“Voltage Generation with the help of Back Pressure in the Muffler of an I.C. Engine”

Submitted in partial fulfilment of the requirements

of the degree of

Bachelor of Technology

Mechanical Engineering

By

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(2015-16)

CERTIFICATE

WALCHAND COLLEGE OF ENGINEERING, SANGLI

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DEPARTMENT OF MECHANICAL ENGINEERING

This is to certify that the project work entitled

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In

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From

Walchand College of Engineering, Sangli

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This report is a record of student's own work carried out by him under my supervision and guidance during the session 2015-16.

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ACKNOWLEDGEMENT

We wish to take this opportunity to express our deep gratitude to all the people who have extended their cooperation in various ways during our project work. It is our pleasure to acknowledge the help of all those individuals.

We would like to thank our project guide Prof. Dr. U. A. Dabade, Mechanical engineering Department for his guidance and help throughout the development of this project work by providing us with required information. With his guidance, cooperation and encouragement we had learnt many new things during our project tenure.

We would also like to thank Mechanical Workshop assistants for their cooperation, guidance and help throughout the development of the project work.

We specially thank Prof. Dr.U.A.Dabade Head, Mechanical Engineering Department for his continuous encouragement and valuable guidance in bringing shape to this dissertation.

We specially thank Dr. G.V. Parishwad Director of Walchand College of Engineering, Sangli for his encouragement and support.

In completing this project successfully, all our faculty members have given an excellent cooperation by guiding us in every aspect. We also thank our lab faculty and librarians.

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ABSTRACT

The world is facing great energy challenge today. The world's energy consumption is at an all-time high with the demand continuously increasing. It is also a well-known fact the supplies of fossil fuels is limited and are diminishing at even faster rates. Increasing population and high per capita use making it even worse. That is why the field of energy conservation is becoming an increasingly notable subject of research among the scientific community today. The intention of this project is to use energy from the back pressure generated in the muffler of an I.C. Engine for voltage generation using piezoelectric effect. By converting the voltage generated from that system into current, the generated electricity is used for lighting of headlights in four wheeler automobiles. Due to this extra fuel used for lighting of headlights is saved and thus fuel consumption is reduced. So this can be the great source for conversion into electricity.

This project also gives the opportunity to develop the engineering skills while learning about the clean way generating electricity. Saving of fossil fuels for future is becoming very serious issue for today's society. Industrialists are trying day by day to increase efficiency of engines so that fuel saving can be possible. So, our project is first step in this field. By using this concept fuel saving in huge amount can be possible.

Keywords – Renewable Energy, Electricity Generation, Piezoelectric effect.

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CHAPTER 1
INTRODUCTION

1.1 A Brief

At present, electricity has become a lifeline for human population. Its demand is increasing day by day. Modern technology needs a huge amount of electrical power for its various operations. Electricity production is the single largest source of pollution in the whole world. At one hand, rising concern about the gap between demand and supply of electricity for masses has highlighted the exploration of alternate sources of energy and its sustainable use. On the other hand, human population all over the world and hence energy demand is increasing day by day linearly

As exhaust gas emission standards become more severe every day, manufacturers strive for higher fuel-efficiency in cars. The automotive industry is therefore continuously attempting to increase the efficiency of automobile engines. Reserves of petroleum And diesel are perishable. So, we must try to save these resources as much possible as we can do. This becomes the need of today’s era. For running of headlights of automobiles extra fuel is used. So, to save this extra fuel consumption there are various ways to charge batteries in such automobiles.

In this project we are going to generate voltage with the help of back pressure generated in the muffler of an I. C. Engine. Voltage generation by the application of pressure is nothing but the piezoelectric phenomenon.

Piezoelectricity is the electric charge that accumulates in the certain solid materials in response to applied mechanical stress. The word piezoelectricity means electricity resulting from pressure. The piezoelectric effect is a reversible process in that materials exhibiting the direct piezoelectric effect also exhibit the reverse piezoelectric effect i.e.the internal generation of electric charge resulting from an applied mechanical force can be reversed to the internal generation of mechanical strain resulting from an applied electrical field.

1.2 History of piezoelectricity [06]

The piezoelectric effect was discovered by the end of the last century and it consists in that certain materials when subjected to mechanical stress become electrically charged at their surface and vice versa. This effect remained rather a curiosity until the early 1920 when it was utilized to realize crystal resonators to stabilize the oscillations and thereby launching the field of frequency control. Anyhow, the piezoelectric materials have been studied more intensely only by the early 60s, after Jaffe's discovery of a new class of piezo-ceramic materials namely the lead titanate-zirconate system with better properties than those known until then (quartz, Rochelle salt and barium titanate). This category of materials, called PZT materials, consists of solid solutions between lead titanate and lead-zirconate, within a relatively narrow interval of compositions, around Pb(Zr0;5Ti0;5)O3, a composition situated within a zone called morphotropic zone boundary, where two types of crystalline structures coexist, one tetragonal and one rhombohedral, and where the piezoelectric properties have unusual maxima [5], which makes them very useful for applications in almost all areas of activity. The basic properties of these materials are the so called direct and converse piezoelectric effect consisting in the generation of an electrical charge (a voltage) when it is mechanically stressed (direct effect) and vice versa developing a mechanical deformation when subjected to an electrical field (converse effect).Piezoelectricity was discovered in 1880 by French physicists Jacques and Pierre Curie.

1.3 Mechanism [06]

Many materials, both natural and synthetic, exhibit piezoelectricity. Crystals which acquire a charge when compressed, twisted or distorted are said to be piezoelectric. This provides a convenient transducer effect between electrical and mechanical oscillations. The generation of an electric charge in certain non-conducting materials, such as quartz crystals and ceramics, when they are subjected to mechanical stress (such as pressure or vibration), or the generation of vibrations in such materials when they are subjected to an electric field. Piezoelectric materials exposed to a fairly constant electric field tend to vibrate at a precise frequency with very little variation. The nature of the piezoelectric effect is closely related to the occurrence of electric dipole moments in solids. Of decisive importance for the piezoelectric effect is the change of polarization P when applying a mechanical stress. This might either be caused by a re-configuration of the dipole-inducing surrounding or by re-orientation of molecular dipole moments under the influence of the external stress. Piezoelectricity may then manifest in a variation of the polarization strength, its direction or both, with the details depending on (i) the orientation of P within the crystal, (ii) crystal symmetry and (iii) the applied mechanical stress. The change in P appears as a variation of surface charge density upon the crystal faces, i.e. as a variation of the electrical field extending between the faces caused by a change in dipole density in the bulk.

1.4 Piezoelectricity [06]

Piezoelectricity is the electric charge that accumulates in certain solid materials in response to applies mechanical stress. The word piezoelectricity means electricity resulting from pressure. The piezoelectric effect is understood as a linear electromechanical interaction between the mechanical and the electrical state in crystalline materials with no inversion symmetry. The piezoelectric effect is a reversible process in that materials exhibiting the direct piezoelectric effect also exhibit the reverse piezoelectric effect. The inverse piezoelectric effect is used in production of ultrasonic sound waves. The nature of the piezoelectric effect is closely related to occurrence of electric dipole moment. Many materials, both natural and synthetic, exhibit piezoelectricity.

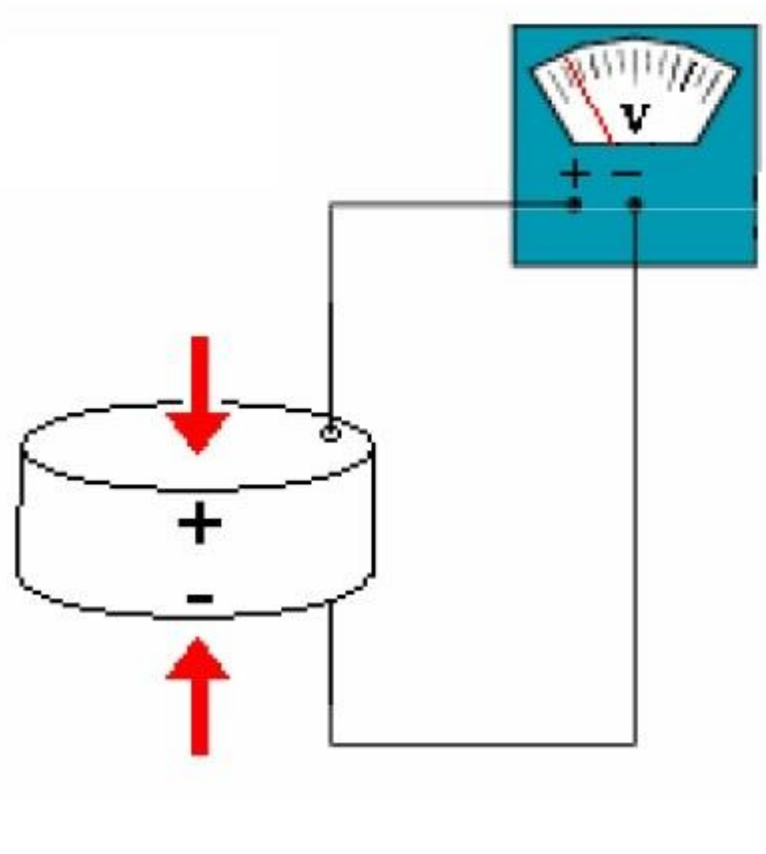

Fig. 1.1 Piezoelectric effect [06]

1.5 Electrical energy harvesting from piezoelectricity [04]

The investigation shows that the power output from a single piezo-film was very low in the range of 0.2 W. Therefore, direct application of the piezo-film as a power source is not practical. It is unavoidable to use a storage device to collect the weak power output for future usage. Fortunately, the voltage outputs from a single piezo-film can produce a root-mean-squared voltage of 1.18 V which is high enough to store the generated electricity into a small nickel metal hydride battery.

1.6 Parallel and Series Connection of Piezoelectric plates [04]

Since the power output from a single piezo-plate was extremely low, combination of few piezoplate was investigated. Two possible connections were tested - parallel and series connections**.** The parallel connection did not show significant increase in the voltage output. With series connection, additional piezo-plate results in increased of voltage output but not in linear proportion. This may be due to the non-linear modification of internal impedance of the system. Further investigation is required to explain this non-linearity occurrence. If this is understood, an artificial modification could be added into the system to achieve the ultimate goal of producing 12V voltage output with high current density.

1.7 Concept of BACK PRESSRE [13]

Back pressure refers to pressure opposed to the desired flow of a fluid in a confined place such as a pipe. It is often caused by obstruction or tight bends in the confinement vessel along which it is moving, such as piping or air vents. Because it is really resistance, friction between molecules, the term back pressure is misleading as the pressure remains and causes flow in the same directions, but the flow is reduced due to resistance. For example, a particularly high number of twists, bends, turns and right angles could be described as having particularly high back pressure.

- Back pressure in automotive (four stroke engine) exhaust:

  Back pressure caused by the exhaust system (consisting of the exhaust manifold, catalytic converter, muffler and connecting pipes) of an automotive four stroke engine has a negative effect on engine efficiency resulting in a decrease of power output that must be compensated by increasing fuel consumption.

- Back pressure in two stroke engine exhaust

  In a piston ported two stroke engine however, the situation is more complicated due to the need to prevent unburned fuel air mixture from passing right through the cylinders into the exhaust phase of the cycle, back pressure is even more undesirable than in a four stroke engine due to shorter time available for exhaust and the lack of pumping action from the piston to force the exhaust out of the cylinder. However, since the exhaust port necessarily remains open for a time after scavenging is completed, unburned mixture can follow the exhaust out of the cylinder, wasting fuel and increasing pollution, and this can only be prevented if the pressure at the exhaust port is greater than that in the cylinder.

  This conflicting requirement are reconciled by constructing the exhaust pipe with diverging and converging conical sections to create pressure wave reflections which travel back up the pipe and are presented at the exhaust port. The exhaust port opens while there is still significant pressure in the cylinder, which drives the initial outflow of exhaust. As the pressure wave from the pulse of exhaust gas travels down the pipe, it encounters a diverging conical sections; this causes a wave of negative pressure to be reflected back up the pipe, which arrives at the exhaust port towards the end of the exhaust phase, when the cylinder pressure has fallen to a low level, and helps to draw the remaining exhaust gas out of the cylinder. Further along the exhaust pipe, the exhaust pressure port after scavenging is completed, thereby “plugging” the exhaust port to prevent spillage of fresh charge, and indeedmay also push back into the cylinder any charge which has already spilled.

  Since the timing of this process is determined mainly by exhaust system geometry, which is extremely difficult to make variable, correct timing and therefore optimum engine efficiency can typically only be achieved over a small part of the engines range of operating speed.

1.8 Muffler

A muffler is a device for decreasing the amount of noise emitted by the exhaust of an I.C. Engine. When gas enters in the muffler for sound proofing, it creates back pressure in the muffler. Back pressure refers to the pressure opposed to the desired flow of a fluid in a confined place. Because it is really a resistance, friction between molecules, the back pressure is misleading as the pressure remains and causes flow in the same direction but the flow is reduced due to resistance. Back pressure caused by the exhaust system of an automotive four stroke engine has a negative effect on engine efficiency resulting in a decrease in power output that must be compensated by increasing fuel consumption. In a piston ported two stroke engine however, the situation is more complicated due to the need to prevent unburned fuel-air mixture from passing right through the cylinders into the exhaust. During the exhaust phase of the cycle, back pressure is even more undesirable than in four stroke engine due to the shorter time available for the exhaust and the lack of pumping action from the piston to force the exhaust out of the cylinder. Typically mufflers are classified under two different categories,

- Dissipative
- Reflective

A **dissipative muffler** consists of ducts and chambers which is lined with acoustic absorbing materials which absorb the acoustic energy and convert it into heat. These mufflers are useful for broad frequency band at high frequencies. The benefit of this muffler is that the pressure drop across the system is relatively low as the flow path is not significantly altered by flow reversals, twists and turns inside the muffler. The downside of dissipative muffler is that they are insufficient at low frequencies as the wavelength is much too large to be attenuated. But it could be overcome by using an absolute thickness of absorbing material. The second type of muffler is **reflective muffler**. Reactive mufflers generally composed of several chambers of different volumes and shapes connected together with of pipes. They reflect the sound energy back to the source and are essentially sound filters. They are useful for noise reduction at fixed frequencies or in hot, dirty and high-speed gas flow system. They contain several chambers, flow reversals and end resonators.

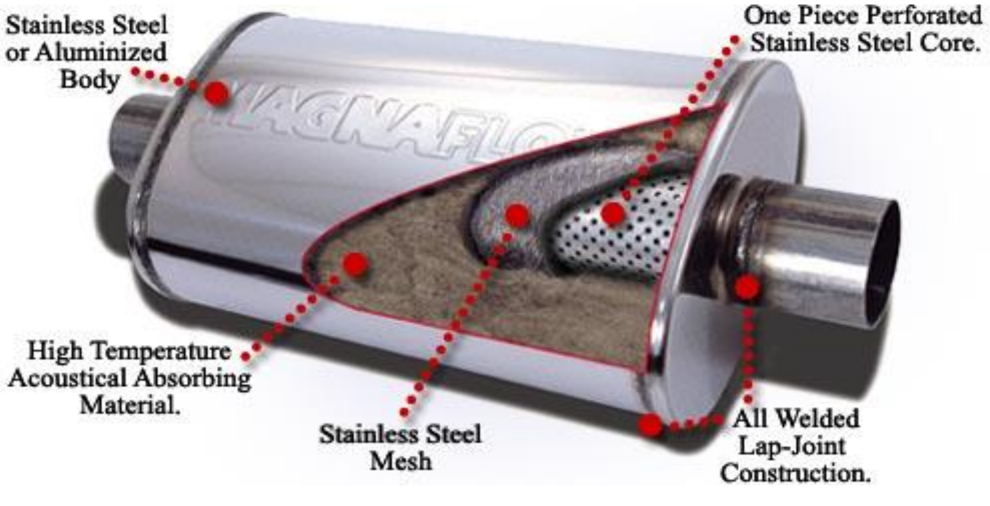

Fig.1.1 Muffler

CHAPTER 2
LITERATURE REVIEW

2.1 Construction and working principle [05][06]

In this section we firstly move towards working of a muffler inside an automobile system. If you have heard an engine running without a muffler, you know what a huge difference a muffler can make to a noise level.

Inside a muffler you will fine deceptively simple set of tubes with some holes in them. These tubes and chambers are actually tuned as finely as a musical instrument. They are designed to reflect sound waves produced by the engine in such a way that they partially cancel themselves out. Sound is a pressure wave formed from the pulses of alternating high and low pressure. In an engine, pulses are created when exhaust valve opens and a burst of a high pressure gas suddenly enters the exhaust system. Located inside the muffler is a set of tubes. These tubes are designed to create reflected waves that interfere with each other or cancel each other out. The exhaust gases and the sound waves enter through the tube. They bounce of the back wall of the muffler through a hole into the main body of muffler. They pass through the set of holes into another chamber, where they turn and go out through the last pipe and leave the muffler. A chamber called resonator is connected to the first chamber by the hole. The resonator contains a specific volume of air and has a specific length that is calculated to produce a wave that cancels out a certain frequency of sound. When wave hits the hole, part of it continues into the chamber and part of it is reflected. The wave travels through the chamber, hits the back wall of the muffler and bounces back out of the hole. The length of this chamber is calculated so that this wave leaves the resonator chamber just after the next wave reflects off the outside of the chamber wall, and the two waves will cancel each other out. There are other features inside this muffler that helps it to reduce the sound wave in different ways. The body of the muffler is constructed in three layers: Two thin layers of metal with a thicker, slightly insulated layer between them. This allows the body of the muffler to absorb some of the pressure pulses. Also the inlet and the outlet pipes going into the main chamber are perforated with the holes. This allows thousands of tiny pulses to bounce around in the main chamber, cancelling each other out to some extent in addition to being absorbed by the muffler’s housing.

Now we will move towards the working of piezoelectricity. In most of the crystal unit cell is symmetrical but in piezoelectric crystals, it isn't. Normally piezoelectric crystals are electrically neutral. The atoms inside them may not be symmetrically arranged, but their electrical charges are perfectly balanced i.e. a positive charge in one place are cancels out a negative charge nearby. However if you squeeze or stretch a piezoelectric crystal, you deform the structure, pushing some of the atoms closer together or further apart, upsetting the balance of positive and negative and causing the net electric charges to appear on opposite and outer faces of the crystal. The reverse piezoelectric effects occur in reverse way. Put a voltage across the piezoelectric crystal and you are subjecting atoms inside it to the electrical pressure. They have to move to rebalance themselves and that's what cause piezoelectric crystals to deform when you put a voltage across them.

Now we will move towards the constructional set-up of our project. In this project, we have lots of better options for piezoelectric materials. But we selected Quartz crystal as our piezoelectric material. The main reason behind this is their availability in India. Those materials were more effective than this quartz crystal but as stated above due to availability in India we have selected Quartz crystal as our piezoelectric material. In this we have made such an arrangement so that we can fit Quartz crystal at an angle of 120 degrees. These Quartz crystals we have fitted in the last chamber of that muffler. So, in the last chamber of that muffler we have placed two Quartz crystals which are at 120 degrees and opposite to each other. Due to this when the exhaust gas enters the pipes of that muffler then it will flow through those pipes and after coming out of those pipes the whole air fuel mixture hits that crystal which is placed in front of the exhaust of that pipe and gets deflected and again this deflected flow hits the second Quartz crystal which is placed in front of the second pipe. As this crystal deflects the whole exhaust gas so that it enters into the next pipe. After this process this exhaust gas comes out of the automobile. During this process when that exhaust gas hits the Quartz crystal then it applies pressure on that crystal. This is nothing but called as BACK PRESSURE. Due to this pressure according to the properties of the piezoelectric material charges are developed on the surfaces of those Quartz crystals. Thus in this way voltage is generated.

2.2 Absorption Materials Used In Muffler -A Review [07]

Over the last decade and half the amount of vehicles are increasing and due to this the amount of noise emitted by the exhaust system of vehicles and emission requirements are also getting more and more. Muffler plays an important role in reducing the exhaust and intake system noise. So there has been a great deal of research and development in the design and performance of muffler. From designer's standpoint transmission loss (TL) or insertion loss (IL) is the main characteristic performance parameter of a muffler.

Transmission loss: Transmission loss is the difference in sound power between the incident wave entering and the transmitted wave exiting the muffler when the muffler termination is anechoic (no reflecting waves present in the muffler). The **benefit of TL** is that it is a parameter of the muffler alone and the source or termination properties are not needed.

Insertion loss: The Insertion loss is the sound pressure level difference at a point usually outside the system, without and with the muffler present.

Typically mufflers are classified under two different categories,

1. Dissipative
2. Reflective.

A **Dissipative muffler** consists of ducts and chambers which is lined with acoustic absorbing materials which absorb the acoustic energy and convert it into heat. These mufflers are useful for broad frequency band at high frequencies. The benefit of this muffler is that the pressure drop across the system is relatively low as the flow path is not significantly altered by flow reversals, twists and turns inside the muffler. The downside of dissipative muffler is that they are insufficient at low frequencies as the wavelength is much too large to be attenuated. But it could be overcome by using an absolute thickness of absorbing material.

The second type of muffler is **Reflective muffler**. Reactive mufflers generally composed of several chambers of different volumes and shapes connected together with of pipes. They reflect the sound energy back to the source and are essentially sound filters. They are useful for noise reduction at fixed frequencies or in hot, dirty and high-speed gas flow system . They contain several chambers, flow reversals and end resonators.

Advantage: They are quiet inexpensive and requires little maintenance.

Disadvantage: The downside of this type is that there are some areas in the frequency range of interest where there is little attenuation of the exhaust sound pressure.

2.3 Advances in Electronic and Electric Engineering. [08]

Vibration energy (mechanical energy) that is generated by vehicle movement on the road converted into electric energy by piezoelectric effect. Piezoelectricity is the electric charge that accumulates in certain solid material (notably crystal, certain ceramic and biological matter such as bone, DNA and various proteins) in response to applied mechanical stress. Many materials, both natural and synthetic, exhibit piezoelectricity. Crystals which acquire a charge when compressed, twisted or distorted are said to be piezoelectric. This provides a convenient transducer effect between electrical and mechanical oscillations. The generation of an electric charge in certain non conducting materials, such as quartz crystals and ceramics, when they are subjected to mechanical stress (such as pressure or vibration), or the generation of vibrations in such materials when they are subjected to an electric field. Piezoelectric materials exposed to a fairly constant electric field tend to vibrate at a precise frequency with very little variation.

The nature of the piezoelectric effect is closely related to the occurrence of electric dipole moments in solids. Of decisive importance for the piezoelectric effect is the change of polarization P when applying a mechanical stress. This might either be caused by a re-configuration of the dipole-inducing surrounding or by re-orientation of molecular dipole moments under the influence of the external stress. Piezoelectricity may then manifest in a variation of the polarization strength, its direction or both, with the details depending on (i) the orientation of P within the crystal, (ii) crystal symmetry and (iii) the applied mechanical stress. The change in P appears as a variation of surface charge density upon the crystal faces, i.e. as a variation of the electrical field extending between the faces caused by a change in dipole density in the bulk. For example, a 1 cm3 cube of quartz with 2 kN (500 lbf) of correctly applied force can produce a voltage of 12500 V. There is a magnetic analogue where ferromagnetic material respond mechanically to magnetic fields. This effect, called magnetostriction, is responsible for the familiar hum of transformers and other AC devices containing iron cores. Piezoelectric materials also show the opposite effect, called converse piezoelectric effect, where the application of an electrical field creates mechanical deformation in the crystal. Piezoelectric materials exhibit both a direct and a reverse piezoelectric effect. The direct effect produces an electrical charge when a mechanical vibration or shock is applied to the material, while the reverse effect creates a mechanical vibration or shock when electricity is applied. Any spatially separated charge will result in an electric field, and therefore an electric potential. In a piezoelectric device, mechanical stress, instead of an externally applied voltage, causes the charge separation in the individual atoms of the material. Generation of piezoelectricity For polar crystals, for which $P \neq 0$ holds without applying a mechanical load, the piezoelectric effect manifests itself by changing the magnitude or the direction of P or both. For the non-polar, but piezoelectric crystals, on the other hand, a polarization *P* different from zero is only elicited by applying a mechanical load. Piezoelectric materials have the ability to transform mechanical strain energy into electrical charge. The amount of energy generated depends on the number of passing vehicles and the number of piezoelectric elements on the road. Vehicles that are moving slowly appears to generate slightly more energy than faster moving vehicles.

2.4 Generation of electricity with the help of piezoelectric material [04]

The recent fluctuations on the price of petroleum have affected worldwide economics which has forced an increased in the price of other items including food. Some even linked the recent collapse of few financial institutions in countries such US and the UK to the recent increased in this price. This shows that we are too dependent to petroleum as a source of electrical power. Besides, petroleum as a source of electrical energy has contributed to severe 1air pollution problem. Therefore, an alternative method to produced electricity has to be put in place. Among other solutions which can be explored are nuclear and hydroelectric power generators. However, these options require huge financial capability to run and to maintain. Besides, not many countries are “allowed” to use nuclear power generator due to world political scenario. Thus, photovoltaic cells and wind turbines have been the popular choices and these renewable energy sources are gaining more attention. However, they are expensive and not affordable to many countries to acquire them. As a consequence other possible energy sources must again be explored. One of the promising options is by using piezoelectric material or PZT. PZT can be used as a mechanism to transfer ambient vibrations into electrical energy. This energy can be stored and used to power up electrical and electronics devices. With the recent advancement in micro-scale devices, PZT power generation can provide a conventional alternative to traditional power sources used to operate certain types of sensors/actuators, telemetry, and MEMS devices. Umeda (1996) for example successfully developed an equivalent electrical model of the PZT transforming mechanical impact energy to electrical power.

2.5 Effect of Temperature and Thermal Cycles on PZT Ceramic Performance in Fuel Injector Applications [09]

Piezoelectric ceramics are implemented in a wide range of applications due to their many favourable properties such as:

- ✓ fast response time
- ✓ high accuracy
- ✓ high stiffness

- ✓ low power consumption
- ✓ precision
- ✓ high force generation
- ✓ ability to be used both as sensors and actuators

Precision application fields such as fuel injection technology are fields in which piezoelectric actuators are being increasingly used for the reasons mentioned above. From this we want to understand how temperature and thermal cycles affect the performance and propertie

s of Lead-Zirconium-Titanate piezoelectric ceramics in order to be able to maintain the accuracy and precision typical of piezoelectric actuators. As exhaust gas emission standards become more severe every day, manufacturers strive for higher fuel-efficiency in cars. The automotive industry is therefore continuously attempting to increase the efficiency of automobile engines. An important step in the ignition cycle that has a great impact on the efficiency is the injection of the air/fuel mixture. Since fuel injectors generally operate in the vicinity of the engine and are therefore exposed to a wide temperature range, the temperature of the piezoelectric actuator inside will change as well. As with all materials, the properties of piezoceramics vary with temperature. Consequently, this change in temperature will affect the properties of the actuator and have a direct effect on its output displacement, whereas fuel injectors require precise displacements to be able to operate the engine at maximum efficiency. The ability to compensate for these changes will allow the engine to run optimally at all times. Upon manufacturing, the domains in most piezoelectric materials are randomly-oriented. Therefore the material has a net polarization of zero and exhibits little or no piezoelectric activity. The most common method used to orient the crystal domains is through poling, i.e. polarizing the ceramic by applying a strong, static electric field at a temperature just below Curie temperature. As a result of polarization, the ceramic exhibits an enhanced piezoelectric effect. The recommended operating temperature of a piezoelectric ceramic is usually up to 50% of its Curie temperature, above which the ceramic begins to lose its polarization. Polarized piezoelectric materials are anisotropic materials. Their properties are tensor quantities that depend on the direction of polarization, electric field, and mechanical stress. Piezoelectric ceramics can be categorized into two main groups: hard and soft piezo-ceramics. Soft and hard refer to the mobility of the domains and the polarization/depolarization behaviour. A comparison of hard and soft piezoelectric materials is presented in Table 2.1.

Table 2.1 - Soft and hard piezoelectric ceramic comparison

Characteristics	**Piezoelectric type**	
	Soft	**Hard**
Domain wall mobility	High	Low
Piezoelectric coefficients	High	Low
Electromechanical coupling factors	High	Low
Mechanical quality factor	Low	High
Dielectric permittivity	High	Low
Dielectric losses	High	Low
Curie temperature	Low	High
Linearity	Low	High

Due to their characteristics, soft piezo-ceramics are used in applications that require large displacements and wide signal band widths. They also exhibit greater hysteresis, and are more susceptible to depolarization. The higher domain mobility in soft piezoelectric materials causes them to be more vulnerable to temperature change and electric field magnitude compared to hard piezoelectric materials. Hard piezo-ceramic properties are opposite those of a soft piezoelectric ceramic making them suitable for applications requiring high mechanical load or applied electric field. It is important to note that a soft piezoelectric ceramic might exhibit properties similar to those of a hard piezo-ceramic and vice-versa. Therefore, when choosing a ceramic for a particular application, it is practical to look beyond the nominal categorization and to the specific characteristics of the material.

2.6 Diesel net technology guide [10]

The exhaust system routes exhaust gas from the engine and exhausts it into the environment, while providing noise attenuation and after treatment of the exhaust gas to reduce emissions. One of the most important sources of vehicle noise, the noise associated with exhausting combustion gases from the engine, is controlled using mufflers. A number of sound reduction techniques are employed in mufflers, including reactive silencing, resistive silencing, absorptive silencing, and shell damping.

- ✓ Exhaust System Components
- ✓ Noise Control and Mufflers
- ✓ Decoupling Elements

The original purpose of an exhaust system was to safely route exhaust gases from the engine so they can be exhausted into the environment, while also providing attenuation of combustion noise. Exhaust gas, however, contains components that are harmful to human health and/or the environment. As a consequence, emission levels of these exhaust gas components became regulated. Since regulated emission levels are often much lower than that which can be achieved through in-cylinder control measures, the exhaust gas must be treated after it leaves the engine. Thus, while exhaust systems continue to serve their original functions, they have evolved into one of the critical elements used for pollution control and abatement in modern engines.

The exhaust system is typically connected to the exhaust manifold, which collects exhaust gases from the engine cylinders' exhaust ports. In light-duty applications, catalytic converters and diesel particulate filters (DPF) can be placed either in the close-coupled position to the exhaust manifold or in the underfloor position. The choice of location is determined by the availability of space and the desired temperature profile, with the close-coupled location providing exposure to the highest possible exhaust gas temperatures. In general, the exhaust system includes the following components:

- ✓ After treatment devices (catalytic converters, particulate filters) to reduce emissions of pollutants,
- ✓ Mufflers, which provide noise attenuation,
- ✓ Decoupling elements, which connect the exhaust manifold with the rest of the exhaust system.
- ✓ Piping and hangers.

The after treatment devices and their piping are sometimes referred to as the "hot end" of the exhaust system, while the mufflers and the tailpipes are the "cold end "of the exhaust system. The hot end piping may include the "downpipe" or "front pipe" (not present in the configuration shown in Figure 1) which connects the exhaust manifold with the catalytic converter, as well as piping between the catalyst and the particulate filter. The after treatment system is connected with the muffler by the "centre pipe" The exposure to high temperature, along with other factors such as strength requirements and chemical exposure, determine the choice of exhaust system materials.

Waste Heat Recovery- Future exhaust systems may also include exhaust gas energy recovery systems. In the diesel engine, the exhaust gas enthalpy represents a significant fraction of the chemical energy of the fuel-up to over 30%-which is one of the most significant sources of thermal efficiency loss. Exhaust heat recovery systems may range from simple heat exchangers to complex technologies such as thermo-electrics. An example vehicle with an exhaust gas heat exchanger is the 2006 Citroen C4 Picasso, where waste exhaust heat transferred via the cooling system is used to more rapidly heat the cabin. Research aimed at using thermoelectric generators to produce electricity from waste exhaust heat in light and heavy-duty diesel engines has been sponsored by the US Department of Energy.

Exhaust systems may also include a number of specialized components. Some diesel trucks are equipped with an “exhaust brake”, which uses the exhaust gas pressure for vehicle braking, to ease the demands on wheel brakes and increase their longevity. By activating a throttle valve placed in the exhaust system when the engine is producing no output and braking is required, exhaust backpressure and subsequently the torque required to rotate the engine is increased. The effectiveness of exhaust brakes can be improved with a feature that holds the exhaust valve open continuously (“bleeder brake”).This can be accomplished with an actuator that pushes the exhaust valve and keeps it open through all four engine strokes. They are however, considerably more costly and require special noise suppression measures to avoid excessive exhaust system noise.

2.7 Footstep Power Generation Using Piezoelectric Transducers [11]

Piezoelectric ceramics belong to the group of ferroelectric materials. Ferroelectric materials are crystals which are polar without an electric field being applied. The piezoelectric effect is common in piezo ceramics like $PbTiO_3$, $PbZrO_3$, PVDF and PZT. The main component of the project is the piezoelectric material. The proper choice of the piezo material is of prime importance. The criterion for selection was better output voltage for various pressures applied. For this the Piezo transducer material under test is placed on a Piezo force sensor. Voltmeters are connected across both of them for measuring voltages and an ammeter is connected to measure the current. As varying forces are applied on the Piezo material, different voltage readings corresponding to the force is displayed. For each such voltage reading across the force sensor, various voltage and current readings of the Piezo test material are noted.

Next to determine the kind of connection that gives appreciable voltage and current necessary, three PZT are connected in series. A force sensor and voltmeter is connected to this series combination. As varying forces are applied on this connection, corresponding voltages are noted. Also the voltage generated across the series connection and the current is measured. Also the voltage generated across the series connection and the current is measured. Similarly the connections are done for parallel and series-parallel connections are done. The graphs are plotted of those readings which are obtained from the experimentation. It can be seen from the graph that the voltage from a series connection is good but the current obtained is poor, where as the current from a parallel connection is good but the voltage is poor. But this problem is rectified in a series- parallel connection where a good voltage as well as current can be obtained.

The piezoelectric material converts the pressure applied to it into electrical energy. The source of pressure can be anything. The output of the piezoelectric material is not a steady one. The output dc voltage is then stored in a rechargeable battery. As the power output from a single piezo-film was extremely low, combination of few Piezo films was investigated. Two possible connections were tested - parallel and series connections. The parallel connection did not show significant increase in the voltage output. With series connection, additional piezo-film results in increased of voltage output but not in linear proportion.

2.8 A Review of Power Harvesting from Vibration using Piezoelectric Materials [12]

The process of acquiring the energy surrounding a system and converting it into usable electrical energy is termed power harvesting. In the last few years, there has been a surge of research in the area of power harvesting. This increase in research has been brought on by the modern advances in wireless technology and low-power electronics such as micro-electromechanical systems. The advances have allowed numerous doors to open for power harvesting systems in practical real-world applications. The use of piezoelectric materials to capitalize on the ambient vibrations surrounding a system is one method that has seen a dramatic rise in use for power harvesting. Piezoelectric materials have a crystalline structure that provides them with the ability to transform mechanical strain energy into electrical charge and, vice versa, to convert an applied electrical potential into mechanical strain. This property provides these materials with the ability to absorb mechanical energy from their surroundings, usually ambient vibration, and transform it into electrical energy that can be used to power other devices. While piezoelectric materials are the major method of harvesting energy, other methods do exist. The piezoelectric effect exists in two domains: the first is the direct piezoelectric effect that describes the material's ability to transform mechanical strain into electrical charge; the second form is the converse effect, which is the ability to convert an applied electrical potential into mechanical strain energy. The direct piezoelectric effect is responsible for the material's ability to function as a sensor and the converse piezoelectric effect is accountable for its ability to function as an actuator. A material is deemed piezoelectric when it has this ability to transform electrical energy into mechanical strain energy, and likewise to transform mechanical strain energy into electrical charge.

Piezoelectric materials belong to a larger class of materials called ferroelectrics. One of the defining traits of a ferroelectric material is that the molecular structure is oriented such that the material exhibits a local charge separation, know as an electric dipole. Throughout the material composition the electric dipoles are orientated randomly, but when the material is heated above a certain point, the Curie temperature, and a very strong electric field is applied, the electric dipoles reorient themselves relative to the electric field; this process is termed poling. Once the material is cooled, the dipoles maintain their orientation and the material is then said to be poled. After the poling process is completed the material will exhibit the piezoelectric effect. One of the most effective methods of implementing a power harvesting system is to use mechanical vibration to apply strain energy to the piezoelectric material or displace an electromagnetic coil. Power generation from mechanical vibration usually uses ambient vibration around the power harvesting device as an energy source, and then converts it into useful electrical energy, in order to power other devices. When using piezoelectric materials as a means of gathering energy from the surroundings, in most cases it is a necessity that a means of storing the energy generated be used. Without accumulating a significant amount of energy, the power harvesting system will not be a feasible power source for most electronics.

CHAPTER 3

DESIGN

3.1 Piezoelectric material [03]

3.1.1 Piezoelectric Crystal: Langasite (LGS)

Langastie crystal ($La_3Ga_5SiO_{14}$, LGS), belonging to the space group P321, point group 32, has been reported to be promising new piezoelectric materials for fabrication of surface acoustic wave (SAW) and bulk acoustic wave (BAW) devices. It is reported that devices made of langasite crystal could be used at a high temperature up to 900°C because of its high thermal stability. Basic Properties of Langasite are shown in the table 3.1 given below Langasite crystal possesses some great properties, such as higher electromechanical coupling factor than quartz, no phase transition from room temperature to melt point. Some properties of langasite i.e. Lanthanum Gallium Sillicate crystal are shown in Table 3.1.

Table 3.1 Dielectric, piezoelectric, elastic stiffness constants and their first order temperature coefficients of langasite crystal

Constant	Relative Dielectric Constant		Piezoelectric Constant (pC/N)		Elastic Stiffness (10^{11} Pa)					
	ε_{11}	ε_{33}	d_{11}	d_{14}	c_{11}	c_{12}	c_{13}	c_{14}	C_{33}	C_{44}
Value	18.96	50.19	5.66	-5.48	1.898	1.058	1.022	0.144	2.626	0.535
First Order Temp. Coeff. ($10^{-6}\cdot K^{-1}$)	150	-760	329	-342	-66	204	-75	-335	-94	-63

According to the project requirement and looking at properties of Langasite we decided to select Langasite as our material to generate voltage with the help of back pressure generated in the muffler of an I.C. Engine by using piezoelectric effect

3.1.2 Piezoelectric Material: Quartz Crystal [02]

Quartz crystal is an electronic component as it shows property of piezoelectricity. Quartz crystals have piezoelectric properties. They develop an electric potential upon the application of mechanical stress. An early use of this property of Quartz crystals was in phonograph pickups. One of the most common piezoelectric uses of Quartz crystals today is as a crystal oscillator. The Quartz clock is a familiar device with a mineral. The resonant frequency of a quartz crystal oscillator is changed by mechanically loading it, and this principle is used for very accurate measurements of very small mass changes in Quartz crystal microbalance and in thin film thickness monitors. Some properties of Quartz are given below in a tabular form. Chemical properties of Quartz crystals are as shown in table 3.2

Table 3.2-Chemical composition

SIO2 purity	Al	Fe	Ca	Mg	Ti	Mn	B	K	Na	Li
>99.8 %	< 30	< 3	<4	<3	<2	<0.5	< 1.0	< 3	< 2	< 2

Similarly various physical properties of quartz crystals are as shown in the table 3.3 given below

Table 3.3-Physical property

Property	Reference data
Density	2.2*103 kg/m^3
Hardness	$550KHN_{100}$
Strength of pulling resistance	3.7*107 Pa
Coefficient of thermal expansion (200-300 °C)	4.5*10-7 cm/cm°C
Thermal conductivity (20 °C)	1.4 W/m°C
Specific heat (20 °C)	660 J/kg°C
Strength of pressure resistance	>1.1 *109 Pa
Softening point	1530 °C
Annealing point	1150 °C

3.2 Selection and Design regarding material

In above section we have studied two piezoelectric materials for our project. By comparing both of these materials we can say that Langasite i.e. Lanthaum Gallium Sillicate is far better than Quartz. Because it is a material obtained from combination of various materials. Thus properties which Langasite shows are perfect for the project purpose. The only reason behind selection of Quartz crystal over Langasite crystal is the availability. Quartz crystal is available in India while Langasite must be purchased from outside. It is very costly so we decided to select Quartz crystal over Langasite as our piezoelectric material.

While deciding size of a piezoelectric crystal the main obstruction is space. Also by considering the factor of fuel efficiency, we must reduce the back pressure developed in the muffler of an I.C. Engine. For this purpose we must give the smooth path for exhaust gas to leave the exhaust system. So, we decided to fit those couple of crystals at an angle of 120 degree between them

Taking into consideration of space restriction and angle between them piezoelectric crystals of 60*40 mm is perfect.So, the size of piezoelectric crystals used in this project is of 60*40 mm.

CHAPTER 4

ANALYSIS

4.1 Readings of BACK PRESSURE

Back pressure before crystal = 0.4 bar

Back pressure after crystal = 0.38 bar

4.2 Readings for fuel consumption

While installing any system on a mechanical instrument, the performance of that instrument must increases or remains same. But at any cost performance of that instrument should not be reduced. If this happens then installation of that system is considered to be failed.

So, in our project it is of main importance to check the efficiency of engine after installation of our system and compare it with the readings before installation of system and to check the effect of installation of that system. So, to check performance of engine after installation of our system we have taken readings of fuel consumption and these readings are shown in table 4.1

Table 4.1-Readings of fuel consumption

Sr. No.	Time taken for fuel consumption before crystals for 10 ml fuel	Time taken for fuel consumption after crystal for 10 ml fuel
1	105	113
2	104	109
3	108	112
4	111	114
5	107	113

4.3 Calculation for fuel consumption[13]

1)

Time taken for fuel consumption for after crystal for 10 ml fuel = 111 sec

Break horse power= 5HP = 3.75 kW=3750 watt

Indicated power = volume flow rate * density of fuel * calorific value

- Before crystal

Volume flow rate = $\frac{15}{105}$

= 0.1428 ml /sec

Density of fuel i.e. diesel = 0.832 kg/L

Calorific value of diesel = 45.5 MJ/kg

Indicated power = 0.1428*0.832*45.5

= 5405.83 Watt

Efficiency = $\frac{Break\ power}{indicated\ power}$

= $\frac{3750}{5405.83}$

= 69.36 %

- After crystal

Volume flow rate = $\frac{15}{111}$

= 0.13513 ml /sec

Density of fuel i.e. diesel = 0.832 kg/L

Calorific value of diesel = 45.5 MJ/kg

Indicated power = 0.13513*0.832*45.5

= 5115.48 Watt

Efficiency = $\frac{Break\ power}{indicated\ power}$

= $\frac{3750}{5115.48}$

= 73.30 %

2)

- Before crystal

Volume flow rate = $\frac{15}{104}$

= 0.1456 ml /sec

Density of fuel i.e. diesel = 0.832 kg/L

Calorific value of diesel = 45.5 MJ/kg

Indicated power = 0.1456*0.832*45.5

= 5511.8336 Watt

Efficiency = $\frac{Break\ power}{indicated\ power}$

= $\frac{3750}{5511.8336}$

= 68.035 %

- After crystal

Volume flow rate = $\frac{15}{109}$

= 0.1376 ml /sec

Density of fuel i.e. diesel = 0.832 kg/L

Calorific value of diesel = 45.5 MJ/kg

Indicated power = 0.1376*0.832*45.5

= 5208.98 Watt

Efficiency = $\frac{Break\ power}{indicated\ power}$

= $\frac{3750}{5208.98}$

= 71.99 %

3)

Time taken for fuel consumption for after crystal for 10 ml fuel = 112 sec

Break horse power= 5HP = 3.75 kW=3750 watt

Indicated power = volume flow rate * density of fuel * calorific value

- Before crystal

Volume flow rate = $\frac{15}{108}$

= 0.13888 ml /sec

Density of fuel i.e. diesel = 0.832 kg/L

Calorific value of diesel = 45.5 MJ/kg

Indicated power = 0.13888*0.832*45.5

= 5257.44 Watt

Efficiency = $\frac{Break\ power}{indicated\ power}$

= $\frac{3750}{5257.44}$

= 73.32%

- After crystal

Volume flow rate = $\frac{15}{112}$

= 0.13392 ml /sec

Density of fuel i.e. diesel = 0.832 kg/L

Calorific value of diesel = 45.5 MJ/kg

Indicated power = 0.13392*0.832*45.5

= 5069.67 Watt

Efficiency = $\frac{Break\ power}{indicated\ power}$

$= \frac{3750}{5069.67}$

= 73.96 %

4)

Time taken for fuel consumption for after crystal for 10 ml fuel = 114 sec

Break horse power= 5HP = 3.75 kW=3750 watt

Indicated power = volume flow rate * density of fuel * calorific value

- Before crystal

Volume flow rate = $\frac{15}{111}$

= 0.1351 ml /sec

Density of fuel i.e. diesel = 0.832 kg/L

Calorific value of diesel = 45.5 MJ/kg

Indicated power = 0.1351*0.832*45.5

= 5144.34 Watt

Efficiency = $\frac{Break\ power}{indicated\ power}$

$= \frac{3750}{5144.34}$

= 72.89%

- After crystal

Volume flow rate = $\frac{15}{114}$

= 0.131578 ml /sec

Density of fuel i.e. diesel = 0.832 kg/L

Calorific value of diesel = 45.5 MJ/kg

Indicated power = 0.131578*0.832*45.5

= 4981.01 Watt

Efficiency = $\frac{Break\ power}{indicated\ power}$

= $\frac{3750}{4981.01}$

= 75.28 %

5)

Time taken for fuel consumption for after crystal for 10 ml fuel = 107 sec

Break horse power= 5HP = 3.75 kW=3750 watt

Indicated power = volume flow rate * density of fuel * calorific value

- Before crystal

Volume flow rate = $\frac{15}{107}$

= 0.14018 ml /sec

Density of fuel i.e. diesel = 0.832 kg/L

Calorific value of diesel = 45.5 MJ/kg

Indicated power = 0.14018*0.832*45.5

= 5306.65 Watt

Efficiency = $\frac{Break\ power}{indicated\ power}$

= $\frac{3750}{5306.65}$

= 70.66%

- After crystal

Volume flow rate = $\frac{15}{113}$

= 0.132743 ml /sec

Density of fuel i.e. diesel = 0.832 kg/L

Calorific value of diesel = 45.5 MJ/kg

Indicated power = 0.132743*0.832*45.5

= 5025.11 Watt

Efficiency = $\frac{Break\ power}{indicated\ power}$

= $\frac{3750}{5025.11}$

= 74.62 %

Average efficiency

1. Before crystals

   Average efficiency = $\frac{69.36+68.035+73.32+72.89+70.66}{5}$

   = 70.853%

2. After crystals

   Average efficiency = $\frac{73.30+71.99+73.96+75.28+74.62}{5}$

   = 73.83 %

After this calculation it is concluded that efficiency of engine increases by 2-3% after addition of quartz crystal which is placed at a angle of 120 degree. This is due to fact that back pressure generated after addition of crystal gets decreased by small amount. So, engine requires less fuel consumption as compared to fuel consumption before addition of crystal.

4.4 Voltage generation for crystals

After installation of couple of piezoelectric crystals we have tasted our system so as to fulfil our aim of generating voltage with the help of back pressure in muffler of an I.C. Engine. After performing some test on our set-up we have taken some readings of voltages shown by those crystals after impact of back pressure on those crystals. These readings are shown in below table 4.2

Table 4.2- Voltage generation after impact of back pressure on them

Sr. No.	Back pressure developed	Voltage generated for crystal 1	Voltage generated for crystal 2	Voltage generated for Series connection
1	0.38 bar	67 Mv	27 mV	94 mV
2	0.36 bar	62 mV	26 mV	88 mV
3	0.38 bar	68 mV	29 mV	97 mV
4	0.37 bar	64 mV	28 mV	92 mV
5	0.36 bar	63 mV	27 mV	90 mV

CHAPTER 5

GRAPHICAL REPRESENTATION OF ANALYSIS

We have plotted a graph for above analysis of back pressure in muffler verses voltage generated in quartz crystal

5.1 Graphical Representation

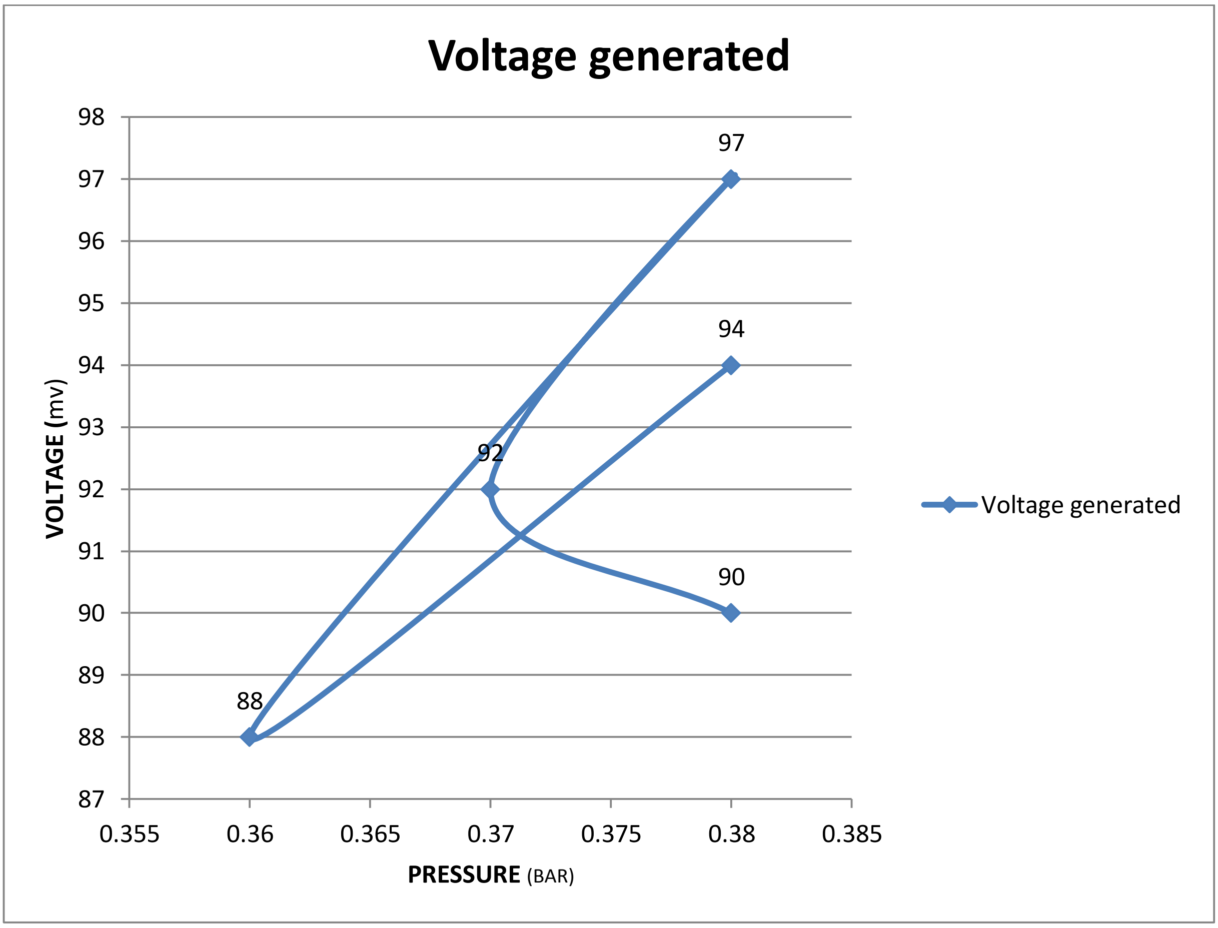

Fig. 5.1 Graph of back Voltage generated vs Pressure developed

CHAPTER 6

DRAWING

In this chapter part drawing of various components used in the project is shown below in fig. 6.1.

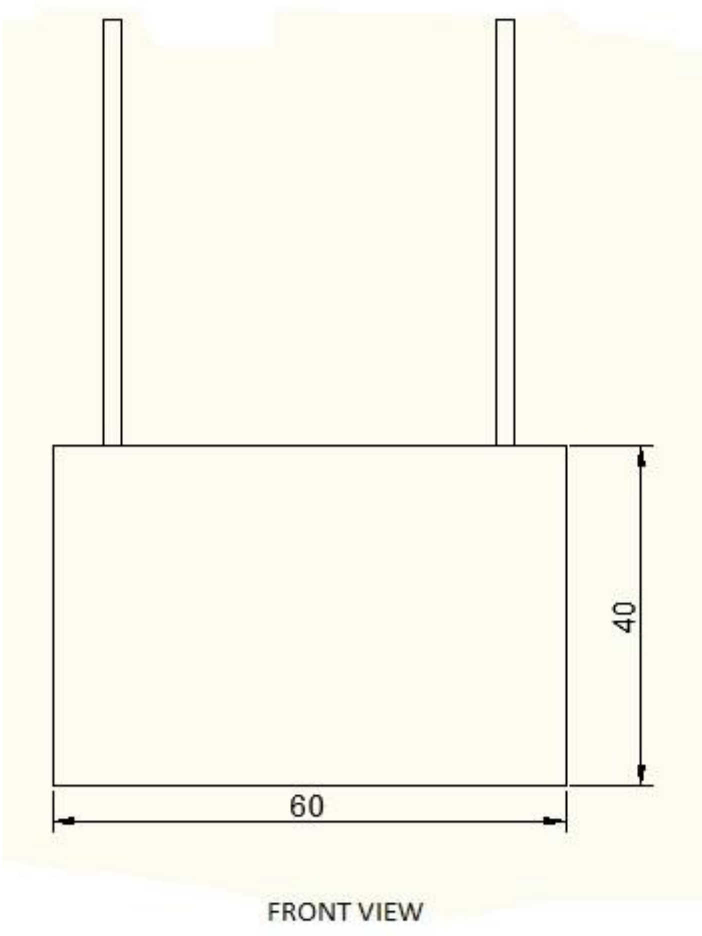

Fig.6.1 Front view of sandwiched Quartz crystals

Top view of sandwiched Quartz crystal is shown in fig. 6.2 as shown below.

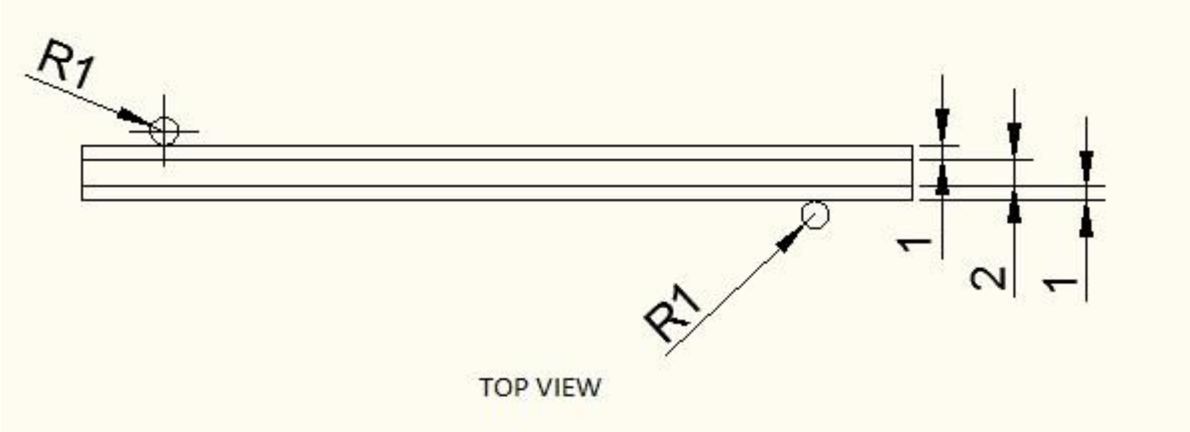

Fig. 6.2 Top view of sandwiched Quartz crystal

Working set-up of our project is shown in fig. 6.3. This figure shows the cut-section of our working model.

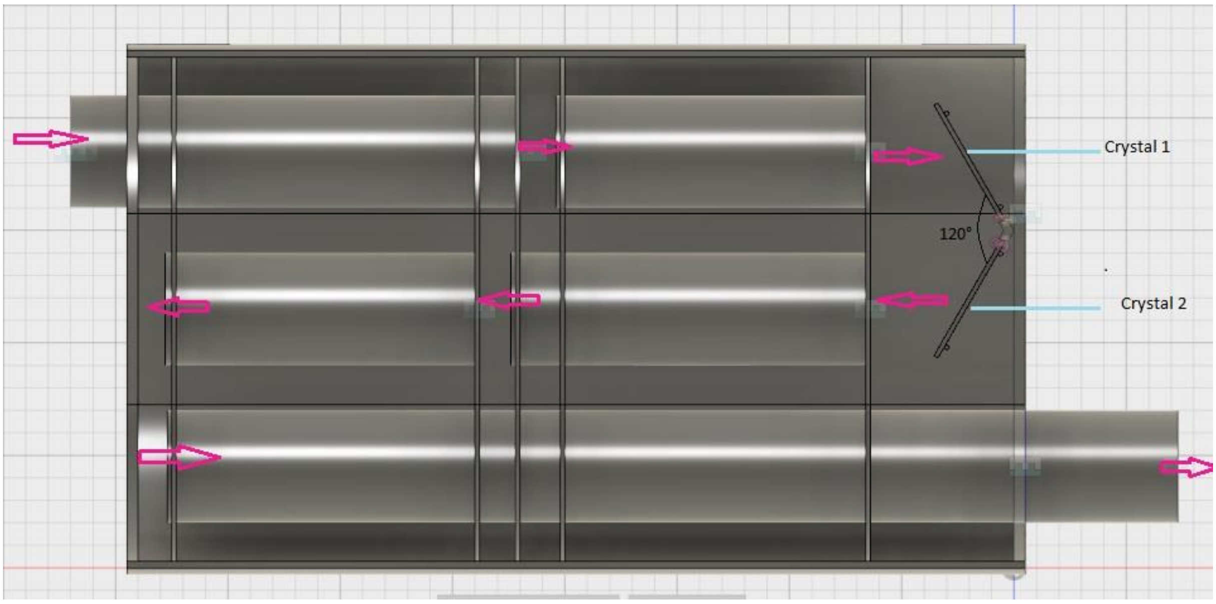

Fig. 6.3 Cut section of working model

CHAPTER 7

ADVANTAGES

There are various advantages of the concept used in this project.

1. Makes use of wasted energy.
2. Back pressure gets reduced.
3. Increased efficiency of engine around 2-3%.
4. Fuel consumption gets less.
5. Requires less space.

CHAPTER 8

LIMITATIONS

1. Quartz crystal produces very less power which is very insufficient.
2. The voltage output that we get from these piezoelectric materials is very small. For the measurement of this small output amplifiers, auxiliary circuit and the connecting cables are required..
3. Quartz is most stable piezoelectric crystal but with small output.
4. Availability of highly effective material in India is the biggest problem.
5. It will be very costly for the production of high voltage.

CHAPTER 9

SCOPE FOR FUTURE

- With the use of high quality of piezoelectric materials we can generate more and more amount of voltage and so thus electricity.
- We can use this electricity for charging of batteries in four wheeler automobiles.
- Thus extra fuel used for running head lights of such automobiles is saved.
- Also this electricity is used for other purposes of automobile.
- This concept is also implemented in industrial use.

CHAPTER 10

BILL OF MATERIAL

Sr. No.	Components	Quantity	Cost per unit	Total cost
1	Muffler	1	1300	1300
2	Pressure gauge	1	350	350
3	Flare nut ¼ forge	2	15	30
4	Tap adaptor	1	30	30
5	Copper tube soft ¼	2	30	60
6	Bakelite sheet	1	60	60
7	No.14 copper wire	1	30	30
8	Araldite	1	48	48
9	M seal	1	60	60
10	Copper sheet	1	60	60
11	Clear quartz square plate	4	632.75	2531
12	Diesel	3.61 L	55.45	200
13	Labour charges			1200
Total				**Rs. 5959**

CHAPTER 11

CONCLUSION

From this we can conclude that though piezoelectricity is very much useful for wasted energy but it requires bulky devices and installation of this concept is very difficult. Also the availability of piezoelectric material is also a main difficulty. So, in India construction of this phenomenon is quite difficult because there are so many materials which are more sensitive than Quartz but due to unavailability of those materials we have selected less effective Quartz crystal for our project.

Engine efficiency gets increased due to use of piezoelectric material. Because of drop in back pressure, fuel consumption gets reduced.

CHAPTER 12

SUMMARY

It is general thinking that exhaust from any engine is waste but through this project we have shown that this waste also has energy which can be used for various purposes. Piezoelectric materials are those materials which can generate voltage when mechanical stress is applied on them. With the help of this concept we have used the back pressure generated in the muffler of an I.C. Engine to generate voltage. The Quartz material in our project is poor piezoelectric material. But by using high quality piezoelectric material the more and more voltage is generated and this can be used for lighting of headlights in automobiles. This can be done without affecting engine efficiency.

CHAPTER 13

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12.2 Patents

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2. Piezoelectric pressure transducer US 3349259