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Bicycle Seat Cover Free Energy Generator

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Abstract : Bicycle Seat Cover Free Energy Generator is an energy generator using a piezoelectric main energy source. Piezoelectric materials can transform mechanical strain and vibration energy into electrical energy. This property allows opportunities for implementing renewable and sustainable energy power harvesting. This project aims to design and develop a bicycle seat-free energy generator which covers the investigation of stress distribution onto the piezoelectric and examines the interaction between the piezoelectric connection and its capability to charge Li-Po batteries. Product development involves mechanical component design using SolidWorks, material selection, fabrication, 3D printing manufacturing, assembly, and testing for result evaluation. The portable generator can produce direct current voltages between 6 to 7 volts from the test implemented. By using Solidworks@simulation, it is possible to reduce the amount of time required to investigate stresses, strains and safety factors, or component deformation analysis. This is implemented to ease the process of product development without any complications, and the time spent analyzing the data can be reduced.

Keywords: Renewable and Sustainable Energy Power, Piezoelectric, SolidWorks

1. Introduction

Electrical energy is important to our society and economy since it is now an integral part of modern life. Domestic uses, including lighting, cooling, heating, and refrigeration, consume a large portion of overall power generation [1]. One of the contemporary period's global goals is conserving non-renewable energy sources and developing new renewable energy sources [2]. A transducer is an apparatus that converts shock or vibratory motion into an optical, mechanical, or, more often, electrical signal [3,4]. Piezoelectric materials shift an electric charge within its linear elastic range in response to

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an applied force. Piezoelectric materials are passive circuit materials; they do not need electrical conductivity to create electricity from stress [5].

A bicycle seat covers free energy generator is a power generator that creates electricity using the piezoelectric mechanism to produce volts in voltage generation. To detect the vibration in this instance, a transducer was used, which, when applied to the pressure or force, converted the pressure and force into electrical energy [1]. The notion proposes installing the piezoelectric transducer into the bicycle seat. On the saddle, the vibration is more intense than in other locations. As the bicycle moves, the transducers will detect and create power from vibrations. It is a bicycle-mounted free energy generator that may be fueled by any source of renewable energy, such as air or water.

The purpose of this study is to investigate whether the piezoelectric case design and material is suitable to be used as a suppressor on the piezoelectric. Additionally, identify the best circuit design to obtain the highest voltage value from the piezoelectric. The SolidWorks Simulation offers several types of linear studies including static (or Stress) studies that calculate displacements, reaction forces, strains, stresses, failure criteria, the factor of safety, and error estimation. Loading conditions include point, line, surface, acceleration (volume) and thermal loads available to be selected and imposed in the analysis [6]. The required loads are automatically obtained from a calculated motion analysis study in section 4. The rest of this paper is organized as follows: The next section presents the materials used and the method implemented in the development of the machine. In section 3, the machine test result and evaluation. The conclusion and recommendations for future works are in section 4.

2. Materials and Methods

In this project, the development of the machine has been divided into several stages. Starting with idea generation and identifying the problems of this project followed by the identification of the project objective and scope. Preliminary design is where the initial design is done based on the problems identified. The design roughly sketches where the design ideas are listed to get the best design options. The next stage is the detail design stage where the final design that has been selected were being detailed in every aspect including exact dimensions, type of material, appropriate size, and functionality of the machine components. The detailed design is then visualized in 3D using SOLIDWORKS 2021 software to get a clearer picture of the design of this product. The material selection process is carried out to select suitable materials for each machine component which considers the mass, weight and flexibility so that this product is easy to fabricate and low cost. The next stage is the fabrication process where this process is done to produce each machine component according to the detailed design drafted using SOLIDWORKS according to its exact size, shape, and dimensions using a 3D printer. The machine functionalities are tested to their designed purpose in the machine testing stage. Next, testing was conducted for each different design and circuit to obtain the highest voltage value possible. The result of testing is being recorded and discussed for reference and future work.

2.1 Circuit Connection

In this study, a zirconate titanate (PZT) lead piezoelectric transducer was used to harvest the electrical voltage from mechanical stresses imposed onto the bicycle seat. The normal output voltage is roughly ranging from 0 to 12 V. However, the immediate impact on this transducer could attain up to 30 V while the output current is around 5 mA.

2.2 Rectifier Circuit

The piezoelectric transducer is chosen to be connected in three different configurations during the testing stage, which is in series, parallel and series-parallel arrangements. The piezoelectric produces an AC output. Before it can be stored in components such as a battery or capacitor, it must be rectified into DC form and supplied to DC loads. In this research, the piezoelectric circuit output was rectified using a full wave bridge rectifier. **Figure 1** shows the shcematic diagram of the rectifier circuit and components of the full wave bridge utilized in this study: 2W10 Full Wave Bridge Rectifier, 1N4007 diode, capacitor, switch, and 1k resistor. The operation of this full-wave bridge rectifier is separated into two cycles, a positive half-cycle and a negative half-cycle. During the positive half-cycle of the supply, two diodes conduct in series while two other diodes are in the OFF state because they are now reserve-biased and current is flowing via a capacitor. The electrical energy generated is stored temporarily in the capacitor. Resistors are used to reduce the current flowing at the output. Next, 1N4007 is used so that the current does not reverse and flows in one direction only.

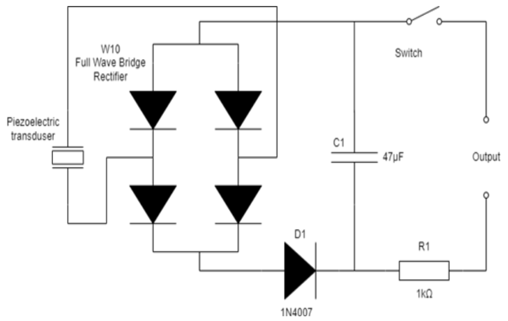


Figure 1: Schematic diagram of the rectifier circuit

2.3 Material Selection

Each design of the piezoelectric casing is modelled in 3D using SOLIDWORKS. The casing is then printed using a 3D printing printer. The usage of this fabrication method is due to the small component to be fabricated and can reduce cost [7]. The Ultimaker Cura (version 4.12.1) is used to slice the design developed and printed using Creality Ender Pro 3 3D printer.

A pusher is designed to be seated on the piezoelectric transducer as a mechanism to press the transducer. In this study, the pushers are fabricated using different materials, Polylactic Acid (PLA), Balsa wood and rubber. The PLA pusher is fabricated using the same 3d printer. The plywood and rubber pusher are fabricated manually. A band saw and a wood rasp file is used to cut the plywood to the desired shape in the pusher fabrication process [8, 9]. The rubber pusher is made from synthetic rubber that is used in stationary applications.

The most common synthetic rubber is made from chemicals such as styrene and butadiene [10]. This material is very easy to cut and shape because of its soft properties and the process of shaping is using a cutter. All the pushers made from different materials are fabricated to the same size and dimension to reduce error. In the testing stage, the product is tested for its design functionality. Three different piezoelectric cases and circuit designs were carried out alternately. A total of 18 types of testing were conducted to obtain results for each piezoelectric case design and circuit type. The testing was carried out using three types of pusher material, wood, polylactic acid and rubber, two pusher attachment configuration, and three different piezoelectric circuit connection arrangements. The three different types of circuits, namely series circuits, parallel circuits, and series-parallel circuits were used in the test. Each value obtained from each test was read through a multimeter. Each test data conducted were recorded and discussed.

2.4 Simulation

The material selection in this project is very important in identifying the material to be used for each component involved in this project. Basically, three materials are used to analyze the stress distribution in the piezoelectric case. The first material is wood, the type of wood selected for this project is Balsa wood. The second material is rubber and finally Polylactic Acid, better known as PLA. These three materials are used to make piezoelectric case material. The purpose of these three materials selected and compared is to decide the best material to be used in this project, which can accommodate the force that will be applied to the bicycle seat. **Figures 2(a)** to **Figure 2(e)** show the piezoelectric and pusher used in the separate tests carried out, with three different types of materials, and three distinct pusher configurations.

Figure 2(a) shows a cylinder-shaped pusher with a 27 mm diameter and an 8mm height. Hence, **Figure 2(b)** shows a cylinder-shaped pusher with a diameter of 27 mm and a height of 8mm that is attached to a 2 mm thick glue layer at the bottom. **Figure 2(c)** shows a pusher with a three-quarters circle design. This is called the moon case. This moon case is 35 mm in diameter and 2 mm thick. In the middle, there is a half-circle press that is also 2 mm thick. In addition to the pusher, there are two other parts that are needed to run the simulation as shown in the next figure. **Figure 2(d)** shows that the first piezoelectric has a 35 mm diameter, and **Figure 2(e)** shows a circular piezoelectric case that can fit a 35 mm diameter piezo.

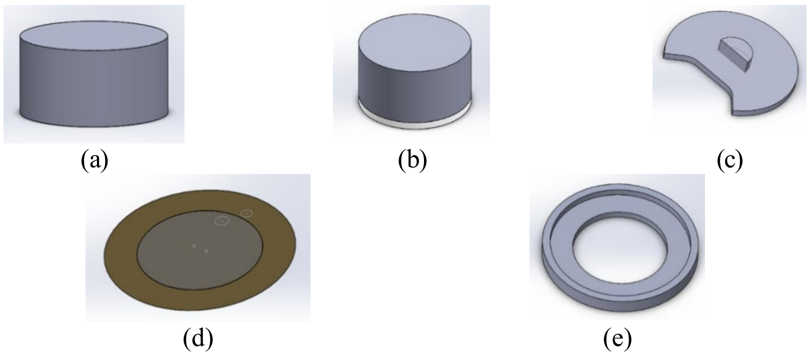


Figure 2: (a)Cylinder shape pusher (b) Cylinder shape pusher with glue on the bottom (c) Three-quarter circle pusher (d) 35 mm piezoelectric (e) Piezoelectric case

In conducting the simulation, the piezoelectric case is positioned at the bottom, followed by the piezoelectric and its pusher. All repetitive tests were conducted while simply varying the pusher and material type. The shape of the bottom portion of the piezoelectric case was then set such that the case does not move when the force is imposed onto the pusher. A value of 10 N force is placed at the top of the pusher depending on the calculation and assumption made. The mesh utilized for all these simulations repetition is using solid mesh. Afterwards, the simulation was executed, and the outcome of the simulation is recorded and reported. In this simulation, the value of force assumed from an average weight for a female cyclist is around 50 kg while a male cyclist is 65 kg, but not the entire weight is applied to the bicycle seat. Therefore, the estimated assumption weight that is effectively exerted onto the piezoelectric pusher is approximately 1kg for both cyclists. A 10 N of force is to be considered in the simulation that is by multiplying the weight with the gravitational force which is 9.81 m/s [11].

2.5 Force equation

The normal force is comparable to a contact force. If two surfaces are not linked, it is impossible for them to exert a normal force on one another. Consider a table and a container: while they are not in contact with one another, it is impossible for them to exert normal force on one another. However, when two objects are in direct contact, they exert a normal force on one another that is perpendicular to the surface that they are contacting. Here, normal is referring to the perpendicular. When the body is decelerating, the normal force is equal to the body's weight. When a body is about to fall depends on its location on the ground at the moment it is about to fall. The normal force is represented by the symbol FN and stated in terms of the unit N (Newtons) [5].

Eq.1 describes the gravitational pull experienced close to the Earth's surface as follows:

$$F = \frac{G^{mM}}{r^2} \quad \textbf{Eq.1}$$

The distance to the centre of the Earth is represented by the equation r = Re, while the mass of the Earth is denoted by the equation $M = Me$. This force will create an acceleration, as described by the equation $F = ma$, which can be found in Newton's Second Law, as shown in **Eq.2** and the result of solving it is shown in **Eq.3**.

$$F = ma = \frac{G^{mMe}}{Re^2} \quad \textbf{Eq.2}$$

$$a = \frac{G^{mMe}}{Re^2} \quad \textbf{Eq.3}$$

The right-hand side of the equation consists completely of constants: G represents the gravitational constant, Me represents the mass of the earth, and Re represents the earth's radius. It will create the following if the right numbers are entered, as shown in **Eq.4**

$$a = 9.8\, m/s^2 \quad \textbf{Eq.4}$$

That is just the value that was referred to earlier as g. This phenomenon is referred to as the "acceleration of gravity." Therefore, the force is calculated as follows in **Eq.5**

$$F = ma \quad \textbf{Eq.5}$$

2.6 The properties of a material

The qualities and integrity of materials are essential to the design and production of safer and more sustainable products, as well as their processes and human safety. The mechanical properties of a material explain its reaction to external forces. They address the elastic and plastic properties of materials [12].

3. Results and Discussion

Data is collected and analyzed to evaluate products according to their intended use. The results of testing on functionality and performance were established. The results of the test are provided and discussed in the next section. The output voltage and current are then compared to the circuit design, pusher material, and piezoelectric arrangement.

3.1 Circuit Connection

The output of the piezoelectric transducer is an AC waveform. Prior to being applied to the storage in the Lithium Polymer (LiPo) battery, the output of the transducer must be rectified and filtered.

3.2 Piezoelectric Connection

The piezoelectric transducer was connected in series, parallel and series-parallel arrangement. To measure the voltage and current across the connection, the multimeter was attached to the piezoelectric transducers. The piezoelectric transducer was arranged to collect the data as shown in **Figure 3**. The arrangement of the piezoelectric is targeted to obtain the optimal location of the piezoelectric in harvesting electrical energy from the weight imposed by cyclists.

(a) (b)

Figure 3: (a) Piezoelectric arrangement 1 (b) Piezoelectric arrangement 2

The result of testing for the arrangement with the pusher can harvest the highest voltage and current output. The series-connected piezoelectric circuit generates high output voltage but a low output current. In contrast, the parallel connection of piezoelectric transducers produces high output current but low output voltage. Series-parallel piezoelectric circuits are formed by connecting series and parallel piezoelectric circuits with parallel connections.

Figure 4 shows the average value of voltage over time from the repetitive testing implemented. From the graph, the stable and highest value of voltage can be achieved through a series-parallel circuit arrangement. While the series circuit produces the lowest voltage value. In series, the electricity can only flow in one path [14]. The total percentage of voltage loss for the series circuit is 84.14%. For the parallel circuit, the percentage of voltage loss is slightly less compared to the series circuit which is 47.43%. In parallel, the electricity can flow in more than one path [14].

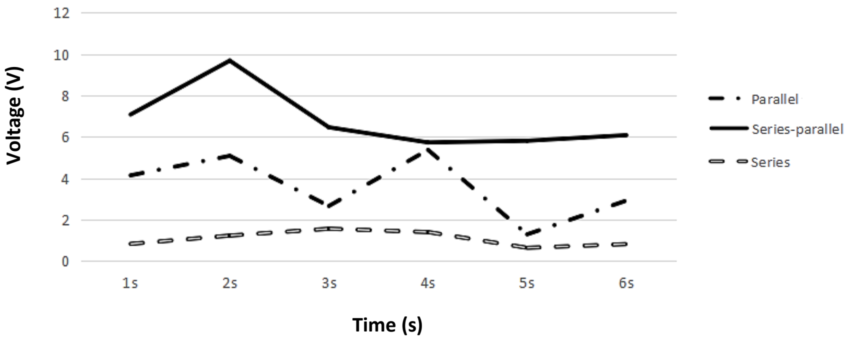


Figure 4: Graph of Average Voltage in All Circuit

3.3 Pusher Material

This series-parallel circuit arrangement is selected based on the previous testing that proves this arrangement capable of producing stable and higher volts and current outputs. Based on the test implemented, the wooden material reading produces the highest voltage value. This is because the wooden material structure is hard and dense compared to other materials. The strength of the wooden sample when the load is applied parallel to the grains is about ten times more compared to when the load is applied perpendicular to the grains [15]. Compared to rubber, the compression rate of this material is lower than wooden. For rubber, the percentage of voltage lost is 17.94% compared to the total voltage produced by the wooden pusher. Meanwhile, the percentage of voltage loss is 8.76% for PLA material. This shows that wood is the best material to get high voltage values.

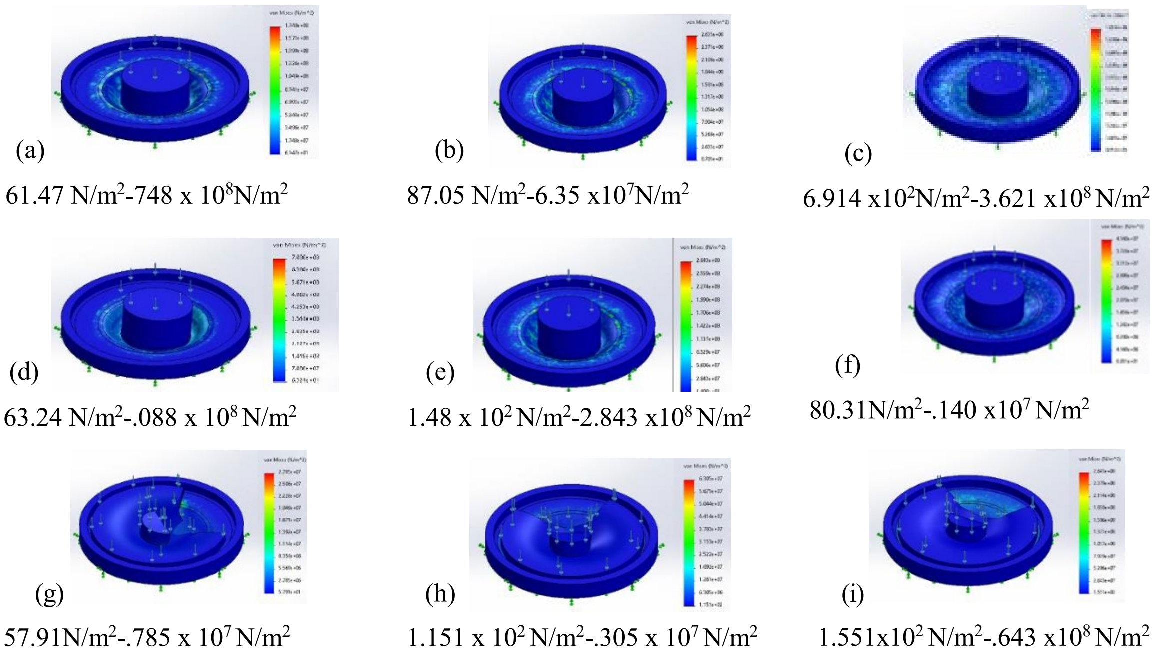
3.4 Pusher Location

There are two different types of positions used to obtain data, namely the pusher that is attached to the bicycle seat cover (pusher up) and the pusher that is attached to the piezoelectric (pusher down). In this test, both positions will be done alternately by maintaining the type of material used. Testing data were taken based on a series-parallel circuit.

Based on the three tests conducted, the pusher attached to the piezoelectric plate is in the practical position to harvest piezoelectric energy according to the data obtained. From the test, the value of average voltage generated by using the pusher down arrangement produces higher voltage compared to the pusher up arrangement. The average value of volts for pusher down is 7.16V, while the average value of volts for pusher up is 6.45V. The value of pusher down is 11% higher compared to pusher up. High voltage values can be achieved due to the contact between the pusher with the piezoelectric surface being wider and no air gap for the piezoelectric attached to the piezoelectric sheet. Piezoelectric strains are very small, and the corresponding electric fields are very large which is small strains can produce large electric fields [16]. The absorption rate of the material also plays a high role in obtaining a large voltage value. The material used for the bicycle seat case is a silicone sponge. Silicone maintains its resiliency over a broad temperature range and resists taking a permanent compression set [17].

3.5 Simulation

Figure 5(a) to **Figure 5(i)** shows the result of the simulation for von Mises stress on the piezoelectric pushers. **Figure 5(a)** shows the von Mises stress for the wooden case and pusher. The casing and pusher shown in **Figure 5(b)** are fabricated from PLA. The rubber case and pusher components are shown in **Figure 5(c)** for the casing and the pusher. In **Figure 5(d)**, a layer of hot glue is placed on the pusher for the wooden case pusher. **Figure 5(e)** is the pusher and case from PLA material with hot glue on the pusher side. **Figure 5(f)** shows a rubber case and pusher with hot glue on the pusher side. **Figure 5(g)**, **(h)** and **(i)** shows the half-moon pusher and case for wood, PLA and rubber material respectively. The maximum stress is shown in **Figure 5(d)** with 708.8 x 10^6 N/m^2. While the minimum stress is shown in **Figure 5(g)** with 27.85 x10^6 N/m^2. The distinction between **Figures 5(d)** and **Figure 5(g)** is the relative difference in the pusher form and the volume of the pusher affect the surface contact to the piezoelectric from the force exerted.



(a) 61.47 N/m^2-748 x 10^8N/m^2

(b) 87.05 N/m^2-6.35 x10^7N/m^2

(c) 6.914 x10^2N/m^2-3.621 x10^8 N/m^2

(d) 63.24 N/m^2-.088 x 10^8 N/m^2

(e) 1.48 x 10^2 N/m^2-2.843 x10^8 N/m^2

(f) 80.31N/m^2-.140 x10^7 N/m^2

(g) 57.91N/m^2-.785 x 10^7 N/m^2

(h) 1.151 x 10^2 N/m^2-.305 x 10^7 N/m^2

(i) 1.551x10^2 N/m^2-.643 x10^8 N/m^2

Figure 5: Analysis Result of von Mises stress

3.6 Analysis of Bicycle Seat Cover

Six numbers of piezoelectric transducers are positioned between the seat cover and the bicycle seat. The Portable Seat Cover is designed with a pusher attached using hot glue on a piezoelectric made of Polylactic Acid (PLA). The piezoelectric case is glued to the top of the sponge, while the sponge is taped to the seat cover using fastening tape. Subjects were instructed to conduct a cycling activity while seated on a seat cover to measure the voltage produced by six numbers of the piezoelectric transducer.

From the test conducted, it is found that the mass does not affect the generation and increment of voltage and current. Voltages and currents increase when cyclists pedal their bicycles at high frequency and on uneven road surfaces. Significant differences can be observed according to gender factors. **Figures 6** and **7** show graphs of voltage against time for a male and female test result. Subjects were asked to pedal a bicycle and voltage values were recorded at intervals of 20 seconds, 40 seconds, 60 seconds, 80 seconds, 100 seconds, and 120 seconds. From the graph, it can be observed that the voltage increased over time. Begins with low voltage as the rider starts cycling until the rider cycles the pedal at a high frequency, promoting the voltage increment and when the rider slows down, the voltage drops.

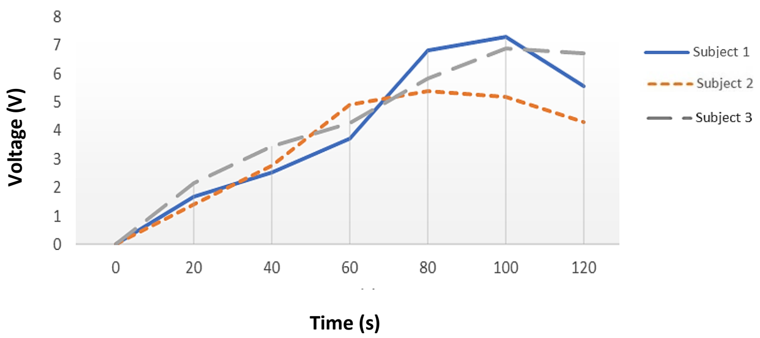


Figure 6: Voltage versus time graphs tested by male

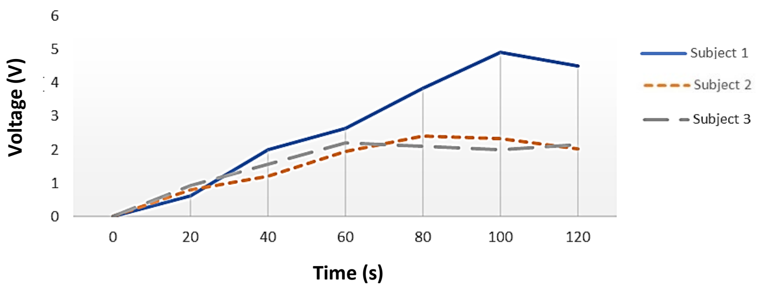


Figure 7: Voltage versus time graphs tested by female

4. Conclusion

Throughout this project, a simulation of a portable bicycle-free energy generator was fabricated and successfully developed. This project is successful in producing a Bicycle Seat Cover Free Energy Generator. The main source of electricity generation for this bicycle-free energy generator is the piezoelectric placed on the bicycle seat. The amount of voltage that be able to be generated using this generator ranges from 6 to 7 VDC. In addition, this product can reduce the rate of consumption of non-renewable energy. Properties required to produce a pusher are a material that is not easily compressed, waterproof, and able to last a long time. The suitable material used for the pusher is polylactic acid (PLA) due to its waterproof properties and not easily decomposed. For the circuit, its have been proved that series-parallel is the best choice for this project. Approximately RM 300.90 worth of materials and labour will be needed to complete this project. The completion of this project will need a significant investment of time and resources; but, in the long term, it will be beneficial since it will make use of renewable energy and will allow for cost savings.

Acknowledgement

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