CONVERTING INTERNAL COMBUSTION ENGINES' EXHAUST GASES KINETIC ENERGY TO ELECTRICAL ENERGY

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Abstract

Over time, clean and affordable energy sources are being embraced to meet the rising global energy demand. This paper reviews kinetic energy harvesting from wastes as a potential localized power supply for automobiles accessories. Multiple sustainable solutions have been developed because of the renewable resources' fast-growing importance and contribution to the field of power generation. Additionally, pollution in the atmosphere is getting worse every day, which is the largest threat to life of human. In the suggested study, waste air from the exhaust system can be used and transformed into power utilizing energy-conversion techniques. The proposed concept can be used to provide vehicles with an alternate source of electricity. The suggested design aims to convert gasses kinetic energy into a useful electrical source which can be used in energized cars' accessories like lighting system and other electronic units or as an optional stored energy source.

INTRODUCTION

Air pollution is the use of materials or energy that endangers the health of people, living things, and ecological systems, damages structures, or interferes with legal environmental uses. The toxicological effects of air pollution on human health and the environment have been a major concern in recent years. From single cigarettes to large quantities of pollution produced by industry processes and automotive engines, pollution comes from a variety of sources. Over the past several decades, new change factors have become important and now significantly affect engine design and operation. First, there is a need to limit how much traffic contributes to urban air pollution since IC engines produce a lot of hydrocarbon and nitrogen oxide emissions. Second, there is a need to significantly reduce the amount of gasoline that cars use [1]. In 1952, Prof. C. Hagen Smith stated that the smog problem was caused by interactions between nitrogen oxides and hydrocarbon compounds in the presence of sunlight [2]. The World Health Organization (WHO) is looking at ways to lessen the use of fossil fuels, which contribute to air pollution and compel people to breathe polluted air, increasing the risk of respiratory ailments in individuals. A large portion of the world's population breathes air that is tainted by smoke emanating from sources like automobiles, industries, cigarettes, etc. To lessen the process of polluted inhaling, air quality measuring equipment is used in 6,000 cities across 117 different nations. [3] As population, traffic, industry, and energy usage rise quickly, air quality is deteriorating, especially in Asian countries. As a result, economies are being severely burdened by declining health, deteriorated ecosystems, biodiversity loss, and higher mortality and morbidity rates. The unrestrained use of fossil fuels in the manufacturing and transportation sectors has also emerged as the main producer of particulate matter and gaseous pollution. Both natural and man-made factors can contribute to air pollution. Natural factors include forest fires, tree emissions, lightning, volcanic eruptions, and surface erosion from rocks, minerals, and buildings. Man-made factors primarily include biomass burning, transportation, vehicle emissions, industrial activities, and mining. [4]. Figure 1 shows the huge air pollution which is produced by consuming fossil fuel, and the huge amount of waste air that daily drivers produce.

Figure 1. Fossil fuel consumption and air pollution from vehicles

Problem statement

This study aims to use the air pollution caused by the automobiles exhaust system and convert it to usable electric source to power several electric accessories in the vehicle such as (interior or exterior lights, air conditioning system, electrical seat calibrations, media system, sensors, camera…etc.) and reduce the overall load on the motor and reduce the fuel consumption. The goal of this work is to provide a kinetic energy conversion method for using unused energy in all sorts of vehicles. Even the most effective motor produces more heat and air than it moves the vehicle. However, some of this wasted energy could be converted into electricity using generators. The significance of the study is to exploit as much as possible of the waste air from the exhaust system and use it to power up electrical accessories in vehicles and automobiles. Despite the possibility of this significant energy recovery at full engine output, practical duty cycles need to be examined in order to assess possible energy recovery.

Kinetic Energy from Exhaust Gases

The energy an object has as a result of motion is known as kinetic energy in physics. It is described as the effort required to move a mass-determined body from rest to the indicated velocity. The body holds onto the kinetic energy it acquired during its acceleration until its speed changes. The body exerts the same amount of effort when slowing down from its current pace to a condition of rest. Formally, kinetic energy is any term that includes a derivative with respect to time in the Lagrangian of a system [5]. Examples showing how kinetic energy is changed into and out of different forms of energy may help people better understand kinetic energy. For instance, a biker can speed up a bicycle to a desired pace by using chemical energy from meals. This speed can be maintained on a level surface without additional effort, with the exception of overcoming friction and air resistance. Although the chemical energy has been transformed into kinetic energy, the cyclist experiences heat as a result of the incomplete conversion.[5]. Electric power plants that use a turbine to drive energy generators produce the majority of the electricity used in the U.S. and around the world. A sequence of blades installed on a rotor shaft in a turbine generator are pushed by a flowing fluid, such as air, water, steam, combustion gases, or water. A generator's rotor shaft revolves or spins due to the fluid's force on the blades. In turn, the generator transforms the rotor's mechanical (kinetic) energy into electrical energy. Steam turbines, combustion (gas) turbines, hydroelectric turbines, and wind turbines are a few of the several types of turbines. [6] Figure 2 shows Electricity generation from an electric turbine.

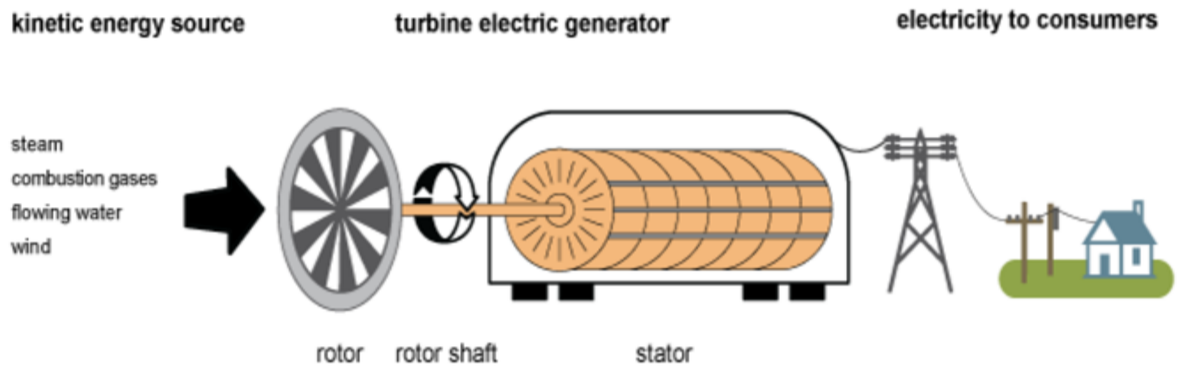

Figure 2. Electricity generation from an electric turbine.

The highest exhaust temperature was discovered by Alvin et al. (2015) during testing of a four-stroke diesel engine at 4000 RPM. He created a heat energy recovery device employing a shell and tube heat exchanger to recover this energy and boost engine performance. The system had a high initial cost, but it eventually turned a profit. [8]

A method to recover energy from exhaust gases was presented by Quang Khong et al. (2019), but it was based on heat exchange. Using the computational fluid dynamics (CFD) tool, he enhanced the design of the heat exchanger's flow field. As a result, the engine load which can reach 33% when the engine is completely loaded is the only factor affecting the energy recovery of the exchanger. [9] Giuseppe-Bianchi et al (2015) Presented a vane pumps work to save energy and vane expanders the slide was used to efficiently convert energy into a mechanical form, where the energy recovery performance of the power unit equipped with sliding spray machines was evaluated using lubricating oil as a heat source, where 1.7 kilowatts were recovered in mechanical form, and the power unit was tested based on ORC with an internal combustion engine at some operating points where the mechanical power recovered was up to 1.9 kilowatts [10]. To fulfill future energy needs and cut carbon emissions, it is essential to harvest energy from the environment. This technology also has the potential to power mobile or integrated devices that are not connected to the grid. This energy can manifest in a variety of ways, such as light, heat, vibrations, or movement. [11] As more sensors, actuators, data tags, and other devices are incorporated into goods, machinery, and perhaps even human bodies, strategies for supplying these devices with energy from the environment will allow them to function without external power sources. [12] Piezoelectric materials can be used in vibration or kinetic energy harvesting to create electrical energy. In order to eliminate the need for external power or increase the battery life of microdevices like sensors, this might potentially be scaled up to exploit stray vibrations and movement from the surroundings (such as from the body or machinery and automobiles). Shoe inserts, self-powered prosthetic/sensor combos, windmills, cantilevers, and other designs are just a few examples of piezoelectric energy harvesting devices that have been investigated in various applications. Other materials used include lead zirconate titanate (PZT) and barium titanate. [12]. A previous study examined the potential localized power supply for wireless applications of kinetic energy collecting. The power output of harvesting devices, which are frequently implemented as resonant devices, is influenced by the size of the inertial mass, the frequency and amplitude of the driving vibrations, the maximum possible mass movement, and the damping. Electromagnetic, piezoelectric, and electrostatic transduction techniques are currently used most frequently to transform kinetic energy into electrical energy. [13]. A mechanical system that connects environmental displacements to the transduction mechanism and a transduction mechanism that converts mechanical energy into electrical energy are required for kinetic energy harvesting. The mechanical system's design, which will be fully determined by the properties of the ambient motion, should maximize coupling between the kinetic energy source and the transduction mechanism. [13]. In piezoelectricity, there are two different sorts of effects: direct piezoelectric effect and converse piezoelectric effect. The internal generation of mechanical stress as a consequence of applied electric potential is related to the converse effect, whereas the direct piezoelectric effect is related to the internal development of electric charge as a result of applied mechanical force. Piezoelectric actuators are made using the opposite effect. [14]

METHODOLOGY: MATERIALS AND METHODS

As mentioned above, the goal of this study is to convert kinetic energy to electrical energy to recharge electronic devices by using the exhaust air in automobiles and converting it to new power source and then being saved in the battery, then used to power up different accessories in the car. The experimental work is performed using the following HWs.

Hardware components:

-Air Source

A 600W electric air blower was used as the air source in our project since it gives a great amount of kinetic energy, and it comes with an air duct to focus all the air blown into one specific spot and the blower is shown in figure 3.

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Figure 3. Electric air blower (Air source)

-Blades

Blades were used in this project so it could receive the kinetic energy from the air source and starts turning in circular manner and it is shown in figure 4.

Figure 4. Blades

- Gears (Gear Box)

The gear box is used to convert the rotation from x axis to the y axis because the blades turn in x-axis and needs to be converted to y-axis, with rotation ratio of 1:1. The gearbox is shown in figure 5.

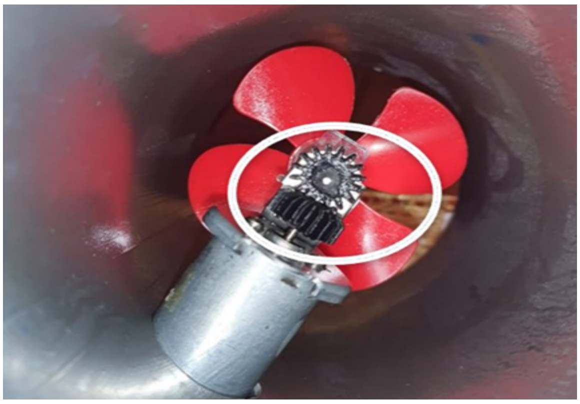

Figure 5. Gearbox

- Generator motor and other all components

The generator motor and all other components used to generate electric energy from the kinetic energy received from the air source, which produce 24V of electricity are shown in figure 6.

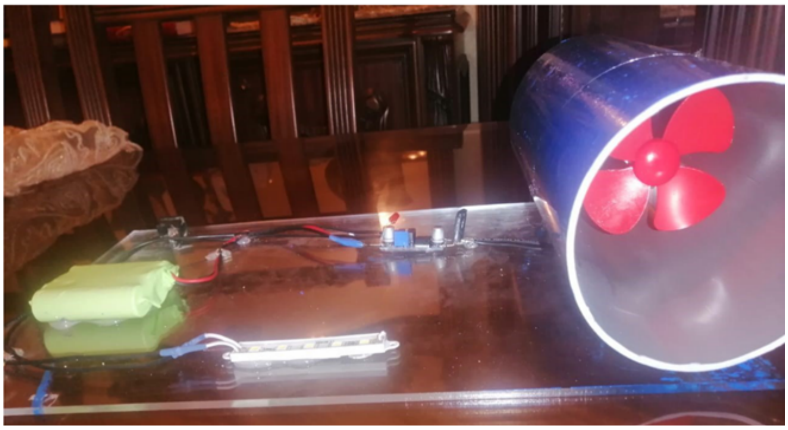

Figure 6. Suggested model

Working principle

The working principle of the suggested model is shown in the block diagram -figure 7 and the flowchart is shown in figure 8.

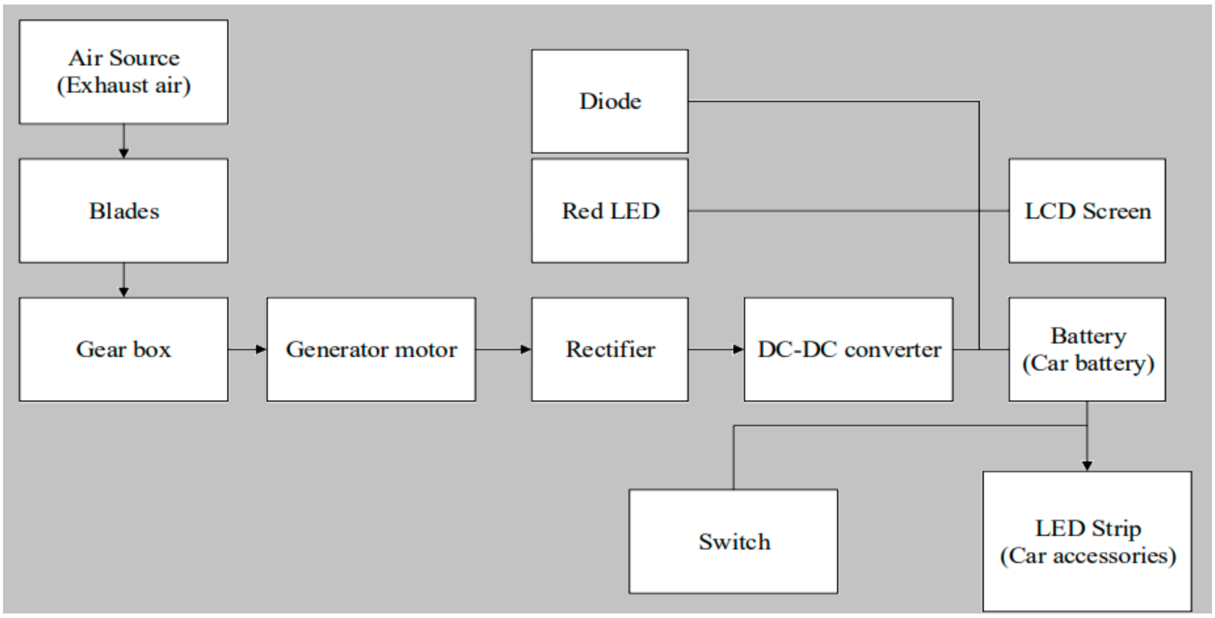

Figure 7. Block Diagram of the principle of work of the system.

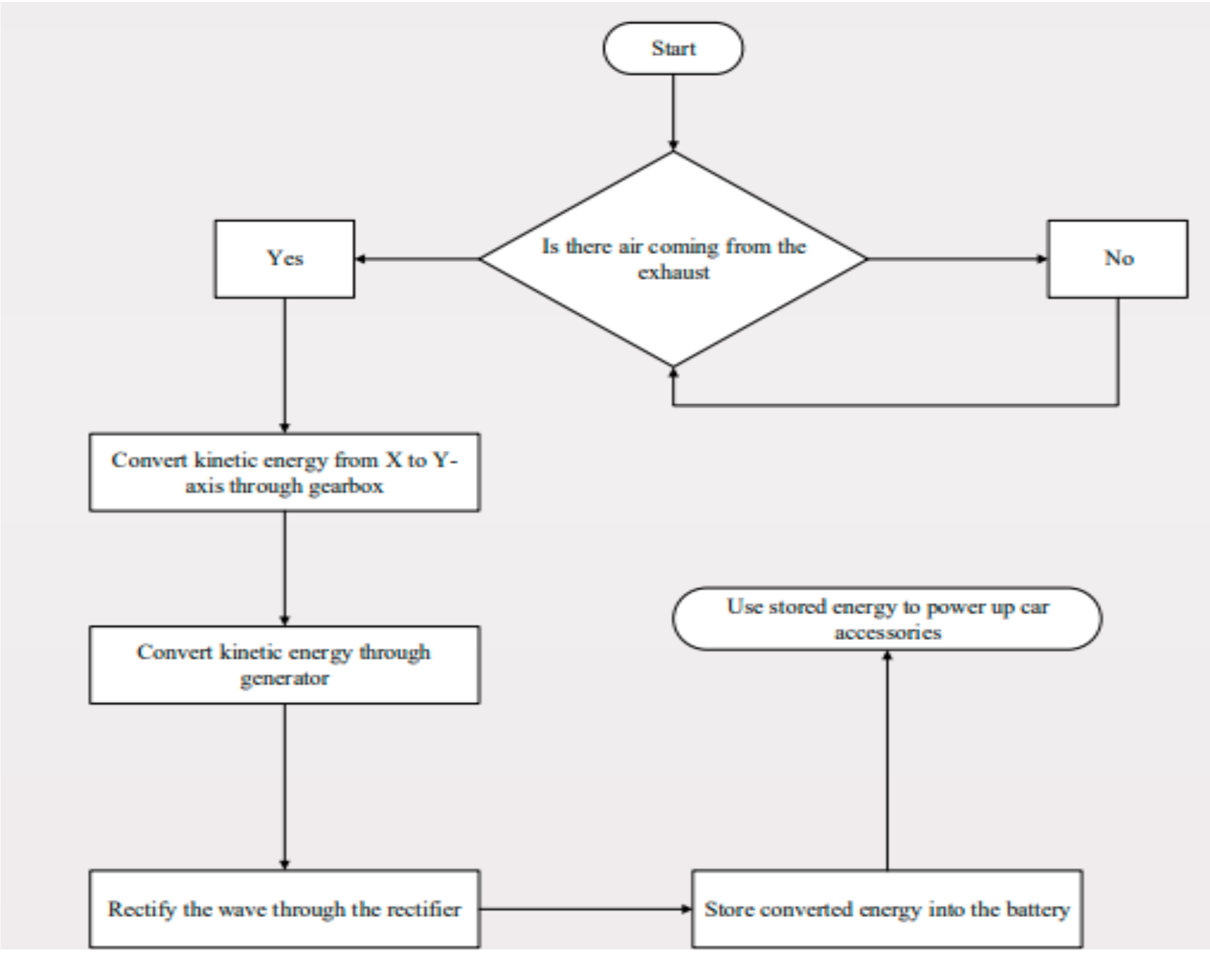

Figure 8. Flowchart of the suggested system

RESULTS AND DISCUSSION

Calculations

Here we are going to calculate the amount to waste heat energy in the exhaust gases for the engine below shown in table 1 a,b.

Table 1.a Engine specifications

Engine type	Inline 4 cylinder
Bore	75mm
Stroke	89mm
Displacement	1573cc
Compression ratio	18

Table 1.b Engine parameters

Item	Value			
Engine Speed (RPM)	1000	2000	3000	4000
Engine Power (KW)	14.9	50.2	70.8	84.8
Exhaust Temperature (K)	801.5	862.4	890.8	900.5
Exhaust mass flow rate (g/s)	18.7	59.6	83.3	108

Heat Content of Exhaust gas calculations

According to table 2. the heat amount at every specific RPM can be calculated by the following equation:

$$Q_{max}=\dot{m}_{ex}*c_{p\ ex}*\Delta T \tag{1}$$

Where $\dot{m}_{ex}$ = mass flow rate of exhaust gas, Cp = specific heat and ΔT = temperature difference

$$Q\ (1000\ RPM) = 0.0187*1.185*(801.5 - 298.15)$$

$$= 11.154kW$$

At 2000 RPM= 39.85Kw, At 3000 RPM = 58.5kW and at 4000 RPM = 77.089kW

It can be noticed that the maximum waste heat energy was at 4000 RPM, it was the maximum heat amount. Figure 9 shows the relationship between DC voltage and RPM.

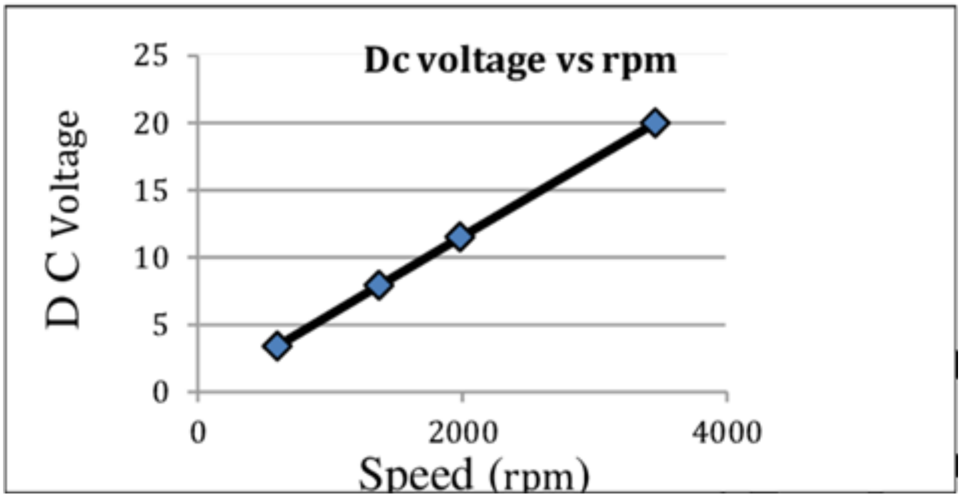

Figure 9. Relationship between DC voltage and RPM

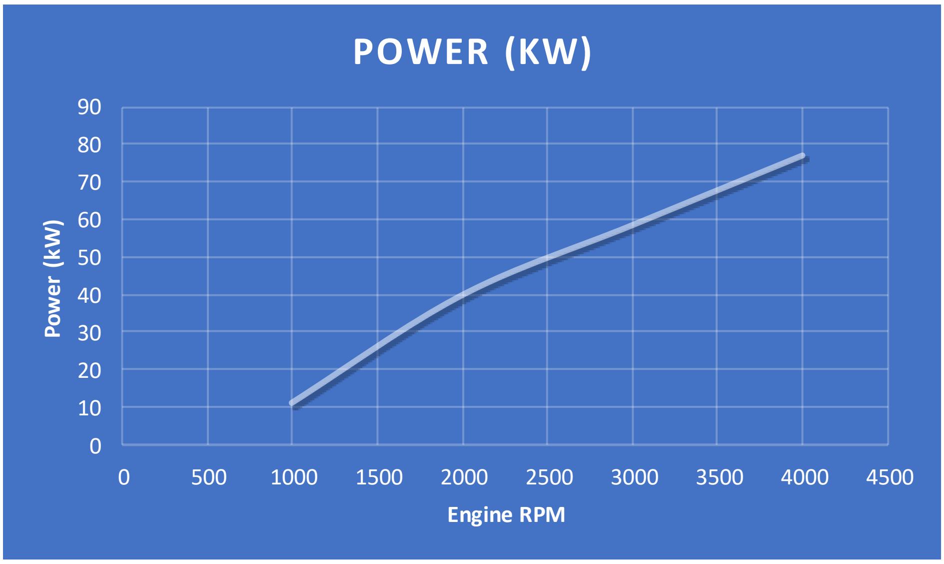

Figure 10. The amount of generated energy at different values of the engine RPM

Figure 9 above shows the relationship between the generated voltage and the rounds per minute, and it shows direct correlation whereas the more rpm's, the more voltage is generated. As the structure of the proposed system is compact, it can be installed in most automobiles which also increases the areas of the applications. Additionally, it might generate a sizable amount of energy from automobiles with powerful engines and those that produce a lot of waste air.

The results were tested, and it concluded that the module can be converted kinetic energy (air) from the air source which was the blower into electrical source of energy to light up the LED module as the car accessories which reduced the overall load on the vehicle engine. In this study a 600W air blower was used as the air source because it gives the perfect amount of air required to move the heavy metal blades. The blades were also used so it could receive kinetic energy from the air source and start turning in circular manner. Whereas the gearbox was used to convert kinetic energy axis so it could power up the motor generator. The 24V motor generator is used to convert mechanical kinetic energy to electrical power source and it was chosen because it has cheap cost and lightweight. We have also chosen the rectifier GBU8J since it can rectify the wave from the generator motor and prevent the circuit from damage. The LM2596 Power Supply's DC-DC is used to convert the 24V received from the generator motor to 12V and is also convenient. A diode was used to avoid the current flowing back to the DC-Converter and the generator which could cause severe damage to these parts. Lithium-ion batteries are used since they are rechargeable and can hold a good amount of electricity in it.

Finally, the LED module was used because it produces high brightness and has low power consumption. The results for the proposed design were all positive. The project was tested a multiple of times and it was able to charge the lithium-ion batteries by converting the kinetic energy received from the air source which was converted and generated into electrical power source, and it resulted into reducing the overall load on the engine and saved up on fuel consumption.

CONCLUSION

This model was developed in the sake of reducing the load of the engine and get use of the waste air from the vehicles. Analysis of current supportive power source equipment that transforms different forms of energy into electric power source was performed. The operating principle of power-generating is described as a supportive source of electrical energy. The project module was tested, and we made sure that it worked as planned. We concluded that the model is convenient and easy to use and could help to reduce the load on the vehicles engine and produce supportive electrical energy by converting kinetic energy. Not limited to standard vehicles, this model can also be integrated into heavy machinery like trucks. At this point we believe we completed our project by reducing the overall load on the engine by converting kinetic energy to electrical energy.

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