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Development of a Pedal Powered Air Compressor Generator

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Abstract – *The demand for electricity increases day by day hence, the researchers conducted a study to generate free electricity by constructing a minimal cost power generating device. Aligned with this objective, this can help people reduce their power consumption and can lessen their electric bills. The Pedal Powered Air Compressor Generator has ten main parts namely the bicycle, air compressor, pressure regulator, control valve, pneumatic cylinder, crankshaft, flywheel, dynamo, charge controller, and battery. This is developmental research hence prototype and test experiments were conducted. The gathered data were treated using multivariate analysis of variance and the Scheffe test was used to determine which pair means were significant. It was found that there is a significant difference in the time to fill the tank, pressure output, the voltage generated, and time to empty the tank when compared across weight classes. The prototype was designed to fill the tank and use used the compressed air simultaneously, and the experiments conducted proved that filling the air compressor tank works faster than consuming it, even if it is regulated at a maximum pressure output of the system (300kPa). The higher the pressure output, the higher the voltage generated but the faster the prototype will operate.*

Keywords – *Pedal Powered Air Compressor Generator, Pedal Powered Generator, Air Compressor Generator, Air Compressor, Generator, Compressor.*

INTRODUCTION

In this modern world, development can be seen everywhere, for everyone wants a better product or a better result. As every country desire industrialization and modernization, technology became one of the most vital elements for growth. The advancement of technology requires much amount of energy; it has, therefore, a great contribution to electric consumption. In short, without electricity, modern life would be impossible. Not surprisingly the electricity demand is rapidly increasing day by day [1].

There are several ways to produce electricity. Fossil fuels such as coal, natural gas, and oil are used over decades as an energy source for power generation, but these fossil fuels are classified as non-renewable, so defined as they cannot be replaced easily [2]. Once a depositor source of these is depleted it cannot be readily replenished. Second, burning those fuels has a great impact on the environment. Long-term dependence on fossil fuels raised issues such as pollution and global warming due to the massive amount of greenhouse gasses emission. Also, fossil fuel is known for its recent dynamic cost. From these problems, the fossil fuel option is gradually fading away [3]. On the other hand, renewable energy resources such as wind and solar energy depend on the topographical location and weather conditions. Each of the classifications shows varying challenges.

The study of [4] dealt with recovering the energy of the flywheel by using the principle of energy recovery system from the flywheel to produce sufficient energy to run the research project set up and also to run external power supply. The AC generator has produced extra electricity by using a flywheel from 1 horsepower motor. This free energy is getting free of cost hence, constructing and developing a zero-cost power generating device is possible. An electric generator is a device that converts mechanical energy into electrical energy as the output. Generators were considered to be the "backup power of choice" but it is also known as one of the greatest contributors of greenhouse gasses emissions and gradually leads to global warming and air pollution [5]. To construct a zero-cost power-generating device does not take too much time and does not require any special skills or competencies, but only a little bit of time and attention. This kind of energy equipment is the prospective weapon for fighting the huge energy crisis the world is facing today.

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OBJECTIVES OF THE STUDY

The main objective of this study is to construct and develop a Pedal Powered Air Compressor Generator (PPACG) that can be used as an alternative source of electricity. Specifically, this study will answer the following questions:

1. What feature does the Pedal Powered Air Compressor Generator have?
2. What is the time required to fill the tank across weight class?
3. Is there a significant difference in the following when compared across weight classes?
   a. time to fill the tank;
   b. pressure output;
   c. voltage generated; and
   d. time to empty the tank?

The scope of the study focused on the design and construction of a Pedal Powered Air Compressor Generator. Due to limited resources, the design and construction of the armature core, stator core, windings, and casting of the DC motor are not part of the study. Also, the study was not designed for loads that use AC sources.

MATERIALS AND METHODS

Below are the identified components and devices needed to develop the project.

Angle Bars & Steel Pipe. The researchers used 2pcs of 3/16"x1 ½ " angle bars 20 feet long each and 1pc ¾" galvanized iron steel pipe to construct the frame of Pedal Powered Air Compressor Generator. The constructed frame has dimensions of 2'x6'x15".

BMX Bicycle. The researchers selected a BMX bicycle instead of a mountain bike by considering its size to make the prototype more portable and lighter.

V-Belt. It is the connecting medium of the rear wheel of the BMX bicycle and the pulley of the pump of the air compressor to transfer the work done. As the rear wheel rotates, the air compressor stores and compresses air.

Air Compressor. The researchers selected a Swan air compressor with a working pressure of 5kg/cm2 or approximately 70psi. It's original rating with its motor is ¼ HP, 600rpm, and a capacity of 46L/min. The prototype only uses 50psi from the tank and replaced the motor of the air compressor with a BMX bicycle.

Pneumatic Hose. Three meters of 6mm-diameter pneumatic hose were used by the researchers to convey the pressurized air from the air compressor tank, pressure regulator, push-pull pneumatic control valve, and pneumatic cylinder. The hose is designed to withstand the working pressure of the system.

Fittings. Pneumatic fittings are parts used to connect sections of pipe, tube, and hose in pneumatic (pressurized gas) systems. Compared to hydraulic fittings, pneumatic fittings are typically characterized by tighter seals and lower pressure requirements. Pedal Powered Air Compressor Generator used 2pcs of 1/8" in size, 3pcs of ¼" in size, and 3pcs of 3/8" in size of pneumatic fittings.

Pressure Regulator. Pressure regulators, commonly called pressure-reducing valves, maintain constant output pressure in compressed-air systems regardless of variations in input pressure or output flow. For example, the air compressor is set to generate air at 50psi or 345kPa, a pressure regulator positioned just downstream can be set to provide the entire system of the prototype by 300, 200, or 100kPa. This was also used in the prototype to control the speed of the pneumatic cylinder. The researchers used AR 2000 with a pressure gauge range of 0-1000kPa. It also comes with a pressure gauge to monitor the working pressure selected.

Push-Pull Pneumatic Control Valve. A manually operated valve is needed for the design of the prototype. A push-button valve can make the system operational but needs more maintenance because of the spring inside. Therefore, the researchers selected a push-pull valve, specifically, UNi-AiR 4L310-10 that can withstand 800kPa of air pressure. It is also a 5 port and 2 position valve, 1 port for the input inlet, 2 ports for the pneumatic cylinder, and 2 ports for the exhaust. It is a two-position valve because the cylinder is double-acting.

Crankshaft. A crankshaft used by the researchers is a mechanical part of a motorcycle's engine, specifically Yamaha RS100. This component performs a conversion of reciprocating motion to rotational motion. It translates the reciprocating motion of the piston rod of the pneumatic cylinder into rotational motion. It is typically connected to a flywheel.

Flywheel. In the design of the prototype, the flywheel is coupled to the shaft to reduce the pulsation characteristic of the system and to evenly distribute the power of the pneumatic cylinder.

Pulleys. There are 4 different pulleys used in the prototype, the rear wheel of the BMX bicycle, pulleys of the pump, flywheel, and dynamo. Pulleys are used to transfer power through a v-belt.

DC Motor. Pedal Powered Air Compressor Generator has a 24 Volts, 630 rpm DC motor. It drives by the rotational motion of the flywheel connected with a pulley. The researchers used not too high and not too low rpm rating of dynamo to fit to the design.

Charge Controller. The prototype has a charge controller to limit the rate at which electric current is added or drawn from the rechargeable battery. It also

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protects the battery from completely draining and overcharging that will reduce the battery's performance and lifespan.

Battery. The researchers used a 7.2Ah, 12V rechargeable Panasonic Battery. It is the energy storage of the project. The battery will supply DC loads like lightings and charging of electronic devices.

The researchers designed and developed the Pedal Powered Air Compressor Generator based on its schematic diagram shown in Figure 1. The prototype of this research project has ten main parts namely the bicycle, air compressor, pressure regulator, control valve, pneumatic cylinder, crankshaft, flywheel, dynamo, charge controller, and battery. This study can be used to replace small generators which are harmful to our environment.

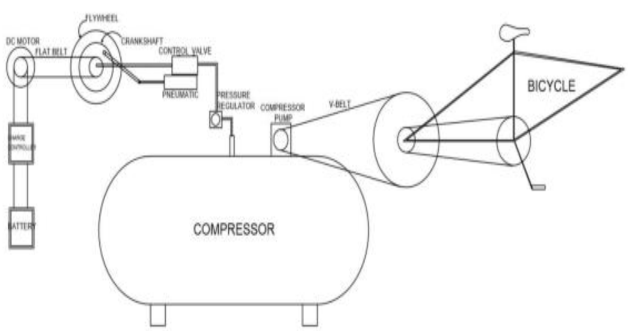

Figure 1. Schematic Diagram of Pedal Powered Air Compressor Generator

The motor of the air compressor is replaced by a rear wheel from a stationary bicycle; the pedal is used to drive the pump of the air compressor. As the rotating part of the pump moves, the air compressor stores air until it becomes full. The potential energy from the compressed air is used as the input energy for the pneumatic cylinder to operate. The pneumatic cylinder consists of a cylinder barrel and piston rod, which is controlled by a push-pull pneumatic control valve that makes the piston rod extend and retract. The forward and return motion of the pneumatic cylinder's rod is repeated continuously and it is converted to a rotational force using a crankshaft. The rotational force is used to rotate the flywheel to increase the machine's momentum in order to produce extra energy and thereby provide greater stability or a reserve of available power during interruptions in the delivery of power to the machine to produced extra electricity, which is connected to the dynamo or a DC motor with the use of a belt. The DC motor is the heart of the research project. In this research project, the motor act as a generator. This will convert the rotating mechanical energy from the pneumatic cylinder into electrical energy. The horizontal position of the motor can be adjusted to lessen the tension on the belt.

The pneumatic cylinder is one of the main parts of the prototype. A double-acting cylinder uses air pressure that can be applied to either side (supply and exhaust) of the piston, thereby providing a pneumatic force in both directions. To extend the piston rod, pump flow is sent to the blank end port. Compressed air from the rod end port returns to the reservoir. To retract the piston rod, the pump flow is sent to the rod end port and fluid from the blank end port returns to the tank as in Figure 2.

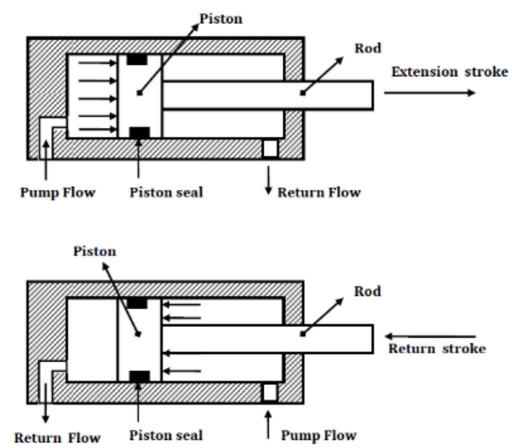

Figure 2. Double-acting cylinder with piston rod

Statistical Treatment of Data

After conducting the experiments, the gathered data was treated using multivariate analysis of variance (MANOVA). It is used when there are two or more dependent variables. The weight of the user of PPACG was dependent on the time to fill the tank, pressure output, the voltage generated, and the time to empty the tank.

It is followed by a significance test involving individual dependent variables separately. The Scheffe test was used to find out which pairs of means are significant. The Scheffe test corrects alpha for simple and complex mean comparisons.

RESULTS AND DISCUSSION

Human energy is converted into rotating mechanical energy using a stationary bicycle by means of pedaling. The rotation of the rear wheel of the bicycle drives the pump of the air compressor using a v-belt. Pneumatic parts consist of the pressure regulator, pneumatic control valve, and pneumatic cylinder. The compressed air from the air compressor will pass in the pressure regulator to limit the output pressure of the system depending on the desired speed. The controlled compressed air will consequently go to the pneumatic

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control valve which controls the directional flow of air incoming to the inlets of the pneumatic cylinder. The linear force (forward and return) of the pneumatic cylinder's rod is converted to rotational force using the crankshaft which is coupled to the flywheel. The flywheel is connected to a pulley that drives the pulley of the dynamo converting mechanical energy to electrical energy. The generated energy will be stored in a battery. A charge controller is used to monitor the charging state of the battery, also to avoid the battery from damage due to overcharging or undesired discharging. A fully charged battery can be utilized by dc loads like a fan, lightings, and charging of electronic devices.

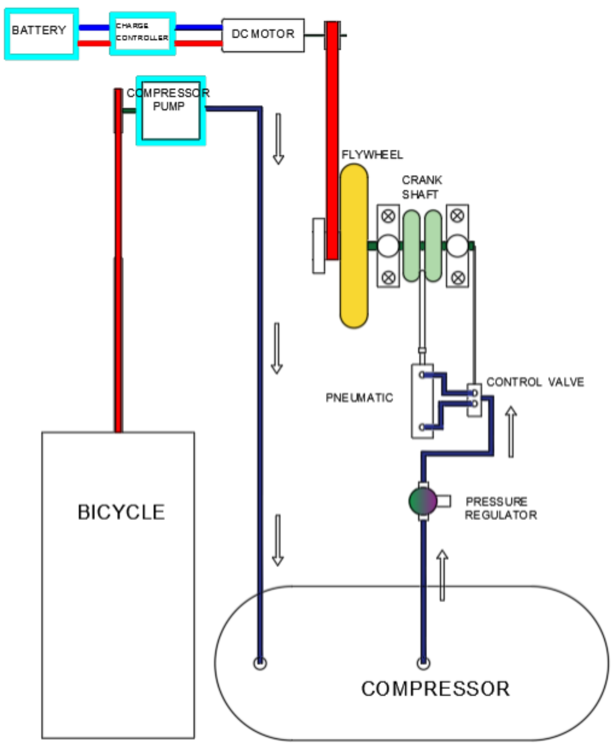

Figure 3. The working system of the project

Figure 3 shows the energy flow of the system. The arrow gives the direction of the compressed air flowing. When the user of the Pedal Powered Air Compressor Generator pedals the bicycle, the compressor pump operates using the bicycle's rear wheel, a pulley of the pump, and v-belt. When the pump operates, it stores air in the air compressor tank. The compressed air releases, and will pass through the pressure regulator to regulate the air outflow to be used by the control valve and pneumatic cylinder.

The pneumatic cylinder and the control valve must be in the exact position to function the prototype properly considering the extension and retraction length of their rods. The piston rod of the pneumatic cylinder is connected to the crankshaft. It converts the reciprocating motion of the piston rod of the pneumatic cylinder into rotational motion. The crankshaft is coupled to the flywheel to store rotational energy in order to reduce the pulsation characteristic of the system and to evenly distribute the power of the pneumatic cylinder. It serves as the prime mover of the DC motor that produced a maximum of 17.3 volts. The charge controller is also used to limit the rate at which electric current is added or drawn from the rechargeable battery which is the energy storage of the project. The battery will supply DC loads like lightings and charging of electronic devices.

Design and Features of the Project

Other pedal-powered generators will stop the generation when pedaling stopped. However, the Pedal Powered Air Compressor Generator (PPACG) can still generate electricity even if the pedal stopped because of the stored air in the air compressor tank. Also, the test results found out that PPACG can store air faster than the operation time. Therefore, the project created extra time for an operation.

On the Size Selection of Pneumatic Cylinder. Pneumatic cylinders are sized by multiplying the bore and stroke size. Bore is the inside diameter size of the cylinder barrel while stroke is the length of the piston rod which the pneumatic cylinder can release. Having a crankshaft, the researchers initially identify the stroke size of the pneumatic cylinder before the bore. The linear displacement of the crankshaft used in the prototype is 40 mm. The nearest commercially available stroke of cylinders is 50 mm. Therefore, the researchers used a 50 mm stroke to have an allowance space of 5mm each for extension and retraction of the rod and also to avoid the contact of the piston to both ends of the cylinder barrel.

On the Mechanical Energy of Flywheel. The researchers used a 2.5 kg, 8.255cm-radius, and 2.54cm-thick flywheel. A flywheel was utilized in the project to efficiently store rotational energy and resist changes in rotational speed by its moment of inertia, and reduce the pulsation characteristic of the system, and evenly distribute the power of the pneumatic cylinder. From this, the mechanical energy computed is 0.4272 Joule which is enough to reduce the pulsation characteristic of the system.

The researchers conducted 9 trials which were performed by 3 persons. Person A, B, and C weighs 58, 63, and 67 kg., respectively. Each person filled the tank three times. From a tank with 50psi or approximately 345kPa, the researchers released it at 9 different pressure outputs starting from 100 up to 300kPa. Table 1 shows the generated output voltage of the pedal-powered air compressor generator. Also, the table presents the speed obtained by persons A, B, and C in each trial made, in terms of revolutions per minute. The last column shows the extra time of operation of the Pedal Powered Air Compressor Generator yield.

Table 1. Output of the Pedal Powered Air Compressor Generator

Trial	Person	Speed (rpm)	Time to fill tank (s)	Pressure Output (kPa)	V_{max} Generated (V)	Time to empty tank (s)	t_{empty}-t_{fill} (s)
1	A	450	152	300	17.30	165	13
2	A	433	158	275	16.28	183	25
3	A	412	165	250	15.24	196	31
4	B	361	194	225	13.93	212	18
5	B	350	200	200	12.68	223	23
6	B	341	205	175	11.22	242	37
7	C	316	212	150	9.73	257	45
8	C	310	216	125	8.25	268	52
9	C	303	221	100	6.70	284	63

It can be seen from Table 1 that the prototype generated 6.7 volts up to 17.3 volts and can last from 165 seconds to 284 seconds. Hence, the higher the released pressure, the faster the compressed air is consumed.

To maintain the pressure inside the tank, it is recommended to pedal simultaneously during the operation of the machine. The table showed that filling the tank takes faster than consuming the pressurized air. Therefore, it will never make the tank empty when the user pedals.

Table 2 shows the charging test results of the conducted experiment on how long the 12V-battery can charge with respect to pressure output used. This process was done to verify if the project is able to charge a 12V battery which can be used to supply DC loads like charging or electronic devices and lightings.

Table 2. Charging Test Results

Pressure Output (kPa)	Initial Voltage (V)	Final Voltage (V)	Time to charge (min)
300	10.7	13.7	167
275	10.7	13.7	177
250	10.7	13.7	188
225	10.7	13.7	200
200	10.7	13.7	214

It can be gleaned from Table 2 that the battery has an initial voltage of 10.7 volts and 13.7 when fully charge. It takes from 167 to 214 minutes to charge the battery. The generated voltage must be higher than the voltage rating of the battery to charge. Therefore, we only used the pressure outputs ranging from 200 to 300 kPa because these can yield from 12.68 to 17.3 volts.

Difference Across Weight Class

On Time to Fill the Tank. The average time that person A, B, and C can fill the tank was recorded at 158.33, 199.67, and 216.33 seconds respectively as shown in Table 3.

Table 3. The difference in the time to fill the tank across weight class

Weight (kg)	Mean (s)	Fc	Sig.
A- 58	158.33^{c}		
B- 63	199.67^{b}	**86.294****	**.000**
C- 67	216.33^{a}		

***Highly Significant*
Means with the same superscript are not significantly different at 5% level using Scheffe.

Person A filled the tank with an average of 158.33 seconds while Person B filled the tank with an average of 199.67 seconds. However, person C filled the tank at 216.33 seconds. A highly significant difference in the time it takes to fill the same tank across weight class was observed based on the Fc=86.294 with an associated significant value lower than the 0.05 level. It is concluded and recommended that the user of the Pedal Powered Air Compressor Generator must be light and physically fit to meet the desired output.

On Pressure Output. The average working pressure used by persons A, B, and C were 275, 200, and 125 kPa respectively as shown in Table 4.

Table 4. The difference in the pressure output (kPa) across weight class

Weight (kg)	Mean (kPa)	Fc	Sig.
A- 58	275.00^{a}		
B- 63	200.00^{b}	**27.000****	**.001**
C- 67	125.00^{c}		

***Highly Significant*
Means with the same superscript are not significantly different at 5% level using Scheffe.

Person A released the compressed air at an average of 275kPa, while person B at an average of 200kPa. Lastly, person C released the compressed air at an average pressure of 125kPa. A highly significant difference in pressure output across weight classes was observed based on the Fc=27.000 with an associated significant value lower than the 0.05 level.

On Voltage Generated. From the working pressure used for each person, Table 5 shows the average voltage generated by persons A, B, and C.

Table 5. Difference in the voltage generated across weight class

Weight (kg)	Mean (V)	Fc	Sig.
A- 58	16.27^{a}		
B- 63	12.61^{b}	**28.111****	**.001**
C- 67	8.23^{c}		

***Highly Significant*
Means with the same superscript are not significantly different at 5% level using Scheffe.

Using the compressed air from the tank and released at the assigned pressure, person A generated an average of 16.27 volts, person B was 12.61 volts, and person C generated 8.23 volts mean. A significant difference in the voltage generated across the weight class was observed based on the Fc=28.111 with an associated significant value lower than the 0.05 level. The higher the pressure output of the system, the higher the output voltage generated.

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On Time to Empty the Tank. From the assigned pressure outputs, Table 6 shows the average time of persons A, B, and C to empty the tank.

Table 6. Difference in the time to empty the tank across weight class

Weight (kg)	Mean (s)	Fc	Sig.
A- 58	181.33[c]		
B- 63	225.67[b]	**26.722****	**.001**
C- 67	269.67[a]		

***Highly Significant*
Means with the same superscript are not significantly different at 5% level using Scheffe.

Table 6 explained the relationship of the time to empty the tank to the pressure output assigned to persons A, B, and C. With the highest-pressure output, person A made the tank empty at an average of 181.33 seconds. Person B takes about 225.67 seconds. However, person C made the system operational for the longest period which took an average of 269.67 seconds. A significant difference in the time it took to empty the same tank across weight class was observed based on the Fc=26.722 with an associated significant value lower than the 0.05 level. The higher the pressure output the faster the tank empties.

SUMMARY, CONCLUSION, AND RECOMMENDATION

Summary

The study aimed to develop a generating machine as an alternative source of electrical energy during power interruptions by only using human energy. The following are the summary of findings:

1. The prototype of this research project has ten main parts: the bicycle, air compressor, pressure regulator, control valve, pneumatic cylinder, crankshaft, flywheel, dynamo, charge controller, and battery.
2. Pedal Powered Air Compressor Generator uses air to produce electricity. It uses pneumatic parts like a pneumatic cylinder and control valve to convert the potential energy of air mechanically. The prototype can store air faster than consuming. Other pedal-powered generators will stop the generation when pedaling stops, but the Pedal Powered Air Compressor Generator can still generate even if the pedal stopped.
3. The experiment conducted to fill the tank of the prototype takes 2 minutes and 32 seconds to 3 minutes and 41 seconds. PPACG yields a maximum of 17.3 volts during 300kPa.
4. There is a significant difference in the following when compared across weight classes: (a) time to fill the tank, (b) pressure output, (c) voltage generated, and (d) time to empty the tank.

Conclusion

Based on the findings of the study, the following conclusions were drawn:

1. The Pedal Powered Air Compressor Generator worked. The project successfully utilizes the pneumatic cylinder as one of the main parts.
2. The prototype was designed to fill the tank and use the compressed air simultaneously, and the experiments conducted by the researchers proved that filling the air compressor tank works faster than consuming it, even if it is regulated at a maximum pressure output of the system (300kPa).
3. The higher the pressure output, the higher the voltage generated but the faster the prototype will operate. When releasing the pressure of 300 kPa, the prototype generated 17.3 volts.
4. It is concluded that the user of the Pedal Powered Air Compressor Generator must be light and physically fit to meet the desired output.

Recommendation

On the basis of the findings and conclusions drawn, the proponents recommend the following for the enhancement of the project:

1. Add a quick exhaust valve for quicker extension and retraction of the piston rod of the pneumatic cylinder.
2. Install an inverter to accommodate AC loads.
3. It is recommended that the dynamo should have a smaller diameter of pulley for higher rpm and generation.
4. Install a stepping platform to help the user to ride the bicycle easily.
5. There should be a bigger air compressor tank for the pneumatic cylinder. This will help the system to generate higher output.
6. Include a check valve to the air compressor tank for overpressure protection.
7. Add a pulley on the pump and connect to the crankshaft to make the system self-sustaining.

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