normal Angle | Default (18.0 °) |
| Bounding Box Diagonal | 28.1810 m |
| Average Surface Area | 52.9350 m² |
| Minimum Edge Length | 1.57080 m |
| **Quality** | |

Picture 4.1.16

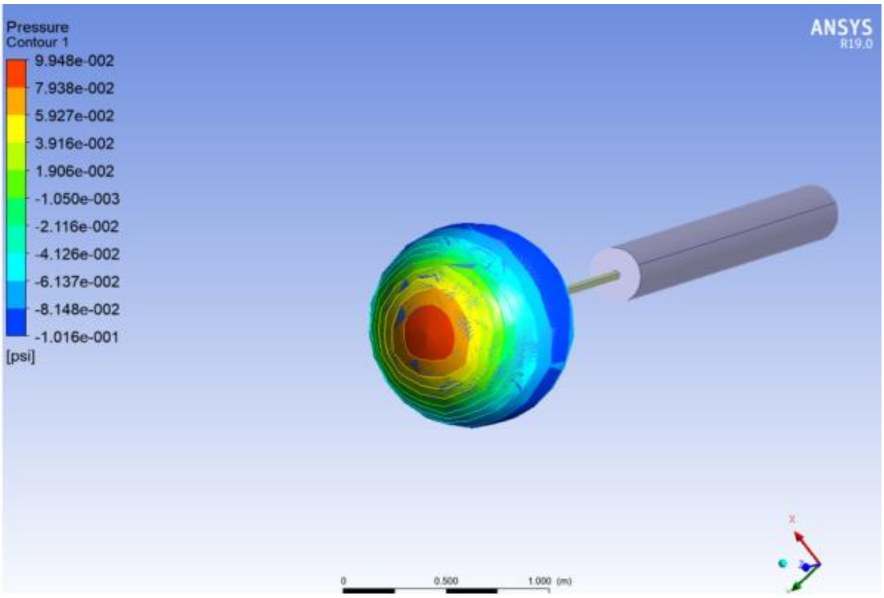
This shows the details of mesh as sizing is the most important thing for meshing a design as it will show an accurate result of analysis. In here max face size is about the triangle faces you can see in picture 4.1.9 which is called mesh face size. Max

Tet size is the length of 1 side of triangle mesh face. It's a random size selection for meshing as starting from minimum to maximum and if the size is more bigger it takes longer time to mesh and analyze the result.



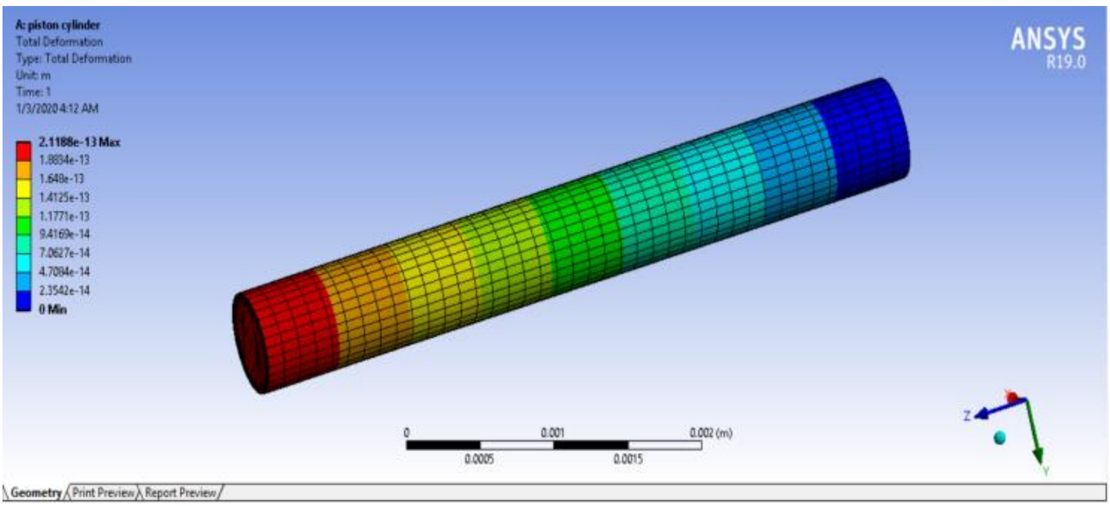

Picture 4.1.17

This graph shows that the analyzed results are good / smooth at 203 iterations. When the analyze starts there are some normal errors in starting point so it shows an informal graphic lines as shown above and when the results get smoother with smaller errors its decreases the formation of informal lines and in the end of analysis it started a smooth streamline from 0.0000001 until 0.0001 point which means the analysis of the design was good.



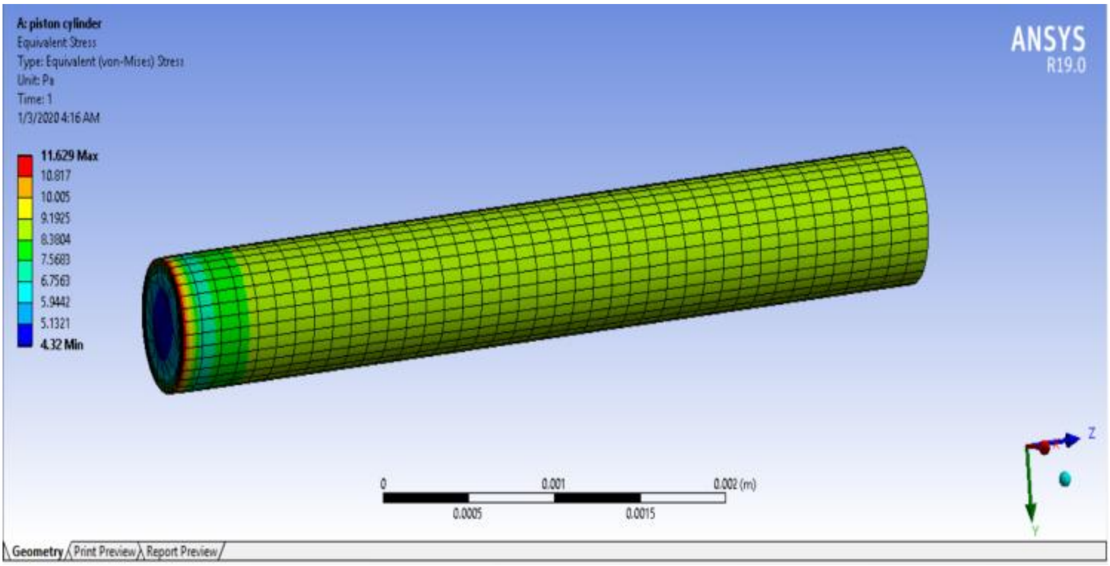

Picture 4.1.18

The maximum pressure made on 1 floating buoy by wave is 9.9 psi which will then push the buoy up and make pressure in the chamber (same function like a bicycle hand pump).




Picture 4.1.19

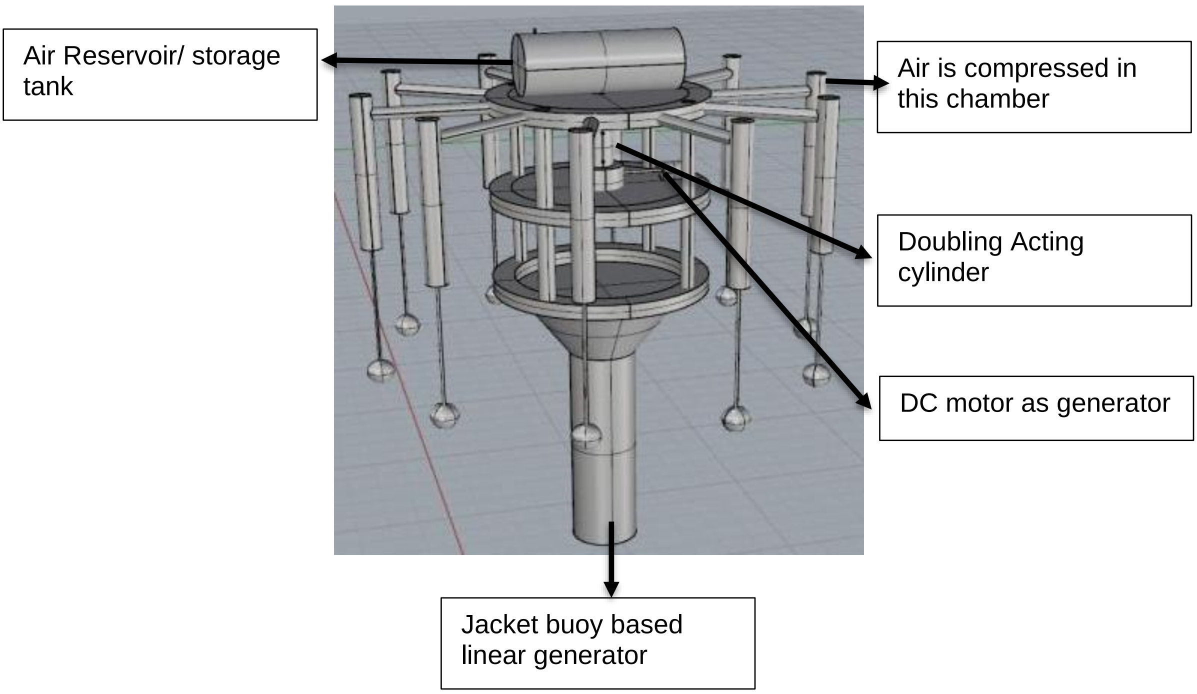
This is the stress analysis of the chamber, the “Red” area is in high pressure which is the top side of chamber near inlet and outlet valve. This analysis is done to know that the designed object does not have any abnormal condition which could damage the object.




Picture 4.1.20

The “Red” area which is the down part of the chamber near the floating buoy. The stress is high on the sides because the movement of the buoy starts by the wave force. This analysis is done to know that the designed object does not have any abnormal condition which could damage the object at the point of reciprocating movement

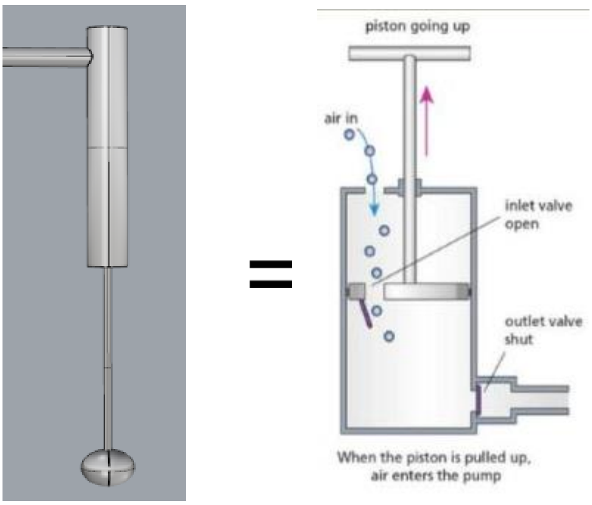
## 4.3 3D model of Jacket based Linear generator




Picture 4.3.1

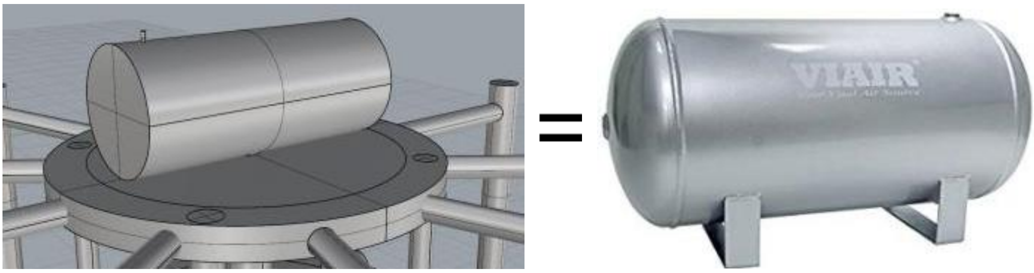

Picture 4.3.2

**Jacket buoy** will be fixed in the sea bed as to get the maximum wave pressure / force to the floating balls. The Jacket is designed in a circular shape as to avoid unwanted construction because it will directly be fixed in sea bed.



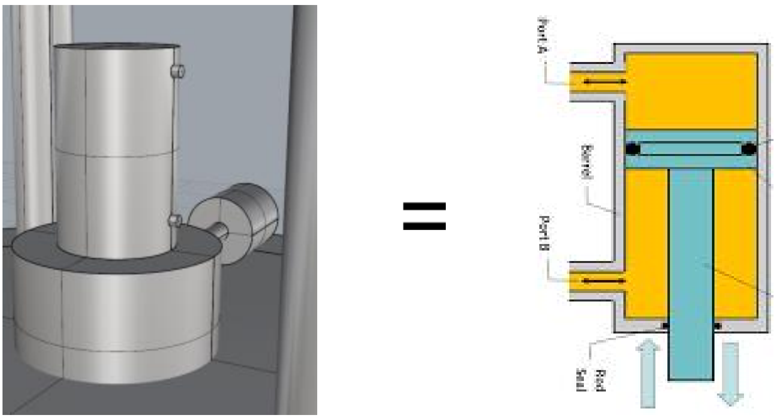

Picture 4.3.3

**Compressing chamber** As the ball floats and move up / down by the force of water , its pushes the rod and so the piston and thus it creates a pressure inside the chamber (functions same like a bicycle pump) while the ball comes down back to the sea surface it takes air from inlet valve (the air inlet is from the atmosphere) and the compressed air is then transferred to the air reservoir / storage tank.



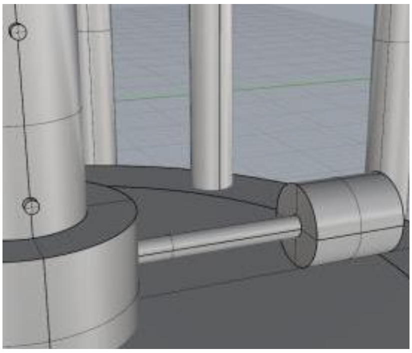

Picture 4.3.4

**The Air reservoir** then transfers the air to the oscillating Double acting actuator, which then helps to rotate the shaft which is connected to the DC motor (generator) and thus the rotational force of dc motor generates electricity




Picture 4.3.5

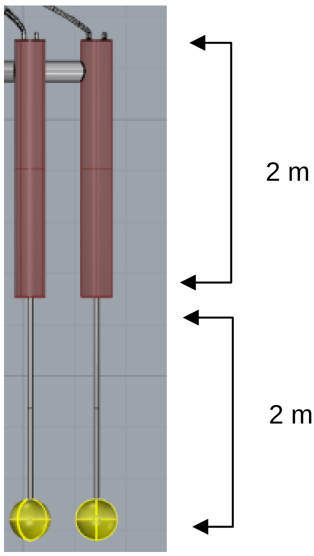
**Double acting oscillating linear piston** which takes pressurized air from reservoir on both inlet and outlet and rotates the crank shaft and thus rotates the generator (DC motor)



Picture 4.3.6

**DC motor as Generator** which has an internal formation of magnets and coil which produces an EMF force when a rotational force is applied from an external source for converting rotational energy from crank shaft to electrical energy and store it in battery or connect to the dockyard or also a ship can consume the energy from it.

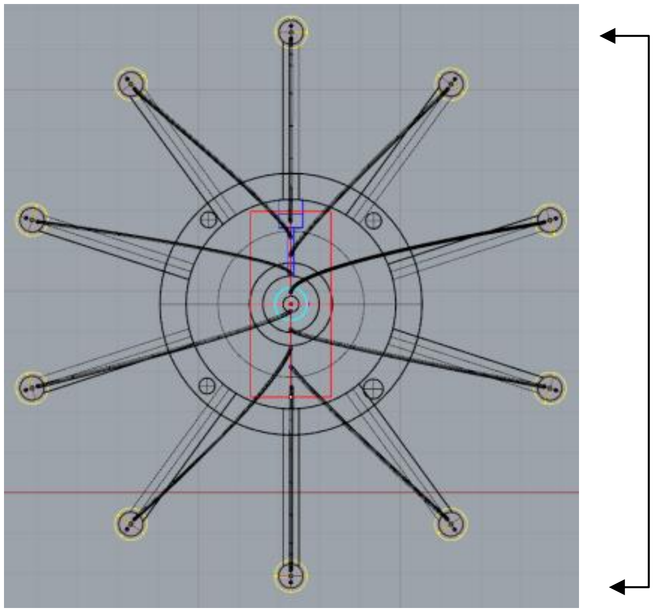





Picture 4.3.7

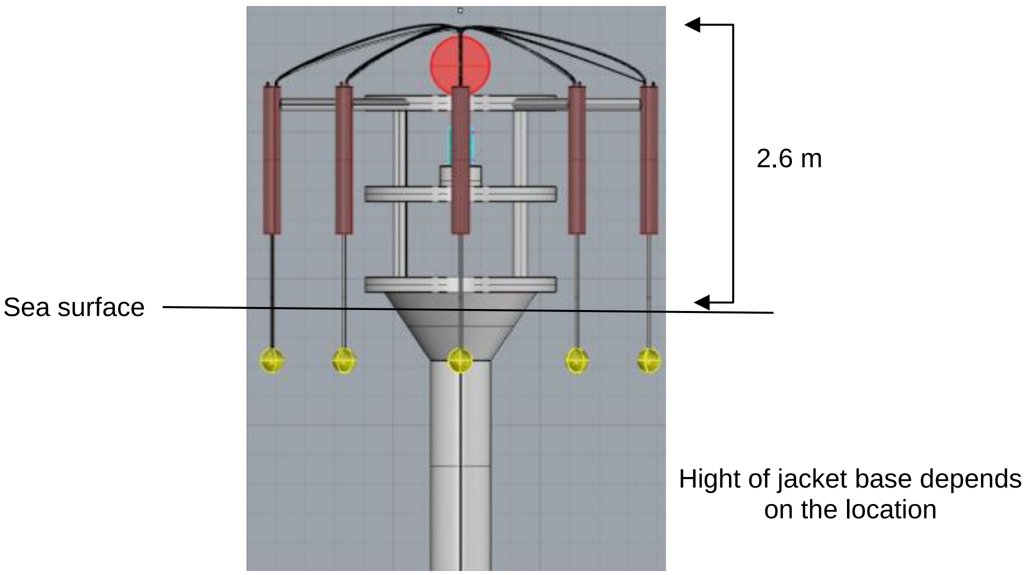
Height / Length of chamber and floating buoy

The buoy could reach max about 2 m above sea level after the force from wave is applied as from picture 4.1.7, we can see that the average max height of wave is 1.8 m.




Picture 4.3.8

Width of the model. The width is 3 m because as in picture 4.1.5, we can see the power buoy has a floating diameter of 2.65 m



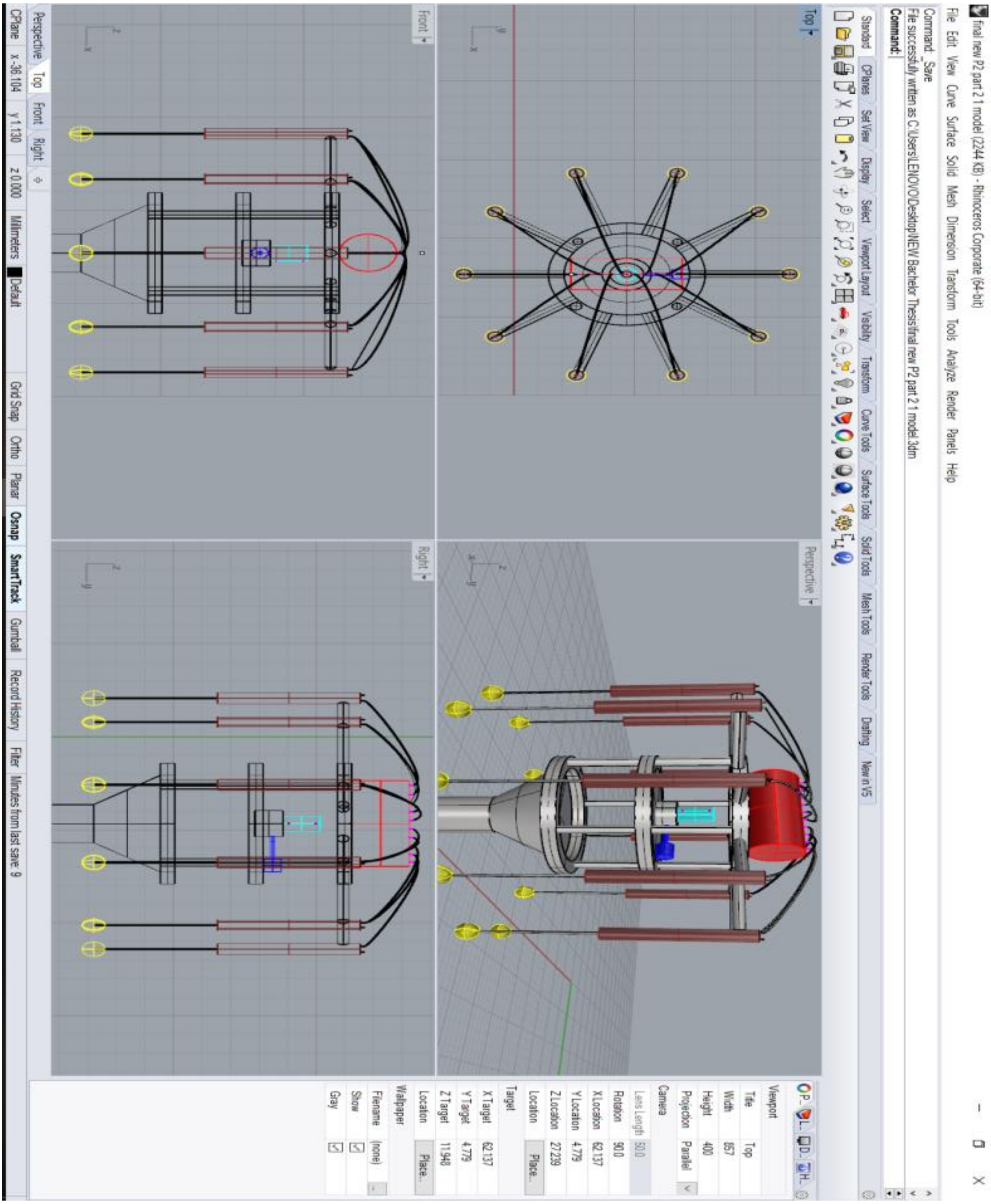

Picture 4.3.9

Height of the power plant above sea level to avoid the corrosion of the chamber so as to have less maintenance.

| Recommended Receiver Volume | | |
|---|---|---|
| (cu ft) | (gal) | (m3) |
| 3 | 20 | 0.1 |
| 4 | 30 | 0.1 |
| 5 | 40 | 0.2 |
| 8 | 60 | 0.2 |
| 11 | 80 | 0.3 |
| 13 | 100 | 0.4 |
| 16 | 120 | 0.5 |
| 21 | 160 | 0.6 |
| 27 | 200 | 0.8 |
| 32 | 240 | 0.9 |

Picture 4.4.0

Based on the result from picture 4.1.18 a **20 gallon** of air receiver can be used as a storage tank.




Picture 4.4.1

3D model showing different angles so the reader can understand the concept of design and can try build a practical model if the reader is a professional designer

# CHAPTER 5
# CONCLUSION and SUGGESTION

## 5.1 Conclusion

As we know water is our basic need and it has many potential to be a renewable source of energy in many ways. As Indonesia is widely surrounded by oceans it has a great potential of tidal / wave energy. There are to many ways to make a wave energy device / design as since 15-20 years countries like Germany, Canada, UK and few more others have built an incredible and innovative design to gain energy from ocean and still processing with new different methods like EMF (electro magnetic force), Hydrolics and etc..

If we remember from our senior secondary school basic physics knowledge that a pressurized air have the highest force to move / rotate / push an object with high velocity.

In this paper I am talking about a new method by "Compressed air which drives a double acting cylinder as a Linear generator" in which the pressurized air is created by wave force.

## 5.2 Suggestion

As the designed model is far from the perfect result due to the lack of availability of software and since the author is not a professional designer but it might help the designer / reader / manufacturer to understand the idea and develop it.

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Department of Ocean Engineering, Amirkabir University of Technology, Tehran, Iran