UTILIZATION OF SEA WAVE AS POWER PLANT WITH PISTON

Almadora Anwar Sani [1)], Widiyatmoko [2)]

[1)] *Mechanical Engineering, Politeknik Negeri Sriwijaya, Jl. Srijaya Negara Bukit Besar, Palembang, Indonesia*
E-mail: almadora@polsri.ac.id

[2)]*Refrigeration and Air Conditioning Engineering, Polytechnic Sekayu, Jl. Kol. Wahid Udin Sekayu, Musi Banyuasin, Indonesia*

Abstract. Energy is an indispensable daily necessity for the community, particularly electrical energy since the need of electrical current for human life is increasing rapidly. The power plant is currently using non-renewable energy such as oil, gas and coal in which it will experience a shortage of resources in the future. In addition, the use of operational costs to obtain and possess the non-renewable energy sources requires great cost. The impact of mining is the destruction of nature. The use of non-renewable energy releases carbon emissions into the air, resulting in the problem of global warming. One of the energy that is being developed by several countries today is the utilization wave energy. Indonesia has the potential source of wave energy. Indonesia mostly consists of seas. The potential to develop wave energy is very great. The utilization of renewable energy sources as the solution to substitute the non-renewable energy is in line with the rapid development of technology. Waves are renewable energy source that is natural and environmental friendly. The continuous movement of sea waves can be used as power plant. The potential of sea wave energy in Indonesia is very great, and proportional to the area of the existing marine waters. One of the potentials that can be taken is to convert the sea wave energy into electrical energy. The need for the design and the conversion of sea wave into power plant employs piston system. System piston with the utilization of buoyancy of an object can be optimized as driving force for the power generator.

Keywords**:**Power Plant, Sea wave, Piston, Renewable Energy

I. INTRODUCTION

A. Background

Indonesia is an archipelago surrounded by the majority of sea. Some regions still need electrical energy source for supporting infrastructure. Currently, the need of electrical energy in Indoensia still depends on the non-renewable energy (such as oil and coal).

Along with the development of human civilization, the level of human energy need is also increasing. The fulfilment of the energy is mostly from the burning of fossil fuel of million years, this is not renewable, and only a small part is from the use of other energy resources (Wijaya, 2010).

The electricity demand in the future is predicted to continue to grow along with the economic development and citizen development. To fulfil the need of electrical energy, various types of power plants are needed. The electricity production in BAU (Business as Usual) scenario will grow from 167,9 TWh in 2011 into 760,4 TWh in 2030 or increasing approximately 7,8% per year. In NEP(National Energy Policy)scenario, the electricity scenario increases even higher, which reaches 8,2% per year (Energy and Mineral Resources, 2012).

Many countries realize the importance of utilizing renewable energy sources that are environmental-friendly. One of the energy that is being developed by several countries nowadays is the utilization of ocean wave energy. Indonesia has the potential of ocean wave energy resources. Indonesia consists of most seas and several islands. The potential to develop wave energy is excellent.

The utilization of renewable energy sources becomes the solution of the need to replace non-renewable energy, along with the advance of the development in technology. Wave energy is natural and eco-friendly renewable energy source. The continuous movement of the wave can be utilized as power plants.

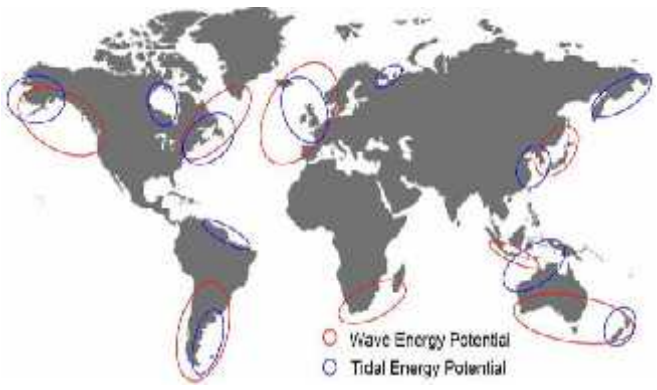


Fig. 1 Location of Wave Energy Potential
(http://www.aseli.co/)

Indonesia is the biggest archipelagic country in the world since it hasa large number of sea areas and islands. The length of Indonesia coast reaches 95.181 km with the sea

area of 5.8 million square kilometres (Ministry of Maritime Affairs and Fisheries, 2010). The potential of Indonesia can be seen in the detailed marine physical indicator in Table 1.

TABLE I
MARINE PHYSICAL INDICATORS IN INDONESIA

No	Description	Total
1	Indonesia's area	7,7 million km^2
2	Indonesia's land area	1,9 million km^2
	Percentage of Indonesia's land area	24,68
3	Indonesia's sea area	5,8 million km^2
	Percentage of Indonesia's sea area	75,32
	a. Inland sea area Percentage to sea area (%) b. Territorial sea area Percentage to sea area (%) c. ZEE area Percentage to sea area (%)	2,3 million km^2 29,87 0,8 million km^2 10,39 2,7 million km^2 35,06
4	Coastal Line	95.181 km
5	Islands a. Named islands Percentage to the total islands (%) b. Unnamed islands Percentage to the total islands (%) c. Verified islands Percentage to the total islands (%)	17.504 islands 8.651 islands 49,42 8.853 50,58 9.842 56,23
6	Islands registered to UN Percentage to the total islands (%)	4.981 islands 28,46

Source :Ministry of Maritime Affairs and Fisheries, 2010

Waves in the ocean can be classified into several types depending on the generator. Wave generator can be indicated by : wind (wind wave), gravity between earth-moon-sun (tidal wave), earthquake (volcanic or tectonic), seabed (tsunami wave), or the waves caused by the movement of ship. Ocean wave is the energy in transition, which is the energy carried by its nature (Fig. 2).

Fig. 2Ocean wave movement
(Ocean Energy Studies Forum, 2011)

Ocean waves keep huge energy that is not optimally utilized. Researchers from Indonesia and other countries keep researching about the utilization of ocean waves to be converted into energy that is beneficial for human. Potential and kinetic energy in the ocean waves can be converted into the utilization of electrical power and water pump as well as irrigation (Nuarsa, 2008).

The research about the utilization of ocean waves as power plants has been numerously researched, one of them is by Made Nuarsa in 2008 entitled Penangkap Energi Gelombang Laut (Ocean wave Energy Catcher) which concludes that Piston can absorb the ocean wave energy that convert the wave power to become mechanical energy indriving gear.

The problem in the research is "Construction tool is made sturdier to avoid or reduce the loads that can reduce the tool performance" (Nuarsa, 2008). Thus, there is a need for solution or other applicable alternatives.

B. Objective

1. to get a concept or idea to utilize sea wave
2. to know the period of first piston that move by sea wave
3. to know the Potential Power for one piston

II. LITERATURESTUDY

A. Study Reference

- Research on Wave Power Plant Prototype with Oscillator System

  According to Soebyakto (2011), wave power plant with oscillator system is to seek the solution for energy to substitute oil fuel. Wave energy can be in the form of kinetic and potential energy.

  Ocean wave is the upward and downward movement on the sea surface that regularly shows the high parts as the crests and the low parts as the troughs that moves in certain direction. The movement of the wind wave can be caught by the wave energy gauge (Figure 3).

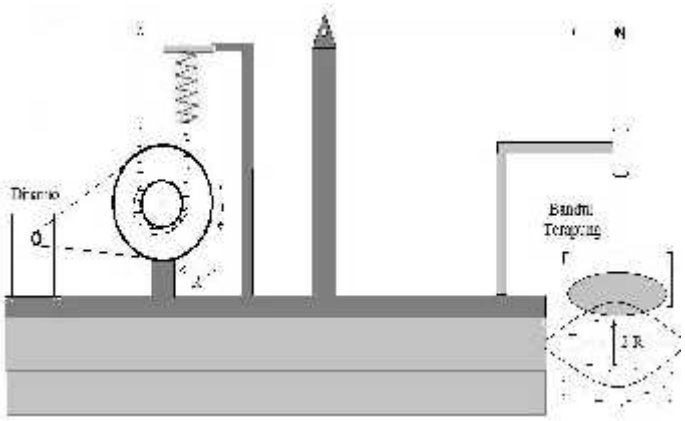


Fig 3Development Assembly System of Wave Energy Conversion from Ocean Waves Oscillator

From the research conducted by Soebyakto (2011), it was concluded that the wave power based on the function of wave speed is a linear graph meaning that the wave energy power increases in line with the speed wave linearly, the resulting power is that the more force, the more powerwill be. To estimate the potential of the wave energy in the sea territory, the graph resulted from the function of the power to the wave speed can be used.

According to Ai Yuningsih and Achmad Masduki (2011), based on the tides type, the current pattern of the tides in Larantuka Strait can be categorized into two different flow directionstwice in 24 hours, in which at low tide the current flow pattern heads to the north and at high tide the current flow pattern heads to the south. Based on the duration, the water position takes 7-8 hours to start rising until the optimum rise. Meanwhile, it takes 5-6 hours for the water to start receding until minimum recede.

The technology of hydraulic piston changes the wave energy to move the piston, lift the water in the high-pressure line, and move it to the hydroelectric generator, one of the well-known systems nowadays is Oyster, made by aquamarine power ltd. The potential of the use of hydraulic piston in the world reaches up to 60Gw (A. Hasnan : 2013).

- Research on Wave Energy Catcher

According to I Made Nuarsa (2008), the ocean waves keep huge energy that has not been optimally utilized. Researchers from Indonesia and other countries keep researching about the utilization of ocean waves to be converted into energy that is beneficial for human.Wave power plant for electrical energy with a single piston system with the variation of square, circle, oval, and cylinder has been researched by Reza (Nuarsa, 2003). In fact, square and cylinder pistons (single piston-single action) have the most excitation energy. However, it can be sure that with the double action system the resulted excitation energy will be greater.

This research employs experimental method with two experimental stages, which are: in 2008 testing on cylinder piston in single piston with double action system to get the spin and maximum torque. In 2009, the prototype of the wave energy power plant is made with the system of single piston double action (Fig. 4).

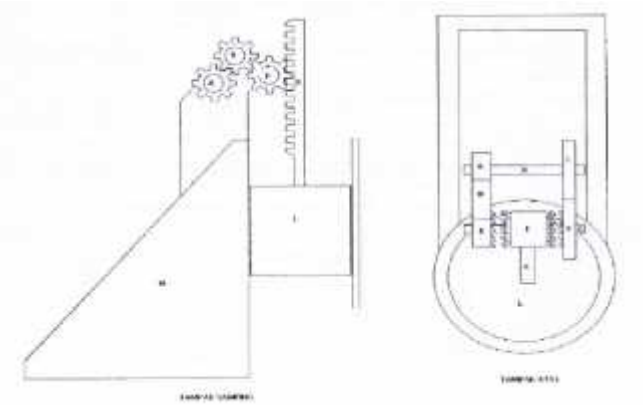
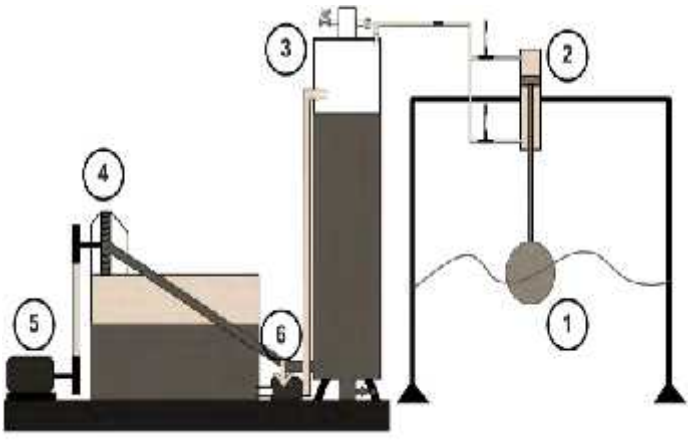


Fig. 4Scheme of Ocean Wave Catcher with Double-Acting Piston System (Nuarsa, 2008)

According to Nuarsa (2008) the most effective energy conversion from the wave to the piston occurs when the (piston) buoy is given weight W half of the total Fa (W=Fa/2 total) compared with when there is no weight (W=0) and when the piston is full (W=total Fa).

M.B Subagyo, et al. (2012) designed the Pneumatic Conversion System of Wave Energy as Power Plant. The scheme of the gauge is shown in Figure 5 as follows:



Note:
1. Buoy
2. Pneumatic System

3. Hydrophone Tank
4. Turbine
5. Generator
6. Pump

Fig. 5Scheme of Pneumatic Conversion System (M. B. Subagio, S.P. Fitri and Soemartojo, 2012)

B. Theory

- Ocean Waves

Ocean waves are the energy in transition carried by its nature. Based on Waldopo (Wijaya, 2010), the basic principle of the ocean waves is as follows:
"Whenever two masses of objects with different densities are against to each other, a wave will be formed in their movement area"
Wave is the upward and downward movement of water, whichis perpendicular with the surface of the ocean forming sinusoid curve/graph (Fig. 6). Ocean waves are caused by wind. Wind above the ocean transfers its energy to the water causing ripples and turn into what we call as waves.

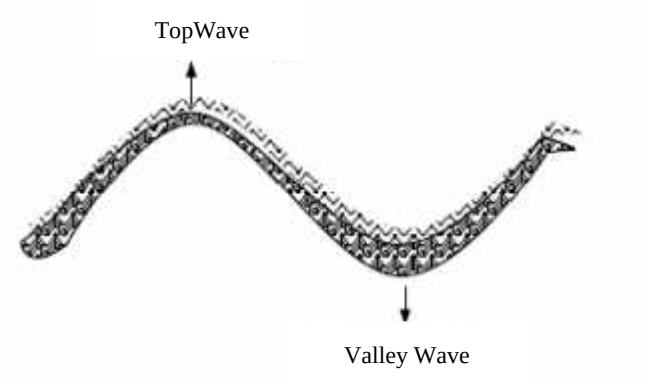


Fig. 6Water Motion (Waldopo, 2008)

The combination of gravity force, water surface tension, and wind intensity are the main factors in forming the ocean waves (Rodrigues, 2008). Figure 7 illustrates the ocean waves that are formed by storms. The wave's size is determined by the wind speed and fetch (the distance of the wind that causes the waves) and the depth or the topography of the seabed. For the distance far from the fetch, the ocean waves have the regular waves and this phenomenon is called swell.

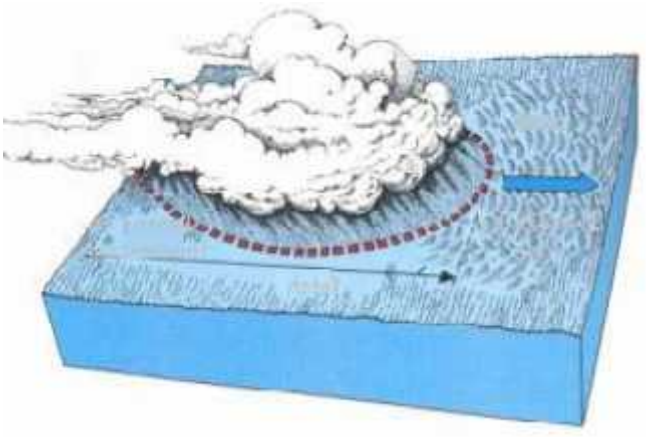


Fig.7Illustration on ocean waves forming(Rodrigues, 2008)

The water particles are moved by the wind in each location with circular water movement, in which the highest diameter is in the surface of the water, and decreases exponentially to the depth. The circular movement causes the shape of the waves as seen in Figure 8.

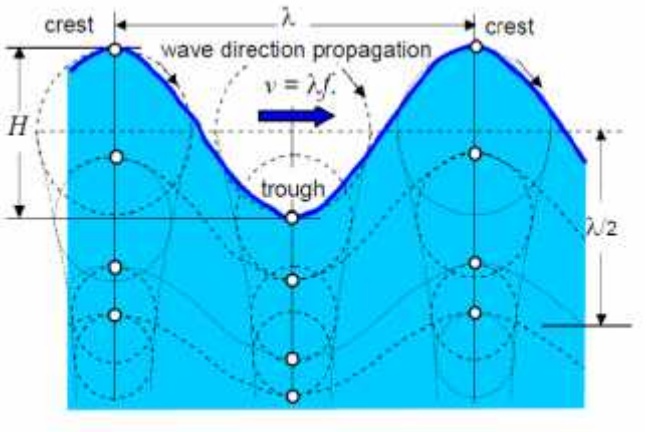


Fig.8Ocean Wave Motion (Rodrigues, 2008)

The distance between to crests or two troughs is called wavelength λ. The height of the wave H (distance from the crest to the trough) is proportional to the wind intensity and duration. The wave period T (crest to crest) is the time needed for waves to move as far as λ and proportional to the ocean depth. The frequency f=1/T indicates the number of the waves that appear in certain positions. Therefore the wave velocity is v = λ/T = λ/f. The ration λ/2H is called wave declivity and when this is greater than 1/7 it can be proved that the waves become unstable and disappeared.

Waves with longer period have longer and faster λ. Generally, it can be stated that the huge waves have greater power (Rodrigues, 2008).

To simplify the theory of surface waves, assumed sinusoidal waveform is represented by a curve at

figure 8. This assumption states wave displacement (η) as a simple harmonic motion that is a variation round dalan water level caused by the wave trajectory. Figure 8 shows how variable displacement versus time waveform at a certain point. Prior to the determination of displacement, we must first recall the relationship between period and frequency.

The curve shown in Figure 8 is sinusoidal. However most waves generated by wind is not a simple sinusoidal shape. The more steep wave sine curve farther away (http://staff.unila.ac.id/ekoefendi/2011/10/28/wave/,)

There is a mathematical relation between wavelength characteristics (L), period (T) and wave height (H) of the velocity of the waves and the sea wave energy. First, the speed of the wave (c) wave speed is determined from the time given to wavelengths that pass a certain point,

$C = L/T$ …… (1)

Two terms are found in the literature oceanography is the wave number, k, where k= 2π / T. The wave velocity in the Deep Sea and Shallow WaterIt should be noted, that the speed of the wave mentioned above is for traveling waves in the deep sea. In shallow waters, the depth of the water affects the speed of the wave, the wave velocity can be expressed in the equation:

$$C = \sqrt{\frac{gL}{2\pi}\tanh\frac{2\pi d}{L}} \quad \text{……..……(2)}$$

where the Earth's gravitational acceleration, g = 9.8 ms^{-2}, L = wavelength (m) and d = water depth (m), tanh is a mathematical function called a hyperbolic tangent. If x is small, such as less than 0.05, then tanh $x \approx x$. If x is greater than π, then tanh $x \approx 1$

Assumptions In Surface Wave Theory.Simple wave theory is assumed as follows :

1. The waveform is sinusoidal.
2. The amplitude of the wave is very small compared to the wavelength and the water depth.
3. Viscosity and surface tension negligible.
4. Coriolis and vortices forces, which both rely on the Earth's rotation can be ignored.
5. The water depth uniforms and basic water no lumps.
6. Waves do not reflected by land or other obstructions.
7. three-dimensionalwave analog with two-dimensional model.

No assumptions above are valid, but in practice, the prediction using a simple wave surface model enough to understanding the waves behavior generated by the wind. (http://staff.unila.ac.id/ekoefendi/2011/10/28/wave/),

In 1779, Benjamin franklin says, "The air that moves is the wind, past the smooth surface, would disturb the surface and make the surface bumpy, if the wind keeps blowing, then it becomes a wave element".

In other words, if two layers of fluid which has a speed difference meet, then there will be friction stress between them, then there will be a transfer of energy. At sea level, most of the energy that is transferred is the result of a wave, but with a small proportion is the result of the current generated by the wind. In 1925 Harold Jeffrey S. assume waves gain energy from the wind due to the pressure difference caused by the effect of the wave crests. Although the hypothesis of Jeffrey failed to explain waveforms are very small, but apply if:

1. Wind speed greater than wave speed.
2. The wind speed exceeds 1 m / s
3. Wave steep enough to give shade effect.

Empirically, it can be shown that the effects of shade will be the maximum if the wind speed is approximately three times more greater than the waves speed. In the open sea, the waves generated by win it has a steepness (H / L) of about 0,03 to 0,06. In general, greater speed difference, greater steep waves. Wave velocity in deep sea has nothing to do with wave steepness. but greater wavelength, faster the wave.

Ocean wave heights vary, and may change at any time. Below is a table height of sea waves (Table 1)

TABLE II. SEA WAVE HEIGHTS EFFECTIVEDATE 30 NOVEMBER 2015 07:00:00 PM TO DECEMBER 7, 2015 07:00:00 PM

No	Location	high average (meter)	Max high (meter)	Wave freq> 3 meter
1	Aceh north waters	0,4 - 1,0	0,6 -1,3	0 - 5%
2	Aceh west waters to North Sumatra	0,4 - 1,25	0,6 - 1,5	0 - 5%
3	West Sumatra waters	0,3 - 1,25	0,75 - 1,6	0 - 5%
4	Bengkulu waters to West Lampung	0,3 - 1,25	0,75 - 2,0	0 - 5%
5	Sunda Strait	0,3 - 1,3	0,75 - 2,0	0 - 5%

6	Banten south waters to West Java	0,4 - 1,5	0,75 - 2,0	0 - 5%
7	south waters Mid Java	0,4 - 1,25	0,6 - 2,0	0 - 5%
8	south waters East Java	0,4 - 1,25	0,6 - 1,3	0 - 5%
9	Bali south waters to NTB	0,4 - 1,25	0,6 - 1,3	0 - 5%
10	Sawu sea	0,6 - 1,0	0,75 - 1,25	0 - 5%
11	Timor sea	0,4 - 0,8	0,5 - 1,25	0 - 5%
12	Etc			

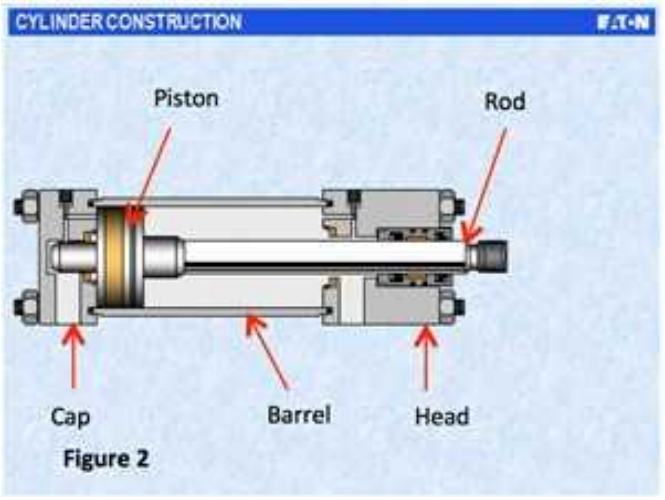
(http://www.bmkg.go.id/BMKG_Pusat/Informasi_Cuaca/Maritim_-_Cuaca_Pelayaran/Rata_Rata_Gelombang_(Mingguan).

C. Hydraulic Cylinder

Hydraulic cylinder is a mechanical actuator resulting unidirectional force through unidirectional stroke movement. It becomes one of the parts in hydraulic system, besides hydraulic pump and motor. If the hydraulic motor changes the hydraulic fluid pressure into a spinning movement, then the hydraulic cylinder results in unidirectional stroke movement.

Anocean wave power generation device includes: a motion bar, a platform, a platform-supporting upper upright post for supporting the platform, a platform-supporting lower upright post, a hydraulic lift post, a flywheel set for connecting power generation equipment, and a platform lift control device, wherein ocean wave pushes floating ball to drive the motion bar to move upwards, a rack section of the motion bar drives a first flywheel on first side to rotate, which drives a generator to generate power through a spindle; wherein after theocean wave, the floating ball drives the motion bar to move downwards under action of gravity. The rack section of the motion bar drives a second flywheel on second side to rotate, which drives the generator to generate power through the spindle, in such a manner that continuous power generation is achieved (US 2015/0176561 A1).

Hydraulic cylinder gets the power from the pressurized hydraulic fluid. Inside the hydraulic cylinder there is a piston connected to the rod that can move back and forth, depending on which side is filled with the pressurized hydraulic fluid. The different pressure used in both sides of the cylinder depends on the weight, area of the cylinder and rod sides.



Fog. 9Cylinder Construction
http://www.hyspecs.com.au/

D. DC Generator

Generator is a machine functions to change the mechanical energy into electrical energy. The electricity resulted by the generator can be AC or DC depending on the type of the generator (onny, http://artikel-teknologi.com/prinsip-kerja-generator-dc/.

The generator is an application of electromagnetic induction. It works on the principle that when a wire is moved in a magnetic field, then the current is induced in the coil. A rectangular coil is made to rotate rapidly in the magnetic field between the poles of a horse shoe type magnet. When the coil rotates, it cuts the lines of magnetic force, due to which a current is produced in the generator coil. This current can be used to run the various electrical appliances (http://www.tutorvista.com).

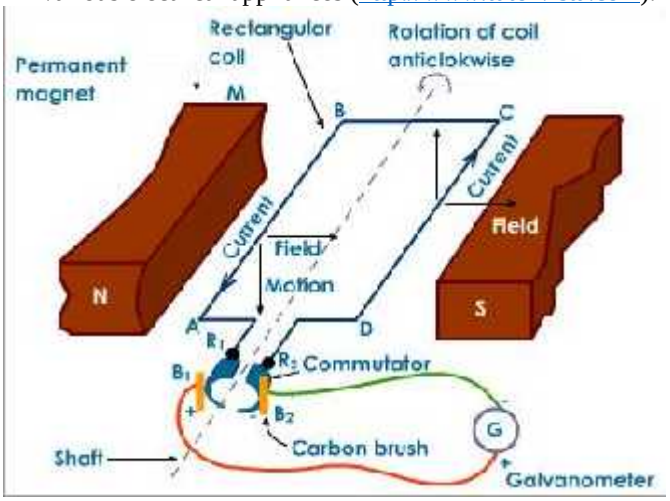


Fig. 10 .DC Generator
(http://www.tutorvista.com)

E. Power Analysis Approach

Theoterically, the power that can generate by water power is :

$$P = 9{,}8\ \rho . Q . H .$$

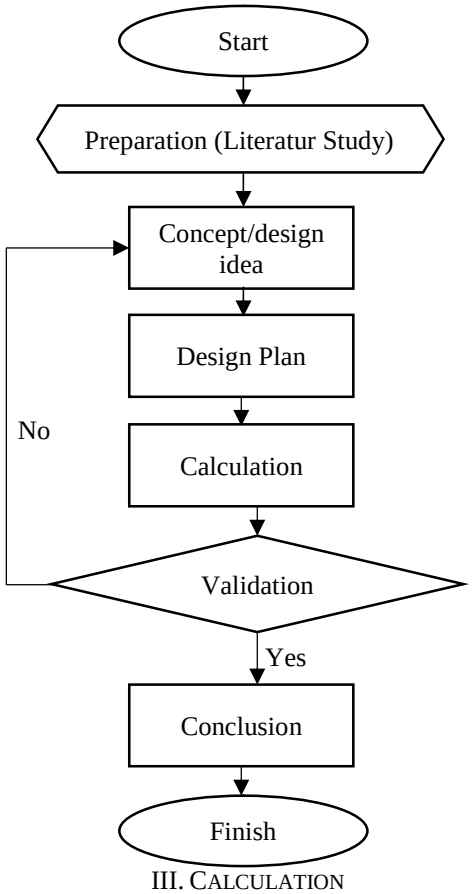
Where : P = Power (watt)

ρ = density of water (kg/m^3)

H = head fall (m)

Methodology

Methodology yang digunakanmenggunakan diagram alirberikutini :



III. CALCULATION

From the equation 2, and information from table 1, we can calculate the period of average wave, with g = 9,8 m/s^2

No	H (m)	H/L	L (m)	d (m)	C (m/s)	T (s)
1	0.3	0.03	10	2	3.95	2.53
2	0.6	0.03	20	2	5.59	3.58
3	1.5	0.03	50	2	8.83	5.66
4	0.3	0.04	7.5	2	3.42	2.19
5	0.6	0.04	15	2	4.84	3.10
6	1.5	0.04	37.5	2	7.65	4.90
7	0.3	0.05	6	2	3.06	1.96
8	0.6	0.05	12	2	4.33	2.77
9	1.5	0.05	30	2	6.84	4.38
10	0.3	0.06	5	2	2.79	1.79
11	0.6	0.06	10	2	3.95	2.53
12	1.5	0.06	25	2	6.25	4.00
13	0.3	0.03	10	5	3.95	2.53
14	0.6	0.03	20	5	5.59	3.58
15	1.5	0.03	50	5	8.83	5.66
16	0.3	0.04	7.5	5	3.42	2.19
17	0.6	0.04	15	5	4.84	3.10
18	1.5	0.04	37.5	5	7.65	4.90
19	0.3	0.05	6	5	3.06	1.96
20	0.6	0.05	12	5	4.33	2.77
21	1.5	0.05	30	5	6.84	4.38
22	0.3	0.06	5	5	2.79	1.79
23	0.6	0.06	10	5	3.95	2.53
24	1.5	0.06	25	5	6.25	4.00
25	0.3	0.03	10	15	3.95	2.53
26	0.6	0.03	20	15	5.59	3.58
27	1.5	0.03	50	15	8.83	5.66
28	0.3	0.04	7.5	15	3.42	2.19
29	0.6	0.04	15	15	4.84	3.10
30	1.5	0.04	37.5	15	7.65	4.90
31	0.3	0.05	6	15	3.06	1.96
32	0.6	0.05	12	15	4.33	2.77
33	1.5	0.05	30	15	6.84	4.38
34	0.3	0.06	5	15	2.79	1.79
35	0.6	0.06	10	15	3.95	2.53
36	1.5	0.06	25	15	6.25	4.00

From the calculation, we know that the first piston will move with periods about 1.7 secon (the lowest wave) to 5,6secon (the highest wave).

If one piston can move sea water about 30 liter per minute, and difference of reservoir to the turbine about 5 meters, it means the maximum Potential power that can produce by a single piston is :

$$P_{one\ piston} = \rho . g . Q . h$$

$$P_{one\ piston} = 1000.9{,}8.0{,}0005.5$$

$$P_{one\ piston} = 24{,}75\ watt$$

We can multiply the piston. So, for n-piston it has Potential Power about P_{total} = n x $P_{one\ piston}$

IV. WAVE ENERGY PLAN

This gauge is just a design. The plan is that this gauge will be researched furthermore and applied in the seas. This gauge employs piston work plan to change the mechanical energy into electrical energy. The head of the piston will be given buoy so that when the ocean waves move, the piston will move up and down following the movement of the waves.

The head of the piston functions as the buoy. If the waves move downward, the piston will move downward as well. If the waves move upward, then the piston will move upward

too. So keep the generator rotation stable, the water is pumped and collected in the collector. Then from the collector the water is flown to rotate the turbine. Flow

"The most effective energy conversion from the waves to the piston occurs when the (piston) buoy is given weight W half of the total Fa (W=Fa/2 Total) compared with when the piston has no weight (W=0), or when the piston if fully filled (W= Fa Total). This is because when the piston (W=0) or (W-Fa Total) the excitation force is big but transferred all by the piston to the transmission system and occurs in a very short time. Thus, the inert pressure with the friction of the transmission gears accelerated by the piston is very big." (Nuarsa, 2008).

A primary piston that is connected to a secondary piston that is part of a compressor, primary and secondary piston are connected by a connecting rod, the primary piston is driven by the pressure and vacuum produced by a pressure chamber that is driven by the variation of theocean wave. The output of the compressor is applied to a pressure tank, and then the output flow is controlled and applied to the turbine.(US 2012/02513 A1, Oct. 4, 2012).

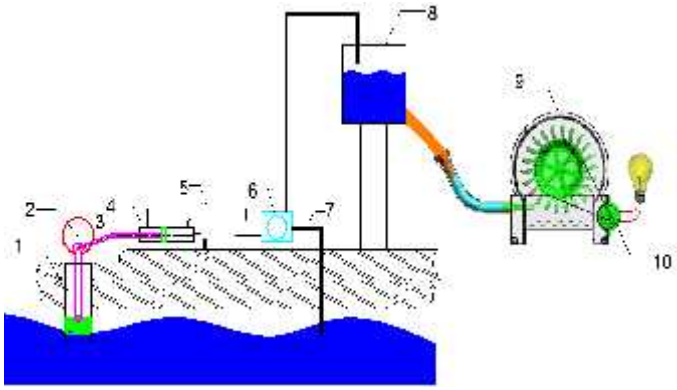


Fig. 11Ocean Wave Energy Design Plan

Note:

1. Piston
2. Connecting rod
3. Piston rod
4. Double acting
5. Hydraulic Hose
6. Pump
7. Pipe
8. Collector
9. Turbine
10. Generator

How it works:

- Piston moves up and down following the waves and moved to the hydraulic cylinder
- Hydraulic cylinder continues it to the pump
- Pump sucks water and collect it in the tank
- The collected water is used to rotate the turbine

V. CONCLUSION

1. Technology of the ocean wave utilization is being developed in all over the world. Indonesia is the country with wide sea area and has the potential to develop the technology to utilize the ocean wave as the great power plant.

Piston utilization can be conducted if the movement of the ocean waves is high. With the great distance of the crest and the trough, the piston movement can be optimal. If the movement of the ocean wave is low, the efficiency will be less. To overcome the low ocean waves, the water can be collected first and then moved to the turbine. Therefore, the generator can work optimally.

Power plant in ocean wave using piston can be developed and investigated in further research. The challenged that must be faced is to do further research about the technology of power plants in ocean waves so that it can be optimally used in sea territory in Indonesia.

2. the Period of the first piston is about 1,7 secon (for the lowest wave) to 5,6 secon (for heigest wave)

3. one piston it has potential power about 24,75 watt

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