POWER GENERATION MODULE FROM EXHAUST GAS

By

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ABSTRACT

A waste product is formed on any device. In some cases, those waste products are used as inputs to other process or let it as waste. In that case, the exhaust gas is released into atmosphere. This can be used as an input for electricity production. The idea is that when the exhaust gas is made to hit the turbine placed near to it, tends to rotate. This rotational movement is converted into electric power by using direct current (DC)generator. The material for the turbine should be good enough to withstand the force and heat ejected from the exhaust gas. When the turbine rotates, the generator also rotates which produces power. To avoid slippages the turbine and the shaft should be fitted with appropriate couplings. The generator is connected to Day time Running Lights (DRL). DRL is mandatory in Bharat Stage Emission Standards (BSES) – IV norms of vehicles.

Keywords: Exhaust Gas, Power, Module, DRL, Battery, Vehicle.

Introduction

Introduction about Exhaust Gas

Electricity is the future fuel of the vehicle. It can replace all the Internal Combustion (IC) engines. This situation happened by a lack of resources to use for IC engines and it causes harm to nature. Recently, the scientific and awareness on environmental and energy issues have brought in major interests to the research of advanced technologies, particularly in highly efficient internal combustion engines. On the socio-economic perspective, the level of energy consumption is directly proportional to the economic development and total number of population in a country, the growing rate of population indicates an increase in energy demand (Ganesan, 2009, Venkatesh et al., 2018).

A heat engine is the system that converts heat or thermal energy into mechanical work. Examples of heat engines are the steam engine, the diesel engine, and the petrol engine in an automobile. The efficiency of a modern internal combustion engine is about 37% in a normal spark ignition engine. The heat is rejected by means of exhaust gas, cooling water, lubrication oil and radiation (Saidur et al., 2008; Kumar et al., 2015).

Electricity Usage

Alternatively, there are many fuels to run a vehicle, but among those electric motor driven vehicle is a first choice. It makes better when compared to IC engines in many aspects. The future is moving towards the electric driven vehicles, and we are also tend to produce electricity. Major automakers around the world are investing in electrification of mass-produced vehicles. The consumer view of electric cars is growing slowly. Here, we took a simple way to produce electricity from a exhaust gas.

Principle

A heat engine is the system that converts heat or thermal energy into mechanical work. The heat is rejected by means of exhaust gas, cooling water, lubrication oil & radiation. The principle used here is that the velocity of exhaust gas is used to produce torque, which produces electricity by the generator (Shu et al., 2013; Saidur et al., 2012).

1. Literature Review

This section reviews the experiments conducted in the area of recovery of exhaust gases. The exhaust gases from the engine are released to the atmosphere, this can be used for power generation. In the previous years, only the research in the reduction of harmful elements in the exhaust gas was considered. At present, the concepts of maximum utilization of exhaust gases have been experimented and the techniques have been discovered serving the purpose. The following sections provide a literature review on recovery of exhaust gases.

The idea of increasing demand in the need of energy for the running world and the requirements for alternative heat recovery methods is being studied (Saidur et al., 2011). The implementation of findings are being compared with the internal combustion engine's capability, which is then evaluated to acquire a high level of energy recovery condition pursued through modifications of the engine (Saidur, 2010; Ganesan, 2009).

The engine exhaust properties are carefully studied, including exhaust temperature, appropriate method for temperature measurement, emission contents and the progress (Saidur et al., 2008; Kee et al., 1998; Khurmi, 2005).

Different possible methods that suits to the practical applications are analyzed, compared and evaluated. This results in the design of turbine in the path of exhaust gas, which includes the factors such as material of turbine, selection of location for turbine, consideration of losses etc., by considering the factors influencing the turbine performance and a clear review (Guduru & Ipak, 2015; Kumar et al., 2015) has been made which ends with the design of turbine that yields a power of 43 watts.

The necessary thermoelectric generation facilities should be discovered and the proper analysis are made in order to execute the obtained facility with the engine exhaust. The use of a DC generator has been found to serve this purpose (Patil & Arakerimath, 2013; Saqr & Mohammed, 2008; Ramade et al., 2014).

Leading through the successful evaluated results, the designed power generation module has been found to be an appropriate possible technique of waste exhaust gases retrieval, which tends to produce a ripple effect. It has been achieved through the detailed review of heat recovery systems (Shu et al., 2013; Saidur et al., 2012).

1. Experiment

2.1 Components

2.1.1 IC Engine

The IC engine is a device, which is used to convert the chemical (fuel) energy into a mechanical energy. Nowadays, this engine is commonly found in every automobile. This produces the exhaust gas, which is discharged into the waste product. This exhaust gas is the main source for the generation of power in this module.

2.1.2 Turbine

A steam turbine is a mechanical device that coverts the energy from the exhaust gas, and converts it into a rotary motion. The turbine generates rotary motion, it is particularly suited to be used to drive a generator. This turbine operates with exhaust gas at high temperature, so the turbine should be made of such materials in order to withstand high temperature. Here, we used stainless steel material to withstand those high temperature.

2.1.3 DC Generator

The generator is a device which is used to convert the mechanical power into electrical energy. This is the basic opposite working of the motor, which converts electrical energy to mechanical energy. Here the generator is being connected to turbine which produces the rotary motion. Now with the input rotary motion being provided to the generator, this produces the electrical energy.

2.1.4 Rechargeable Batteries

Batteries are the charge storing devices. The electricity produced in the generator cannot be fully utilized in a single time. The battery is used in order to store the power for future uses. Here rechargeable batteries are used for long time usage. This also regulates the power of the LED.

2.1.5 Bearings

The bearings are the elements which constrain movements in a certain directions. This also serves as a load carrying member and provides lubrication between rotating members.

2.1.6 Light Emitting Diode (LED)

LED's are the lights used for the headlights of the vehicles. Nowadays daytime running lights are made as rule, so the power requirement of the battery also increased along with it. This can be solved by using the electric power generated from the exhaust gas.

2.2 Experimental Setup

In the setup, we have the basic equipment for producing electricity. Here, we are placing a turbine in the path of the exhaust gas from the engine. Depending upon the air flow from the exhaust, the turbine rotates.

The turbine is connected to a DC generator, which is used to produce electricity. DC generator is a device that converts kinetic energy into electrical energy. Further, it is connected to DRL and also to rechargeable battery. Here, the battery acts as a storage device for future purpose. Refer Figure1for better understanding (Patil & Arakerimath, 2013; Ramade et al., 2014).

2.3 Working

IC engine is a device used to convert heat energy into mechanical work. The efficiency of the engine is quite low due to several factors. The heat is liberated in the form of exhaust gas, circulating cooling water, lubrication oil and radiation. The turbine is being placed in the place of outlet of the exhaust gas from the engine. The radial turbine is being used in order to convert the force into rotational torque. Due to the velocity of exhaust gas, the turbine starts to rotate.

The pressure energy is converted into rotational movement, which leads to the creation of torque. This torque is transmitted to DC generator simultaneously, with the help of coupling and shafts. The DC generator is a device used to convert the mechanical energy into electrical energy. The turbine rotates the DC generator which in turn produces the electric power. This power is being directed towards the battery and it is connected parallel to the DRL. The battery is a storage device used to store the electricity for the future purpose, which can be used for several equipment in a vehicle. This electric power can also be transmitted to many electric components in the vehicle (Saidur et al., 2011; Saidur, 2010).

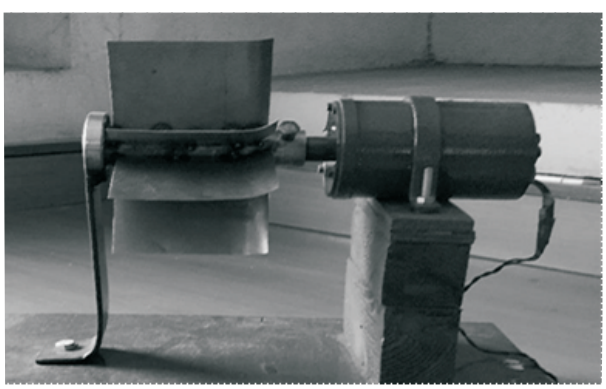

Figure 1.The Scaled Model of the Power Generation Module.

2.3.1 Block Diagram

The basic block diagram for the better understanding of the power conversion and power flow is given in Figure 2.

2.4 Calculations

Let us consider a two wheeler generator vehicle for the calculation purposes.

Force produced by engine

- Engine speed = 7000 rpm
- Turbine speed = 5000 rpm
- Radius of turbine (r) = 0.075 m
- Displacement = 109cc = 109×10^{-6} m^3
- Displacement = $109 \times 10^{-6} \times 7000$
  = 0.763 m^3/min
- Exhaust diameter(d) = 27.7 mm
- Flow rate (Q) = 0.013625 m^3/s

Area of the exhaust valve (A_e)

$$A_e = \frac{\pi}{4} \text{ x } d^2$$

$$A_e = \frac{\pi}{4} \text{ x } 27.7^2 = 6.0262 \text{x } 10^{-4} m^2$$

Velocity of exhaust gas (v_g)

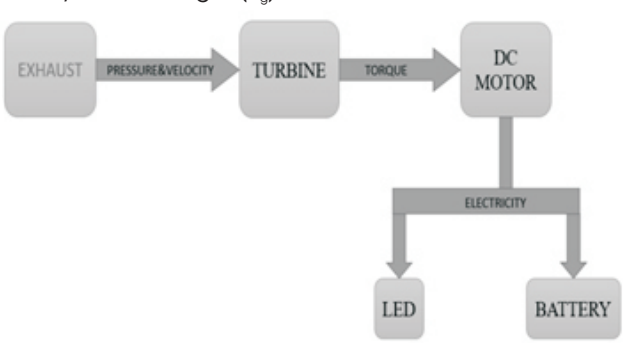

Figure 2. The Flowchart of Energy (Power) Conversion

$$v_g = \frac{Q}{A_e}$$

$$v_g = \frac{0.013625}{6.0262 \times 10^{-4}} = 22.6092 \text{ m/s}$$

Swept area (A_s)

$A_s = \pi x r^2$

$A_s = \pi x (0.075)^2 = 0.0176 m^2$

Velocity of turbine (v)

$$v = \frac{\pi D N}{60}$$

$$v = \frac{\pi \times 0.15 \times 5000}{60} = 39.26 \text{ m/s}$$

Pressure(P) $= 4 bar = 4 x 10^5 N/m^2$

Temperature (T) $= 673 K$

Density of exhaust gas (ρ_g)= $(4\times10^5)/(287 \times 673) = 2.07$ kg/m^3

Mass flow rate ($\dot{m}$)

$\dot{m} = Q x \rho_g$

$\dot{m} = 0.0136 x 2.07 = 0.0282$ kg/sec

Impulse force (F)

$F = \dot{m} x v$

$F = 0.0282 x 39.26 = 1.1074 N$

Power at turbine

- Length of turbine blade (l) = 10 cm
- Breadth of turbine blade (b) = 7 cm
- Thickness of turbine blade (t) = 1 mm
- Material of turbine blade = Stainless steel
- Density of stainless steel (ρ_s) = 7700kg/m^3

Area of the blade (A_b)

$A_b = l x b$

$A_b = 0.1 x 0.07 = 7 x 10^{-3} m^2$

Volume (V)

$V = A_b x t$

$V = (7 x 10^{-3}) x (1 x 10^{-3}) = 7 x 10^{-6} m^3$

Mass of turbine (m)

$m = \rho_g x V$

$m = 7700 x 7 x 10^{-6} = 0.0539$ kg

Mass for 8 blades of turbine

$m = 8 x 0.0539 = 0.4312$ kg

Weight of turbine (W)

$W = m x g$

$W = 0.4312 x 9.81 = 4.23 N$

Torque (T) (Saqr & Mohammed, 2008; Guduru & Ipak, 2015; Khurmi, 2005) = Force x radial distance

$T = 1.1074 x 0.075 = 0.083 N m$

Power (P)

$$P = \frac{2 \times \pi \times 5000 \times 0.083}{60} = 43.48 \text{ W}$$

3. Result and Disscusion

To design an operative module for the generation of power by heat recovery from the exhaust gas of an IC engine. For this objective to be achieved, it was necessary to know the basics of the outlined technique.

The main component of this module is the turbine, which produces the mechanical energy required for power conversion. Considering the general emissions of the exhaust gas, the turbine material is selected considering high temperature factors, and the selected material is stainless steel. A standard IC engine was considered and the exhaust velocity was calculated to be 23 meters per second, which was used for calculation purpose. By varying the exhaust velocity, the corresponding power achieved was 6.26W, 28.98W and 79.51W, respectively. Thus, by varying the speed, this module is able to produce the power effectively. Refer Table 1 for the values and Figures 3 and 4 for the comparisons.

The results from Table 1 are obtained with the module location at the exhaust, it was found that the efficiency of the module can be further improved by relocating the

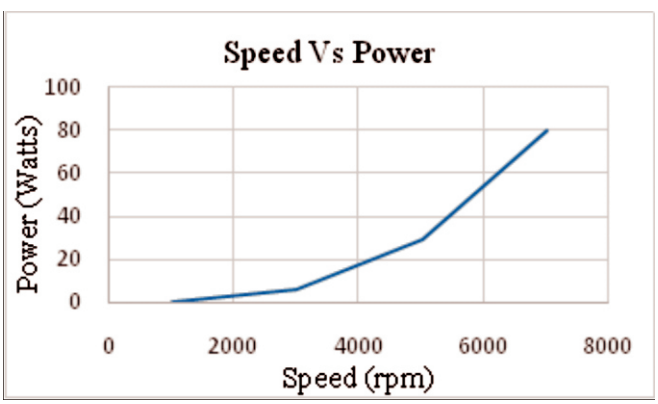

Figure 3. Graph Showing the Comparison Between the Speed and Power.

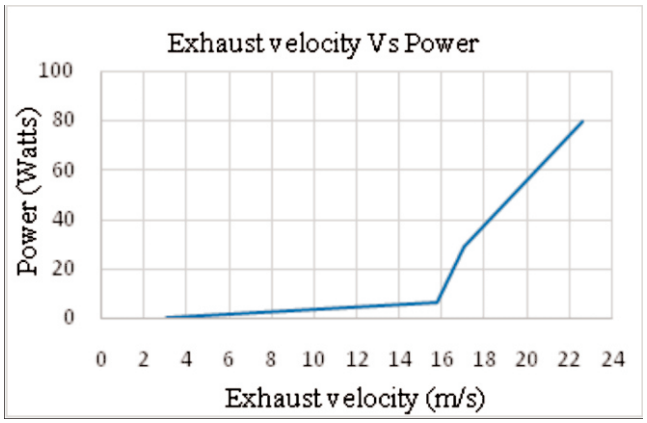

Figure 4. Graph Showing the Comparison Between the Exhaust Velocity and Power.

SPEED (RPM)	EXHAUST VELOCITY (m/s)	FLOW RATE (m^3/s)*	POWER (W)
1000	3.016	1.816	0.23
3000	15.78	9.5	6.26
5000	17.03	10.03	28.9
7000	22.63	13.625	79.5

Table 1. Power Values for the Corresponding Speeds

position of the module followed by necessary modifications of material properties.

4. Scope

- This module can be used in every automobile which has an IC engine. Modification of this module can be done to have more compact design and minimum losses.
- This paves a way for increasing efficiency of the IC engine and battery of the vehicle.
- This can be modified according to different application wherever the exhaust gas is present.
- This can be modified according to the future vehicles which can serve as a source of the battery.
- In the future of hybrid vehicles, this could be a revolution for being a source of input to the vehicle.

Conclusion

This briefs the way of generating electricity using exhaust gas. With the help of turbine, the exhaust gas is converted into electricity. The electricity should be stored in battery. The electricity being stored can also be used for our specific future purposes. Thus, the module is completed successfully. Hence, this project turns to be an advantage of using waste gas, which is an additional source of power generation.

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