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Final Year Project Report

"Structure to obtain energy based on worn tyres"

Miguel Muñío Gay

Supervisor: Ruslan Gareev

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Abstract

The title of the project is called "Construction of the structure to obtain energy based on worn tyres". The purpose of this project is to study and determine the feasible of the worn tyres structure. The main aim is the highest use of wave movement, in order to create energy with a simple structure, based on joined worn tyres with a simple electrical gadget.

At first, the structure is made up of a whole of floating tyres joined with steel wires, in order to achieve a high freedom of movement, creating the shape of a raft. Within each tyre is the electrical structure, a series of electrical gadgets with a reel around a magnet.

The exploitation of wave movement is achieved with other whole of submerged tyres joining to the structure through a cylinder, which own a magnet in the top allowing the connection with the raft. This last part converts the wave movement into a vertical movement.

To sum up, the energy creation is obtained by means of the inexhaustible wave source, developing a vertical magnet movement within steel. A simple exploitation way of natural resources using waste materials.

Introduction

Nowadays, the world lives under a constant threat related to the global warming, which is changing the way to obtain energy. The renewable energy is becoming an important point of view for different companies and governments.

The main aim is the reduction of greenhouse effect gases, with the purpose of reducing and stabilizing the Earth temperature and stops the global warming. Flannery has estimated that in the 2050 the emissions of CO_2 should be reduced by 70%, still knowing that the global consumption will continue increasing on exponential way in the next decades. [Flannery, 2005]

Due to the fact that this reasons the development of clear energies politics has increase, knew as Renewable energies, like biomass, solar energy, wind energy, sea energy or geothermal.

The sea energy embraces six types of different energy, which are explained below:

- Tide energy or Tidal power: The principle is the same of hydraulic central. It is made up of the water storage in natural intel, taking advantage of tide slope which are created by the gravitational action of the Moon and Sun. The kinetics energy is achieved with the accumulation water.
- Energy of oceanic gradient thermal: The conversion gadgets take advantage of the highest temperature gradient (between surface and hundreds meters of deep) developing thermodynamic cycles. A temperature difference of 20ºC, at least, is needed to obtain good performance.
- Osmotic energy: Related to salinity gradient. It has been the less development until this moment.
- Wind sea energy: Using the sea wind similarly to wind energy.
- Ocean currents energy: The kinetics energy of the ocean currents are used similarly to wind energy. The problem showed with this method is the same of wind energy: red connection and financing, despite of the waves are more predictable than wind.

- Wave energy: The wave is a method of energy storage. Until this moment, it hasn't been exploited properly.

[Center, 2004]

This project is focused on the wave energy, in order to create a structure based on worn tyres including electrical system, allowing the change of wave movement into electric energy. The aim is, using waste material; obtain a cheaper and feasible project which could be attractive to different companies.

Background knowledge

During the 70's world crisis, the oil price experienced a strong increase highlighting the needs of reducing the developed countries dependence to fossil fuel. Since then, it began the investigation of alternative renewable sources in order to produce electric energy. Nowadays, the EU political aim is to triple the primary energy consume due to renewable energy setting a deadline of 2020.

[AEA Energy & Environment, 2006]

Solar, hydraulics and wind energy have an important grade of developing in market, being a remarkable factor in national energy production. Nevertheless, sea energy extraction is still under investigation, having just a few examples of this kind of operative devices.

Waves generated by wind contain most part of energy. This is understood as a product of solar energy; the earth surface is warmed by the sun in a non-homogeny way, producing air displacements by density gradient. Wind blows and frictions the free water surface generating waves, which are able to travel thousands of kilometres with negligible loss of energy. As waves get closer to the coast line, experiment an energy loss due to the interaction with sea bed.

The number of companies that design a device capable of exploiting this plentiful source is increasing day to day. Most of mechanisms are just small scale prototypes under investigation process; others had achieved a higher level creating full scale operational devices. However, it is not possible to distinguish between all this technologies an only model which shows better future perspectives than its competitors, since none of them has been proved in a wave farm like a commercial prototype.

The technologic development level is still not enough to make waves a competitive electric energy source. An economic balance would show that those studied mechanism have a huge initial inversion and costs that can't face the low energy efficiency. In Europe, UK is a pioneer county in the development of this kind of devices.

The most important last step to achieve the prototype of a structure, in order to create a commercial exploitation, is to have the infrastructures necessary to test, research and prove the gadget function in a higher scale than laboratory. Nowadays, in Europe there are four installations:

- **EMEC (European Marine Energy Centre, Orkney, Great Britain)**

Located in Orkney Islands, in British. Since 2005, the only real scale infrastructure available in this area.

[European Marine Energy Center (EMEC) Ltd, Old Academy, 2005]


Fig. 3.1. Different parts of the EMEC

- **WAVE HUB (Cornwall, Great Britain)**

Located in Cornwall, south west of England. Recently available, since 2010.

[Wave Hub, John Harvey House.]
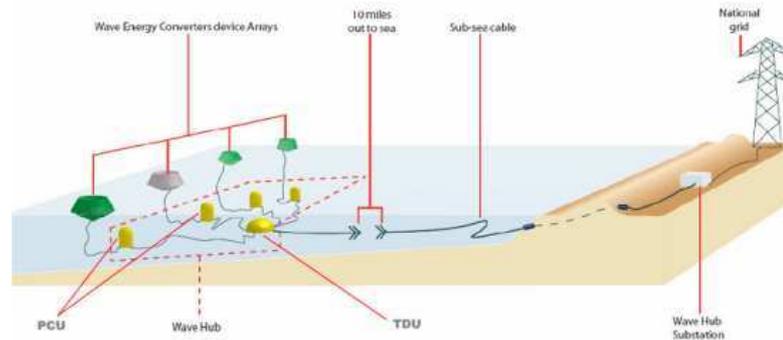
Fig. 3.2. Structure of the Wave Hub

- **MARINE INSTITUTE (Galway, Ireland)**

Located in the bay of Galway, an optimum place for prototypes with a scale of 1:3 or 1:5.

- **PILOT AREA (Portugal)**

Located near of Provoa de Varzom (North of Portugal), it has a important presence due to be a commercial exploitation.

It could be made a classification, using different discernment.

According to the relative position relative to the shore:

- Onshore
- Near shore (10-40m)
- Offshore (>50m)

Between 2004 and 2008 the power esteemed of conversion gadgets are 8% of onshore, 34% near shore and 58% offshore.

[Sea shore life, 2005]
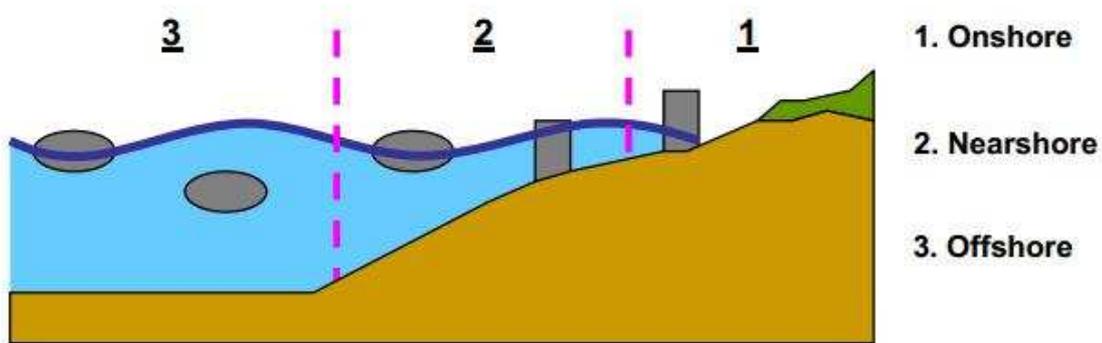
Fig. 3.3. Classification of Shore

The main recruitment types are:

1) Oscillating column of water: The water pressure is transmitted through the air which at the same time creates a movement in a turbine.

2) Archimedes: Is based on the relative movement between two objects which pressurise the inside content.

3) Buoy object with mobile reference: The energy is extracted by the relative movement of the structure equipment.

4) Floating device with a mobile reference: The energy is achieved with the relative movement of the structure

5) Overtaken device: Could appear floating or submerged, it storages the sell water creating the movement in a turbine. These take advantage of the powerful swell.

6) Impact device: Take advantage of the horizontal wave energy in order to move a piston driving the turbine at the same moment. These take advantage of a small quantity of kinetic energy.
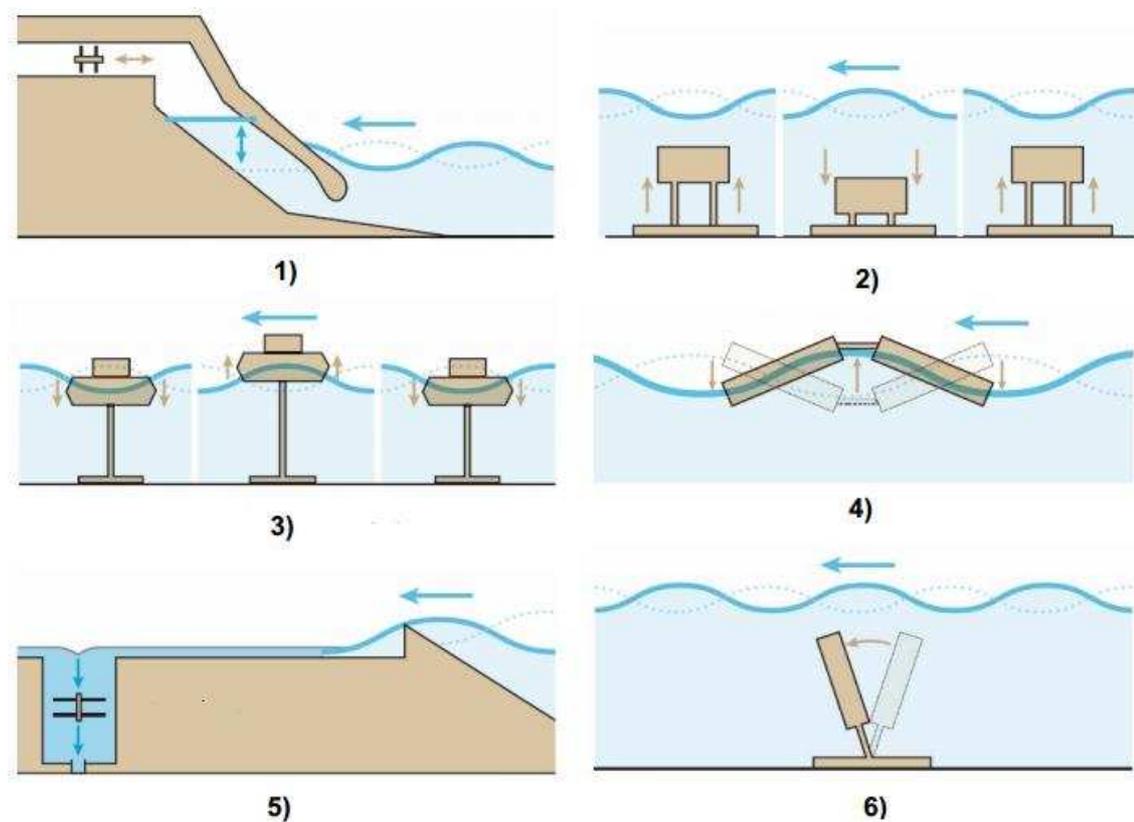
Fig. 3.4. Different types of recruitment

The different device developed until this moment, the project is focus on the off shore. The next devices are located on a distance more than 40 meters away of shore. In this area the powerful of sea has a high level, due to the fact that the swell has not experimented the lost of energy.

The previous devices, which are going to be explained, have a related idea with this project, the exploitation of mechanical wave movement.

Device developed in different world areas:

- **Archimedes wave swing (AWS)**

This system consists of conversion system which take place totally submerged, creating a unremarkable visual impact. It is compound of two cylinders: first fixed on the ground and the other carries out the function of ballcock, creating a vertical movement due to the fact that the swell is applied on the cylinder. The relative movement between ballcock and fixed part creates the electricity through a hydraulic system and a engine-generator.

The first plant has been installed in Viana do Castello (Portugal) in 2004.

[AWS Ocean Energy Ltd.]
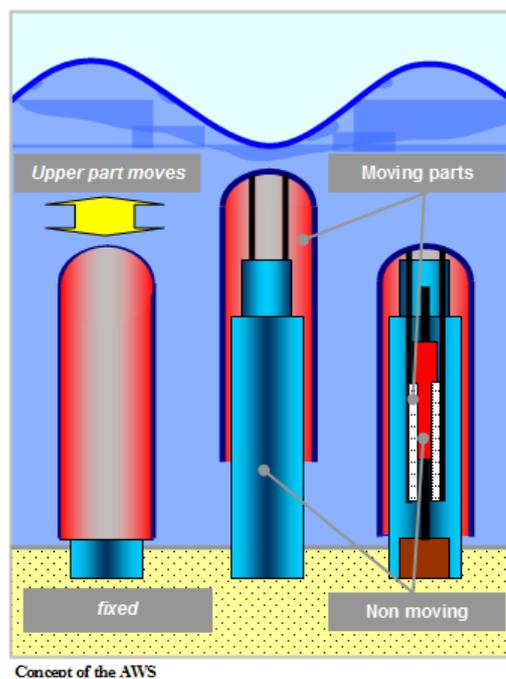
Fig. 3.5. Structure of Archimedes wave swing

- **Power buoy**

Technology developed by OPT (Ocean Power Technologies, U.S.A.). The system consists of taking advantage of the vertical and pendular swell movement through a buoy of 2-5 meters of diameter opened in the bottom. The buoys obtain the energy using a hydraulic system which uses the relative movement.

The system pumps a fluid (oil) with a high pressure which, at the same time, activates a electric generator. The obtained energy is carried to the shore through a wire, installed on the bottom of the sea.

[Ocean power technology Ltd., 1994]
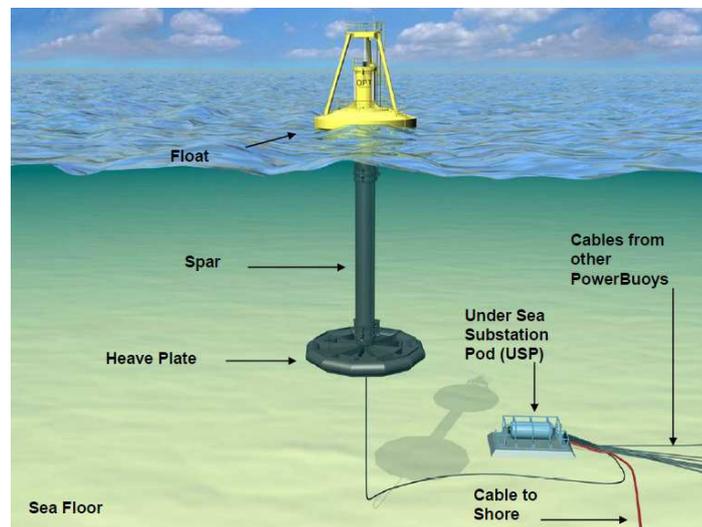
Fig. 3.6. Structure of Power buoy

The three more famous projects carry out are located on the Atlantic and Pacific:

-Oahu (Hawai, 2004-2007)

- Atlantic City (New Jersey, 2005)

- Santoña (Spain, 2006)

- **Pelamis wave power**

System developed by the Pelamis Wave Power Ltd Company. The Pelamis device consists of a cylindrical semi-submerged structure which axel is positioned in line with the swell propagation. It is articulated in several points which create mobile nods with two degrees of freedom: vertical and horizontal.

The relative movement between the articulated parts switch on the hydraulic system which feeds a pressured tank, at the same time, moving an electric generator. It is fixed to the bottom of the sea with weights and ball cocks restricting the movement.

[Pelamis wave power Ltd., 1998]
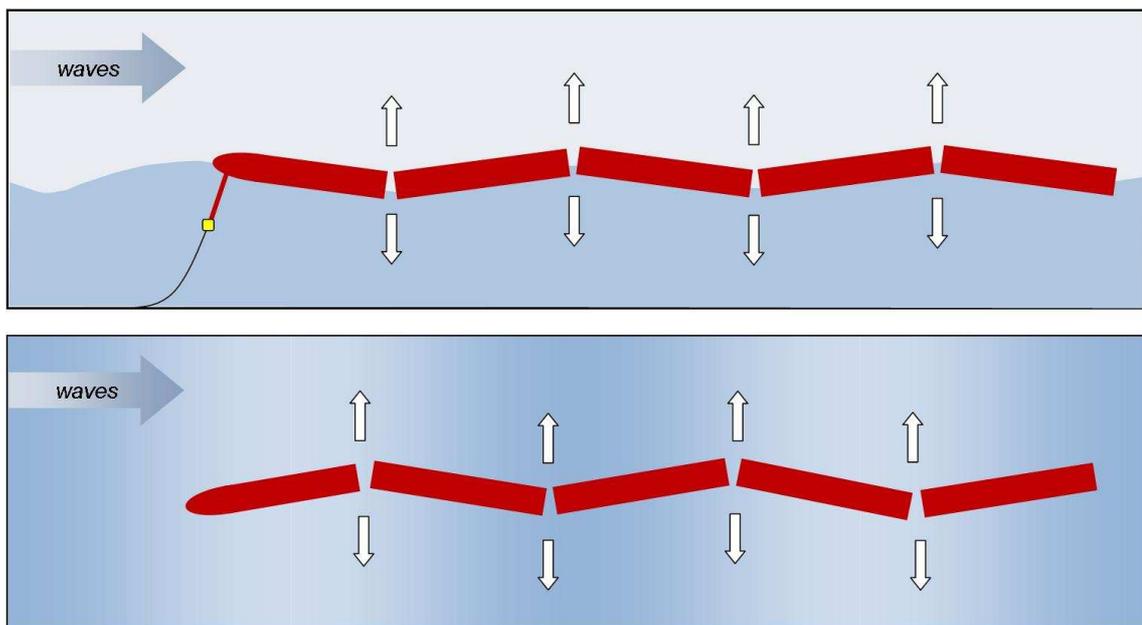
Fig. 3.7. Pelamis wave power structure

Aims of the project

The aims of the project are focused on topic too present nowadays in the society, the renewable energies and recycle, topics which have grown up in a exponential way on the last decades and this growth doesn't stop increasing due to the fact that the factors as the pollution without control and the world exhaustion of the natural sources.

First, the renewable energy is the ground of the project using the inexhaustible source of energy of the sea with the wave movement, the maritime currents ant the tilde's change. This renewable energy can be contributed with a continuo and repetitive movement created on the sea.

Second, the use of waste material, which is based on worn tyres creating a new way to recycle this material. The tyres are a huge source of pollutions with an uncertain end, usually all this waste material finish stored in dumps or burning with damage gases emissions, in this project this worn tyres could be used after the vehicle use, giving a new use which can contributed to a second live avoiding future pollution and damage to the world and atmosphere.

Another aim in this project is the creation of a sustainable structure. The construction of this structure looks for the utilization of materials and mechanism of low cost, although this doesn't involve that the structure can be characterized like a soft and owning a low security. It was referring to the recycle materials, the use of worn tyres as the aim element of structure giving the shape and the structure consistence. The uses of this material contribute a minimum cost, even though they are not going to be used in other projects and their live end are stored in dumps. The rest of components are the connections between materials and the system of exploitation of wave mechanic movement.

To sum up, this project look for the obtaining of a equipment which owns a high performance with the minimal possible cost.

Analysis of sea

Sea parameters

Definition of Ocean Wave Power or Tidal Power

The waves are a way of kinetic energy, which can achieve using several harmonic mechanisms, which react with wave movement capturing part of the energy. To sum up, The Ocean Wave Power consists of taking advantage of wave kinetic and potential energy, in order to create electricity.

One of the properties characteristic of wave is his capacity of moving a large distances without losing with a hardly loss of energy.

There are a high number of gadgets think for the exploitation of this energy type. The concepts, in which it is based on, could be classified in the next:

-Water oscillating column: Consist of the water oscillating inside of a semi-submerged chamber and opened in the bottom in the level sea. A pressure change is produced.

-Summator Systems: Could be floating or fixed to the shore. They catch the wave, storing the water on an elevated dam. Turbines are activated when the water is liberated.

-Swing systems: Could be floating or submerged. The swinging movement is converted through a hydraulic or mechanic system in lineal or rotational movement for the electric generator.

-Hydraulic Systems: Are floating system interconnected. The relative movement of floats is using to pump oils at high pressure through hydraulic engines, which move electric generators.

-Pumping Systems: using the vertical movement of water particles. Generating a pumping system by means of a float. [Julio Gonzalez en Nava, 2006]

Advantages and disadvantages of Ocean Wave Power

Advantages:

- The waves can move for large distances without losing energy
- Is a resource close to a huge number of consumers.
- High availability, due to the fact that is an abundant resource and with lows of high energy.
- The development of this energy will give security to the energetic supply to remote areas.
- Could absorb the swell in port or eroded areas.
- Clean energy, no gases emission
- The visual impact is minimum.
- It allows the alternative used of electric energy, like hydrogen production on drinking water.

Disadvantages:

- Problems with extreme weather (storms, hurricanes)
- Seascape vegetation grows up in all structures installed on the sea.
- The corrosive effect of salt water.
- Obtain the maximum performance is difficult due to the fact that the waves show irregularities.

Energy source

The sea wave is a tertiary derivative of the solar energy: the warm of the earth's crust create the wind and this, at the same time, creates the wave energy. This is the way of 0.3% of the Sun energy is using to create wave energy.

The power exerts on the wave is proportional to the high of wave, the incline and the square of relative velocity between wind and wave.
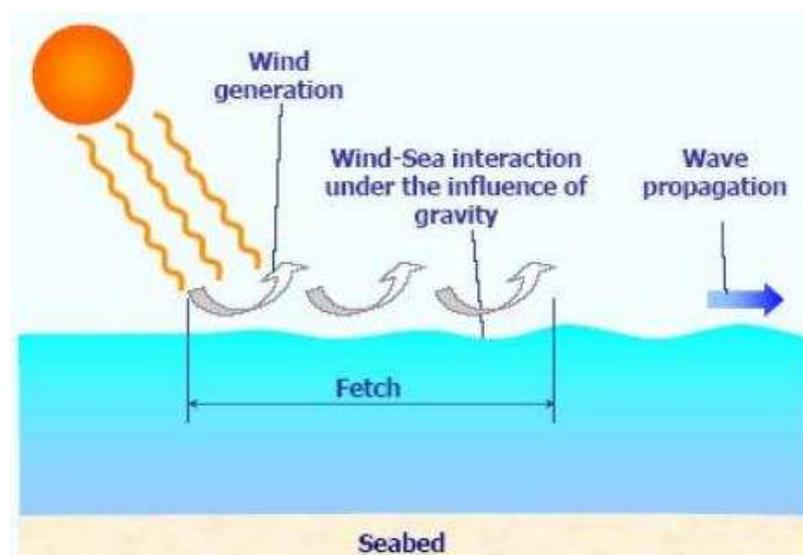

Fig. 5.1. Origin of waves

The wind is another factor, which creates the waves. The different waves has the characteristic of moving in hundred of meters without losing energy, only changing the global wave form. The next picture shows the process of a wave throughout his live period.
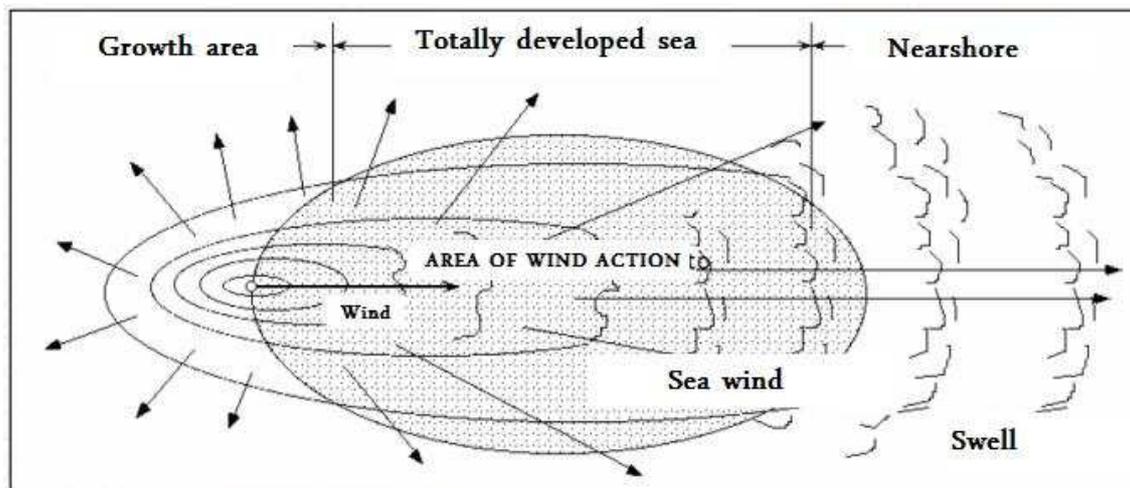
Fig. 5.2. Wind area action

This picture is a global image of a wave creation, a constant action of wind in the free sea surface.

Parameters which define the waves

The waves are generated by several factors like wind, gravitational strength of moon and sun, storms, tides or seaquake. However, the wind generates the most common and high energetic density waves.
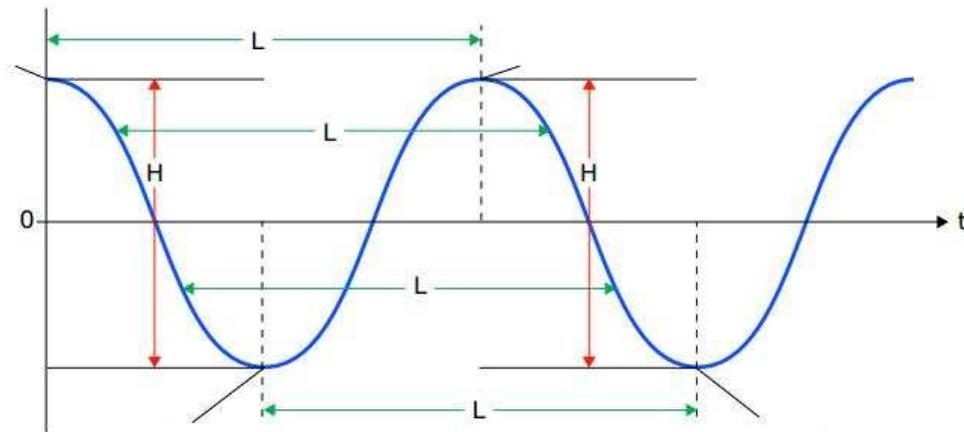

Fig. 5.3. Graphic of wave movement

The diagram shows the parameters related with the wave shape. Other parameters are the velocity of propagation and the amount of power.

The waves have a horizontal translation, although the particles which make up the wave have an orbit elliptical or circular movement. The next sketch shows the particles movement and the different classification of the waves depending of the depth sea.
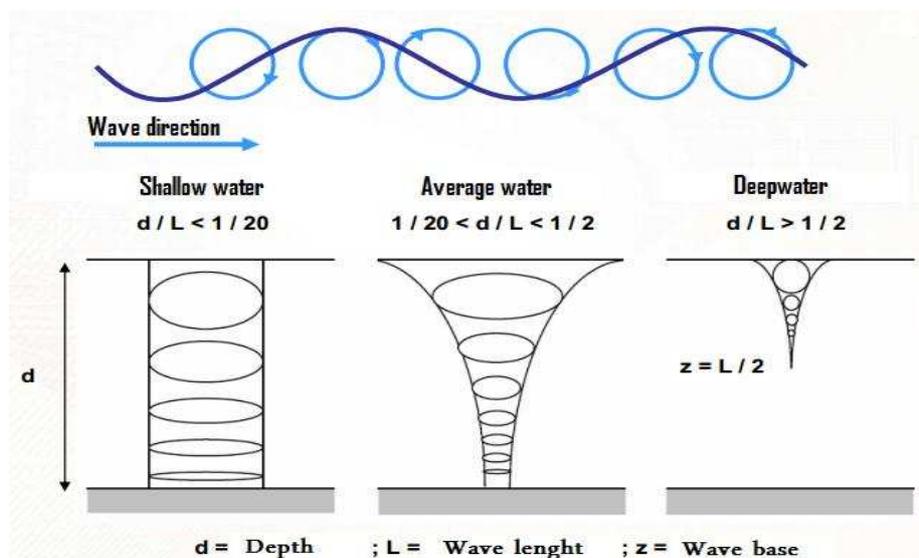
Fig. 5.4. Wave direction and depth characteristic

Definition of parameters

-Wavelenght (L): Distance between two consecutive crests.

$$L = \frac{gT^2}{2\pi}$$

-Wave period (T): Time between two crests.

$$T = \frac{2\pi}{w}$$

-Velocity of wave (c):

$$C = \frac{L}{T} = \frac{W}{k} \; ; \; k = \frac{2\pi}{L}$$

-Density of sea water: $\rho = 1028$ kg/m^3

-High of wave (H): Distance between crest and vale.

How much power can get from wave?

The energy possessed by a wave is in two forms:

1. Kinetic energy, which is the energy inherent in the orbital motion of the water particles.
2. Potential energy possessed by the particles when they are displaced from their mean position.

The total energy (E) per unit area of a wave is given by:

$$E = Epot + Ekinetic = \frac{\rho g L h^2}{8} \text{ J/m}$$

Deep-water wave [h], the density is [ρ] and the wavelength is [L]

[The open University, 1989]

Per meter of wave front with gravitational constant [g] and in terms of Period [T]:

$$E = \frac{\rho g^2 h^2 T^2}{16\pi}$$

Divided by T, gives the power:

$$P = \frac{\rho g^2 h^2 T}{16\pi} \text{ W/m}$$

Using: g = 9.8 m/s^2; ρ = 1028 kg/m^3 and π = 3.14

One example, waves with high period [T] (7-10s) and high amplitude [H] (2m) has energy flows which usually exceed 40-50 KW/m.

[lged-rein, 2008]

Study of situation

Wave energy on the world

The waves suppose a source of 2TWyear/year of power, equivalent to an annual energy capacity of 17520TWh, which could supply 200TWh/year of electricity. The CLIEMAT created a study which concludes in "The wave energy could cover the 10% of global consumption with an investment of 820 billions of pounds.

[Thorpe,2000]

In the same manner of others renewable energies, the wave energy is divided up in an uneven way. The areas with more activity are divided into 30º and 60 of altitude, in both hemispheres.
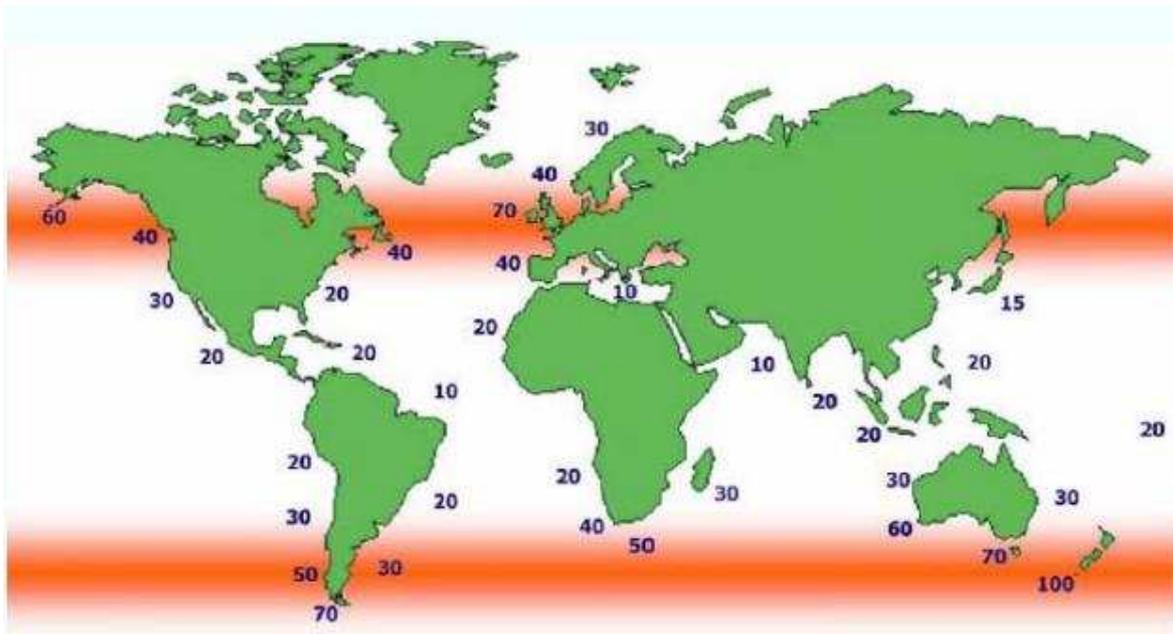
Fig. 5.5. Global average distribution of annual wave power

The powerful of the sea has a high range, depending of the world area; this previous sketch shows the global average of annual wave power. This has taken as a reference to choice the area of UK.

The wave energy in Europe

The energy resource of Europe is one of the richest in the World, only exceeded by some place like South America or the Antipodes. The energy capacity changes between 25 KW/m in the south of Europe to 75KW/m in Irish and Scotland.

Fig. 5.6. European Distribution of wave power (KW/m)

According to the previous diagram, the decision of implantation in this project is on the West Irish Coast. The powerful obtained in this area is around 70KW/m with a maximum of 76 KW/h (obtained on "atalayaluanca.wordpress.com"). This place has been decided like the best place to incorporate the structure due to be an accessible area without a weather extreme, like another choice showed on the world diagram like the South of Argentina or New Zealand close to the Antarctic. The high level of rain and wind create this conditions and powerful waves.

The next figure shows with more detail the powerful of waves in the United Kingdom.
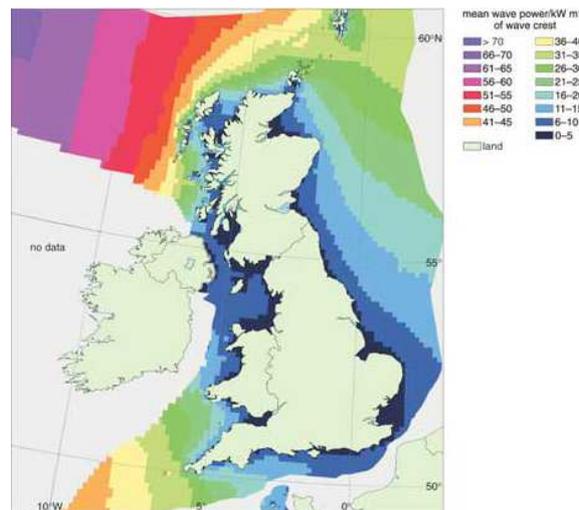

Figure 5.7. Graphic of the U.K. area

General information of structure

The main components of the structure are: worn tyres, and electrical components, the secondary components are used to put in contact all components and create the global structure, wires and cylinders.

Global structure

The next picture shows the global image of the structure, which determines the different parts of the structure.
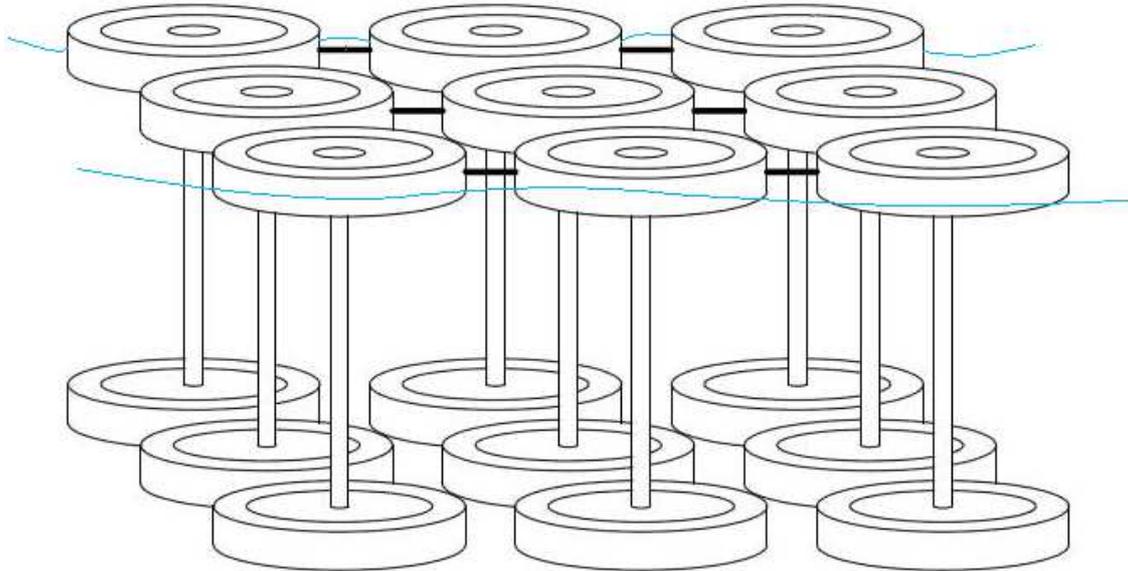
Fig. 6.1. Global structure

The blue line, defined in the previous picture, stress the free surface of the sea creating a division between the area not submerged and submerged.

The previous structure can be divided in 3 groups, according to the function carries out: The superior, intermediate and inferior area.

The superior area is characterized by the visual part, located floating area. This part is divided in 9 worn tyres, which contains the electrical mechanism, fixed between them using a steel cable.
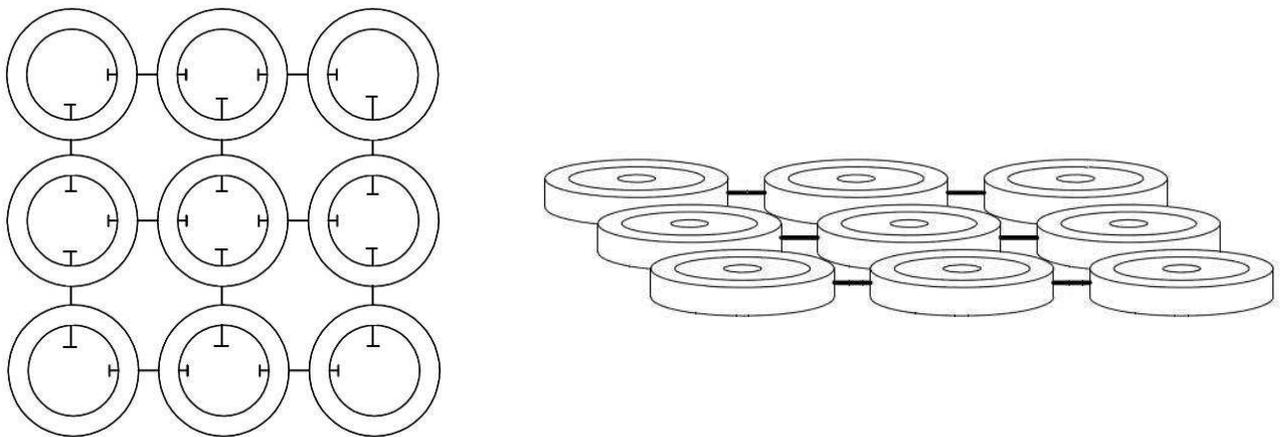
Fig. 6.2. Superior area of structure

The previously sketch defines the real dimensions and components of this area; the aim of this area is to create the stiffness of the raft and the base for the next parts.

The intermediate area, which consists of a cylinder, has the role of connecting the superior and inferior area. The aim of this area is simple but essential to give the shape of the structure.
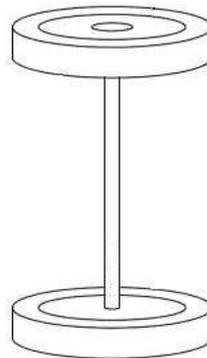

Fig. 6.3. Intermediate area of structure

The cylinder shows in the picture is the aim component of the intermediate area, creating the connection and allowing the movement.

The inferior area is based on the same number of tyres of the superior structure, in order to create a uniform shape. The difference is that the tyres are not connected between each one to create a freedom of movement. All the tyres are fixed to the global structure using the intermediate area.
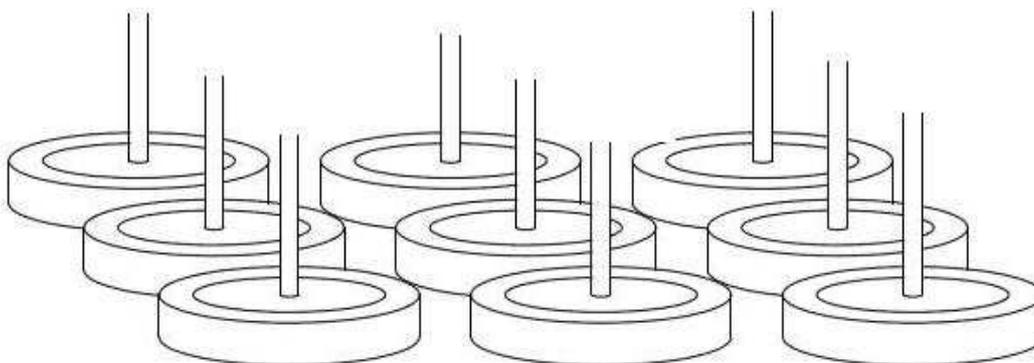

Fig. 6.4. Inferior area of the structure

This picture shows the 9 tyres added to the cylinders and creating a raft shape although without fixed between them.

These previous 3 parts of the structure are going to be the base of the project, trying to create a way to obtain energy. Each part of this structure is defined with different materials and characteristics which are going to be explained in the next step.

How to fix the structure

The idea of fixing the structure is one of the most important factors; it is going to restrict the stability and efficiency.
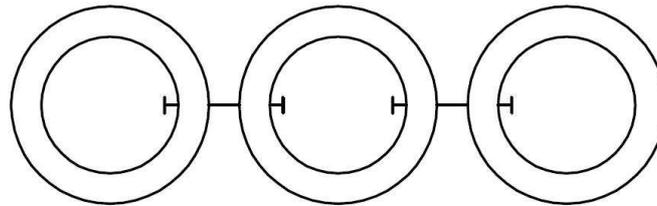

Fig. 6.5. Steel wire fixing the tyres

This picture shows the decision of how to fix the structure, this way to fix the structure is, in order to avoid problem with possible knocking and creating a better freedom of movement. The aim is to fix the worn tyres with a steel wire fixed inside of each tyre allowing a high movement using the waves.
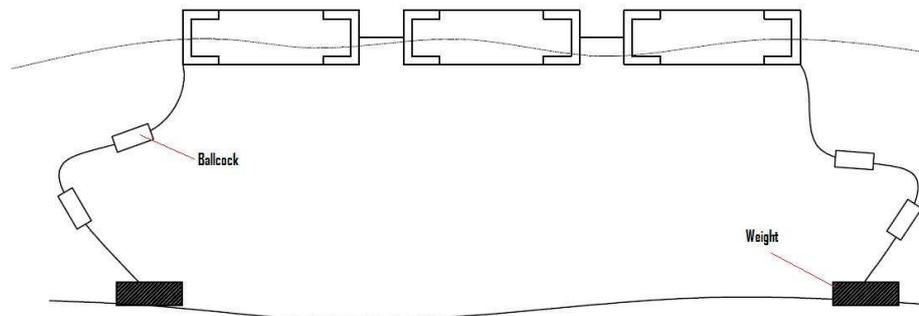

Fig. 6.6. The way to fix in the ground of the sea

The way to fix in the bottom of the sea is using a wire with weights at the bottom and ball cocks at the middle, these ball cocks are installed to have a huge range of movement avoiding that the whole wave movement is directly applied in the weights and making the use of less weight to fix in the bottom easier.
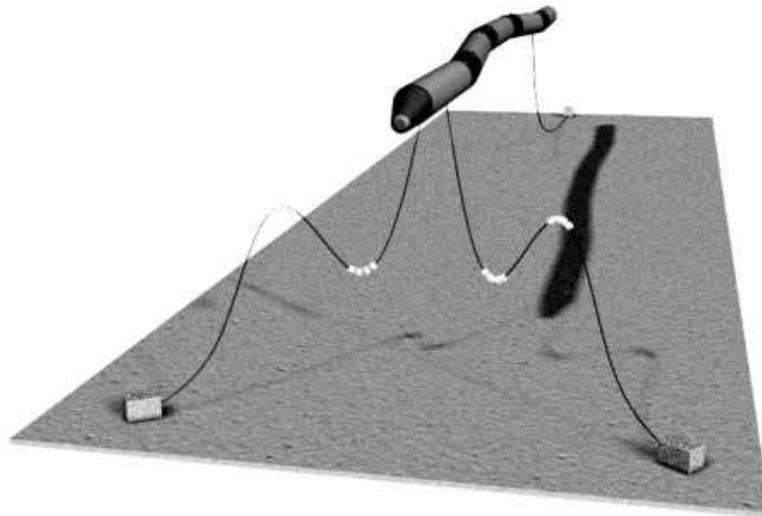
Fig. 6.7. Real project of fixing a structure

The idea of fix the structure in this way is based on a real structure, adapting this way to fix in the project. The different elements allow a high freedom of movement adding a low price of equipment.

[Science direct, 2012]

Characteristics of materials:

Worn tyres

The main material is worn tyre, these tyres were already used on vehicles and have a few thousand kilometers behind them and the product's useful service life has arrived to the end, the characteristics are:

-Compound material $\begin{cases} \frac{2}{3} \text{ Rubber} \\ \\ \frac{1}{3} \text{ Steel} \end{cases}$

Weight (waste material) $\approx 9 - 10$ kg $\approx 20 - 22$ pounds

Density $\approx 100 \frac{kg}{m3}$

-Characteristics:

- Permeability

- Low weight

-Chemistry properties $\longrightarrow$ - $\downarrow$ reactivity against gas and liquid

- $\downarrow$ Degree of biodegradable

- Resistance against bad weather

-Mechanical properties $\longrightarrow$ - Vibration absorbent

- Flexibility

- High resistance

-Equivalences:

1 m3 ≈ 1.3 cubic yards

5 – 6 worn tyres ≈ 1 cubic yard

Basic dimension:
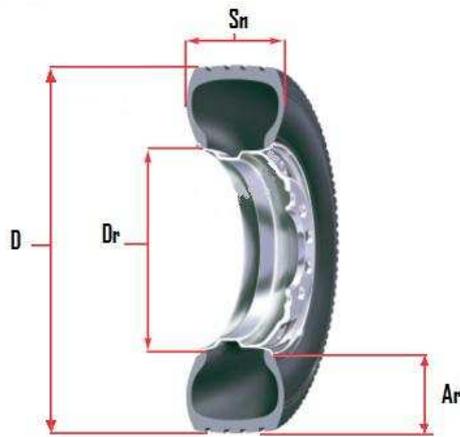
D – External diameter (mm)

Dr – Nominal diameter of wheel rim (inches ["])

Sn – Nominal width of section tyre (mm)

Ar – Profile height (mm)

Fig. 6.8. Tyre Sketch

Standard dimension, the most common in the world which are going to be used in this project, 195/65/R15 (Sn/Ar/Dr/).

$$D = Dr + 2\, Sn\, Ar = 634.5\ mm$$

$$\text{Volume} = V = \pi r^2 \text{Sn} = \pi \frac{d^2}{4}\ 195 = 0.0616\ \text{m}^3$$

The cost of a worn tyre of a car is approximately 1.57 €/unit.

[Consumoteca, 2009-20011]

Using this data, an approximation of the structure shape could be designed.
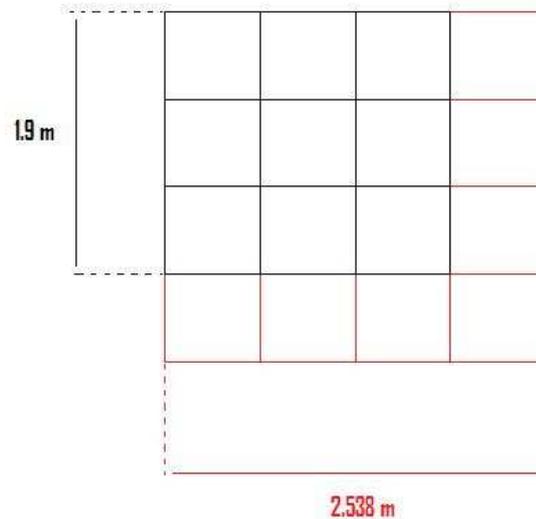

Fig. 6.9. Global dimension

This sketch show, two different ways to build the structure, one of the best advantages is that the structure could be extended according to the necessity.

The first structure is based in a structure of 9 tyres, with a volume of 0.704m3 and a weight of 90kg.

The second structure is based on 16 tyres, with a volume of 1.256m3 and a weight of 160kg.

Magnet

This part of the structure takes care of the energy transformation, introducing the wave movement in the electrical mechanism.
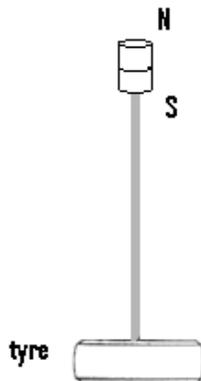
The dimensions of the magnet are delimited by the tyres shape, and it takes place in the top of a cylinder following a vertical movement.

Fig. 6.10. Intermediate area

The advantage of using a magnet is the way of creating energy, thanks to the north and south pole the structure can take advantage of the up and down movement.

Reel

A reel could be defined as a wire or cable cylinder coiled around a metal tube. It is a passive component of an electric circuit, which storage electric energy on a magnetic circuit way. The symbol of   this gadget is:
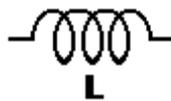
Henry [H] is the measurement unity, it could be measure on miliHenry [mH], and it depends of the characteristics of the reel.
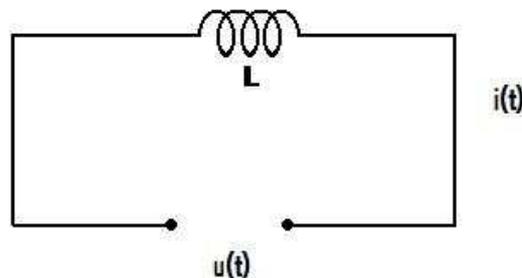
Fig. 6.11. Reel circuit

This picture shows a typical circuit with a reel:

$$u(t) = L\frac{di}{dt} \qquad \varepsilon = \frac{LI^2}{2}$$

ε = Energy stored

L = Inductance, measure the opposition value of reel against the current flow.

Parameters which define a reel:

-Spiral number (N): ↑ turns ↑ inductance, it means more value of Henry.

-Spiral diameter (ø): ↑ Ø ↑inductance

-The wire length (L).

-The material in the core.

Cables

Steel cables are used in this structure, in order to create the shape of a raft. The structure is mixed trough these elements, contributing with a security connection between worn tyres and allowing a freedom of movement.

The material should be steel, in order to avoid the corrosion of the sea water. The way to build the raft shape is creating holes in the different tyres and introducing the cable, in each cable end are fixed to the tyre.

Fig. 6.12. Steel cable

Electrical mechanism
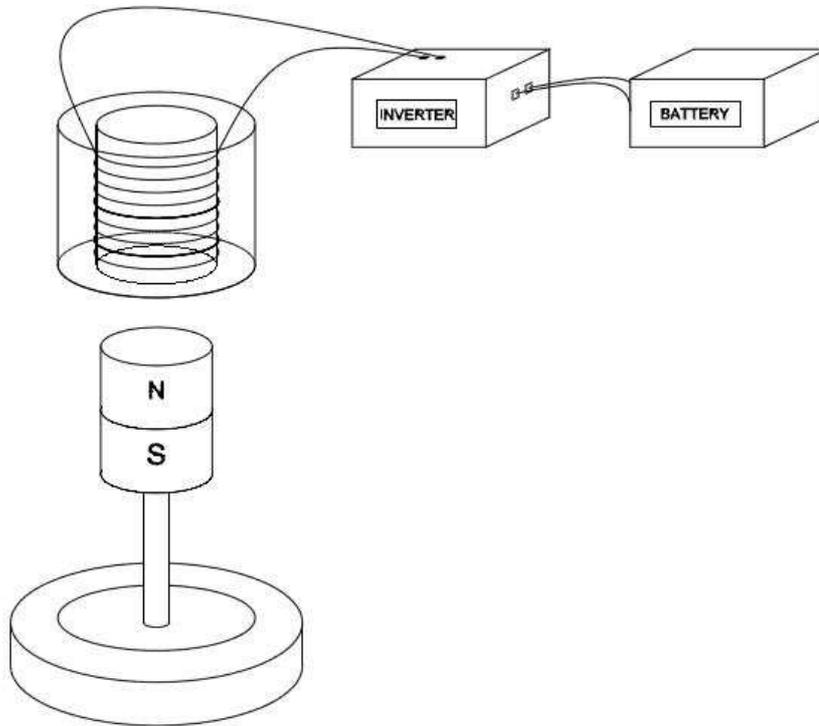
Fig. 7.1. Global picture of electrical mechanism

The electrical mechanism is the main part of the structure, all the structural elements have the same aim of creating energy. This mechanism attempts the most economic and simple, in order to obtain energy using the inexhaustible source of waves movement.

The electrical equipment should be correctly isolated, in order to avoid future problems related to humidity and corrosion, it could be appear problems with the knocks of the waves in storms too, however the worn tyres act like reinforcements to this possible problem.

The electrical mechanism of the structure is in the interior of the worn tyres. The different parts, which this mechanism is constituted, are:

1. MECHANIC ENERGY:

Created by the wave movement of the tyre which achieves the movement of magnet into the reef.

2. USE OF MOVEMENT:

The vertical magnet movement creates a magnet field which allows the electricity creation, the rotation of the magnet around his axle.

3. INVERTER:

The CA energy is received trough a wire from reef to inverter. This gadget has the role to convert the CA into CC, in order to allow the future storage.

4. BATTERY:

The aim is to accumulate the energy which has been converted from the inverter.

The electrical mechanism is based on different principle, Lenz and Faraday's principle. Another principle is the magnetism, the magnet is a material able to create a field external magnetic, there are permanent and temporally magnets; permanents have always the same properties and temporally change after being magnetized.

The magnetic field is the space region where the action of a magnet is showed. It is defined by imaginary lines, closed, which go to the north to the south pole of the magnet. The magnetism has a high connection with electricity. An electric charge has a field electric and if it is on movement a magnetic field appears.

The electromagnetism induction is the ground of this project. When we have a permanent magnet inside of the spiral of one solenoid reel, formed with copper cable, an electromotive force is created immediately, in other words, an electrical current appears flowing through the reel's spiral, produced by "magnetic induction" for the magnet movement.

Lenz's law

The magnet movement, which involves a change in the magnetic field on the reel, it creates a electrical current in the reel called "Induced current", this induced current is generated due to fact that the variation of magnetic flow. If the magnet stops, the current will be zero.

When the magnet is near of the reel the magnetic flow increase and the inducted current is against this increase, being opposite sign and when the magnet is moved away the magnetic low decrease, the inducted current is against with the same sign.

The law of _Lenz shows that the inducted current creates a magnetic field which is always against the magnetic flow that has produced it. The inducted current is more intensive if the velocity of the movement, between magnet and reel, is increased or if the reel has more spirals or if the magnetism of the magnet is increased.

[Manzanares J, Bisquert J, García-Belmonte G, Fernández-Alonso M., 1994]
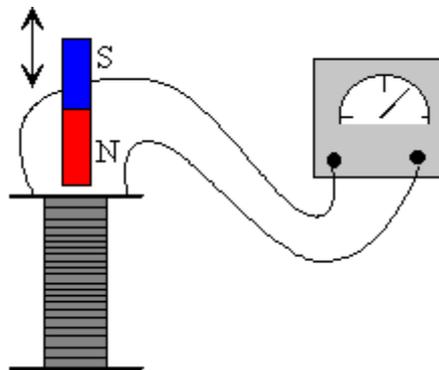
Fig. 7.2. Lenz's law

Faraday's Law

Faraday's laws of electromagnetic induction may be summarized as follows. An electromagnetism is induced in

1. A rigid stationary circuit across which there is a time-varying magnetic flux.
2. A rigid circuit moving in a steady field in such a way that the magnetic flux across it changes.
3. Part of a circuit which moves and, in doing so, cuts magnetic flux.

We shall discuss the principle of three different methods.

(i)   Using Faraday's rotating disc. A metal disc is rotated at a steady speed in a magnetic field. An e.m.f. is generated in the circuit formed by the milivoltmeter and the radius momentarily between the contacts of the circuit. The rate of change of the flux is proportional to the speed of rotation of the disc.
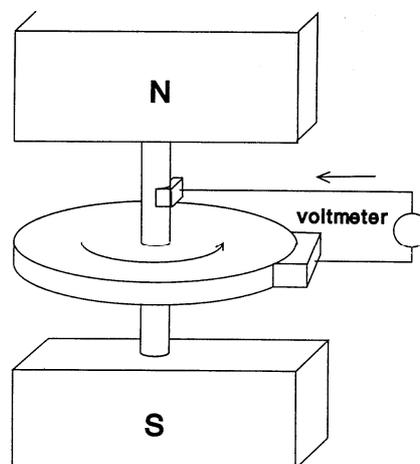
Fig. 7.3. Faraday's law

(ii)   Using a long magnet and a solenoid. A long thin magnet which can be moved along the axis of a solenoid. As the magnet advances, the number of turns of the solenoid through which the flux from the pole passes increases and an e.m.f. is produced in it. The rate of change of flux is proportional to the speed of the magnet.
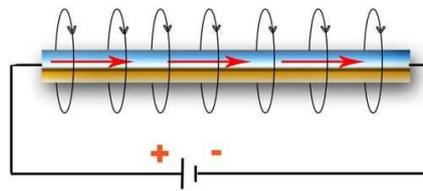
Fig. 7.4. Magnet field

(iii)   Using a rotating magnet and cathode-ray oscilloscope.

        [Live physics, 2005]

Mechanical mechanism

The mechanical mechanism contributes one of the most important part combine with the electrical. The mechanic part of this project is focused on the exploitation of swell movement and the equipment which allow this exploitation.

The waves are superficial mechanic wave which are propagated through the interface of atmosphere-ocean created by the wind and gravity action. These waves create a movement in the free surface of the sea. This surface elevation changes with the time and space. The most simple theory and applied in these cases is the lineal theory or Airy principle. Following these theory, the waves have a sinusoidal curve shape described in two dimensions (axis "x" horizontal and axis "z" vertical), which are propagated in a constant direction x. The spread of the swell is dealt as a no lineal process; however the Airy theory simplifies the formulation, taking the following consideration:

- For this project, in the study of the undulating movement, the main powers to consider are the gravity and which are created by the differences of pressure. The fluid is assumed as no viscous (μ=0), and the tangential tension can be disregarded.
- The water is an incomprehensible fluid.
- The movement is accepted, in fact three-dimensional, is reduced to a horizontal and vertical component.
- The flow is dealt as no rotational movement.

[Lineal theory of Ary, 2012]

Therefore, using this data a velocity potential [ϕ] can be defined dependent on the position (x, z) of fluid particle and the instant [t], which formation is the next:

$$\phi = (1+x)^n \frac{aw}{k} + \frac{\cosh[k(z+d)]}{\sinh kd} \sin(kx - wt)$$

Where:

a = wave amplitude (H/2)

w = wave frequency (rad/s)

k = wave number

d = height of water sheet

The wave number can be determinate according to the no lineal relation:

$$w^2 = gk \, \tan kd$$

From the derivation of ϕ function, the necessaries properties are calculated and used to characterize the swell:

Surface elevation	$X = \cos(kx - wt)$
Horizontal velocity	$u = aw \dfrac{\cosh[k\,(z + d)]}{\sin kd} \cos(kx - wt)$
Vertical velocity	$w = aw \dfrac{\sinh\,[k(z + d)]}{\sin kd} \sin(kx - wt)$
Horizontal acceleration	$a_x = aw^2 \dfrac{\cosh[k\,(z + d)]}{\sin kd} \sin(kx - wt)$
Vertical acceleration	$a_z = -aw^2 \dfrac{\sinh\,[k(z + d)]}{\sin kd} \cos(kx - wt)$

The waves are not always regulars, as it shows the waves theory formulated previously. The natural swell on the sea is irregular, knowing like confused sea. The unidirectional profile and regular sinusoidal, there are a mix of length, height and direction. Since a two-dimensional view, irregular and unidirectional wave profile is described as the next form:

$$\zeta(x,t) = \sum_{i=1}^{n} c_i \cos(k_i x - w_i t + \varepsilon_i)$$

Where:

n = Total number of partial waves

c_i = Amplitude of wave "i"

k_i = Number of wave "i"

x = Irregular wave propagation direction

w_i = Frequency of wave "i"

ε_i = Phase of wave "i"

Each wave has a random phase, expressed by a constant probability density $1/2\pi$ on the 0.2π rank.
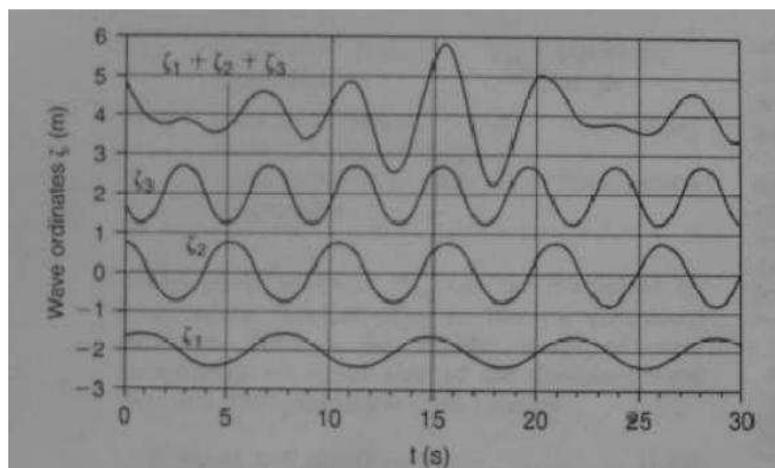

Fig. 8.1. Irregular wave compound of the sum of regular wave

The next sketch creates a swell association in 3D.
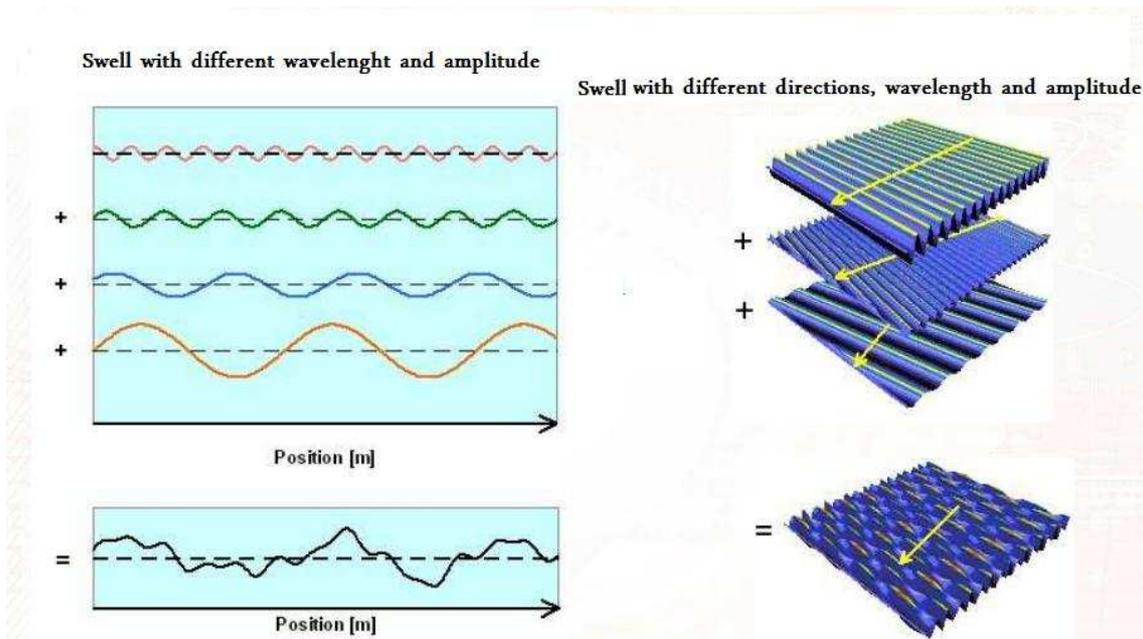
Fig. 8.2. Swell on 3D

The amplitude c_i of each partial wave is calculated through a swell spectrum $S_{\zeta i}$, using the next formulation:

$$c_i = \sqrt{2} S_{\zeta i} \delta w_i$$

The swell is considerate stationary if there are no significant on the wave profile or the energy contained in a wave on a period of time.

The exploitation of the swell movement could be analyzed based on the undulating harmonic movement, it can be defined when a particle moves through an axis [x], being his position (x), defined by the time function with the equation:

$$x = A \sin(wt + \varphi)$$

The exploitation of wave mechanical movement is carried out through two methods: the use of the structure as a general and the movement of submerged tyres.

The movement of the tyres is defined as "submerged mechanical system", the structure is based on a cylinder which owns in the top a magnet and in the bottom a tyre. The use of swell is executes with the freedom of movement, which can be divided on two types:

- **Vertical movement**:

    The waves are superficial mechanic wave which are propagated through the interface of atmosphere-ocean created by the wind and gravity action. These waves create a movement in the free surface of the sea. This surface elevation changes with the time and space. These changes produce an ascent and drop movement created between the crest and valley of swell.

    The variation of the tide can be added as a help to create this movement adding a new variation of the surface.

- **Rotary movement:**

    The maritime currents, which circulate under the structure, create this movement. The cylindrical shape takes advantages of these currents, thanks to this shape the rotator movement is carried out.
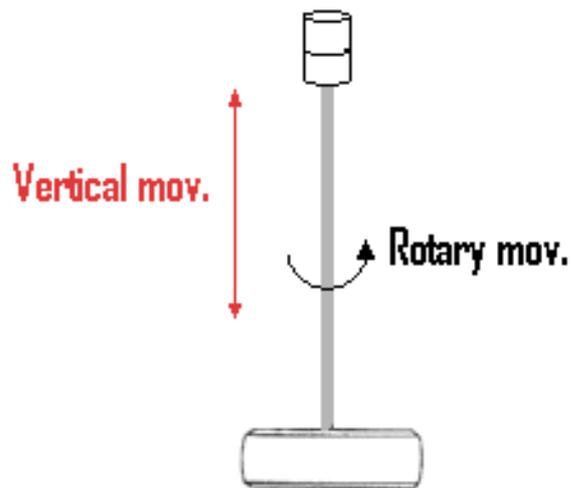
Fig. 8.3. Rotary and Vertical movement.

This picture shows the two movements in a visual form.

The vertical movement is the aim, through which most of the electrical storage amount is obtained, however the combination of the two movements are combined to obtain a high level of movement, which carries out a maximal performance.

According of the mechanical structure, the movement of the raft could be added like another way of use of swell movement. Due to the association of the tyres, allowing a freedom movement which is used by the submerged system.
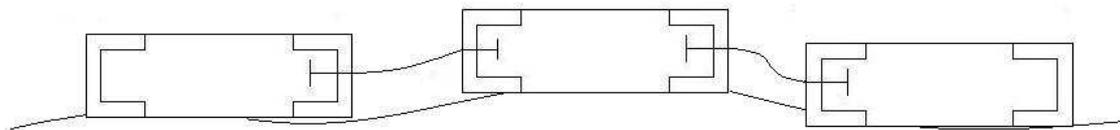
Fig. 8.4. Global structure movement

The connections are executes through wires, fixed between them in the inside of each tyre in a medium height creating the shape of the raft. This connection choice allows the use of the undulating movement of waves too, allowing a freedom of movement in the submerged mechanism avoiding creating a rigid structure. Adding a high security about the meteorological factors, even though if the structure would be rigid and the fixed connection could be appearing break problems.
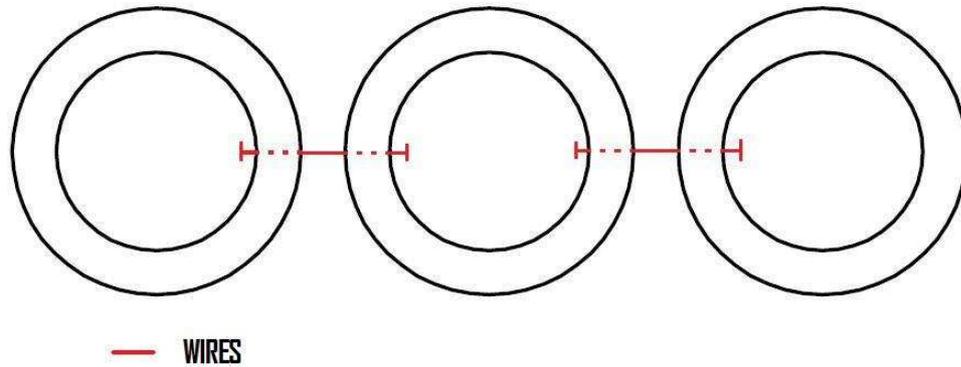
Fig. 8.5. Steel wires on each tyre

The previous diagram shows the way to fix, using the wires, the different tyres of the raft.

These wires should have specific characteristics, a high resistance against the corrosion of the sea water adding a high breaking strength. The flexibility of this wires type shouldn't be elevate, in order to avoid losing the shape of the raft or to create problems with possible knocks between the submerged systems.

Design Process

The process of design of project structure has been carried out with the utilization of "Autocad2009" software provided on the library installations of Glyndwr University.

The structure design can be divided in a different collection of steps

First, the creation of the raft made up of the group of tyres, the first dimension is the creation of a rectangular shape integrated by the tyres.


2.7m
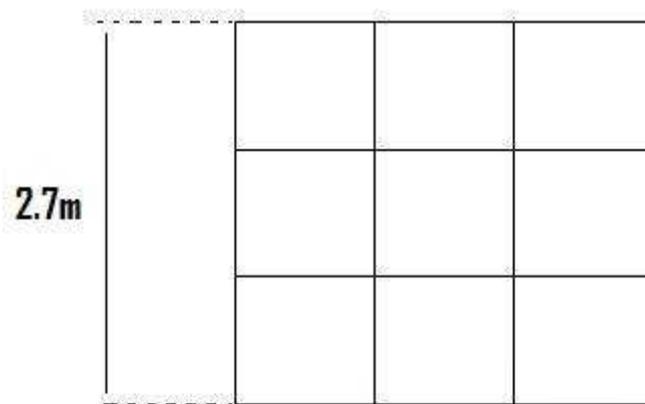
Fig. 9.1.Dimensions

Consist of a group of 9 worn tyres, which dimensions are given in the previous sketch of the general shape.

Second, the previous sketch should have a 3D design in order to show the real shape which is going to install.
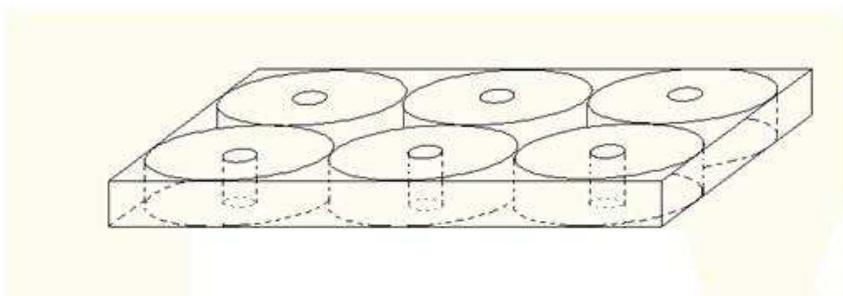
Fig. 9.2. Superior area

In the next step, the inferior part of the structure is added to create the complete shape of the structure. This part consists in the submerged system based on the worn tyres added to the raft through a cylinder, which allows the connection between the top and bottom. The next picture shows the submerged system.

Fig.9.3. Intermediate area

Joining the last two design, the global structure is created.
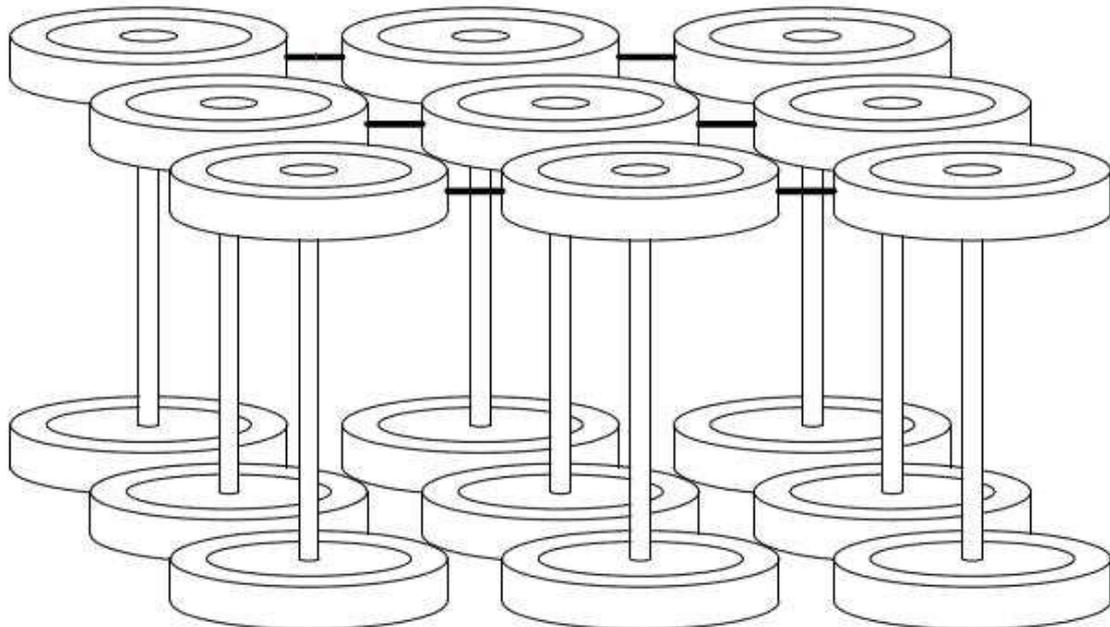
Fig. 9.4. Global structure

Continued with the design, the next steps are to create the specific parts of the mechanism like mechanic and electric or the way to fix the structure.

The design of electrical mechanism is focus on the reel, magnet and the way to carry and store the electricity.
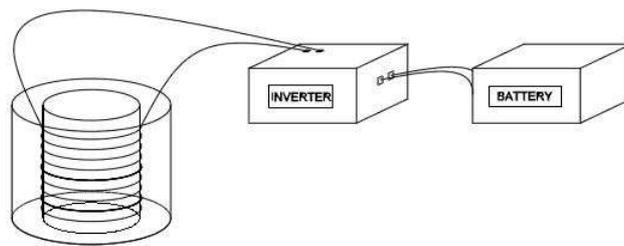
Fig. 9.5. Electrical mechanism

This sketch shows the reel situated in a hollow cylinder allowing the movement of the magnet. The inverter consists of converting the electrical current AC (alternating current) into current CC (direct current) and the battery allow the storage of the electricity produced.

The last design is the drawing of the way to fix the structure to the ground and the connection between worn tyres.

Section A-A'
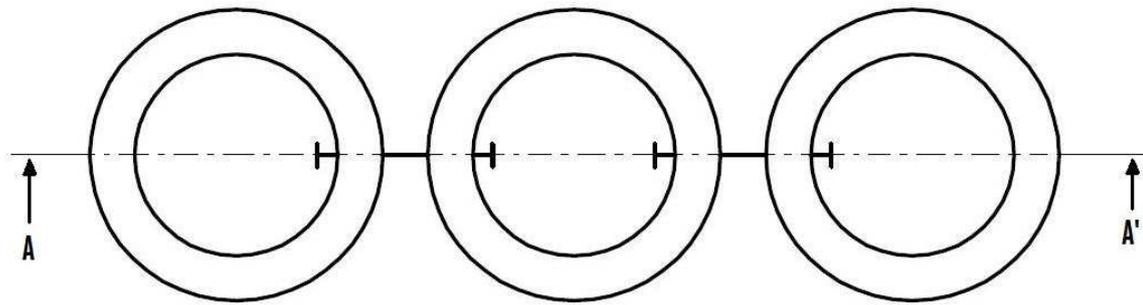
Fig. 9.6. Section of tyres

This picture shows the way of fixing the different worn tyres which compound the raft of the structure.

The last design creates for this project is the way to fix the structure in the ground using ball cocks and weights.
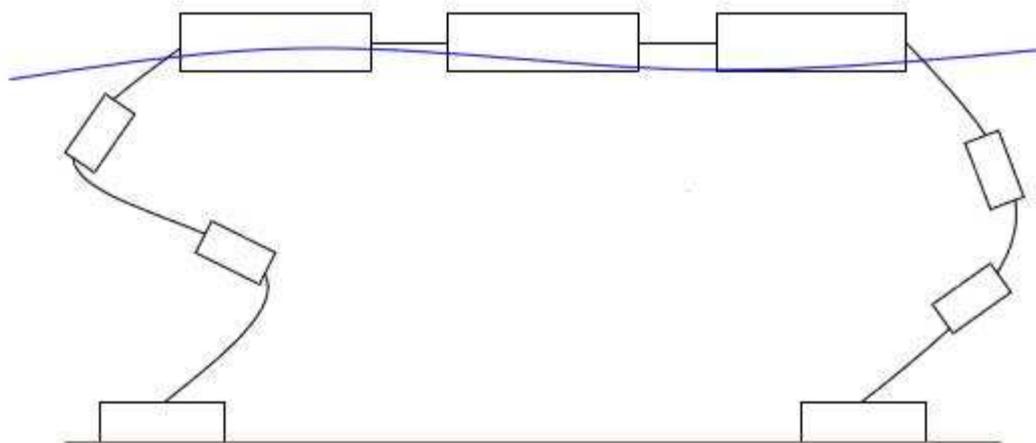
Fig. 9.7. Fixation to the ground of the sea

The ball cocks are situated between the raft and the ground and the weights allow a stability situation in order to avoid movements caused by the meteorological conditions.

Calculation

The calculation of the project are focused on the average of energy produced using the mechanical movement which is converted in electrical with the electrical mechanism.

At the beginning the powerful of the sea is taken out the global average of wave power data. Using the previous information the global average on the U.K. area is around 70KW/m. Nevertheless the calculation should be carried out to compare the theoretical with practical studies.

First, A brief introduction in the dimensions and characteristics of the global structure:

- Superior part (raft)

  9 tyres with a diameter [ø] of 634.5 mm

  Height of each tyre [H] = 195mm

  Area of each tyre = A_{et}

  Total area = A_t

  $$A_{et} = \pi\, R^2 = \pi\, (\tfrac{634,5}{2})^2 = 316193.645 \text{ mm}^2 = 0.316 \text{ m}^2$$

  $$A_t = 9\, A_{et} = 2.844 \text{ m}^2$$

  Volume of each tyre = V_{et}

  Total Volume = V_t

  $$V_{et} = \pi R^2 H = \pi(\tfrac{634,5}{2})^2\, 195 = 0.062 \text{ m}^3$$

  $$V_t = 9\, V_{et} = 0.555 \text{ m}^3$$

2.7m
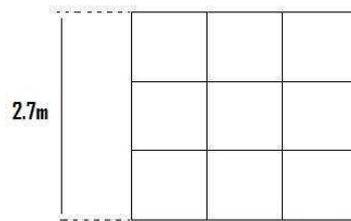
- Intermediate part (cylinder)
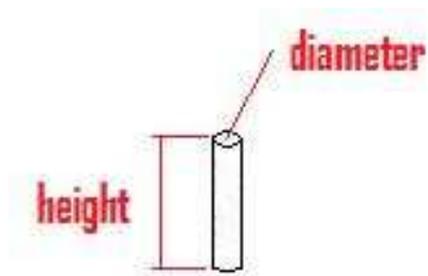

Diameter [ø] = 381 mm.

Height [h] = 3 m.

$V_{cylinder} = 0.342$ m^3

- Steel cable

634.5 mm

400 mm
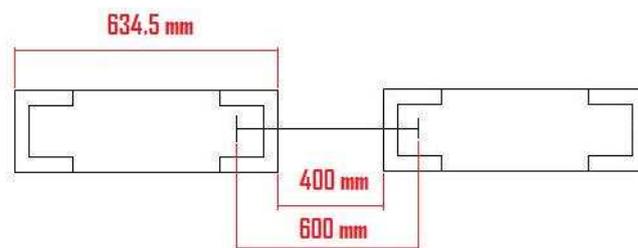
600 mm

Section [S] = πR^2 = 1963.49 mm^2

Length [L] = 600 mm

Diameter [ø] = 50 mm

Second, the global characteristics of the sea and the U.K. area, which has been chosen to introduce the structure.

The idea of the structure location is to locate near shore area, in order to avoid future problems with the installation in open sea, the distance between the structure and the coast should be approximately 2 or 5 km. The depth in the near shore area has the average of 20-60 m.

Another important data related to the sea is the density of salt water, is similar to the fresh water ($\rho = 1000$ kg/m^3) with a value of 1027 kg/m^3.

[Windows to the Universe.]

The most important characteristics which define the waves are the wave period [T] and the height of wave [T]. In order to define the wave is needed more characteristics which are explained previously in the "Analysis of sea", although this two are the only used in the calculation of wave powerful.

The period of waves in this area is approximately between 10 - 20 seconds, adding a wave height of 3-4 meters taking this average in a normal weather conditions without to consider the extreme weather and the irregularities of the sea which creates a huge range of values with a high range.

The next formula shows the way to calculate the energy of sea surface per square meter:

$$E[J/m^2] = \frac{\rho\, g\, H^2}{8}$$

G (gravity) = 9.81 m/s^2

H = 4 meters (taking the high height of wave)

ρ (sea water density) = 1027 kg/m^3

E = 20149.74 J/m^2 = 20.15 KJ/m^2

The energy obtained is 20.15 KJ/m^2, adding the structure dimensions calculated before; using the area of 2.844 m^2, the global energy obtained is equal to 57.3 KJ.

In order to obtain the powerful of the sea per lineal meter of surface wave in this structure, the next formula is used:

$$P \left[\frac{W}{m}\right] = C_g E = \frac{\rho g^2 T H^2}{32 \pi} = 314599.9 \text{ W/m} = 314.6 \text{ KW/m}$$

This formula could be approached to P [KW/m] = T H^2 = 320 KW/m

Archimedes Principle

Ts= Thrust Strength

W= Weight

Ts = W = ρ_{sw} * g* V ; ρ_{sw} = Sea water density
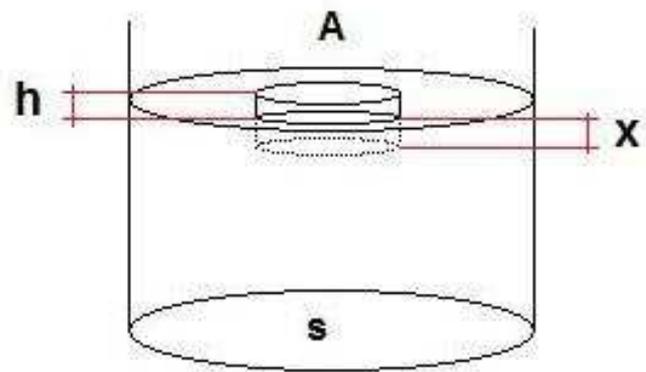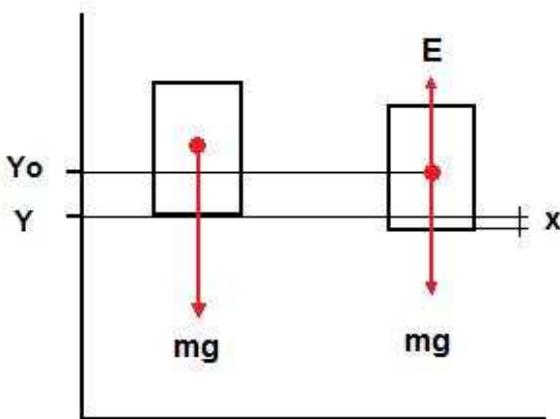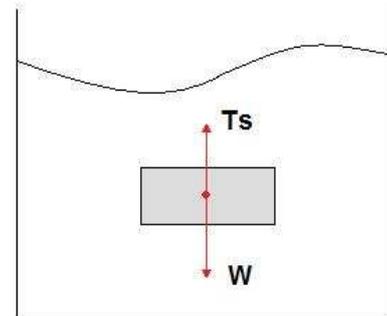
$$Ep = \rho_s \, S \, h \, g \, y + \frac{1}{2} \rho_f \, S \, g \, x^2 = \rho_s \, S \, h \, g \, y + \frac{1}{2} \rho_f \, S \, g \, (yo - y)^2$$

$$Fy = -\frac{dEp}{dy} = -\rho_s \, S \, h \, g + \rho_f \, S \, g \, (yo - y) = -\rho_s \, S \, h \, g + \rho_f \, S \, g \, x$$

Position balance $\longrightarrow$ Ep Minimum $\longleftrightarrow$ $Ep = \dfrac{dEp}{dy} = 0$

$$\rho_s \, S \, h \, g = \rho_f \, S \, g \, x$$

$$x = \frac{\rho s \; h}{\rho f} = \rho_r \, h$$

ρ_s = Solid density

ρ_f = Liquid density

h = height

In this case: h=195mm , ρ_s=127,68 $\frac{kg}{m^3}$, ρ_f = 1027$\frac{kg}{m^3}$

$$x = \frac{127{,}68\frac{kg}{m^3} \, 0.195 \text{ m}}{1027\frac{kg}{m^3}} = 0.024 \text{ m}$$

This principle allows calculating the depth which the tyre is going to be submerged.

x = 24 mm

h = 195 mm
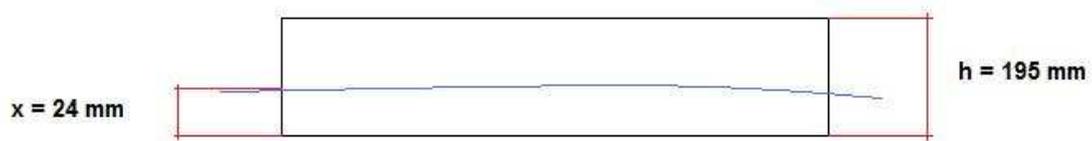
Project Time line table

Index	Task	Nov. 11		Dec. 11	Jan. 12	Feb. 12	Mar. 12	Apr. 12	may-12
		w.3	w.4	w.1 w.2 w.3 w.4	w.1 w.2 w.3 w.4	w.1 w.2 w.3 w.4	w.1 w.2 w.3 w.4	w.1 w.2 w.3 w.4	w.1 w.2 w.3 w.4
	Structure to obtain energy based on worn tyres								
1	**Background study**								
1.1	Background reading								
1.2	Draft literature review preparation								
2	**Development**								
2.1	Requirements analysis								
2.2	Initial design								
2.3	Final design								
2.4	Test								
3	**Progress reporting**								
3.1	November progress report								
3.2	December progress report								
3.3	January progress report								
3.4	February progress report								
4	**Final assessment**								
4.1	Draft final report preparation								
4.2	Submission of draft final report								
4.3	Draft final report completion								
4.4	Final report printing								
4.5	Final report								
5	**Presentation**								

The diagram shows the global itinerary followed during this year, in order to achieve a project with successful.

A brief summary of the timeline table. First, the study of different background research and theories of the topic are involved, in order to create a global idea of the topic which is going to be developed in the next steps.

After achieve enough information of the topic, the development of the design is the next step; creating a global sketch of the future design.

The progress reporting is developed during the 7th month of the project period, adding different information, own calculation and design and research on books or magazines.

The final assessment is the most important step of the timeline, in order to create a project with a real efficiency and sustainability using a formal language and perfect writing.

The last steps in this project are the correct reference and to achieve conclusion to give the real sense in the calculation and development.

The timeline table is created to have a reference of developing. Nevertheless this structure is changed as a result of several factors like information research, mistakes or deadline of handing in.

To sum up, the project is a constant work which should be made daily adding different information of different source. The project could be defined as a method to show and to convince of the information and reliability of the study developed.

Results and discussion

The results obtained in the development of the project have achieved in the calculation section using the different formulas and data obtained the final results, on the final results it can be added the final dimensions of the structure.

This document has presented a global analyze of the actual situation of the exploitation of sea waves source, with a emphasis in the development of future structure in order to install in future years with a low investment.

The work carried out in the production of the present document has considered a series of topics which are focus on the outstanding main subjects as; the global situation of renewable energy research, the background knowledge of structure focus on wave movement, powerful of world wave defined each area, exploitation of mechanical wave movement, the way to fix the equipment, the conversion of energy using an electrical mechanism, analyze of materials and characteristics of materials and calculation of the global equipment.

Each chapter of the document has presented specific conclusions for each thematic axle considered. It is based on the thematic content the work chapter, adding data, information and pictures to create a better explanation of the content in each chapter using different information source (library books, web pages of renewable energy, magazine documents or lectures.)

The results and discussion could be classified in topics:

1. Dimension and shape of structure

The final dimensions of the different components have been chosen in order to create homogeneity in the equipment and in the structure with a stiffness and resistance, which could be carried out in future constructions.

The tyres dimensions have been taken as standard measures and more used by conventional cars, due to the fact that they are taking as waste elements and it can be appear in high quantity.

The tyres, which compound the structure, are divided in two groups: semi-submerged and submerged. The semi-submerged tyres create the superior part; the first calculation of these tyres is the calculation of the submerged area. In order to calculate the are submerged, the Archimedes' principle is used like the method, adding the global weight of the each tyre adding up the weight of the electrical mechanism, which is minimum, due to the fact that only consist of the reel and the cylinder containing the reel. The area submerged has a low value regarding what the height of the tyre, this data shows that the tyre is going to install with a security area to avoid the problem of being totally submerged. The second group of tyre presents the minimum calculation and problems, located submerged. This situation is created by the own sea water inside of each tyre and the tyre weight, creating a stability position.

The structure shape is approximate to a raft to create a base; the dimensions taken are used to create a real project, which could design on a scale. These can change depending of the investment or budget, although the aim is to create a believable and attractive idea.

The submerged area of the structure should have similar dimensions, in order to create a symmetric structure. The depth of the structure is limited by the sea depth and the problems with possible breaks creating by the powerful waves. The length of the cylinder, which creates the intermediate area, has chosen as a measure of security and trying to create the highest movement taking advantage of wave powerful and maritime currents.

2. Location for the structure

The discussion of this project part is realized depending of the power wave which is wished. The idea is to obtain the maximum performance. Mentioned previously, the U.K. area has one of the highest powerful taking as a reference to choose the area.

The west Irish coast is the selected area an accessible area with high level of rain and wind, compared with other areas with a similar average like Switzerland or the south of Argentina.

Another decision to introduce the structure on this area have been the University where the project is developed, situated on Wales (U.K. area), taking an area near which represent the state. Adding a high availability in order to check and test the results.

3. How to install the structure.

The idea to install the structure is to create a firm fixation with the ground of the sea avoiding problems with the swell, as drift movement losing all the investment. The use of wires adding weight and ball cocks are the best way to fix the structure, the wire allows strength to the fixation, at the same time, creating a degree of freedom without losing the aim of fixing the structure to the sea ground. The ball cocks, added in the middle of the wire, create a reinforcement of the fixation avoiding that the all the powerful been applied on the weight, which made up the last step of the fixation. These weights have the role to fix the wire to the ground.

The way to fix each tyres of the superior structure has decided to realize using steel cables, in order to create a freedom of movement following the undulating surface movement of the sea. Another idea is to fix all the tyres, however this has been eliminated due to the fact that the irregular movement of the sea and the possible breaks creating by the knock of waves could damage the structure.

4. Mechanical mechanism.

The global structure is studied like a mechanical mechanism due to the fact that the aim is to use the mechanical movement of the waves in order to create a source of energy. The movement of the global structure has divided in two groups: superior movement and submerged movement. In the superior movement has been included the worn tyres movement created by the surface movement and the use of steel wires, these tyres reproduce the undulating wave movement. The second group, submerged movement, is developed by the tyres submerged movement fixed in a cylinder with a magnet on the top; this movement describes a vertical and rotary movement allowing the introduction of the magnet in a reel. The use of a cylinder is to create the vertical movement, which allows a vertical movement following the axle, and the cylindrical shape of the cylinder allows too the rotator movement.

5. Electrical mechanism.

The electrical mechanism is focused only in the reel, magnet and the way to convert and transport the electricity. The idea of making the installation inside of each tyre is to create a homogeneous structure avoiding projections, which could create irregularities in the electrical obtaining. The location of the electrical mechanism, compound of cylinder with a reel inside and the magnet, is inside of each tyre creating a security area. The tyres act like a reinforcement and insulating material allowing an isolated area, far of knocking wave's problem or humidity and corrosion.

6. Calculation

The calculations carry out in this project are related to submerged area or energy obtained. The submerged area is an important data, in order to know the maximum weight available from each tyre. The Archimedes' principle is the base of the submerged area, using the different formulas of this principle the area calculate has an average acceptable to install the structure without problems. Compared with the height of the standard tyre, the submerged area is approximately an eighth.

The energy obtained of the energy is carried out using two different formulas; each formula gives the results in different units. The first one is used to obtain the powerful using the unit of KW/year and the second one is to obtain the energy units in KJ.

Conclusions

The project, which has been developed, has contributed in an important way to identify and stand out the different steps which should be completed and considered, in order to carry out a successful installation of the equipment and the structure.

Inside of the project, there are a high number of important points to take into account.

The renewable energies have as definition large advantages of being clean resource with limited visual impact, which come from an inexhaustible natural source. The case deals in this project is one of them; the swell energy. With an efficiency running of this kind of energy, the external dependence of fossil fuel will be reduced and allowed a high energetic autonomy.

The state of sea area can be predicted with certain advance. However, the exploitation of this resource entirely is difficult due to the fact that the impossibility of connecting the energy on a point to extract. Although at first, the swell is a source with a high capacity and continuity, it has worst results than wind power or solar energy.

The swell presents high irregularities in the amplitude, phase, wave direction, wave height and the power is totally random. The gadgets, which have been developed in this project, try to follow this irregular mechanical movement. In spite of the equipment, is difficult to obtain a maximal performance in all the interval of frequency.

The structure design in this project presents a structure, which takes advantage of the chance to change the shape. The construction of this structure has been made in order to obtain different level of energy, due to the fact that the shape of the "raft" can change in a easy way. The data of energy, obtained in the different calculation, shows a quantity in a low scale, the idea was to create a simple area to create an easy idea of a structure. The dimension of this structure could be changed according to the investment and the average of energy to obtain, taking this model as a reference point to know the average of energy wished.

The visual impact created on this project has a minimum average, due to the fact that the structure designed has the role of creating energy without emission and not visual impact. The structure shape creates a shape under the sea surface similar to a raft; the worst visual impact is the colour of the worn tyres, which could be stood up over the crystalline sea water. The problem of the installation in the sea is the future problems creating by the growth of seascape, which is impossible to avoid only using some harmful products.

The technology used in this project has a simple application, the creation of a magnet circuit with a reel creating the magnet field with the mechanical movement.

The financial inversion presents a low value; only recycle materials (worn tyres) and the use of an electrical mechanism (reel, magnet and batteries). This value can be seen increased with the electrical necessity, with higher electrical necessity more electrical gadgets adding the increase of worn tyres number.

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Glyndwr University
Miguel Muñío Gay
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