# Power Generation by using Kinetic Energy of Exhaust Gases from an Internal Combustion Engine

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***Abstract*— Mankind has relied on fossil fuels for their energy needs for a long time. Reckless usage of these fuels has caused immense amounts of pollution and continued usage can lead to irreversible damage to the environment. In such circumstances, any step towards reducing the consumption of fuel or at the least making sure that most of the energy produced by burning these fuels is extracted without any wastage is a step in the right direction. This work proposes the usage of a miniature turbine at the silencer outlet to produce electricity. The results obtained in this work show that the technique used is suitable for implementation across all domestic vehicles for energy reclamation.**

***Keywords*— Silencer Turbine, Waste Heat Recovery.**

## I. INTRODUCTION

Over the last couple of decades, mankind has realized that the continuous usage of petroleum fuels to meet the world's energy demand, over the course of more than a century, has led to innumerable consequences. An inclination towards other sources for energy has come into the forefront. Yet, we are still a long way from completely phasing out petroleum as an energy source altogether. In such a time, any progress towards reducing the amount of fuel consumed during energy generation is good progress and cannot be neglected. Only 30 to 40% of total energy produced in an engine is utilized to run the vehicle and engine accessories. The rest is wasted in the form of exhaust heat and noise. So, there is a scope for reclaiming the wasted power produced by the engine. Various methods to reduce the wastage of energy from automobile engines have been put forth. Some of these methods include the usage of catalytic converters, piezoelectric generators etc. Among these methods, turbine-based power generation through the exhaust gases has proven to be an efficient source of energy generation.

*Turbine Based Power Generation*

It works on the principle of conversion of kinetic energy into electric energy. In this process, a turbine is fixed near the opening of the silencer. A dynamo is attached to the turbine, which converts kinetic energy generated through the turbine into useful electrical energy.

Various researchers have implemented the concept that this work aims to implement. The inferences of the papers written by the researchers have been discussed below.

Kranti Kumar Guduru et al. [1] studied that electrical energy can be obtained by utilizing the kinetic energy of the exhaust gases. They made use of a turbine, dynamo, battery and nozzle for this purpose. After carrying out the experiments they found that the voltage produced at the output is directly proportional to the exhaust velocity. They also found that the efficiency increases with increase in velocity.

Shrikant Gawas et al. [2] worked on a turbocharger system and found that the emission rate can be controlled by using exhaust energy recovery and by providing proper compressed air into the inlet of the cylinder. They used a turbocharger, a thermal activator device and a dynamo to achieve it. By carrying out the study they found that the efficiency of the engine can be significantly increased by this method.

Shaikh Mobin et al. [3] stated that electric energy can be produced by utilizing the exhaust gas of an automobile. They made use of a turbine, gears and a DC generator to conduct their experiments. From the experiments they found that the power generated is directly proportional to the speed of the turbine.

After referring to all the above papers we concluded that the energy from the exhaust gas can be efficiently derived by implementing turbine based power generation techniques. The kinetic energy of the exhaust gas escaping through the silencer can be converted to usable forms of energy with the help of a miniature turbine and a dynamo.

## II. METHODOLOGY

The following components were required to implement the work proposed.

### *2.1 Four Stroke Petrol Engine*

A 4 Stroke Petrol Engine of Suzuki Heat 125 is being used for the purpose of this analysis. The specifications of the engine are given below.

Engine specifications

- Model of the vehicle used : Suzuki Heat
- Displacement : 124 cc
- Maximum power : 8.83 Bhp @ 7000 rpm
- Maximum torque : 10 Nm @ 3500 rpm
- Number of cylinders : 1
- Cylinder bore : 53.5 mm
- Stroke : 55.2 mm

The 4-stroke petrol engine also known as the Otto cycle engine requires 4 different strokes to complete one cycle. These engines make use of spark plug for the ignition of the fuel. Each Otto cycle consists of an adiabatic compression, addition of heat at constant volume, an adiabatic expansion and release of heat at constant volume.

### *2.2 Turbine*

A turbine is a rotary mechanical device that extracts energy from a fluid flow and converts it into useful work. The work produced by a turbine can be used for generating electrical power when combined with a generator. The mounting is to be done in such that as the vehicle moves, the exhaust gases produced will rotate the turbine blades, which will be used to generate power from a dynamo.

### *2.3 Dynamo*

Dynamo is an electrical generator. This dynamo produces direct current with the use of a commutator. Dynamos were the first generator capable of the power industries. The dynamo uses rotating coils of wire and magnetic fields to convert mechanical rotation into a pulsing direct electric current. A dynamo machine consists of a stationary structure, called the stator, which provides a constant magnetic field, and a set of rotating windings called the armature which turn within that field. On small machines the constant magnetic field may be provided by one or more permanent magnets; larger machines have the constant magnetic field provided by one or more electromagnets, which are usually called field coils. The dynamo used for this analysis is RS-775, which has a maximum output voltage of 12 V.

### *2.4 Hand-Held Anemometer*

An anemometer is a device used for measuring the speed of wind, and is also a common weather station instrument. The term is derived from the Greek word anemos, which means wind, and is used to describe any wind speed instrument used in metrology. The anemometer used in this work was CEM DT-618. According to its specifications, it has a measuring range of 0.4-30 m/s, and an accuracy of ± 0.3 m/s.

### *2.5 Multimeter*

A multimeter or a multitester, also known as a VOM (Volt-Ohm-Milliammeter), is an electronic measuring instrument that combines several measurement functions in one unit. A typical multimeter can measure voltage, current and resistance. Analog multimeters use a microammeter with a moving pointer to display readings. Digital multimeters (DMM) have a numeric display, and may also show a graphical bar representing the measured value. Digital multimeters are now far more common due to their cost and precision, but analog multimeters are still preferable in some cases, for example when monitoring a rapidly varying value. The multimeter used in this work was DT-9205A.

### *Procedure*

A fan made of plastic was repurposed from a centrifugal blower to act as a turbine. The fan specifications are as follows:

- Total Diameter = 100 mm
- Number of blades = 10
- Axial length of blades = 25 mm
- Blade thickness = 2 mm

For generating electrical current, the DC Motor RS-775 was used. It is a 12 V reversible motor, which means that it can be used as an alternator as well. The fan was connected to the motor by soldering a bolt onto the shaft of the motor and fixing the fan in place using a nut. The prepared turbine is shown in Fig. 2.1.

Fig. 2.1: Turbine-Alternator Setup

An anemometer was used to measure the flow velocity of the exhaust gases at different speeds of the engine. This was done to compare the flow rate to the power so obtained at those speeds by the turbine fixed at the silencer outlet. The gas velocity was converted to flow rate by multiplying it to the area of the outlet of the silencer. The diameter of the silencer exhaust was measured using calipers for this purpose.

For the purpose of mounting the turbine onto the silencer, and to prevent environmental disturbances to the turbine while it rotates, an enclosure was prepared using sheet metal to be mounted onto the vehicle. A sheet metal cube of each side measuring 150 mm was made. The top surface was made as a hinged lid for easy access to the turbine and dynamo. A sheet metal pipe of diameter 18 mm, suitable to be inserted into the silencer was taken and a hole was made on one surface of the mounting box, into which the other end of the pipe was brazed. Another larger hole was made on the perpendicular surface of the box for insertion of the dynamo. A supporting clamp was made inside the box to allow for stable mounting of the dynamo inside the box preventing any unwanted motion of the dynamo. Holes were drilled at the bottom surface of the box to allow exhaust gases to escape out when the lid would be closed. Finally, the mounting box was mounted onto the silencer with the help of a fixture. Due to this, the vehicle could be run without any disturbance to the turbine setup. The setup prepared is shown in Fig. 2.2 and 2.3. Analysis of power output from the turbine when the engine speed was varied and the vehicle was stationary was performed. Next, an analysis of power output from the turbine when the vehicle was moved and the speed of the vehicle was incremented by 5 kmph for each reading was performed. The values obtained have been tabulated in the results section.

Fig. 2.2: Turbine mounted onto the vehicle

Fig. 2.3: Close up view of Turbine Mounting

## III. RESULTS

For the purpose of measuring the power output from the turbine with respect to the flow rate of exhaust gases, the flow rate of exhaust gases was required to be measured. The following formulae allow the calculation of the flow rate by measuring the speed of the exhaust gases using an anemometer.

Diameter of the silencer outlet = 19.55 mm

$$Q = A \times V \qquad (1)$$

Where, Q = Flow rate in $m^3/s$

A = cross sectional area of silencer outlet in $m^2$

V = Gas velocity in m/s

$$A = \frac{\pi D^2}{4} \qquad (2)$$

Where D=Diameter of silencer outlet in m

$$A = \frac{\pi\,(19.55 \times 10^{-3})^2}{4}$$

$$A = 3 \times 10^{-4}\ m^2 \qquad (3)$$

Substituting (3) in (1),

$$Q = (3 \times 10^{-4})\ V\ m^3/s \qquad (4)$$

An analysis of power output from the turbine for different engine speeds, in turn for different flow rates of exhaust gases was performed. This was done when the vehicle was stationary. The readings obtained from the turbine are shown in Table 3.1.

Table 3.1. Turbine Analysis for Stationary Vehicle

| Sl. No. | Speed of Engine in RPM | Flow Rate in $m^3/s$ | Voltage in Volts | Current in Amps | Power in Watts |
|---|---|---|---|---|---|
| 1 | 2000 | 0.012 | 0.38 | 0.112 | 0.0425 |
| 2 | 2500 | 0.0162 | 0.65 | 0.192 | 0.125 |
| 3 | 3000 | 0.0171 | 1.06 | 0.313 | 0.332 |
| 4 | 3500 | 0.0207 | 1.9 | 0.561 | 1.067 |
| 5 | 4000 | 0.0258 | 2.01 | 0.593 | 1.191 |
| 6 | 4500 | 0.0303 | 2.12 | 0.625 | 1.325 |
| 7 | 5000 | 0.0321 | 2.16 | 0.637 | 1.376 |
| 8 | 5500 | 0.0324 | 2.27 | 0.67 | 1.521 |
| 9 | 6000 | 0.0363 | 2.35 | 0.693 | 1.628 |
| 10 | 6500 | 0.0375 | 2.49 | 0.735 | 1.83 |
| 11 | 7000 | 0.0381 | 2.7 | 0.796 | 2.149 |
| 12 | 7500 | 0.0393 | 2.85 | 0.841 | 2.397 |
| 13 | 8000 | 0.0405 | 3.13 | 0.923 | 2.89 |

The graph shown in Fig. 3.1 gives the comparison between the flow rates of the exhaust gases to the power output produced by the turbine.

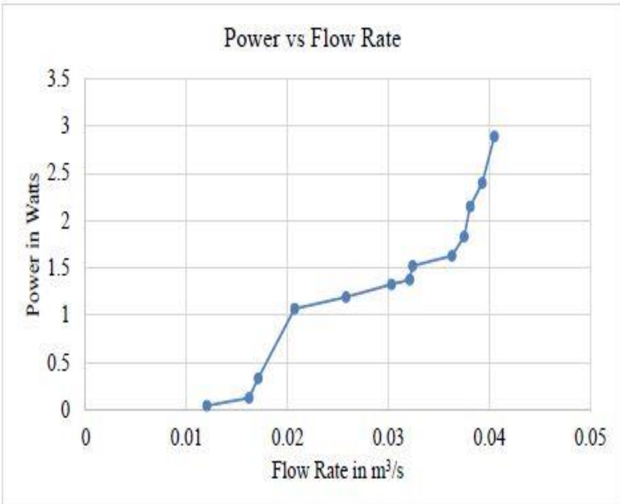


Fig. 3.1: Graph of Flow Rate of exhaust gases vs Power

There is a clear trend of increase in the output power with respect to increase in flow rate of exhaust gases. This is because as more gases impact the turbine blades, the speed of rotation of the turbine increases, giving a higher power output.

The graph shown in Fig. 3.2 gives the comparison between the engine speeds to the power output produced by the turbine.

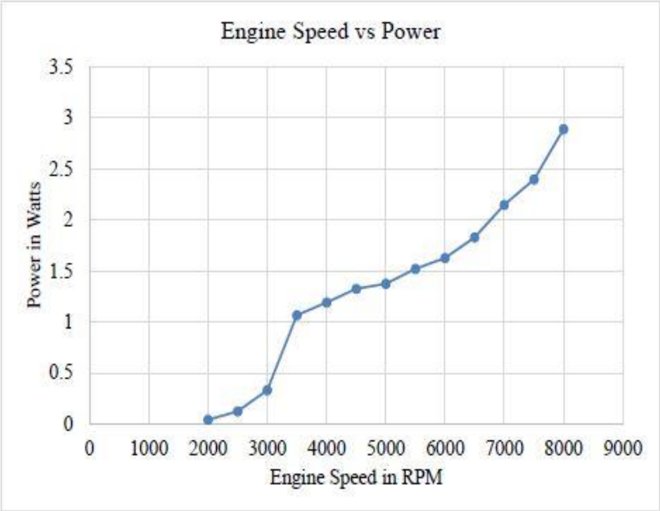


Fig. 3.2: Graph of Engine Speed vs Power

Again, there is an increasing trend in power output as the engine speed increases. This is because the flow rate of exhaust gases is proportional to the engine speed, which increases the power output of the turbine. From the above graphs, it is evident that the power generated by the turbine increases with increase in the engine speed and the flow rate of the exhaust gases.

An analysis of the power output obtained from the turbine at different speeds of the vehicle was performed. The readings obtained are shown in Table 3.2.

Table 3.2: Turbine Analysis for Moving Vehicle

| Sl. No. | Speed in Kmph | Voltage in Volts | Current in Amps | Power in Watts |
|---|---|---|---|---|
| 1 | 0 | 0 | 0 | 0 |
| 2 | 5±1 | 1.26 | 0.3716 | 0.468 |
| 3 | 10±1 | 1.33 | 0.392 | 0.521 |
| 4 | 15±1 | 1.83 | 0.54 | 0.988 |
| 5 | 20±1 | 2.58 | 0.761 | 1.963 |
| 6 | 25±1 | 2.86 | 0.844 | 2.414 |
| 7 | 30±1 | 2.99 | 0.882 | 2.637 |
| 8 | 35±1 | 3.11 | 0.917 | 2.852 |
| 9 | 40±1 | 3.21 | 0.947 | 3.039 |
| 10 | 45±1 | 4.48 | 1.026 | 3.57 |
| 11 | 50±1 | 4.05 | 1.195 | 4.84 |
| 12 | 55±1 | 5 | 1.475 | 7.775 |
| 13 | 60±1 | 6.03 | 1.779 | 10.727 |
| 14 | 65±1 | 6.38 | 1.882 | 12 |
| 15 | 70±1 | 6.88 | 2.03 | 13.966 |

The graph shown in Fig. 3.3 plots the relationship between the speeds of the vehicle to the turbine output power.

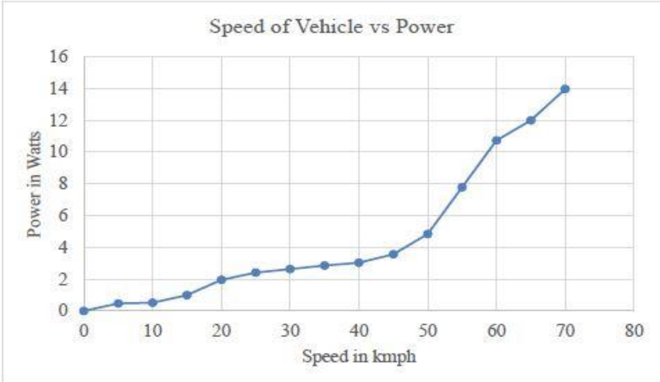


Fig. 3.3: Graph of Speed of Vehicle vs Power

From the above graph, it is evident that as the speed of the vehicle increases, the power output of the turbine also increases. This is due to the fact that as the vehicle is required to move at higher speeds, more fuel consumption is required which in turn results in a higher flow rate of exhaust gases through the silencer. A maximum power of around 14W was obtained from the turbine when the vehicle was in motion and around 3W when the vehicle was stationary. Thus, the apparatus can be implemented onto moving vehicles as well as stationary machines which have an engine.

This shows that electrical power can be easily generated from the exhaust gases of the vehicle. This power may be used to run the appliances of the vehicle or charge any rechargeable devices during travelling.

## IV. CONCLUSION AND FUTURE SCOPE

Automobile engines produce a substantial amount of power. This power helps to drive the vehicle with ease and at great speeds. However, in today's world of economizing fuel consumption and trying to reclaim every watt of power going unused in the vehicle, techniques to reclaim power are important. This work shines light on a technique which has immense promise in reclaiming waste energy from the exhaust of a vehicle. Through this work, a maximum power output of around 15W was obtained from the turbine setup. With proper research in the field, we may be able to produce so much power from other sources of the vehicle that this power may be used as an auxiliary driving source for itself. Turbines are currently implemented in the exhaust of Formula 1 cars according to new regulations passed in 2014. This system is called the MGU-H. In conjunction with other power generation techniques, the method discussed in this work can be implemented onto any vehicle with an exhaust.

The method discussed in this paper can be implemented on any machine with an engine. As all engines have silencers and exhaust gases escaping from them, any energy going wasted through the silencer can be easily extracted for future usage. This method can be implemented on any automobiles like cars, bikes, scooters, trucks etc. Along with mobile vehicles, the method can also be implemented on stationary devices having engines like diesel generators, compressors, crushing machines etc. The method discussed is thus flexible to be implemented across all engines.

Improvements that can be made to the present work to further enhance the output include:

- Use of a higher-powered dynamo/alternator on the turbine setup.
- Separation of the shafts of the turbine and the dynamo and utilizing gears increase the speed of rotation of the dynamo shaft.

## REFERENCES

[1] Kranthi Kumar Guduru and Yakoob Kol Ipak, "Power generation by exhaust gas on diesel engine.", International Journal of Research and Computational Technology, Issue 5, Volume.7, pp. 06-13.

[2] Shrikant Gawas, Abhishek Tawde, Onkar Raorane, Rehan Prabhulkar and Aditya Hule, "Sustainable development in two-wheeler using exhaust gases", IPASJ International Journal of Computer Science (IIJCS), Volume 5, Issue 2, February 2017.

[3] Shaikh Mobin A, Shaikh Saif A, Shaikh Najim N, Pathan Umar Farooq O and Pathan Farhan A, "Utilization of exhaust gas of vehicle for electricity generation", International Research Journal of Engineering and Technology (IRJET), Volume: 04, Issue: 03, Mar -2017.

[4] Luca Piancastelli, Filippo Peli and Eugenio Pezzuti, "The advantage of the split turbocharger in formula 1 engines", Technica Italiana-Italian Journal of Engineering Science, Volume 61+1, June 2018, pp. 36-41.