Design and Development Water Wave Propagator System from Speed Bump Energy Harvester

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Wave Propagation
Speed Bump
Wave Turbine

Abstract
One of the many issues faced in the modern world is the lack of clean, green, and renewable energy sources. Therefore, to address the issue of sustainability, a new system design was proposed, designed, and fabricated. In this work, a novel mechanical design was proposed, namely Wave Propagator and Turbine that produces waves and harvests the energy accordingly. Practically, the energy generated by the speed hump energized a battery that powered a linear actuator. The energy generated from speed humps was converted and boosted to a certain degree, which was preferably at a 150% rate in the form of wave energy. Although the losses were significant, it could be noticed that the proposed system could meet the major objectives of this study by boosting the generated energy by up to 130%, and it had an outstanding range in boosting the power over a period of time. This was attained after it was translated by using wave motion that was indefinite in magnitude and direction as per the speed hump that moves linearly. In terms of assessing the feasibility of this paper, multiple components were adopted, and each had its own unilateral breaking point. CAD software was used to produce a 3D model, and CFD software was also used to figure out the generated waves’ property to get a generalization of the working mechanics. The design was then put under different operating conditions to test its breaking point and to gather its factor of safety.

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1. INTRODUCTION

According to the Malaysian Highway Planning Unit, a speed bump is defined as a raised pavement area with average measurements of 6.71m-9.14m in width and 3.5m-4m in length [1]. Although this is said to be the average, it is not uncommon to find speed bumps in Malaysia that do not meet these requirements. This is partly because many speed bumps have been illegally installed in residential areas and elsewhere by communities to promote a safer environment and discourage cars speeding in areas with small roads. This is understandable as speed bumps serve as traffic calming devices that slow down motor-vehicles and improve safety conditions on roads [2].

By harvesting and storing the energy generated, it is possible to release a regulated flow of electricity rather than rely solely on input [3]. This would have otherwise rendered the project inefficient as it would then require constant traffic flow to produce enough electricity to power a wave propagator. With a system heavily reliant on the availability of a high traffic flow, it is recommended that this type of system could be used as a power source to power crucial systems that do not require a constant power supply [4]. Examples of such places where constant power supply is not critical are perhaps rest areas and shop lots located along a highway, powering lights around the lake, or even powering lights for billboards.

The project’s main goal is to introduce two power generation methods together to use each other. This is to effectively step up the initial power generated and make a self-sustainable system that harvests energy from the unused energy generated by high flow traffic. If it is successful, this project will provide a viable alternative to provide power supply towards areas experiencing high traffic and have lakes due to geographical positioning.

Researches in this area are scarce, and not many have dared to attempt to manipulate mechanical waves as it is seen with the most loss during the conversion of energy [5]. Moreover, mechanical waves are unpredictable and can cause erratic readings, which may never be constant [6]. Only an average power outage can be calculated as
well as the power coming in. The barriers that a mechanical wave propagator can be used may bring light to our energy crisis that seems to be the most common worry within great thinkers and humankind alike [3].

This paper deeply investigates the proposed design of a prototype that acts as a booster from methodical ways to harvest energy and generate electricity. This is despite the fact that several hybrid ways to harvest energy have been a long thought for humankind [7], [8]. This paper, proposed a method whereby a speed hump energy harvester is used to produce electricity using piezoelectric. Subsequently, the electricity is then converted to mechanical force to boost the generated power. This paper aims to provide a safer road and environment without leaving a large amount of carbon footprint. This paper will also explain the mission and vision to achieve a greener environment by utilizing acoustic mechanical waves that exist in natural form to produce miraculous feat. In essence, the roadways, usually surrounded by a body of water, are often not unlit. This creates an opportunity where a hazard may occur and cause us to fret for our lives during a night drive. Furthermore, it can also be utilized for other beneficial selfless acts such as powering pumps, compressors, and many more with the proper implementation.

2. DESIGN WATER WAVE PROPAGATOR SYSTEM FROM SPEED BUMP ENERGY HARVESTER

The proposed prototype is designed and developed to act as a booster in methodical ways. This is to harvest and generate electricity that has been an achievement in humankind, but the hybrid ways to harvest energy have also been a long thought for humankind. For this paper, a method is proposed where a speed hump energy harvester is used to produce electricity with the help of piezoelectric, which is then converted to mechanical force that boosts the energy by 150%. The project’s vision is to act as a natural way to provide a safer road and environment without leaving a large amount of carbon footprint as it is usually done by the masses (gravity). This paper explains in detail the mission and vision to achieve a greener environment by utilizing acoustic mechanical waves that exist in a natural form to produce a miraculous feat that may be seen as revolutionary [9].

A. Selection Design of Speed Bump Energy Harvester

The best way to harvest energy using speed bumps is to be investigated, and the feasibility to be analyzed. The main aim of the proposed speed bump energy harvester is to power a mechanical wave propagator to boost the amount of energy attained from the speed bump. The mechanical wave propagator acts as an energy booster by sending a continuous stream of mechanical waves to be harvested and boosted from the current state, which is in the electric form [10]. The mechanical wave propagator aims to boost the energy by 150% of the input so that it can increase the efficiency and has a likelihood of creating a hybrid system. As for the speed bump energy harvester, the design of the system was split up into several sections, namely, the top, springs, and the base.

Figure 1. Front View of Speed Bump Energy Harvester

The speed breaker dimension was adopted from the standard size set by the local ministry of works in Malaysia, as shown in Figure 1. For the speed breaker design, a flat top would be suitable for areas requiring low speeds and comfortable for larger vehicles, such as in this study. The used springs were installed within the system, which is a crucial part of the proposed system as they directly affect the outcome and working mechanism of the system. There was a total of three springs attached to the underside of the speed breaker, connected to the flooring. Accurate dimensions were carefully set for these three helical compression springs so controlled movements within the unit could be attained. This ensures that no damage could be done to either the vehicle or the piezoelectric set up [11]. The springs’ ends were squared and grounded to provide a better transfer for the load and more stability. The material of Music Wire ASTM A228 was used because of its ability to withstand high stress under repeated loading. The mechanical wave propagation can be seen where it can be seen that the motor is fixed into the ground where it functions in a linear motion. When the bar moves towards the motor, it compresses the spring with the help of the pulley, which pulls the plane towards the wall of the lake. The spring experiences an increase in potential energy. When the bar moves against the motor, it releases the tension in the wire hence, releasing all the energy from the spring into the water body. Therefore, the body of water experiences a displacement and causes the wave to form where it will produce wave energy to be harvested by the floating turbine in a designated lake at a designated distance to harvest the energy, as shown in Figure 2.

The motor will constantly work as long as there is enough power in the used battery. The battery means to be charged by a speed hump energy harvester, which harvests energy from the speed hump through piezoelectric materials, which charge the battery as the car goes over the speed hump [12]. The springs work constantly and release a force as much as 1921.6 N (Newton) in total when it is arranged in such a
manner that is parallel to one another. The face of the panel may be subjected to change due to its area, which may seem to be the best in producing mechanical waves in the body of water. The pulley acts as a conveyor of sorts that transport the energy from the motor in the form of the motion to compression in the spring. The cables play an essential role in the compression of the spring. It also has to withstand the force acting on it by the motor and springs, which may cause tension. However, the cable has a minimum breaking point of 5kN that is high and more than what the spring can produce even after maximum compression. Meanwhile, the pulley acts as the first line of defence of the motor against the water. Motors and water do not come hand in hand due to the motor’s nature of having multiple electronic parts that are not resistant to rust and water damaged should water seep into the motor. The pulley gives a safe distance for the motor to operate without much interaction of water besides rain and unfortunate circumstances such as flooding \[7\], \[13\].

**Figure 2.** Designed Spring.

**Figure 3.** Schematic Drawing of the Mechanical Wave Propagator. Harvester

The motor will constantly work as long as there is enough power in the battery which powers it. The battery is charged by a speed hump energy harvester, which harvests energy from the speed hump through piezoelectric materials, which charge the battery as the car goes over the speed hump \[8\]. The springs work constantly and release a force as much as 1921.6 Newton in total when arranged in such a manner that is parallel to one another. The face of the panel may be subjected to change due to its area, which may seem to be the best in producing mechanical waves in a body of water, which would be as shown in Figure 3. The pulley acts as a conveyor of sorts that transport the energy from the motor in the form of the motion to compression in the spring. The cables play an essential role in the compression of spring, and it also has to be able to withstand the force acting on it by the motor and springs, which may cause tension. However, the cable has a minimum breaking point of 5kN that is high and more than what the spring can produce even after maximum compression \[14\], \[15\]. Meanwhile, the pulley acts as the first line of defence of the motor against the water. Motors and water do not come hand in hand due to the motor’s nature of having multiple electronic parts that are not resistant to rust and water damaged should water seep into the motor. The pulley gives a safe distance for the motor to operate without much interaction of water besides rain and unfortunate circumstances such as flooding.

**B. Design of Stress-Strain Analysis**

The stress-strain analysis on the Plane Wall propagator is essential to ensure that the created dimensions and materials are appropriate. This is because it could be open to the elements such as forces from the spring and the drag force produced by the waves. The simulation was done by using PTC Creo 5.0. Under the force of 7.6576 kN exerted by four springs and drag force of 193.6673 N that are both in opposite directions. The drag force was assumed to be an equal force against the plane wall, and hence the calculations of the moment were neglected. This is due to the uncertainty of a water body that might respond differently to the particles floating on the water, which might constitute different readings. PTC Creo 5.0 ensures that the data calculated tallies with the simulation and get more detailed information on the forces such as stress-strain analysis and the computational fluid dynamic (CFD) of the waves \[8\], \[16\].

The force acting on the plane wall could be seen in total as heading towards the negative on the Z plane with a magnitude of the force of 7.4637kN. The Stress-Strain Analysis can be inferred. Simulations were done to ensure that all the forces acted out in unison to prevent any misplaced force faced by the Plane Wall, as shown in Figure 4.

The springs are essential in handling all the stress as it is the most crucial part of releasing and containing the energies that are transferred to the body of water to propagate waves. In fact, the springs mechanism can impact productivity as well as the functionality of the system. The calculated total force that the springs can hold or withstand in unison is...
7.6567 kN. This is with a spring constant of 30630.272 kN/m in total. The displacement of the springs is expected that of 250 mm, which is designed to provide the length of compression.

The overall view of stress analysis of the springs can be seen as the stress analysis, the strain analysis, and the displacement of the spring which shows how far the springs are subjected to force and the readings that come with it. The springs are simulated with a 7.6576 kN, which acts in unison. The displacement was also subjected to the springs to get a more decisive reading that can further explain the data generated, which shall determine whether the force can be handled by the springs or not. Moreover, the strain analysis can also be inferred through a series of simulations that can be deduced and the extended length or compression length of the springs can be calculated and matched with the criteria of making the spring an essential part of the system in harvesting wave energy.

The stress analysis of the springs is the cause of force being applied at the top of the spring while the other spring is fixed at a stationary wall, which will cause the spring to gain a large amount of potential energy when it is compressed. Furthermore, the spring will, in turn, convert the potential energy to kinetic energy as it has no other methods to release the energy that has been stored by the material. The stress analysis can be shown as the amount of pressure acting onto the spring. From the conducted simulation, it can be seen that the springs absorb most of the stress as the handles on either side have no contact or have a minimal amount of independent forces acting on them. It provides wholesome support for the spring mechanism so that it can withstand the forces acting upon it.

The first step to a CFD simulation is the geometry that the water or liquid will flow through. In this case, the geometry is made of a two meters depth of the body of water, and 5 meters in length. The flow is to emulate and capture not the entirety of the system but rather its component as it passes through the scope of the mentioned data. After visualization, the geometry is concluded. After the geometry is realized, the next step is to mesh the area. This is to visualize where the water will flow, the open air, the boundary, what is stationary and so forth. The geometry has to be realized before the simulations can begin. In this case, the geometry is that of a portion of the body of water that is exposed to the water while the other is flowing as per the waves. The flowing direction of the waves also needs to be realized before it can proceed. After the design is realized, meshing the geometry is required. This is the action of breaking down the geometry into smaller pieces to be read at different rates per part, increasing the accuracy its calculations. After the meshing is done and the way of the water flows are set, and the walls of the body of water are set. This will, in turn, be the time for calculations to be done. The calculations are given either in time steps or iterations that can be set and generated. The following simulation took 7 hours to have more precise data as it requires a lot of information to get the correct and accurate data; however, before the data being accumulated. Sets of calculations are performed and needed to fulfill the criteria that are filled in the simulation. Such equations can find the height of the waves, the amplitude, the wavelengths, and the frequency. Lastly, the data generated through the calculations can be visualized by the generations of 3D viewings to be easily understood and interpreted. The data gathered are then transferred into a more susceptible way to calculate with the variables being known under this controlled simulation that has taken place. The higher the number of iterations, the more accurate it becomes the simulation [16], [17].

C. Speed Bump Energy Harvester Analysis

In designing springs suitable for allowing the speed breaker to descend upon contact with a vehicle and ascend back to the original location once the vehicle has passed, several calculations need are made. In total, the design will accommodate 6 springs, and the calculations below are for each spring:

\[ N_l = N_a + N_e = 6 \]  \hspace{1cm} (1)

With a total of six coils needed per spring, the solid length of the springs can then be found using:

\[ L_s = dN_l = 36\text{mm} \]  \hspace{1cm} (2)

The spring index is defined as below:

\[ C = \frac{D}{d}, \quad C = 13 \]  \hspace{1cm} (3)

Using the applied force as well as the deflection of the spring in reaction to the force, the springs constant can be found using:

\[ F = kx, \quad k = 225N/mm \]  \hspace{1cm} (4)

There are many different shapes and sizes of piezoelectric components. Among the options are piezo actuators, piezo motors, and piezo transducer. Of which, there is soft ceramic. In this paper, a soft piezo transducer will be used. A rectangular piezo plate having a width of 60mm, a length
of 80mm, and a height of 5mm. The piezo plate is sturdy enough to be exposed to daily shock.

\[ V = \frac{Q}{C} = \frac{dF}{C}, \quad C = \frac{tghh}{\varepsilon R \varepsilon_0 h}, \quad V = 5.5766 \text{V per car} \tag{5} \]

The energy harvesting module used is the LTC3588-1 by Linear Technology. This model has a low-loss full-wave bridge rectifier to convert AC to DC with minimal losses. It also has a high-efficiency buck converter, which automatically turns on and off to maintain regulation. The function of the buck converter is to step down voltage while stepping up current between the input and the output. Output voltages can be selected between pins of 1.8 V, 2.5 V, 3.3 V, and 3.6V.

\[ P = IV, P = 0.36 \text{W per deflection} \tag{6} \]

where each vehicle produces 4 deflections resulting in 1.44 W per vehicle.

With the power calculated and an estimation of 20 cars passing over the speed breaker per hour per day, estimations can be made for the power produced per day, month, and also annual power generated. The power ratings are as follows in Table 1.

<table>
<thead>
<tr>
<th>Time Frame</th>
<th>Power Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Daily</td>
<td>691.2Wh</td>
</tr>
<tr>
<td>Weekly</td>
<td>4.84kWh</td>
</tr>
<tr>
<td>Monthly</td>
<td>20.74kWh</td>
</tr>
<tr>
<td>Annually</td>
<td>248.83kWh</td>
</tr>
</tbody>
</table>

Table 1. Estimated Power Output

To conduct the stress analysis on the speed bumps, the theoretical load has to be found. Assuming the average weight of a car is 1,626.5kg (16,265N), the force of two wheels acting on the speed bump simultaneously as the vehicle crosses over it is 8,132.5N, which would be as shown in Figure 5.

\[ F_{spring} - F_{drag} = F_{Total} = 7.4637kN \tag{7} \]

Hence, the force acting on the plane wall can be seen in total as heading towards the negative on the Z plane with a magnitude of the force of 7.4637kN. Stress-Strain Analysis
can be inferred. Simulations are done to ensure that all the forces acted out in unison to prevent any misplaced force faced by the Plane Wall, as shown in Figure 8. From the data inferred in the Stress Analysis that is carried out on the plane wall, the highest stress region is on the spring’s contact with the face because it faces a strenuous and high force due to the sudden and high intensity of force being generated to push the planned wall. The highest Von Mises stress readings are 10760.4MPa. While the lowest stress can be clearly seen at 17.875MPa. The equation which explains in detail of the stress readings are seen as:

\[ \sigma = \frac{F}{A} = 6.936 \times 10^{-7} m^2 \]  

where \( \sigma \) is known as the Von Mises stress (MPa), \( F \) is the force (Newton), \( A \) is Area (m\(^2\)).

The area experiencing the high Von Mises stress is only \( 6.936 \times 10^{-7} m^2 \), which is significantly low compared to even the diameter of the spring arms holder. The springs are essential in handling all the stress as it is the most crucial part of releasing and containing the energies that are to be transferred to the body of water to propagate waves. It is the most crucial part of the whole system and mechanism as it will impact the productivity and the functionality of the system. The total force that was calculated that the springs can hold or withstand in unison is 7.6567 kN with a spring constant of 30630.272 kN/m in total. The area that experiences the highest pressure or force can be calculated. The area that experiences the force and stress is significantly small and therefore causes no alert as it is relatively small, and it is not in the red zone where it is deemed as dangerous and might face failure. The area that is experiencing high Von Mises stress is only \( 6.936 \times 10^{-7} m^2 \), which is significantly low compared to even the diameter of the spring arms holder, as shown in Figure 9. The strain analysis, however, yields a different form of results. It shows that there is minimal yielding in the area where the forces are applied. It shows that the spring is in the comfort zone as it does not fail or has reached its yielding point. This might cause a failure in the functionality of the mechanism. The maximum strain reading is seen to be at \( 5.204 e^{-03} \) at the maximum principal on the spring’s inner side. This can be elaborated more when the equation is elaborated.

\[ \varepsilon = \frac{l}{l_0} - 1 = 0.2513m \]

where \( \varepsilon \) is the strain and has no Units, \( l \) is the elongated length (m) = 0.2513 m, \( l_0 \) is the original length (m). From the formula above, it can be calculated that the length of the spring is compressed and hence get a better understanding of the working mechanism of the springs.

3. RESULTS AND DISCUSSION

The prototype was built to a scale of 1:10 in lieu of collecting data to be validated against calculated values determined earlier. The data were collected utilizing connecting a multimeter to the assembled prototype and recording data. The assembled prototype is shown in Figure 10. The top is made of a section of the modern-day speed breaker commonly found on streets especially shopping malls or condominums. Four springs were placed, with one at each corner. The base was made of wood and the deflectors were also made of wood [18], [19].

\[ \varepsilon = \frac{l}{l_0} - 1 = 0.2513m \]

A total of two piezoelectric strips were included in the prototype, and a breadboard to connect the circuit. The wires were soldered onto both the piezoelectric strips and
then connected in parallel in the breadboard. The energy harvesting module was also installed into the breadboard connected to both the piezoelectric power generators opposing the side to be deflected. Figure 11 shows the base of the fabricated prototype where the piezoelectric modules and the circuit are placed. The prototype was then tested with a weighted loading of 7.5 kg and 9.5 kg. The output voltage and current were then measured by using a multi-meter.

<table>
<thead>
<tr>
<th>Load (kg)</th>
<th>Voltage (V)</th>
<th>Current (mA)</th>
<th>Power (W)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>9.5</td>
<td>22</td>
<td>0.209</td>
</tr>
<tr>
<td>5</td>
<td>11</td>
<td>22</td>
<td>0.242</td>
</tr>
<tr>
<td>5</td>
<td>10</td>
<td>22</td>
<td>0.220</td>
</tr>
<tr>
<td>5</td>
<td>12.1</td>
<td>22</td>
<td>0.2662</td>
</tr>
</tbody>
</table>

The experimental data shows a variance due to the different effects experienced each time the load is released onto the prototype. Although not by much, the variance arose due to not controlling the impact time of the loading. But the results are not far apart and thus conclusive. The average values of the experimental data are to be compared to the theoretical data calculated. The average voltage generated by each deflection is 10.65V. The average current generated by each deflection is 22 mA. Thus, the average power produced by each deflection amounts to 0.2343W. Table 2 shows the experimental results, and Table 3 shows the experimental data compared to theoretical data.

Data from the table above can be interpreted better in a bar graph, as shown in Figure 12.

<table>
<thead>
<tr>
<th>Voltage (V)</th>
<th>Current (mA)</th>
<th>Power (W)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10.65</td>
<td>0.2343</td>
<td>0.36</td>
</tr>
</tbody>
</table>

Figure 11. Base of Prototype

Figure 12. Graph of theoretical against experimental data.

A small-scale prototype was designed and created by using affordable and durable materials for economic purposes. The proposed design has 5 major parts, namely the actuator, pulleys, cables, springs, and the plane wall. For validating the simulation results, experiments have been conducted either on a small scale or an actual scale. In this case, a small-scale experiment was done to validate the simulation results and has proven the functionality of the proposed design [19]. From Table 4, the results were generated to provide a pattern of response from the actual simulation calculations. In this case, the constant variables were classified as the body of water has a constant viscosity and density. In fact, the changing variable is the speed of the actuator to determine the speed of the wave being propagated by running the designed model. In return, the observing variables are the wave height and wavelength, which allow the properties of the wave, such as its frequency. The results are tabulated by making a graph to present data visually. However, since there are no ways to measure the power generated without the utilization of turbines, this experiment is overbudgeted. The more economical approach is to gather the spreadsheet date of the turbines that are supposed to be used in this experiment and the information such as the efficiency of the turbine converting wave energy to electrical energy. The data can then be calculated and used to interpolate the results so that it may be used to gather more intuitive information for the betterment of the project [19]–[21]. The voltage of the actuator and the speed of the are constant hence making it move at a constant rate where the data can be inferred from the simulation with the proper variables. Based on the turbine efficiency and the power loss after travelling through the wires. The estimated loss is about 30%, where 70% can be harvested and utilized.

Figure 13 shows the wavelength and wave height was gathered from an experiment where a scale to measure the waves using a translucent wall, which was used to dictate the magnitude of length and height of the waves. The ac-
Table 4. Results gathered from Experiments and simulation.

<table>
<thead>
<tr>
<th>Voltage to power the actuator (V)</th>
<th>Speed of the Actuator (mm/s)</th>
<th>Wavelength (m)</th>
<th>Height of the Wave (m)</th>
<th>Frequency of the Waves (Hz)</th>
<th>The power generated (W)</th>
<th>Actual Power Generated (W)</th>
<th>Percentage of Boost (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>24</td>
<td>100</td>
<td>2.11</td>
<td>0.25</td>
<td>0.0474</td>
<td>1258.44</td>
<td>880.908</td>
<td>139</td>
</tr>
<tr>
<td>24</td>
<td>100</td>
<td>2.14</td>
<td>0.23</td>
<td>0.0467</td>
<td>1277.31</td>
<td>894.117</td>
<td>141</td>
</tr>
<tr>
<td>24</td>
<td>100</td>
<td>2.47</td>
<td>0.24</td>
<td>0.0404</td>
<td>1476.49</td>
<td>1033.543</td>
<td>163</td>
</tr>
<tr>
<td>24</td>
<td>100</td>
<td>2.65</td>
<td>0.26</td>
<td>0.0377</td>
<td>1582.23</td>
<td>1107.561</td>
<td>175</td>
</tr>
<tr>
<td>24</td>
<td>100</td>
<td>1.89</td>
<td>0.19</td>
<td>0.0529</td>
<td>1127.60</td>
<td>789.32</td>
<td>125</td>
</tr>
<tr>
<td>24</td>
<td>100</td>
<td>2.19</td>
<td>0.26</td>
<td>0.0467</td>
<td>1277.31</td>
<td>894.117</td>
<td>141</td>
</tr>
<tr>
<td>24</td>
<td>100</td>
<td>1.97</td>
<td>0.27</td>
<td>0.0508</td>
<td>1174.22</td>
<td>821.954</td>
<td>130</td>
</tr>
</tbody>
</table>

The actuator was then started to create a series of waves with the plane wall pushing the plane in a linear motion where it can be used to create waves. The wave's height and length were then recorded. In order to find more information such as the frequency of the waves as well as the power that can be generated from the waves, minor calculations were performed to find the theoretical number of waves that may be generated as well as the power that can be generated from the turbine-based on its efficiency.

![Figure 13. Wavelength vs. Power Generated graph.](image)

The wavelength plays an important role in the power generated as it is vital in finding out and determining the speed, magnitude, and frequency of the generated waves. The waves are propagated through a series of repetitive ripples where it breaks the tension of the water and causes it to create energy. However, it can be seen that the wavelengths are not continuous and rather have their amplitude at a high and low. The matter at hand is due to the lapping of water smashing into waves generated. It minimizes the wavelength where the two-wavelengths crashing with each another equates to a magnitude of the force that lessens over time. This is due to the fact that the waves are mirrored back against the propagating waves, which in turn lessen the magnitude of waves as it travels in the opposite direction. Moreover, based on the data inferred, it has a similar pattern where the data are scattered as it is of two different variables that affect one another. The data gathered can be seen as sporadic and are everywhere. This is also due to the standing issues that waves in the opposite direction are mirrored back to the propagating incoming waves, which lessens the magnitude hence its wave height. With the rigorous motion of the actuator that provides the propagation of waves, it is feasible to see that the waves generated need to have a time controller before running again as it can provide no mirrored waves against the propagated, which may decrease the magnitude of the height and length of the waves which will then cause a lesser magnitude that is unfavourable in this project.

![Figure 14. Graph of Wave Height vs. Actual Power Generation.](image)

In addition to the matter of losses that may occur from the waves being reverted from the wall of the surrounding areas that play a significant role in decreasing the amplitude of the waves, another matter is also the losses from the turbine. A standard water turbine that has an efficiency range of 70% - 90%. In this paper, however, an estimation taking the lowest efficiency of the turbine was done [21]. The Mechanical Wave Propagator matches its objectives to achieve 150% of boosting in power averagely. The losses are significant, but it still matches the objectives and meets its requirement as it is considered to be boosting up to 130% at its lowest but has an outstanding range in boosting the power over a period of time. Figure 14 shows that the graph of wave height against the actual power generation and the final comparison have been made between power generated with turbine losses and no turbine loss (Figure 15).

4. CONCLUSIONS

An effective design of a mechanical wave propagator and turbine aims to produce waves and harvest the generated energy. This design is proposed based on an existing design. Prior to the system, the speed hump is put to energize the battery, which is used to power a linear actuator. In order
was then put under different components to test its breaking point and to gather its factor of safety.

Although the use of piezoelectric modules is an interesting and unique concept, it is still far from being a steady power source to be used commercially as renewable energy. Being able to produce high AC voltage but is matched with very low current, the piezoelectric material is unable to generate high amounts of power. It is solely limited by the amount of current it can produce through each deflection. The dependency of this system on the volume of traffic the speed bump is exposed to limits the system from reaching its full potential. It can be concluded that the system is indeed feasible but only to locations with a high and constant volume of traffic.

The purpose of the research is to boost energy from a Speed Bump that harvests electrical energy. This system can be utilized in areas with cars passing accompanied by a body of water either stagnant or flowing at a slow flowrate. The components are easily accessible in the market as long as it is resistant towards water and has the shock-resistant properties. However, to find a linear actuator that can accommodate high speeds and force are hard to come by, and the costs are relatively high.

Based on the simulations’ data, the results show that the mechanical wave propagator’s design could generate a sufficient boost in power with the proper implementation in a body of water. Moreover, with the proper redirection of current in the system, it can help light up streets surrounding lakes or any large body of water and help maintain a safer road scenario and minimize accidents. Besides, it will also lessen the carbon footprint of men to ensure a higher quality of living for the future.

With this system implemented on numerous highways and roads that are surrounded by bodies of water, it will be a giant stepping stone in generating electricity for a safer environment to drive in without using excessive energy that may be lost through the long-distance travelled from power plant all the way to the end-user.

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