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Modeling And Analysis Mechanisms of Electrical Energy Generated By Power Sea Wave Type of Piezoelectric Rowboat

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Abstract

The availability of electricity in the middle of the sea is important for lighting the fishing boat. Therefore, it was designed on a rowboat mechanism associated with piezoelectric energy as the converter. This study simulates the movement of ocean waves with the frequency and amplitude variations that will produce different force. The force of moving components in the mechanism which further encourages piezoelectric cantilever. Deflection caused by the piezoelectric cantilever will produce electrical energy. The greater of the wave frequency, the greater displacement and velocity of thrustmass, so that electric power generated also increases. When the greater the number of Piezoelectric used, the electrical energy produced is getting smaller. This is due to the increasing number of hard piezoelectric added to be deflected. In this study, the maximum electrical energy produces the highest frequency, high amplitude and the number of piezoelectric slightly.

Keywords: Modeling, Power, Wave, Piezoelectric, Rowboat.

1. Introduction

Indonesia is a maritime country that most of the population have livelihoods as fishermen. Fishing activities on the high seas also require lighting equipment. Thus, the necessary electrical energy is as the power for the lights. Usually the electrical energy is available in the form of boat battery, so life duration is limited. Therefore, it needs to find alternative energy sources derived from the surrounding energy that can help fishermen to catch fish at sea in a longer time. Countries world-wide are exploring increased adaptation of renewable energy in order to achieve energy independence and fiscal benefits [1, 2, 3]. Several methods of harvesting energy that are being developed is piezoelectric. Piezoelectric is a smart material that is very sensitive and has a high energy density compared to electromagnetic.

Some studies that discuss such piezoelectric material is Andeza et al. [4] who has taken advantage of the various piezoelectric kinds of tools as transducer that can convert electrical energy into mechanical motion or force. The research conducted piezoelectric simulation to estimate the results of the distributed parameter. Type of piezoelectric cantilever beam modeled has the type of PZT-PIC 255. The force applied to the simulation process is 1 N with the natural frequency of 13.4 Hz beam. The power generated from this simulation depends on several parameters, namely resistance, position, frequency, and length of the piezoelectric. Energy generated maximum electrical power is obtained at the frequency of 13.4 Hz with resistance.

Furthermore, Hendrowati et al. [5] investigated discharging the Multi Layer Piezoelectric Vibration Energy Harvesting (ML PZT VEH) mathematically and simulated mechanism on the vehicle suspension system. The VEH mechanism was used to compress increasing force on the ML PZT elastic mass. Therefore the ML PZT elastic mass can generate electricity which is more than 2.75 times Comparedto with the electrical energy that is generated from the elastic mass ML PZT without the VEH mechanism. In addition, the ML PZT VEH discharging mechanism does not give effect to the characteristic performance of the vehicle suspension system response.

Research on Simulation of Ocean Energy Utilization by using the piezoelectric Coupled mode Buoyancy was conducted by Nan Wu et al. [6]. The working principle of the utilization of marine energy is made of several coupled piezoelectric cantilever attached to a buoy structure. In the structure of the buoy, cylindrical floatation device is connected to a larger cylinder. The electrical energy generated is obtained from transverse movement of ocean waves that touch piezoelectric mounted on buoys fix (stator). In this study, a figure of 24 Watt electrical power can be generated by a piezoelectric cantilever beam with the length of 1m and the length of a float moving along 20 m. The result showed that the largest RMS power was obtained when the cylinder length of 5 m. The maximum amplitude in the length of the cylinder was 19 m.

From this background, the research discussed about

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the characteristics of the electrical energy generated by paddle ofrowboat mechanism combined with piezoelectric. Characters of sea wave energy in Indonesia is used as input in the model simulations on the laboratory scale. With the paddle mechanism by the waves, the movement of the paddle can be transmitted into a mechanism, so that the movement can generate electrical energy. The formulation of the problem in this research is to design and simulate a wave power plant with rowboat mechanism, in order to determine the effect of frequency, sea wave height and the number of piezoelectric on electrical energy produced.

2. Design and Simulation Method

The design of the piezoelectric rowboat is adapted to laboratory scale so that it can be put on an artificial sea waves contained in the laboratory vibration and dynamic systems, Department of Mechanical Engineering, FTI-ITS. Dimensions of Sea Wave Power Plant (SWPP) type piezoelectric rowboat has the length of 30 cm, width 15 cm, and 15.5 cm high chassis, as well as paddle total arm length of 53 cm. Working principle mechanism of the design can be seen in Figure 1.

The working principle of the sea wave power plant on piezoelectric rowboat system is to utilize the horizontal force of the waves. At the time of the waves touch the surface of the paddle, the paddle will rotate and the pivot lever will shift the transmission shaft. Transmission shaft that moves horizontally will drive the thrust axle mass. They are mounted on two slider pads so that the thrust axle mass moves horizontally perfectly. After moving the shaft, the shaft will move the mass pressed upon piezoelectric. The force applied mass will make piezoelectric deflection booster. Deflection occurred in piezoelectric will produce electrical energy.

On Figure 2 it can be seen that the free body diagram of the complete Power Sea Wave Type of Piezoelectric Rowboat, there are three detailed sections. The first section, namely The section of influences and inertia arm's length paddle, the second section of are driving mass and piezoelectric elements. And the third section is a piezoelectric layer of protection with the deflection of a piezoelectric more than 6 mm.

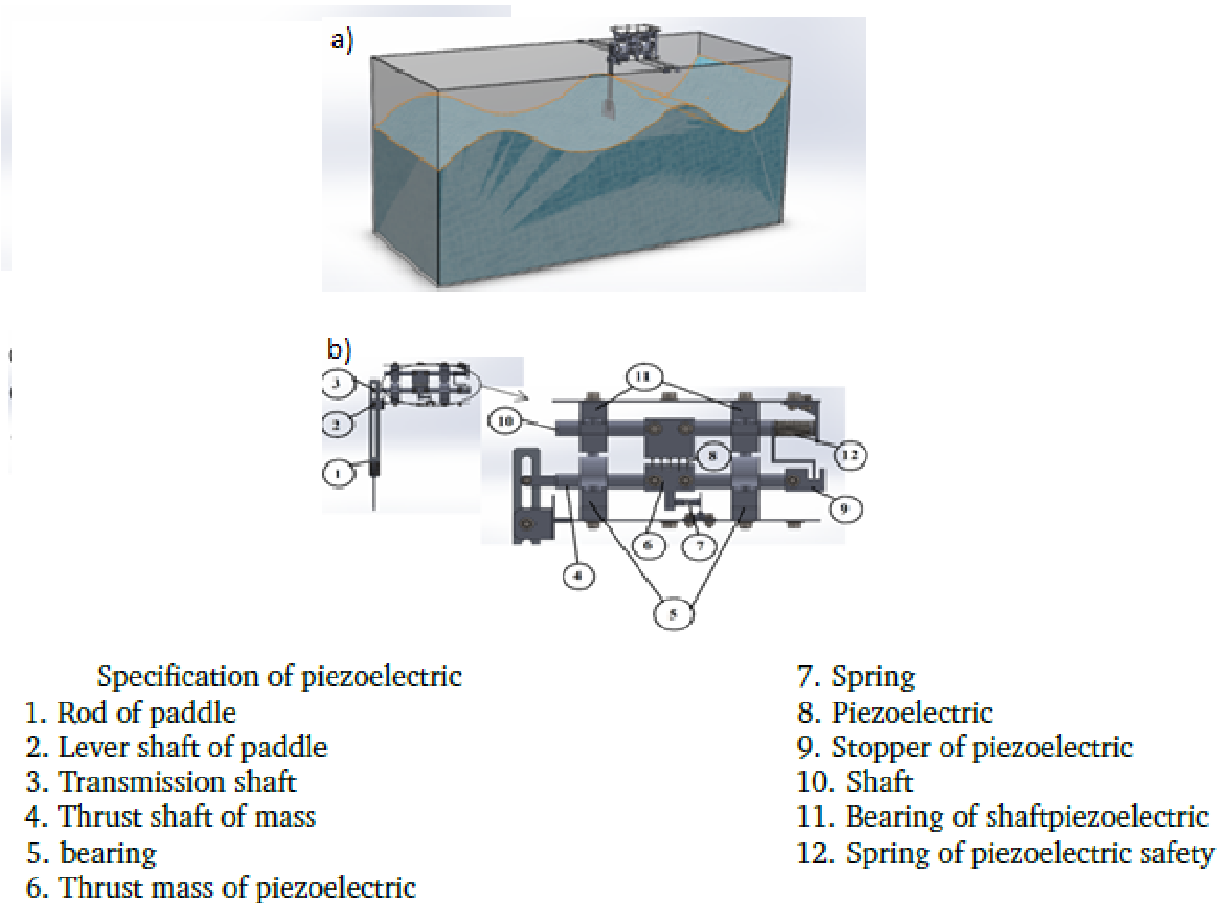
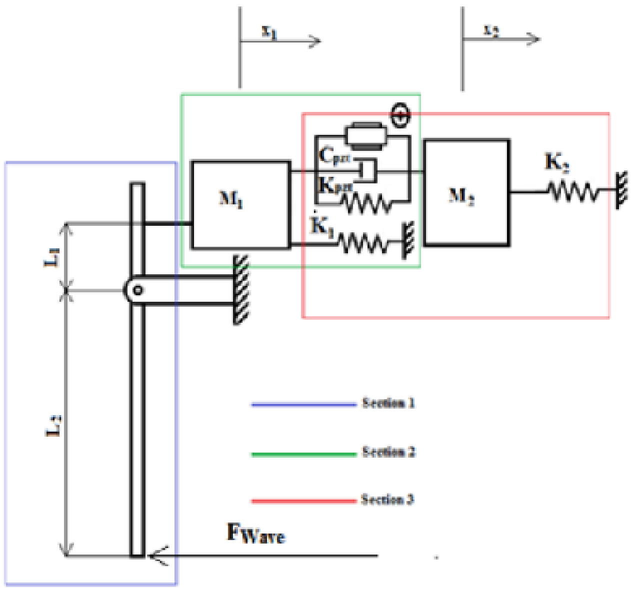


Figure 1. Mechanism of PP (a.) Installation of PP in the pool simulation (b.) Detail of PP Mechanism.



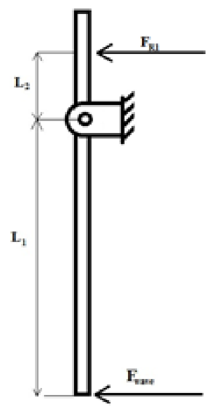
Specification of piezoelectric

- *Name of Piezoelectic* = (MiniSense 100)
- Capacitance *Piezoelectric* (C) = 244 Pf
- *Electromechanical coupling factor(k_{31})* =12 %
- Displacement of *Piezoelectric* (Xp) = 6 mm
- *Piezoelectric* Type = Paralel
- Stiffness of *Piezoelectric* (kp) = 17,5 N/m
- Damping Constant of *Piezoelectric* (Cp) = 0.00065 N.s/m
- Mass of *Piezoelectric* (mp) = 0.6 gram

Specification of rowboat device

- Thrust Mass = 389. 56 gram
- Mass of paddle = 287.73 gram
- Wide of paddle = 0.13 m
- Stiffness 1 = 200 N/m
- Stiffness 2 = 1000 N/m

Figure 2. Free body diagram.



L2 = 56 mm
L1 = 330 mm
L = 530 mm

Figure 3. Free-body diagram of Force mass

3. Results and Discussion

This study conducted a simulation of the characteristics of electrical energy generated by the mechanism of sea wave power plant type of piezoelectric rowboat.

3.1. Characteristics of Sea Wave

Sea waves are simulated artificial waves. The Characters of artificial sea waves provided in the laboratory vibration and dynamic system are described as a representative character of the simple sea waves. High waves generated by artificial sea waves range from 4 cm to 10 cm, and the wave frequency range from 0.8 to 1.2 Hz. Thus the modeling in this study refers to the parameter approaching parameter artificial sea waves.

3.2. Characteristics of Force Generated Mechanism

Characteristics of the force generated mechanism is the force that thrust piezoelectric transmitted through the mass, with the following mechanism of Figure 3 and Figure 4.

$$\sum M = \left(J_o + md^2\right)\ddot{\Theta}$$

$$F_{Wave}L_1 - F_{R1}L_2 = \left(\frac{1}{12}mL^2 + md^2\right)\ddot{\Theta} \tag{1}$$

$$F_{Wave}0.33 - F_{R1}0.056 = \left(\frac{1}{12}0.28773 \times 0.53^2\right)\ddot{\Theta} + \left(0.28773 \times 0.24^2\right)\ddot{\Theta} \tag{2}$$

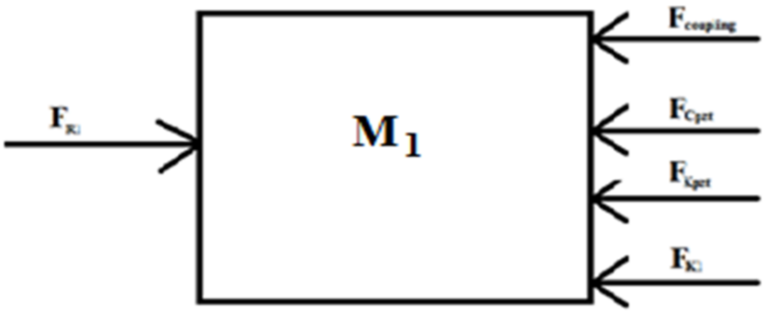


Figure 4. Free-body diagram of Force mass

$$F_{R1} = 5.893F_{Wave} - 7.43179\ddot{x}_1 \tag{3}$$

$$F_{Wave}0.33 - F_{R1}0.056 = \left(\left(\frac{1}{12}0.28773 \times 0.53^2\right) + \left(0.28773 \times 0.24^2\right)\right)\frac{\ddot{x}_1}{0.056} \tag{4}$$

The reaction force then pushes the driving mass, so the equation becomes:

$$F_{R1} - F_{K1} - F_{Kpzt} - F_{Cpzt} = M_1\ddot{x}_1 \tag{5}$$

$$5.893F_{Wave} = 7.82135\ddot{x}_1 + (K_1 + K_{pzt})\,x_1 - K_{pzt}x_2 + C_{pzt}\ddot{x}_1 - C_{pzt}\ddot{x}_2 = 0 \tag{6}$$

So, Fwave which transmitted is:

$$F = 5.893\frac{\rho g H^2 b}{16} \tag{7}$$

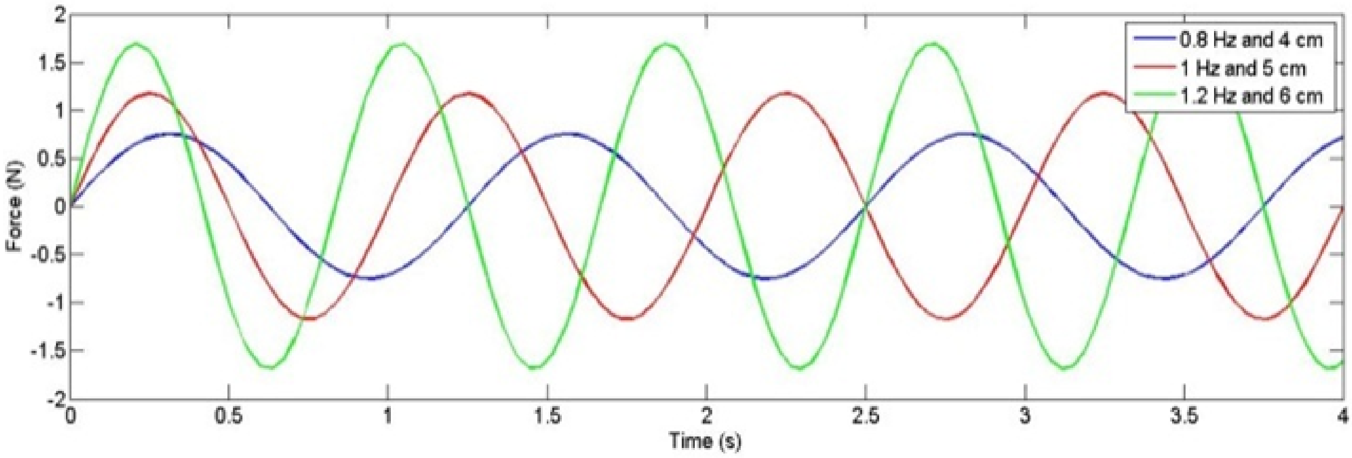


Figure 5. The resulting force rowboat piezoelectric mechanism.

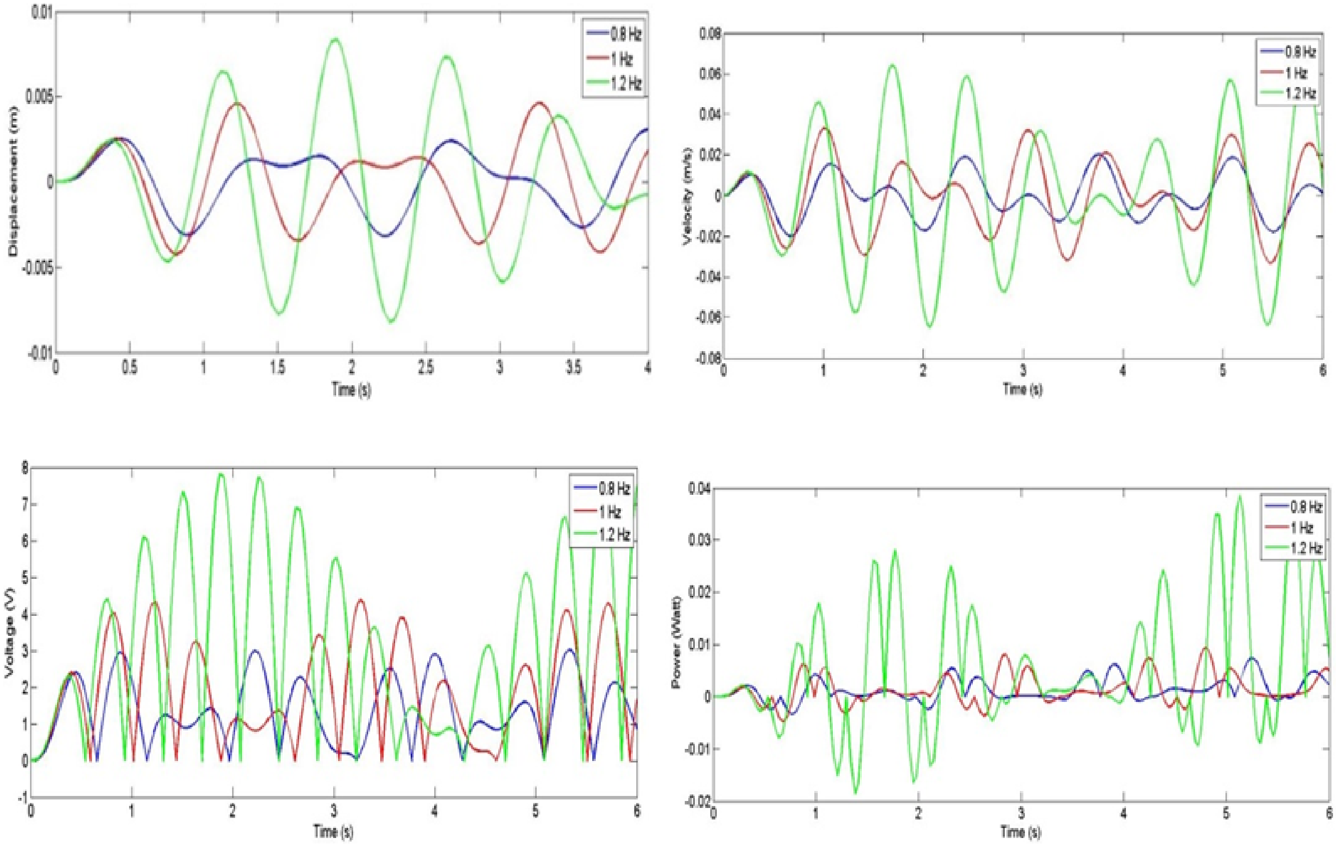


Figure 6. Dynamic characteristics of the thrust mass and energy generation with frequency variation.

By varying the height of the wave, there are 4 cm 5 cm, and 6 cm and wave frequency variation are 0.8 Hz, 1 Hz, and 1.2 Hz, it is shown in Figure 5. From the graph, it can be seen that the characteristic force is transmitted by a different system. The 4 cm wave height and frequency of 0.8 Hz is characterized by waves of blue, have the smallest force and frequency. For the red line, The wave height is 5 cm with the frequency of 1 Hz, with a force of 1.1742 N. The greatest force is 1.691N generated at the wave heights of 6 cm with the frequency of 1.2 Hz.

3.3. Characteristics of Electrical Energy generated Piezo-electric

3.3.1. Variation frequency

Figure 6 is a graph analysis of displacement, velocity and mass of the driving mechanism of the electrical energy generated by the piezoelectric rowboat. The wave frequency variation is 0.8 Hz, 1 Hz and 1.2 Hz at 4 cm of the wave height and 20 Piezoelectrics.

In the Figure shown that all of the graphs represent the highest value generated by the highest frequency. At the frequency of 1.2 Hz, mass displacement plunger has a 3.1 mm rms, with a speed of 33.9 mm / s. While electrical energy generated is 3.01 V and 7.9 x10^{-3} Watt. The highest yield is obtained at the frequency of 1.2 Hz wave, and the lowest result obtained is at the frequency of 0.8 Hz wave.

3.3.2. Variation of wave height

Figure 7 is a graph analysis of displacement, velocity and mass of the driver mechanism of the electrical energy generated by the piezoelectric rowboat variation of wave height is 4 cm, 5 cm and 6 cm, with a frequency of 0.8 Hz wave and the number of 20 piezoelectrics.

In Figure 7 it can be seen that all of the graph represent the highest value generated by the highest amplitude of the wave. In the wave of height 6cm, mass displacement plunger has a 3.1 mm RMS, with a speed of 23.3 mm / s. While electric energy generated was 2.95 V and 8.87 x10^{-3} Watt. The biggest value obtained is on wave height 6 cm, and the smallest value obtained is on wave of height 4 cm.

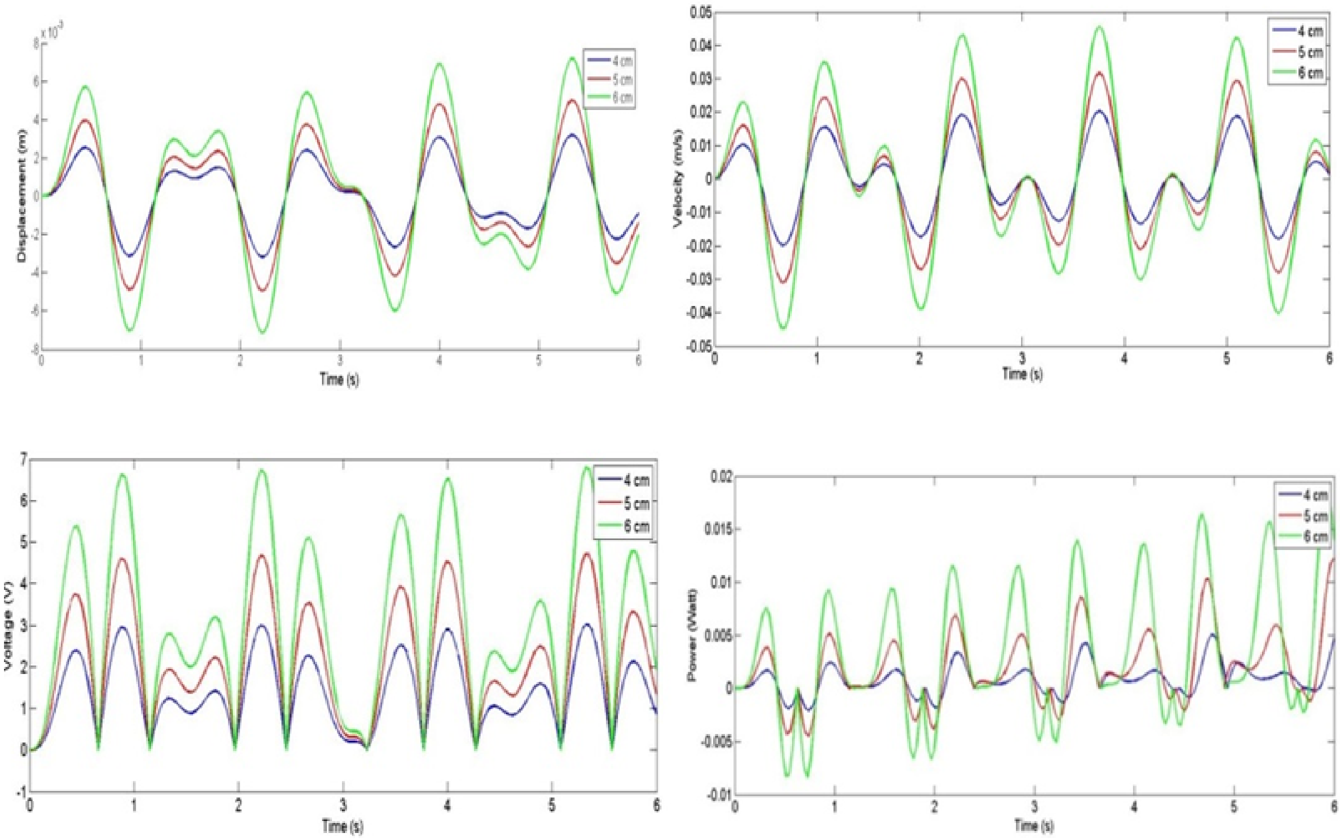


Figure 7. Dynamic characteristics of the driving mass and energy generation with frequency variation.

3.3.3. Variation of total piezoelectric

Figure 8 shows analysis of displacement, velocity and mass of the driving mechanism of the electrical energy generated by the piezoelectric rowboat. The variation number of piezoelectric namely 10, 20 and 30, piezoelectric, with each simulated at 4 cm wave height with the frequency of 0.8 Hz.

The shows that all of the graph representing the highest value generated by piezoelectric fewest number. With the number of 10 Piezoelectrics, mass displacement plunger with rms is 2.5 mm, with a speed of 19.6 mm/s. While electrical energy generated is 2.1 A and 2.6 x10^{-3} Watt. The biggest RMS value is obtained on the number of 10 piezoelectrics, and the smallest RMS value is obtained on the number of 30 piezoelectrics.

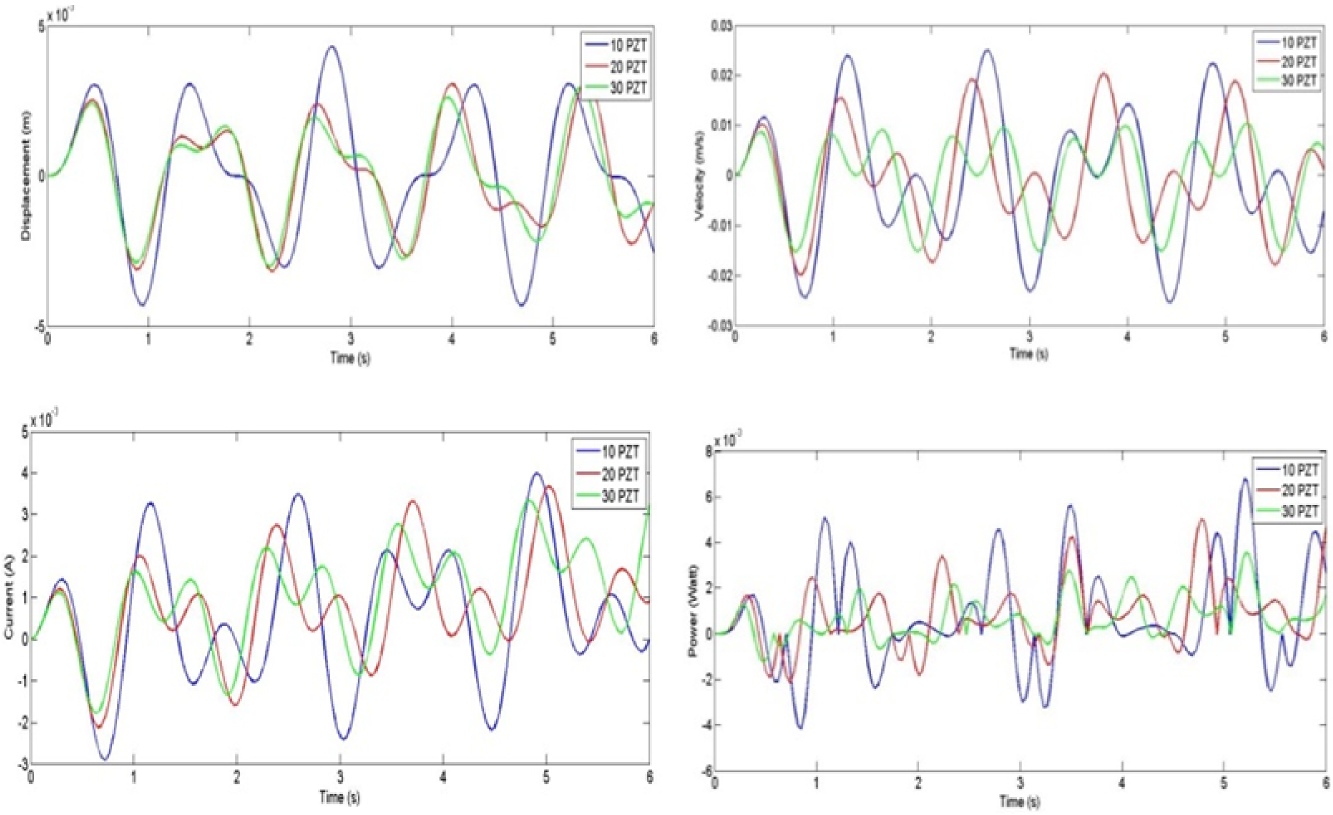


Figure 8. Dynamic characteristics of the driving mass and energy generation by varying the number of piezoelectrics.

3.4. Discussion of The Result

3.4.1. The effect of Frequency Wave, Wave Height and Total Piezoelectric Against Mass Displacement and Speed Booster

Figure 9 shows that the frequency and wave height increase will slightly affect the driving mass displacement and velocity on the number of piezoelectric. But, the increasing number of piezoelectric will be more rigid and reduce deflection. Therefore, displacement and speed of the driving mass become smaller.

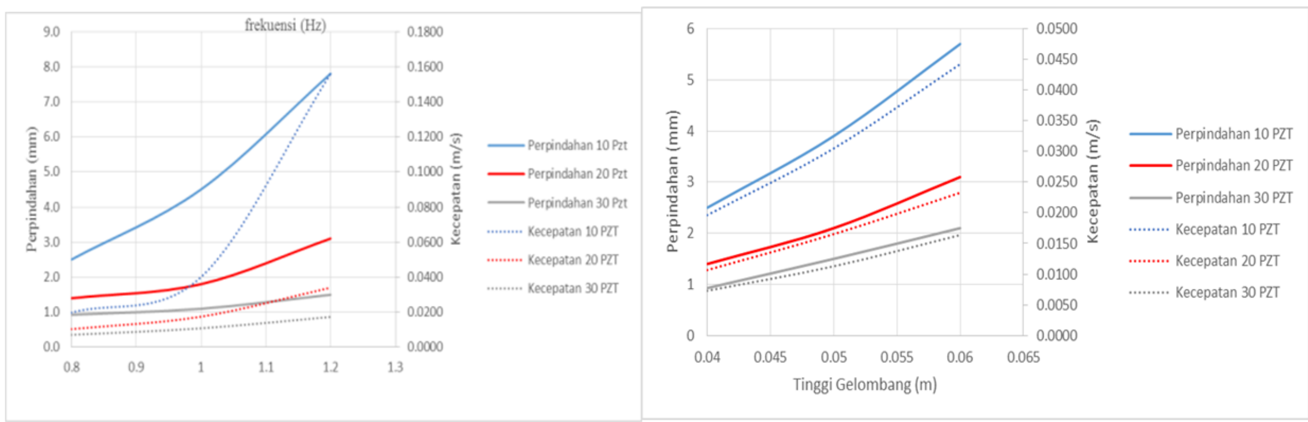


Figure 9. The effect of high-frequency and wave to the driver mass displacement and velocity.

3.4.2. The effect of Frequency Waves, High Waves and Piezoelectric Against Total Energy Generated

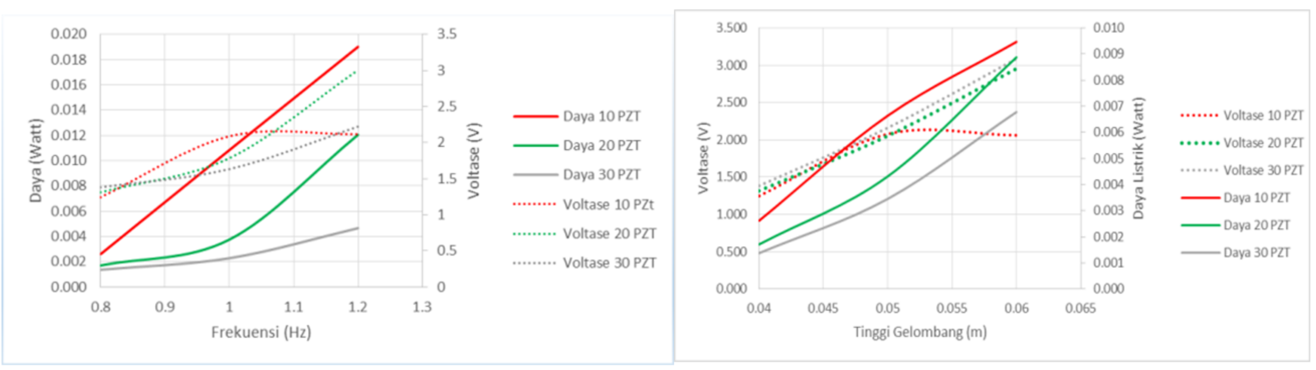


Figure 10. The effect of the frequency of the voltage generated.

Figure 10 shows that the increase in mass transfer is due to the driving force increase. The higher the wave forces, the higher the displacement created. It is in accordance with the formula,F=5.893 $\frac{\rho g H^2 b}{16}$ As for the frequency, it is very effective at the frequency of the power generated, P=$\frac{(E)}{T}$, When E is the kinetic energy, the greater the frequency given, the more energy is generated. However, if the number of piezoelectric increases, the increased stiffness of the mechanism generated will reduce the deflection of piezoelectric. Then the deflection of a piezoelectric velocity will be smaller.

When the wave height and frequency increase, the resulting deflection, deflection also increase. The deflection produced will increase the mechanical energy that occurs in piezoelectric.The mechanical energy will be proportional to the voltage produced as the formula shows V=$k_{31}\sqrt{\frac{2W_mech}{C}}$. It increases the mechanical energy of the more large voltage generated. However, if the piezoelectric and coupling factor increases, the deflection will decrease.

4. Conclusions

The conclusion of this research,

1. The frequency and wave height are inline with the proportion of the mass displacement and speed of driving. The greater the frequency of the waves occur, the greater the driving mass displacement and velocity occur. The greater the speed of deflection of piezoelectric, the greater the electric current generated. Thus, the power will increase when the frequency and wave height also increase.
2. The number of piezoelectric affects the voltage piezoelectric generated. But, it will reduce the strong electric current due to the speed of deflection of diminishing returns. The increasing number of piezoelectric which is not proportional will not raisesignificantly instead of drastically decreased powerful current. Therefore, the increase number of piezoelectric before the saturation point, the piezoelectric will decrease the electrical power.

5. Acknowledgments

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