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DESIGN AND BUILD A MODEL OF A MARINE WAVE POWER PLANT ENGINE FOR EDUCATIONAL TEACHING AIDS

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Abstract :

Renewable energy sources have been widely developed to reduce the consumption of non-renewable energy. However, an energy source that is still underutilized but has significant potential is ocean wave energy, which utilizes lift energy to operate generators that generate electricity. The machine is designed to develop a model that converts water wave energy into electrical energy on a laboratory scale and to examine the correlation between water wave energy and electrical energy generated by changing the length of the float arm. The methodology used in this final project is a literature review to gather information relevant to water waves and electricity-generating machines. Machine design and component manufacturing include making alternative designs, selecting designs, then testing whether there is a linear output and analyzing the relationship between water waves and the electricity output produced. The results of the experiment showed that the largest electrical output was obtained at an arm length of 40 cm with an average electrical power generated of 1,019 watts. Testing on PLTGL components was carried out with variations in the length of the buoyancy arm of 40 cm, 45 cm, and 50 cm.

Keywords : *Electric energy, Laboratory scale, Models, PLTGL, Water waves*

INTRODUCTION

The need for energy for human life is very important. Everything that supports the needs of life depends on the amount of energy available. As the times progress, humans need more energy that can be utilized. Various ways of using energy have been carried out in both modern and traditional ways. The principle of energy utilization is by converting energy into other forms of energy. There are two types of energy, namely renewable energy and non-renewable energy. For renewable energy, there are not many obstacles in terms of its availability, but for non-renewable energy there are problems related to its availability (Ahmed, & Tamim, 2025). Non-renewable energy such as that produced from materials under the earth is decreasing over time, so there must be other energy uses to replace it (Fahmi, 2025). One of the energies that is quite abundant in Indonesia is geothermal and water wave energy. Waves are a considerable source of energy, waves are the movement of water that fluctuates or rolls. Ocean wave energy is an alternative energy generated through the effects of air pressure movement due to fluctuations in wave movement (Satriawan et al., 2021). The use of water wave energy to be used as electrical energy using microhydro power plants. This type of marine wave power plant is not only environmentally friendly, but in its construction and operation it will not damage the natural ecosystem. One of the potentials of the ocean and ocean that is not widely known to the general public is the potential for ocean wave energy to produce electrical energy.

In addition to being useful for generating electrical energy, marine wave power generation machines can be used as educational teaching aids by being made on a model scale (Bordin et al., 2025). The need for teaching aids in the world of education is a very important part because the use of teaching aids can be a real application of the knowledge learned in the classroom. With the working principle of a machine that utilizes fluid movement, the machine can simulate how the energy of rising and falling motion is converted into electrical energy which is closely related to the energy conversion study program. And also the movement of fluids (water) used as the main driving source is a representation of the branch of fluid mechanics which is included in the mechanical engineering and hydrological engineering study programs. The use of prototypes of marine wave power generation machines in the world of education is expected to be a learning tool and can be developed into an alternative energy source for the country in the future. So many studies on seawater wave power plants (PLTGL). Various types of PLTGL have been developed, from laboratory scale to the scale of direct experiments in the open sea. Basically, all of this is done to find alternative energy that can be renewable and environmentally friendly. All of this is due to the depletion of energy supplies from the earth's bottom, such as petroleum and other mining materials, and the large emissions caused by plants that use fuel so that they can be problematic for the health of living beings. Various kinds of power plants that have been carried out such as wind power plants that many people find have resulted in changes in the migration system of birds, bats and several other animals.

From some of these studies, environmentally friendly renewable power plants are seawater wave power plants. Where this plant does not have an effect on marine life. Of these advantages, there are several disadvantages of the marine wave generation system, including requiring considerable costs and the energy produced varies greatly due to changes in wind every month that are not fixed. Research that has been conducted on the potential of sea waves, one of which was carried out by Masjono, 2002 on the design of a sea wave energy converter device which was carried out by utilizing one-way gears consisting of a rotor shaft, one-way gear, floating weights, counter weights that function to maintain the tension of the hanging rope when oscillations occur (Muchtar et al., 2026). The concept of the study is that several tethered floating devices are held together using chains on one-way gears combined with moving mass to hold the chain.

RESEARCH METHOD

Machine design is characterized by the application of scientific concepts, technical knowledge, and creativity to describe a machine or mechanical system that fulfills its specified function with optimal economy and efficiency {Razzaq et al., 2021). Design activities cannot be separated in the manufacture of a machine, the design is carried out before the machine is made, with this stage information will be obtained about the conclusions of the machine that will be made so as to make the manufacturing stage easier. The design stage requires technical drawings that function as an effective communication medium. Technical drawings can provide complete information about the series of a machine, so that the machine to be made can be understood by the maker well (Twigg-Smith et al., 2021) The design stages are depicted in the flowchart as follows;

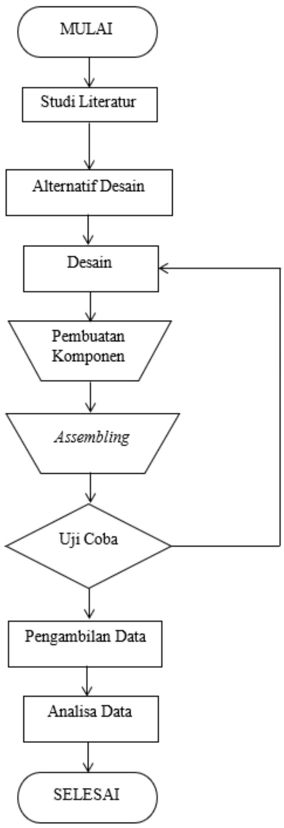
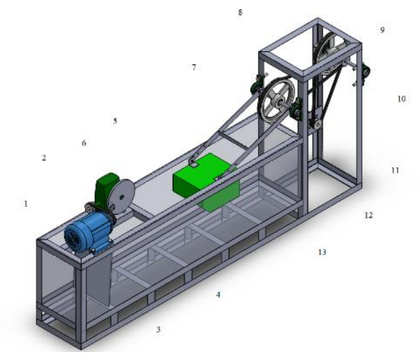


Figure 1. Diagram of the Planning Stages.

1. Literature Study, which is through the process of searching for and collecting relevant studies and materials, including articles, reference books, research journals, and other relevant sources.
2. Design alternatives
   Designing several designs with the aim of getting a design of a marine wave power plant machine that suits the needs and pays attention to the weaknesses and advantages of each design.
3. Selection of design alternatives
   Determine the design of the machine to be made by considering the advantages and disadvantages of several machine designs made and adjusting to the needs.

4. Design
   Creating working drawings from the selected design, the working drawings consist of drawings of machine designs and components contained in the machine.
5. Component manufacturing
   Making machine components that do not include factory standards such as machine frames.
6. Assembling
   The assembly of machine components that have been made in the previous process becomes a machine that is consistent with the design.
7. Trial
   Simulate a marine wave power generation engine in a predetermined location to find out whether the design of the pre-made engine is working well or not.
8. Data retrieval
   After conducting several tests on the machine, supporting data was obtained which will be analyzed to obtain an efficient, environmentally friendly, cheap and suitable engine design.
9. Data analysis
   Processing the data that has been obtained using calculations and literature used.

Tools and Materials



Design Description:
1. Electric motor
2. Gearbox reducer
3. Paddle
4. Water tub
5. Buoys
6. Crankshaft
7. Bearings
8. Pulley
9. Shaft
10. Pillow block
11. Belt
12. Generator

13. Framework

FINDINGS AND DISCUSSION

Working Principle of Marine Wave Power Plant

A wave power generator is a device that rotates the generator shaft in response to the amplitude and frequency of peaks and wave valleys, thus generating an electric current. The rising wave locks the bearing in one direction, which rotates the shaft. A descending buoy causes the arm to move as the water falls. However the shaft cannot rotate because the one-way bearing is not securely attached. The use of two one-way bearings aims to produce continuous movement so that when the buoy goes up or down, the shaft on the generator keeps rotating. In addition, to generate stable electrical energy power the machine relies heavily on the period of the water wave generated and the wave height lifting the buoy.

Table: 1 Test Data For Buoys With 40 cm Buoy Arm Length

	Trial Number									Average
	1	2	3	4	5	6	7	8	9	
Voltage (Volt)	2,69	3,14	2,95	3,24	4,19	3,73	3,46	4,87	3,04	3,47
Electric Current (Ampere)	0,34	0,25	0,31	0,26	0,31	0,28	0,35	0,27	0,28	0,29

Table: 2. Test Data For Buoys With Buoy Sleeve Length 45 cm

	Trial Number									Average
	1	2	3	4	5	6	7	8	9	
Voltage (Volt)	5,03	4,09	3,14	4,23	3,56	3,24	5,59	5,04	4,27	4,24
Electric Current (Ampere)	0,2	0,24	0,31	0,21	0,24	0,25	0,23	0,2	0,21	0,23

Table: 3. Test Data For Buoys With 50 cm Buoy Arm Length

	Trial Number									Average
	1	2	3	4	5	6	7	8	9	
Voltage (Volt)	6,34	4,37	5,59	4,35	4,67	4,88	5,59	4,62	6,23	5,18
Electric Current (Ampere)	0,21	0,19	0,16	0,19	0,15	0,2	0,16	0,16	0,17	0,17

Pembahasan

Calculation on the buoy

Wave Style

From the mechanism, it can be found the wave period (T) and wavelength (λ) with the known wave height of the experiment (H) 14 cm and the water density (ρ) 1000kg/m³

$T = 3{,}55\sqrt{H}$

$= 3{,}55\sqrt{0{,}14} = 1{,}328\ s$

$\lambda = 5{,}12\ .T^2$

$= 5{,}12.\,1{,}328^2 = 9{,}029\ m$

(Dhea,2019:6)

Description:

T = Wave period (s)

λ = Wavelength (m)

H = Wavelength (m)

$$P_w = \frac{\rho a.\,g^{2.}.\,H^2.\,T}{32\pi}\ .\ L$$

$$P_w = \frac{1000\,.\,9{,}81^2\,.\,0{,}14^2.\,1{,}328}{32\pi}\ .\,0{,}26$$

$= 6{,}478\ watt$

(Susanto,2015:46)

$$F_w = \frac{P_W}{cg}$$

$$F_w = \frac{1000\,.\,9{,}81^2\,.\,0{,}14^2.\,1{,}328}{2.\frac{\lambda}{T}}$$

$= 0{,}476\ N$

(Susanto,2015:20)

Description:

P_w = Absorbable power (watts)

F_w = Wave lift force (N)

ρa = Density of water (kg/m³)

g = Acceleration of gravity ()m/s²

c_g = 1/2 fast propagation wave (m/s)

L = Wavelength (m)

Floating Style

It is an upward compressive force in a floating object whose force is equal to the weight of the fluid being moved.

$F_b = \rho a\,.\,V_{benda}\,.\,g$

$F_b = 1000\,.\,0{,}00761\,.\,9{,}81$

$= 74{,}68\ N$

(Susanto,2015:21)

Description:

F_b = Floating force (N)

ρa = Density of water (kg/m³)

V_{benda} = Float volume ()m³

g = Acceleration of gravity ()m/s²

Generated Style (Resultant)

The resultant force generated by the wave to push the arm and is passed on to the pulley.

$F_{generated} = [F_w + F_b] - (m.\,g)$

$F_{generated} = [0{,}476 + 74{,}68] - (0{,}7\,.\,9{,}81)$

$= 76{,}831\ N$

(Susanto,2015:21)

Description:
$F_{generated}$ = Gaya generated(N)
F_b = Floating force (N)
F_w = Waveforce(N)
m_P = Buoyancy mass (kg)
g =Acceleration of gravity()m/s^2

Calculation of Resulting Spins

To obtain the number of revolutions, an example of the angle of rotation formed when the float is lifted upwards with the angle of rotation of the shaft is used.

$$\sin\alpha = \frac{7}{50}$$
$$\frac{1}{2}\alpha = \sin^{-1}\frac{7}{50}$$
$$\frac{1}{2}\alpha = 8{,}05 = 16{,}1°$$

$$\frac{0{,}9375}{60} = \frac{16{,}1°}{n}$$
$$0{,}9375n = 966°$$
$$n_1 = 1030{,}4°/s = 2{,}86\,rpm$$

The ratio between the diameter of pulley 1 and pulley 2 is 1:7, so the rotation on pulley 2 is obtained, namely:

Puli rotation 2

$$\frac{d_2}{d_1} = \frac{n_1}{n_2}$$
$$\frac{38{,}1}{228{,}6} = \frac{2{,}86}{n_2}$$
$$n_2 = \frac{2{,}86.\,9}{1{,}5} = 17{,}16\,rpm$$

Description:
d_1 = Diameter puli 1 (mm)
d_2 = Diameter puli 2 (mm)
n_1 = Pulley rotation 1 (rpm)
n_2 = Pulley rotation 2 (rpm)

Pulley rotation 4 (generator)

$$\frac{d_4}{d_3} = \frac{n_3}{n_4}$$
$$\frac{50{,}8}{228{,}6} = \frac{17{,}16}{n_2}$$
$$n_4 = \frac{17{,}16.\,9}{2} = 77{,}22\,rpm$$

Description:
d_3 = Diameter puli 3 (mm)
d_4 = Diameter puli 4 (mm)
n_3 = Pulley rotation 3 (rpm)
n_4 = Pulley rotation 4 (rpm)

Power Generated

$$P = \frac{2\pi n_1.\ M}{60}$$

$$= \frac{2\pi.\ 2{,}86\ \ 31{,}679}{60} = 9{,}488\ watt$$

Description:

P = Power produced (watts)

M = Moments of style (Nm)

n_1 = Puli rotation 1 (rpm)

Graphing and Data Analysis

Table : 4 Data Results of Calculation of the Efficiency of PLTG With Buoys on Arm Length40 cm Buoys

Number	Voltage (Volt)	Electric Current (Ampere)	Output Power (Watt)	Efficiency (%)
1	2,69	0,34	0,91	18,35
2	3,14	0,25	0,78	15,75
3	2,95	0,31	0,91	18,35
4	3,24	0,26	0,84	16,90
5	4,19	0,31	1,29	26,06
6	3,73	0,28	1,04	20,95
7	3,46	0,35	1,21	24,30
8	4,87	0,27	1,31	26,38
9	3,04	0,28	0,85	17,08
Rata-rata			1,019	20,46

In Table 4, the output power is obtained from the result of the time between voltage and electric current where the highest output power is obtained at a voltage of 4.87 volts and an electric current of 0.27 amperes of 1.31 watts. The highest efficiency value is found in the output power of 1.31 watts of 26.38%. This shows that in the results of the calculation of the efficiency of the PLTGL system, the higher the output power, the higher the efficiency value produced so that the voltage and electric current produced affect the efficiency value. The higher the voltage and electric current produced, the higher the efficiency value obtained. The average efficiency in the test with an arm length of 40 cm was 20.46%.

The average efficiency of 20.46% in this study is in line with the basic theory of the point absorber type wave energy converter (WEC), a concept first introduced by Budar and Falnes in their 1975 article in the journal Nature on the resonant absorber of ocean wave energy. A WEC device is categorized as a point absorber if the diameter of the device is much smaller than the wavelength captured, as is the condition of the buoy used in this study.

Theoretically, the low efficiency of converting wave energy into electrical energy is not caused by a single factor, but rather by the cumulative results of several stages of conversion. The point absorber type WEC system basically goes through three main stages, namely wave energy absorption, mechanical energy transmission, and conversion of mechanical energy into electrical energy, where the efficiency at the wave absorption stage will greatly affect the overall performance of the system. This supports the findings of this study, where energy loss can occur starting from the process of capturing wave lift force by a buoyancy, transmission through a single-way pulley and bearing system, to finally being converted by a generator (Budar & Falnes, 1975).

In addition, researchers such as Evans, as well as Budal and Falnes, have developed theoretical solutions to determine optimal power take-off (PTO) conditions to maximize wave energy extraction. This concept is relevant to the dual one-way bearing mechanism used in this research tool, which serves as a simple PTO system to convert the up and down motion of the float into continuous rotation on the generator shaft. The efficiency of the PTO system is one of the variables that determines how much wave energy is successfully converted into electrical energy, and this has become a focus of optimization in various WEC studies (Budal & Falnes, 1982; Evans, 1976; Falnes & Hals, 2012).

Furthermore, various studies since the 1980s have sought to maximize the efficiency of energy capture in the point absorber type WEC, both through the optimization of the shape of the float and its PTO system. This strengthens the argument that improving the efficiency of this research prototype, for example by increasing the diameter or volume of the buoy, extending the float arm, or improving the puli transmission mechanism is a development direction consistent with WEC research trends in general. Thus, the efficiency value of 20.46% obtained at an arm length of 40 cm is reasonable for a laboratory-scale prototype, and has the potential to be improved through mechanical design optimization as suggested in the literature.

CONCLUSION

Based on the entire design process of the Marine Wave Power Generation Machine Model for Educational Teaching Aids, it can be concluded that the developed model has dimensions of 1900 × 300 × 800 mm, uses an electric motor with a power of 0.5 HP as a drive, produces a water wave height of 14 cm, and is able to produce a maximum electrical output of 6.34 V and 0.21 A. This model uses a variation of 40 cm buoyancy arm length, 45 cm, and 50 cm. The generating system works on the basis of artificial waves generated by the driving paddles to lift the buoys, then convert the linear motion into a translational motion that rotates the generator so as to generate electrical energy. The test results show that the length of the float arm affects the amount of electricity output produced. The largest output is obtained at the arm length of 50 cm, which is 6.34 V and 0.21 A, while at the arm length of 45 cm the output is obtained at 5.59 V and 0.35 A, and the smallest output at the arm length of 40 cm is 4.87 V and 0.27 A. The longer the float arm, the greater the moment and rotation on the pulley, so that the electricity output is also produced.

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