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Pit-Stop Power Generator

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Abstract : A pit-stop power generator is a ramp that produces electricity using piezo plates. Hydroelectric dams, solar panels, and nuclear power are all common sources of electricity. The objectives of the project are to design and develop a pit-stop generator that is suitable to supply small voltage requirements at the highway toll booth. Our purpose is to provide an alternative method of generating electricity at low cost. If this idea is put into action, it will be possible to make changes to supply power to remote areas. The creation and testing of a pit-stop power generator is presented in this project, which attempts to give an alternate method of producing electricity. The generator works on the premise of transforming mechanical force into electrical energy using piezoelectric plates. This project development process includes machine design using SolidWorks, material selection, and metal works fabrication, which includes machining, cutting assembly, testing, and re-modification, to generate a fully working project. Four different elements that influence voltage generation are tested to study their effect. The result obtained shows that voltage can be generated as low as 2 V and up to 15 V depending on the elements.

Keywords: Piezoelectric Plate, Rubber Ramp, Renewable Energy, Generator

1. Introduction

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Electricity has become an essential part of our daily lives and is essential for human survival. Nearly 98% of the appliances in our homes, schools, universities, and offices rely on electricity [1]. It is a crucial aspect of modern living and the world's economy, powering appliances, computers, electronics, machinery, public transportation systems, lighting, heating, cooling, and refrigeration [2]. Without electricity, computers, printing machines, and televisions cannot function. In 2021, total electricity usage in the United States exceeded 3.93 trillion kWh, 13 times higher than in 1950 [3].

In the past, before the invention of electricity, people had to rely on different methods to keep warm during the winter. In certain areas, it was a matter of life and death when the temperature dropped drastically. To stay warm, they used fireplaces, wood-burning stoves, layers of clothing, and the body heat of their loved ones. It was a full-time job just to keep warm. Nowadays, people can heat their homes with the press of a button due to electricity. Stable electricity is critical for hospitals and other healthcare facilities [4]. Lighting, security systems, air conditioning, computerised health records, and medical equipment all require energy. Hospitals and nursing homes are particularly vulnerable to power outages because they are unable to shut down operations, which can lead to patient deaths. When power shortages occur, hospitals and nursing homes are frequently forced to evacuate, which is dangerous. Electricity powers a variety of food preparation and storage appliances. Previously, people had to cook over a wood or coal fire, which required a lot of attention. Ovens and microwaves are more convenient and reliable than older electric devices, for instance. Electricity also allowed for the development of refrigerators and freezers, which revolutionised food storage. The ability to connect to the internet is critical for technologies like cell phones and computers. In 2016, the United Nations General Assembly adopted a non-binding Resolution that designated internet access as a human right since the internet is required for so many functions. Although the resolution does not require governments to provide Internet access, an increasing number of organisations are advocating for universal Internet access. It is possible to access the internet without electricity, but it is more difficult. For reliable Wi-Fi, electricity reliability is vital [5].

Electricity has had an enormous impact on culture. The efficient harnessing of electricity has brought about significant changes in how industries operate. Shift-based labour became possible as it is no longer restricted by daylight hours. The introduction of electricity-based inventions also had a major impact on the economy. The development of radio and television, made possible by electricity, had a profound impact on society. To put it simply, electricity has played a significant role in shaping the world we live in today. Despite its importance, few people actually understand how electricity is produced. Windmills are used to generate energy from the wind, waterfalls provide energy for hydroelectric power, and photovoltaic electricity is generated by beams [6]. It's clear that electricity is an essential component of our daily lives and is not something to be taken for granted. While people in poverty-stricken countries continue to live without electricity, those who rely on it every day would most likely be unable to survive without it. The objective of our project is to create a Pit Stop Energy Generator that functions by utilizing piezoelectric plates placed underneath a ramp. The purpose of this machine is to create an alternative energy source for toll booths on highways. As cars pass over the ramp, the mechanical pressure is converted into electricity which is stored in a battery and used to power an LED bulb inside the toll booth. The goal of this project is to reduce our dependency on hydroelectric dams and create an alternate source of electricity. This paper is organized as follows: The materials and methods used in developing the machine are discussed in the next section. The machine test results and evaluation are presented in section 3. Finally, our conclusion and recommendations for future work are outlined in section 4.

2. Materials and Methods

The flowchart in **Figure 1** depicts the project process, starting with problem formulation that includes defining project objectives and scope. The next stage design, which involves generating ideas and developing and selecting preliminary designs. In the detail design stage, the selected design is refined further. Here, details like dimensions, component functioning and integration, and materials for each component are chosen and finalized. The parts and components are then developed in a 3D design model using CAD software (SolidWorks 2021). The 3D model developed is shown in **Figure 2**.

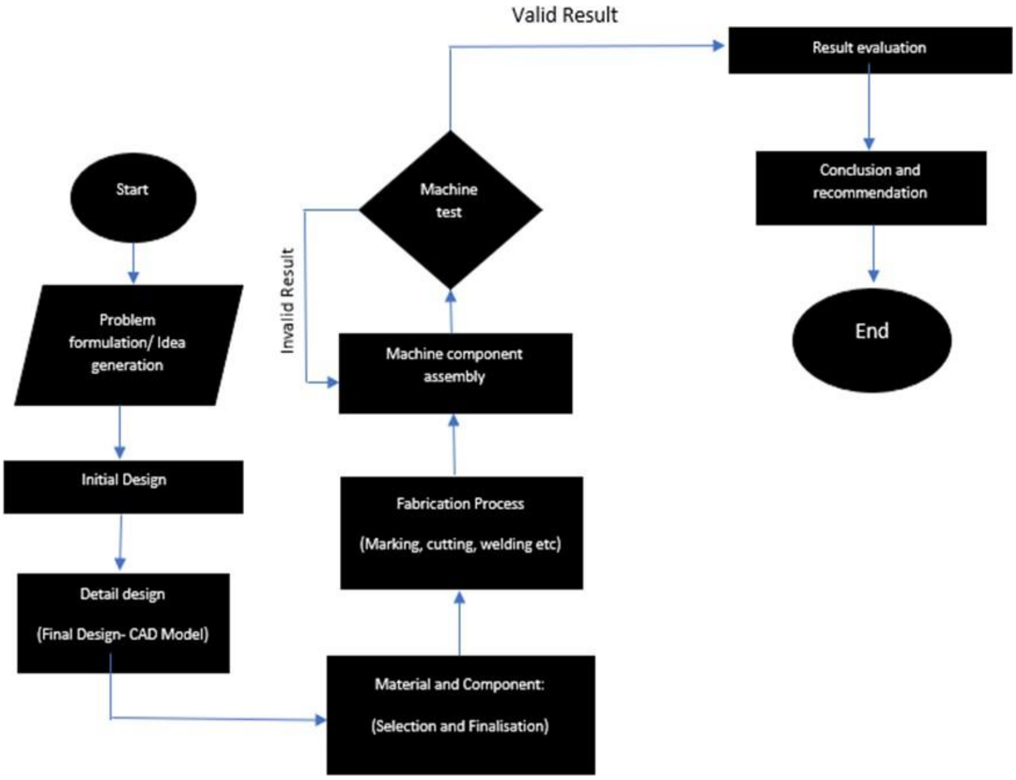

Figure 1: Project Implementation

During the fabrication stage, raw materials are measured and cut to specific sizes and shapes, project components are completed, and all components are assembled. The ramp features are thoroughly tested during the project testing phase to ensure they work as intended. Testing results are recorded and reviewed to evaluate performance. If any portion or component of the project does not function properly or perform well, the machine will be adjusted or reassembled to meet established objectives. The testing results are documented and used for future reference and development discussions. The materials and methods section, otherwise known as methodology, describes all the necessary information that is required to obtain the results of the study.

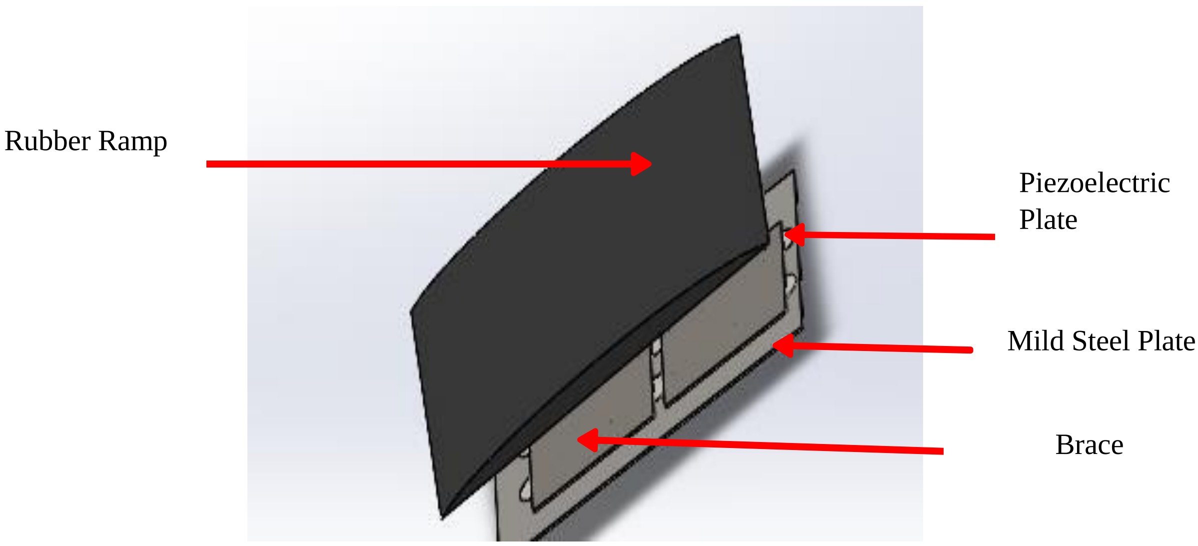

Figure 2: SolidWorks Assembly for Pit-Stop Energy Generator

2.1 Materials

Table 1: List of Materials

No	Materials	Description
1.	Piezoelectric plates (49 mm)	Piezoelectric materials generate an electric current when subjected to mechanical stress. This process is reversible, meaning that applying an electric current to these materials causes them to change shape slightly (up to a maximum of 4%) [7].
2.	Diode (1N4007)	A diode is an electrical component that enables the flow of current in a single direction. The maximum voltage that this particular diode can handle is 700 V. It has a high current capacity and minimal forward voltage drops. Additionally, it has low reverse leakage. [8]
3.	Capacitor (47u)	A capacitor is a component that can store electrical energy in an electric field. It is passive and has two terminals. It is important to note that this specific capacitor has a maximum charge capacity of 25 V [9].
4.	Rectifier bridge	Converting AC to DC [10].
5.	Rubber ramp	There is a rubber vehicle ramp designed for cars to apply mechanical pressure. The ramp is black in colour and measures (500 x 350 x 50) mm in dimensions as stated in reference [11].
6.	Steel plate	To accommodate the piezoelectric plates, a mild steel plate measuring (500 x 350 x 3) mm is required, as stated in reference [12].
7.	Bolts (pushers)	In order to generate electricity, M10 steel bolts are utilized as pushers to press the piezoelectric plates. This information is referenced in [13].
8.	Electrical Wire	To transfer the electricity generated by piezoelectric plates to the LED bulb output, wires are connected. This is done using connecting wires. [14]
9.	Lippo Battery 11.1v	A rechargeable battery that utilizes lithium-ion technology and a polymer electrolyte instead of a liquid electrolyte is called a lithium polymer battery, or more accurately, a lithium-ion polymer battery. For this purpose, an 11.1 Lippo battery was used [15].
10.	Multimeter	A handheld tester known as a multimeter or volt-ohm meter is used to measure electrical voltage, current (amperage), resistance, and other values. For this project, the multimeter is used specifically to measure the output voltage [16].
11.	PCB board	A printed circuit board (PCB) is the board base for physically supporting and wiring the surface-mounted and socketed components in most electronics [17].
12.	Wooden base	A wooden plank for the piezoelectric plates to be placed. The dimension of the ramp is (500 x 350 x 13) mm.
13.	Wooden Brace	Two wooden planks for the piezoelectric plates to be placed under. The dimension of the plank is (250 x 120 x 8) mm.
14.	Mild Steel Brace	Two mild steel plates for the piezoelectric plates to be placed under. The dimension of the plate is (250 x 120 x 2) mm.

The materials used in creating the machine are listed in **Table 1**.

2.2 Methodology

The raw materials selected are measured and cut before the rubber ramp and steel plate are joined through drilling and bolting. Once the fabrication and joining process of the frame is complete and the remaining components are ready, the assembly process begins. Most components of the ramp are joined using mechanical fasteners such as bolts, nuts, glue, and tape. These fasteners offer several advantages, including ease of assembly without requiring special tools or equipment, high strength, and low maintenance requirements for the parts. The output charge is stored using an 11.1 V Lippo battery. A single piezoelectric plate produces an average output voltage of 0.5 V [18]. Therefore, the more piezoelectric plates used, the higher the output voltage produced.

Figure 3 depicts the circuit employed for the conversion of piezoelectric alternating current to direct current. When force is applied to the piezoelectric sensor, it generates a current that travels to a diode bridge rectifier labeled 1N4007. This rectifier converts the current from alternating current (AC) to direct current (DC). The DC current then moves on to a 47u capacitor where it is stored as a charge. The current flows from the capacitor to a 1k ohm resistor where its flow is controlled. It then goes to a Lippo battery where the remaining current is stored. When the switch is turned on, the current from the Lippo battery powers the 12 V light bulb. Jumper wires and connecting cables are used to facilitate the flow of current.

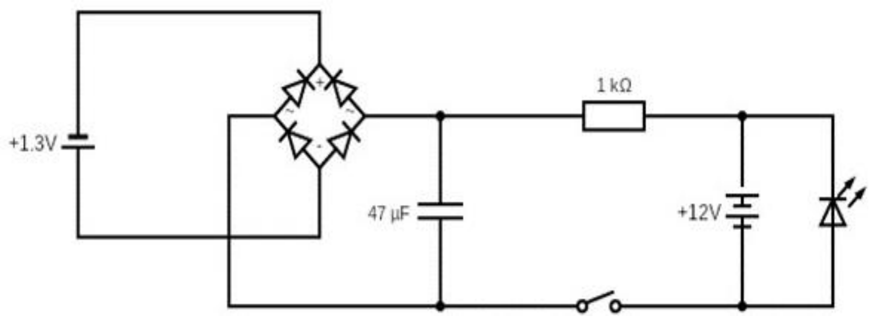

Figure 3: Schematic Diagram of the machine AC to DC circuit

To calculate the voltage generated from multiple piezoelectric plates, the voltage generated from a single plate is multiplied by the number of plates used. To measure the voltage from a plate, a multimeter is used. The maximum voltage generated by the piezoelectric is 1.3 V. For this project, 12 piezoelectric plates are utilized to produce electricity. In an ideal situation, the total voltage is approximated to be 15.6 V. It is important to keep in mind that the voltage generated by each piezoelectric plate may vary, resulting in a differing total voltage.

$$P = IV \quad \textbf{Eq. 1}$$

To calculate the power generated by the machine, **Eq.1** is used when the current value is known with P as the power generated, I as the current, and V as the total voltage generated. The current can be measured during the testing stage using a handheld multimeter.

During the testing stage, the project undergoes evaluation to determine its functionality and capabilities as per the design. The configuration test involves testing three types of piezoelectric arrangements (series, parallel, and combination) and measuring the output voltage of each configuration using a multimeter, which is then recorded. This experiment is repeated three times for each type of configuration, and the average output voltage is calculated. Additionally, the machine's functions, such as electrical circuit operation and maintenance, are tested under the machine functionality test. Finally, a performance test is conducted to determine the machine's capability and durability to withstand a vehicle's weight.

3. Results and Discussion

The machine has undergone testing to obtain and analyze the results for its intended objectives. The testing includes a functionality test and a performance evaluation, which have been completed and determined. The results of the testing are presented and discussed in the following section. Additionally, the output voltage produced is compared to various factors that influence it.

3.1 Piezoelectric Plates Configuration

Figure 4 presents the average output voltage produced and compares it with each circuit configuration. The graph clearly shows that there are voltage fluctuations observed in all three circuit configurations tested. The combination circuit produces the highest voltage compared to the other two configurations. The graph clearly shows that there are voltage fluctuations observed in all three circuit configurations tested. Out of the three configurations, the combination circuit generates the highest voltage. This voltage fluctuation is caused by the instability stress that is imposed on the transducers. The gap between the pusher and transducers is one of the factors that contribute to this stress. On average, the combination circuit produces a voltage of 7.6 V, while the parallel and series circuits produce 5.4 V and 6.6 V respectively.

The average current measured for the combination circuit is 2.8 mA which gives an average power generated of 2 mW that is sufficient to charge a 40 mAh button cell battery in one hour [19]. According to the test results, the combined circuit of series and parallel is found to produce the highest output voltage. While a series connection provides good voltage, the obtained current is poor, and a parallel connection provides good current but poor voltage. However, this issue can be resolved through a series-parallel connection, which yields both good voltage and current [20].

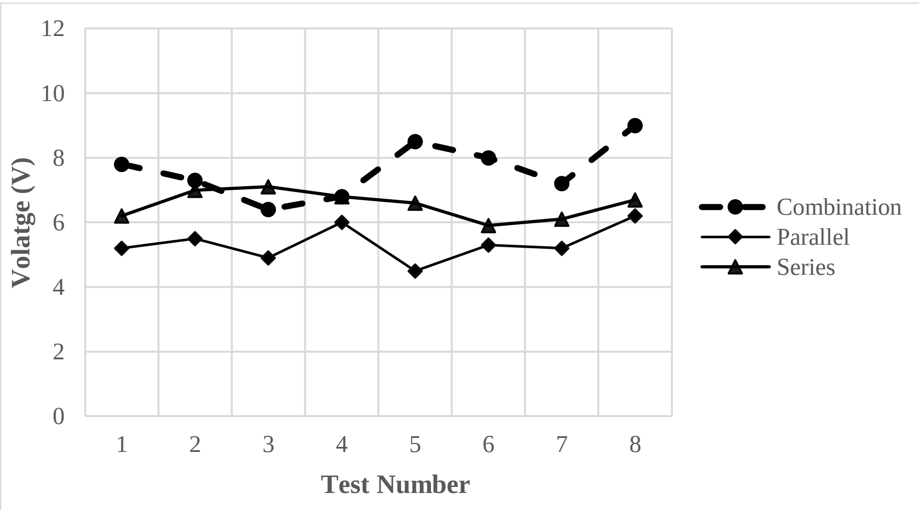

Figure 4: Voltage generation based on circuit configuration

3.2 Piezoelectric Sizes

In this test, three different sizes of piezoelectric plates were connected using a combination configuration and tested to evaluate the amount of voltage generated. The voltage generated that is recorded during the test is shown in **Figure 5**. The 35 mm, 42 mm, and 49 mm piezo plate sizes produce average output voltages of 3.4 V, 5.1 V, and 7.3 V, respectively. This is because piezo plates with a larger surface area produce more output voltage compared to smaller ones. A larger surface area contains more crystals, which results in a higher output voltage [21]. The 49 mm size piezo plate produces an average of 2.5 mA of current thus the average power generation is 18.25 mW.

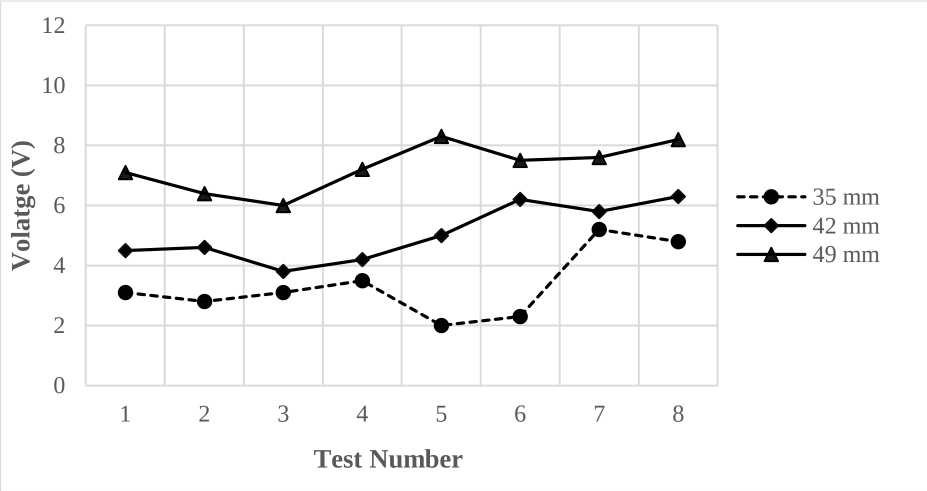

Figure 5: Voltage generation based on piezoelectric size

3.3 Piezo Plate Locations

Figure 6 shows the voltage generated for three different locations of the piezoelectric plate installed. The three focus location is at the edge, middle, and both edge and middle section of the ramp. The average output voltage produced by the three different locations of the piezo plate stated above is 2.9 V, 3.4 V, and 6.4 V respectively. The highest reading was recorded when the piezo plate was placed at both the middle and edges of the ramp. These locations experience more force from a moving car than other areas where the plate is placed. This is because the thickness of the ramp varies between the edges and the middle. A noticeable disparity exists where there is a 120% increase in voltage generated when comparing the edges with both location placements. The average current measured for the combination circuit is 1.8 mA and thus gives 11.6 mW of power generated.

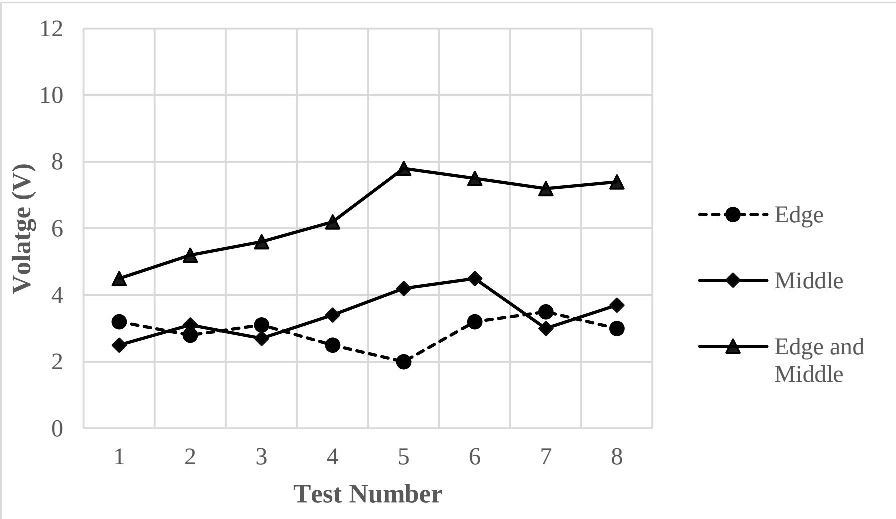

Figure 6: Voltage generation based on piezoelectric plate location

3.4 Base Material

In this test, the base material used to support the ramp is tested respectively. The type of material used in this test is mild steel plate with a thickness of 3mm and plywood with a thickness of 13 mm. The dimension for both plates is consistent except for their thickness. The test is extended by imposing a pusher on each plate to examine its effect on voltage generation. The pusher is made from M8-size bolts dan installed vertically with the base material surface to touch and push the piezo plate. The voltage generated is shown in **Figure 7**. From the results, the voltage generated is higher with the appearance of a pusher for both materials. The average value of voltage generated with the pusher is 9.6 V and 10.2 V for mild steel and Wood respectively. Using a pusher configuration has been proven to increase power harvesting by 93.7% to 103.4% compared to not using it. This configuration can greatly benefit energy efficiency and sustainability efforts.

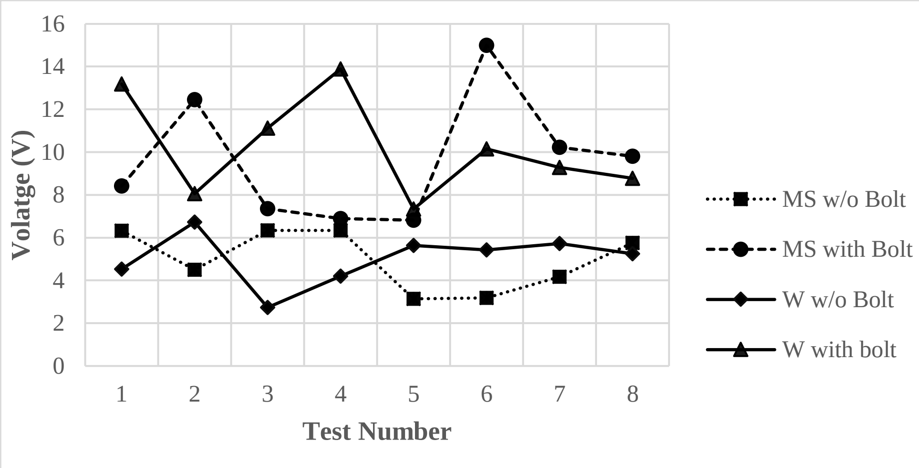

Figure 7: Voltage generation based on ramp base material

4. Conclusion

This project has successfully designed and developed a pit-stop power generator which will expect to be installed outside the toll booth just after the first hump to slow down cars. By slowing down the cars, the ramp will not slide away or deform due to the car's weight. The development of the machine involves design stages and metalwork fabrication. The machine is designed to withstand average-weight passenger cars by using a thick rubber ramp and mild steel plate. From this project, the combination of series and parallel circuits of piezoelectric plate connections be able to produce higher voltage generation. The size of the piezoelectric plate also makes an important contribution to voltage generation. For this project, the piezo plate locations, base support material, and additional pusher onto the piezo plate give additional force in harvesting power from the piezoelectric.

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