POWER GENERATION THROUGH EXHAUST GAS ENERGY

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ABSTRACT

In this modern days , mankind has relied on fossil fuels for their energy needs for a long time. Incase of Transportation we use I.C engines to develop power. During the combustion process more amount of heatis produced, in that only a small amount of heat is used to generate power. Remaining energy is wasted in the form of exhaust gases.To attain a valuable power we can reuse the wasted heat from the exhaust gases and kinetic energy of the exhaust gases to produce electrical power. Our project proposes the usage of miniature turbine at the silencer outlet and Thermo Electric Generator(TEG) attached to the silencer. When the vehicle starts, due to the kinetic energy of the exhaust gas ,the turbine starts rotating.A dynamo is connected to the turbine and since it acts as a generator it produces power. The TEG which is fixed to the silencer converts the thermal energy into electrical energy.The conversation of thermal energy to electrical energy is low at first, when the temperature raises the rate of electrical energy produced raises gradually. Now the produced power can be stored in the battery for later use or it can be used at the time of production itself.

Keywords: Turbine , Dynamo ,Thermo Electric Generator, Flow rate of exhaust gas

1.Introduction:

Energy conversion also termed as the energy transformation, is the process of changing one form of energy into another. Energy conversion occurs everywhere and every minute of the day.There are numerous forms of energy like thermal energy, electrical energy, nuclear energy, Electro magnetic energy, mechanical energy, chemical energy, sound energy etc. On the other Hand , the term Energy transformation is used when energy changes forms from one form to another. Whether the energy is transferred or transformed, the total amount of energy doesn't change and this is known as the Law of Conservation of energy.

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 and TEG based power generation from exhaust gas heat energy has proven to be an efficient source of energy generation.

2.Literature Review

Vijaya Kumar et al [1] performed an analysis on modifying an automobile for producing power from the vehicle exhaust to generate the electricity which can be stored in battery for the later consumption. In combustion engines a huge amount of energy is lost in the form of heat through the exhaust gas. The percentage of fuel energy converted to useful work only 10.4% and also found the thermal energy lost through exhaust gas about 27.7%. The second law (i.e., exergy) analysis of fuel has been shown that fuel energy is converted to the brake power about 9.7% and the exhaust about 8.4% .In another research the value of exhaust gases mentioned to be 18.6% of total combustion energy. It is also found that by installing heat exchanger to recover exhaust energy of the engine could be saved up to 34% of fuel saving.

S Malarmannan et al [2] have aimed to utilise the waste heat to reduce global warming and increasing efficiency. Due to increase in the carbon dioxide level and other harmful gases specially which are contributing in increase in pollution and global warming, our automobile industries are one of the easy and clear target therefore many researches has been undertaken in this field . Globally, it is estimated that about 1/3 of the total energy is utilized while remaining is rejected as waste heat. The maximum efficiency of an engine is around 25% which means that 75 % of the energy left is wasted in the form of heat from parasitic losses and friction which causes 30% waste in the engine coolant and 40% in the form of gases in exhaust .

A.Supernath Reddy et al [3] made a research on how to directly convert the heat energy from automotive waste heat to electrical energy.The research work proposes and implements a thermoelectric and waste heat energy system for internal combustion engine automobiles, including gasoline vehicles and hybrid electric vehicles. The key is to directly convert the heat energy from automotive waste heat to electrical energy using a thermoelectric generator, which is then regulated by a DC–DC converter to charge a battery using maximum power point tracking. Hence, the electrical power stored in the battery can be maximized.

Venkatesh.J et al [4] presented various methods to generate electricity. The turbine and dynamometer are used in this project. Dynamo is connected to the turbine which is used to generate power. The turbine is placed in the exhaust path of the silencer. The generated power differs, depending upon the airflow in the exhaust path. The dynamo starts to rotate using turbine and converts kinetic energy into electrical energy. The battery stores the generated power. The voltage has to be inverted, to be used in the equipments. The stored power is used depending upon our comfort.

Dineshkumar C et al [5] presented the need of electrical energy for running the electronics system. The exhaust heat recovery system turns the thermal losses in the exhaust manifold into electrical energy. The heat recovery technology seems to be more and more increased due to the interest by car manufactures. The technology plays a great role to increase the heat energy to electrical energy to save the fuel and reduces the emissions. This technology used in exhaust manifold of the internal combustion engines to produce the electrical energy for the batteries. The technology also can be introducing in hybrid engines and can be introduced in future. The 30 to 35% of energy in fuel is lost as heat in gasoline engines as well in diesel engine 40 to 55% is lost as heat.

3. Experimental Details:

3.1 Key Components:

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.

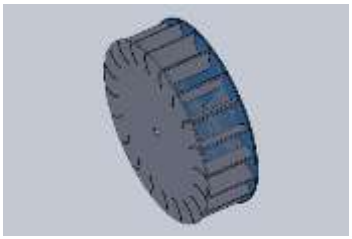

Fig.1 Turbine

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.

Fig.2 Dynamo

Battery:

A rechargeable battery, storage battery, or accumulator is a type of electrical battery. It comprises one or more electrochemical cells, and is a type of energy accumulator. It is known as a secondary cell because its electrochemical reactions are electrically reversible. Rechargeable batteries come in many different shapes and sizes, ranging from button cells to megawatt systems connected to stabilize an electrical distribution network. Several different combinations of chemicals are commonly

used, including: lead–acid, nickel cadmium (NiCd), nickel metal hydride (NiMH),lithium ion (Li-ion), and lithium ion polymer (Li-ion polymer).

Fig.3 Battery

Thermo Electric Generator(TEG):

Thermo electric generators are used for generate the electrical energy from thermal energy from exhaust gas. The electrical energy converts to useful energy by using exhaust gas. The exhaust gases from the exhaust manifold made to flow over the turbine and the turbine is rotated. The turbine which is connected to the generator or dynamo through the shaft and which is connected from the turbine and the bush is connected between the turbine and generator.

Fig.4 TEG

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.

Fig.5 Anemometer

Multimeter:

A multimeter or a multi tester, 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.

Fig.6 Multimeter

Four Stroke Petrol Engine:

A 4 Stroke Petrol Engine of Hero Honda Passion Plus is being used for the purpose of this analysis. The specifications of the engine are given below.

Engine specifications:

• Model of the vehicle used : Hero Honda Passion Plus

• Displacement : 97.2 cc

• Maximum power : 7.5 Bhp @ 8000 rpm

• Maximum torque : 7.95 Nm @ 5000 rpm

• Number of cylinders : 1

• Cylinder bore : 50 mm

• Stroke : 49.5 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.

3.2 Experimental Setup:

Fig.7 Turbine and TEG mounted on the vehicle

4. Working Methodology:

4.1 Working of TEG:

When the engine runs the exhaust gas is produced, the exhaust gas from the chamber is allowed to pass through the exhaust pipe and the silencer. The silencer consists of the thermo-electric module inside it, which makes hot exhaust gas to pass through it. The thermo electric module has a thermo-electric material which produces a voltage when there is any occurrence of the temperature difference. Due to the exhaust gas in the silencer, the temperature difference is produced in the thermo-electric material, due to this temperature difference the voltage is generated in the thermo-electric module, based on the See beck effect. Hence thermoelectric devices can act as electrical power generators.

The See beck Effect is the conversion of temperature differences directly into electricity. It is a classic example of an electromotive force (emf) and leads to measurable currents or voltages in the same way as any other emf. Electromotive forces modify Ohm's law by generating currents even in the absence of voltage differences.

The equation of See beck effect: $V=\alpha (T_h - T_c)$

Where,

V – Voltage Generated in Volts

α – See beck coefficient in $\mu V/K$

T_h-temperature of hot surface (silencer) in Kelvin

T_c-temperature of cold surface (fins)in kelvin

As the surface of the silencer gets more and more heated the heat transfer rate will increase due to the increase in the temperature difference. The Peltier module is placed between the Heat Source

(Hot Silencer Surface) and the Heat Sink (atmosphere) and the fins are placed above the module .The obtained voltage is boosted with the help of booster circuit and noted in the table ,and this is then stored in the battery for the further usages.

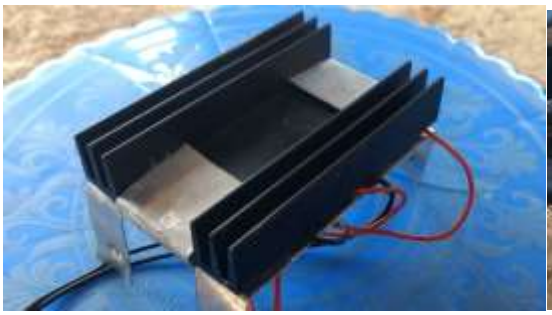

Fig.8 TEG module with alluminium fin

Fig.9 TEG mounted on the silencer

After when the gas passes through the thermo-electric generator, it is allowed to pass through the turbine. The gas enters the turbine with some force, which can make the turbine blade to rotate. Thus making the blades of the turbine to rotate. This ultimately makes the turbine to rotate. When the shaft of the generator rotates, due to the generator effect, some electrical energy is generated. This produced energy is stored in the battery for the further usage. The turbine is made according to our design and the procedure to generate power from the exhaust gas kinetic energy is described below.

4.2 Design of Turbine

A turbine (cross flow) fan made of Alluminium , specifications are as follows:

- Total Diameter = 150 mm
- Number of blades = 20
- Axial length of blades = 50 mm
- Blade thickness = 0.5mm

With the required dimensions the turbine is designed by using the Solid works Software.

Body:

Step1: Select the sketch plane(front plane) ⟹ select sketch ⟹ using circle command draw the periphery of the part with required dimensions and extrude the base by using features command.

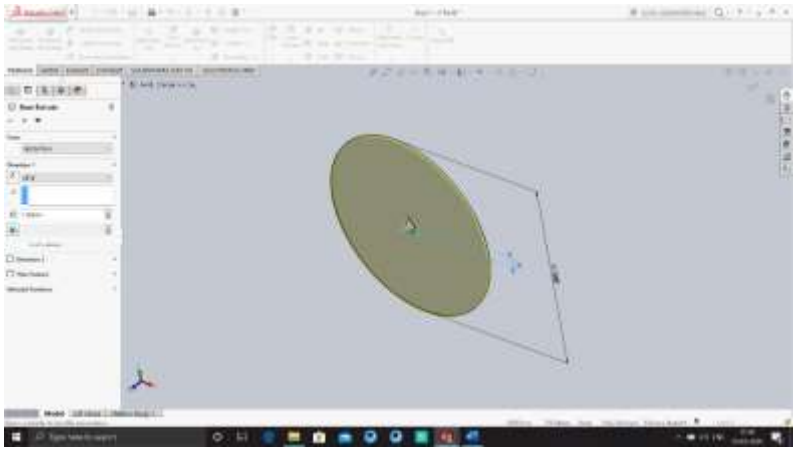

Fig.10 Extruded body

Step 2: Select front plane → select sketch → select arc command → draw the arc as per the required dimension and select circular pattern and do extruded cut.

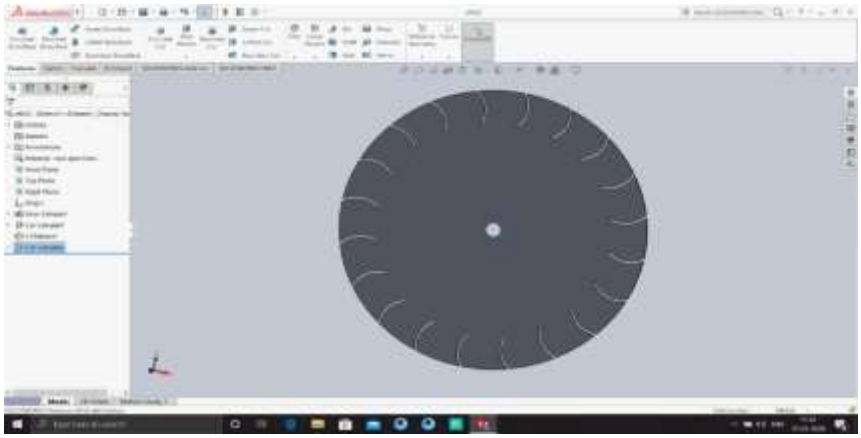

Fig 11.Grooves of Blade

BLADE:

Step1: Select front plane → select sketch → draw the blade → using arc command as per the dimensions.

Step2: Go to features → extrude base.

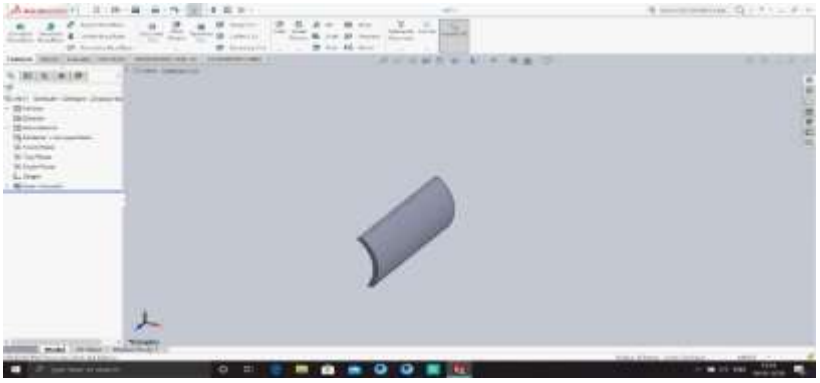

FIG.12 Blade of Turbine

ASSEMBLY:

STEP 1:Open solid works → select assembly → open each part → then assemble the parts.

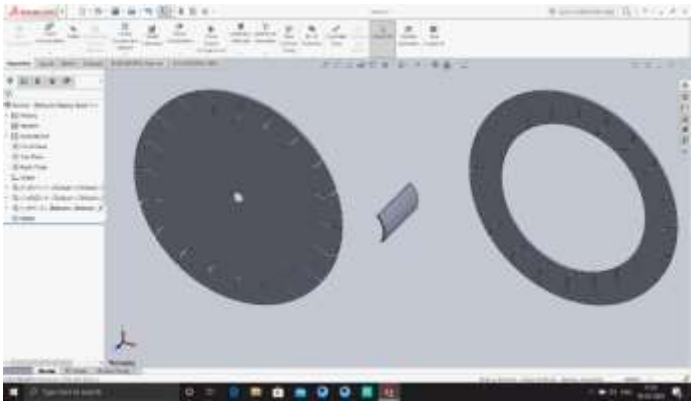

Fig.13 Assembly Parts

Step 2: Final assembly of the turbine

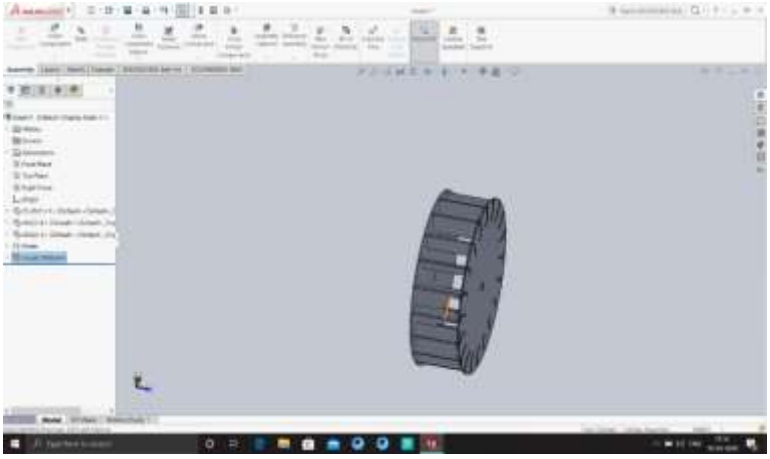

Fig.14 Assembled Turbine

4.3 Working of Turbine:

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 turbine was connected to the motor by soldering a bolt on to the shaft of the dynamo.

Fig.15 Turbine mounted on the bike

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, an alluminium sheet is used and it is rolled to the silencer such that the turbine is fixed to the silencer, the turbine is connected to a wooden piece which acts as a support to it, which can be seen in Fig15 .

Thus the power generated from the Thermo Electric Generator and the rotation of the turbine is shown by the multimeter individually and later on the power outputs are summoned in the final result table.

5. Results & Discussions:

The power generated from the Thermo Electric Generator at different temperatures is noted in the below table1 .

Table.1 voltage outputs at different temperatures

Temperature Of Silencer (K)	**Voltage with booster (Volts)V**	**Current (amps)I**	**Power Watt (V*I)**
40	0.35	0.15	0.0525
50	1.26	0.35	0.441
60	2.45	0.76	1.862
70	3.64	0.92	3.348
80	4.86	1.23	5.977
90	5.86	1.42	8.321
100	6.20	1.66	10.292

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 = 20 mm

$$\mathbf{Q = A \times V} \qquad (1)$$

Where,

Q = Flow rate in m3 /s

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

V = Exhaust gas velocity in m/s (2)

$$A = (\pi * D^{2}) / 4$$

Where , D=Diameter of silencer outlet in m

$$A = (\pi * (20 \times 10^{-3})^2) / 4$$

$$A = 3.14 \times 10^{-4}\ m^2 \qquad (3)$$

Therefore , substitute (3) and (2) in (1)

Flow rate Q= A * V

Q= 3.14 x 10^{-4} V m^3/sec (where V is obtained from anemometer)

An analysis of power output from the turbine for different 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.2 .

Table.2 Power output from the turbine

S.No	Flow rate in (m^3/sec)	Speed in (Kmph)	Voltage in (volts)	Current in (Amps)	Power in (watts)
1	0.0125	20	0.35	0.11	0.0385
2	0.0178	30	1.07	0.30	0.321
3	0.0270	40	2.03	0.61	1.238
4	0.0335	50	2.46	0.72	1.771
5	0.0379	60	2.75	0.79	2.172
6	0.0411	70	3.15	0.92	2.898

The graph shown in Fig.16 gives the comparison between the flow rates of the exhaust gases to the power output produced by the turbine.

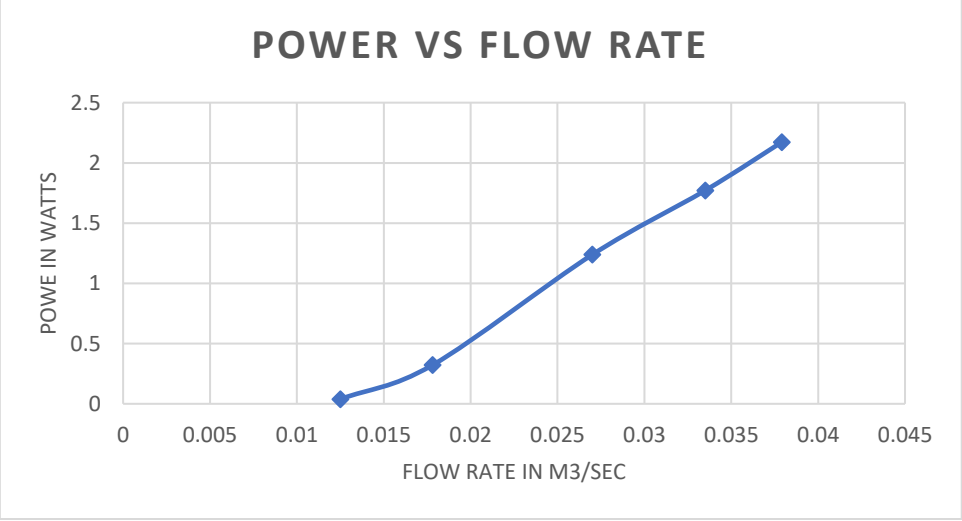

Fig.16 Graph of flow rate of exhaust gas vs power output

The graph shown in Fig17 gives the comparison between the speed of the vehicle to the power output produced by the turbine.

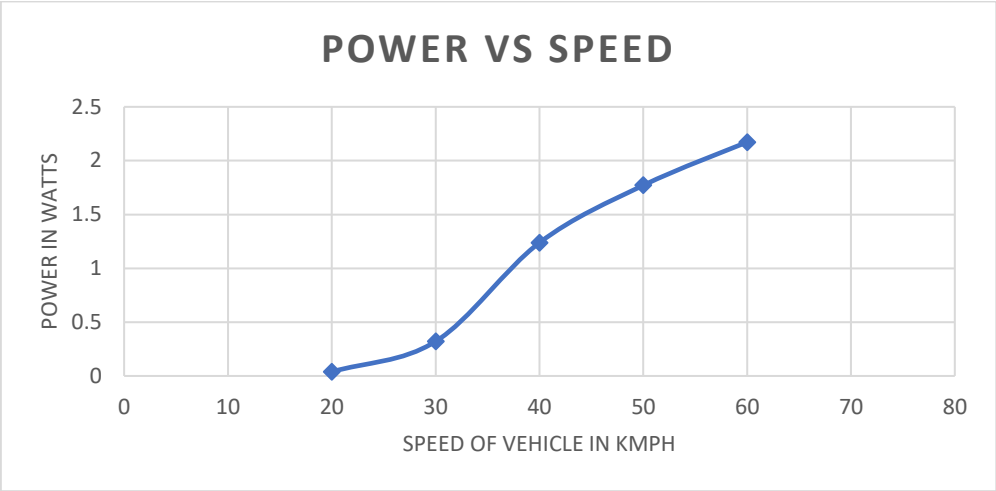

Fig.17 Graph of speed of vehicle vs Power output

6. Conclusion:

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. In conjunction with other power generation techniques, the method discussed in this work can be implemented onto any vehicle with an exhaust .This project work has provided us an excellent opportunity and experience, to use our limited knowledge. We gained a lot of practical knowledge regarding, planning, purchasing, assembling while doing this project work. We feel that the project work is a good solution to bridge the gates between the institution and the industries. The **"POWER GENERATION THROUGH EXHAUST GAS SYSTEM"** is working with satisfactory conditions. We can able to understand the difficulties in maintaining the tolerances and also the quality. We have done to our ability and skill making maximum use of available facilities. Thus we have developed a **"DUAL POWER GENERATION SYSTEM FOR AUTOMOBILE"** which helps to generate electricity using the exhaust gas of the vehicle with the help of generator and also with thermo-electric modules. By using more techniques, they can be modified and developed according to the applications.This project not only has related the theoretical knowledge of our team to a practical implementation, but it has also provided the knowledge and experience one should have if they wish to develop a product and while carrying out this project we were able to learn and deal with challenges , we might face doing any project locally of this caliber.

Future Scope:

- 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 dynamo shaft.
- Experimenting with Piezoelectric materials as an added source of Power generation.

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