USE OF THERMOELECTRIC GENERATOR FOR HEAT RECOVERY FROM AN INTERNAL COMBUSTION ENGINE

Om Prakash[1], Mukesh Pandey[2], Savita Vyas[3]

[1] Research Scholar, [2,3]Assistant Professor, School of Energy and Environmental Management, UTD, RGPV Bhopal, MP, (India)

ABSTRACT

Energy crisis and Thermal energy management are the burning issues of present scenario .As we know that a major part of the heat supplied in an Internal combustion engine is not realized as work output, but dumped into the atmosphere as waste heat so it becomes crucial to recover this waste heat. This study shows the crucial role that Thermo electric generator plays for heat recovery from an Internal combustion engine .Thermo electric generators are solid state devices that are used to convert Thermal energy from a Temperature gradient to Electrical energy. In this way we can say that Thermoelectric generators may play an important role by enhancing the overall efficiency of an Internal combustion engine as they help in tapping and converting this waste heat energy into usable energy.

Keyword: Energy Crisis, Thermoelectric Generators, Internal Combustion Engine, Temperature Gradient, Waste Heat Recovery.

I. INTRODUCTION

Viewing from socio-economic perspective, as the level of energy consumption is directly proportional to the economic development and total number of population in the country, the growing rate of population in the world today indicates the energy demand is likely to increase [1].

Today we are facing the problem of shortage of fossil fuels as well as the problem of pollution. Out of all the available sources, the internal combustion engines are the major consumer of fossil fuel. Out of all the available sources, the internal combustion engines coolant in the form of heat .By utilizing a portion of the lost thermal energy to change the battery instead of using an alternator the overall fuel economy can be increased by 10%.Depending on the engine load the exhaust temperatures after the catalytic converter reach about 300-500ºcentigrade .Thermoelectric generators are small with no moving parts and they are relatively efficient at these temperatures so they are ideal for such applications . Thermoelectric parts and they are relatively efficient at these temperatures so they are ideal for such applications [2, 3].

According to national energy conservation law and regulations for energy, consumption investigation and energy audit management. [4]

Recovery activities in general order include:

- Identification of all energy systems
- Evaluation of conditions of the systems

- Analysis of impact of improvement to those systems

1.1 Need of Waste Heat Recovery

There is need of waste heat recovery because we are facing the problem of energy crisis in terms of conventional sources of energy.

By using waste heat we can save not only conventional sources of energy but also we can enhance the efficiency of these sources of energy.

By using waste heat we can go along with sustainable development in an easy way as it is the demand of today's world.

It is better to have something rather than having nothing and in the case of heat recovery we are saving some amount of energy which we can use not only for our self but also for upcoming generation.

In general we can say that by saving waste heat we are not only securing our self but also upcoming generation from facing the problem of energy crisis which is the current issue of today's world and it also play an important role in making India a developed country as energy plays an important role in other dimensions which are related to our economic zones.

1.2 Methods Of Waste Heat Recovery

Waste heat can be recovered though different ways:-

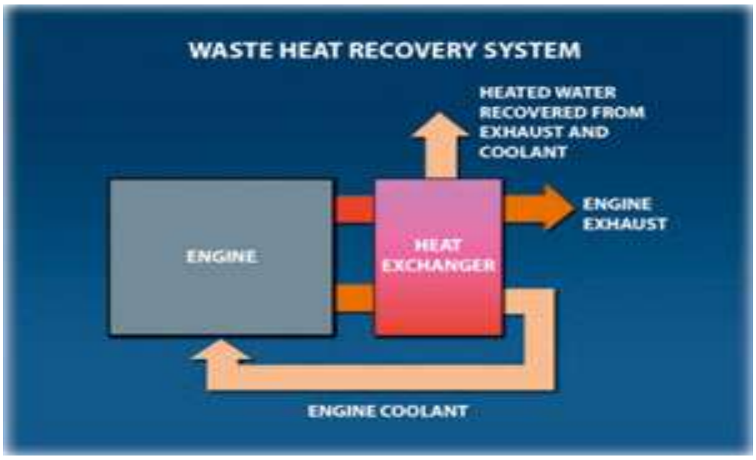


Figure 1: Waste heat recovery system.

Theory and operation of thermoelectric based system is based on the phenomenon called See back effect. When a temperature difference is established between the hot and cold junctions of two dissimilar materials (metals or semiconductors) a voltage is generated, i.e., See back voltage. Based on this See back effect, thermoelectric devices act as electric power generators.

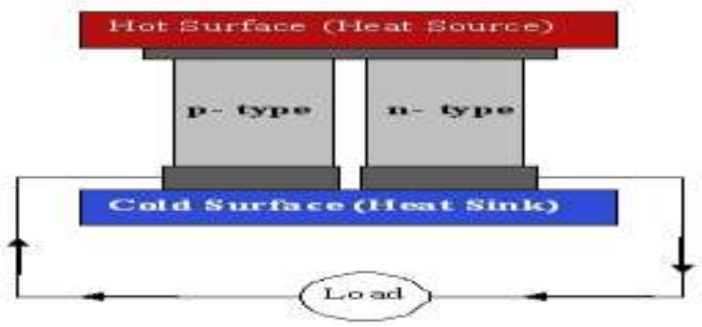
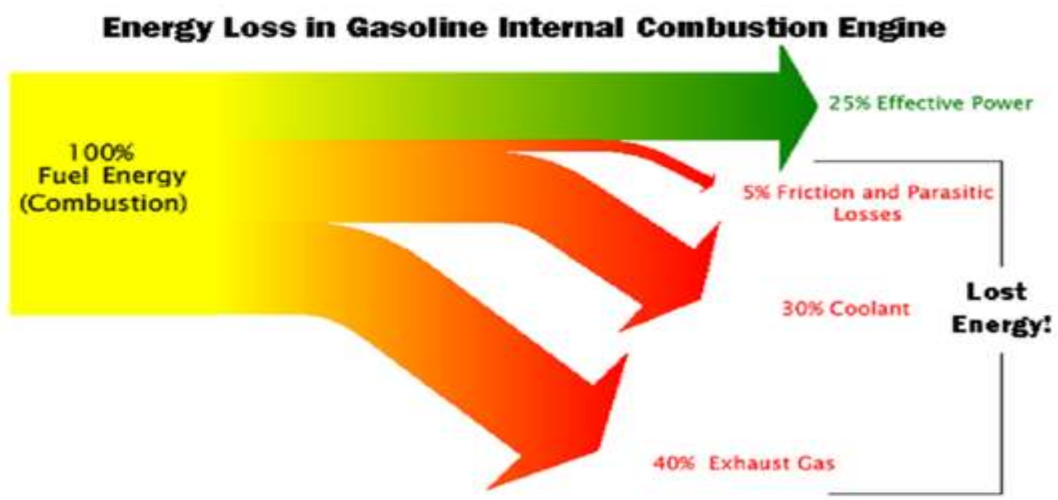


Figure 2: Concept of a thermoelectric power generator based on see back effect.

Thermoelectric power generation have a capability to recover some exhaust heat from I.C. Engine. A schematic diagram showing how the exhaust heat converted into electric power applied to an internal combustion engine using thermoelectric power generator.

The overall power losses in an Internal combustion engine are as follows:-



1.3 Possibility of Waste heat recovery

Sr. No.	Engine type	Power output kW	Waste heat
1	Small air cooled diesel engine	35	30-40% of Energy Waste loss From I.C. Engine
2	Small agriculture tractors and construction machines	150	
3	Water air cooled engine	35-150	
4	Earth moving machineries	520-720	
5	Marine applications	150-220	
6	Trucks and road engines	220	

Table 1: Various engines and their output

In general, diesel engines have an efficiency of about 35% and thus the rest of the input energy is wasted. Despite recent improvements of diesel engine efficiency, a considerable amount of energy is still expelled to the ambient with the exhaust gas. In a water-cooled engine about 35 kW and 30-40% of the input energy is wasted in the coolant and exhaust gases respectively. The amount of such loss, recoverable at least partly, greatly depends on the engine load. Mr. Johnson found that for a typical 3.0 l engine with a maximum output power of 115 kW, the total waste heat dissipated can vary from 20 kW to as much as 400 kW across the range of usual engine operation. It is suggested that for a typical and representative driving cycle, the average heating power available from waste heat is about 23 kW, compared to 0.8–3.9 kW of cooling capacity provided by typical passenger car VCR systems [5]. Since, the wasted energy represents about two-thirds of the input energy.

Sr. No.	Engine	Temperature in °C
1	Single Cylinder Four Stroke Diesel Engine	456
2	Four Cylinder Four Stroke Diesel Engine (Tata Indica)	448
3	Six Cylinder Four Stroke Diesel Engine (TATA Truck)	336
4	Four Cylinder Four Stroke Diesel Engine (Mahindra arjun 605 DI)	310
5	Genset (Kirloskar) at power 198hp	383
6	Genset (Cummims) at power 200hp	396

Table 2: This temperature can be taken from various surveys.

1.4 Availability of Waste Heat from I.C. Engine

The quantity of waste heat contained in a exhaust gas is a function of both the temperature and the mass flow rate of the exhaust gas:

$$\dot{Q} = \dot{m} \times C_p \times \Delta T$$

Where, Q is the heat loss (kJ/min); is the exhaust gas mass flow rate (kg/min); is the specific heat of exhaust gas (kJ/kg°K); and is temperature gradient in °K. In order to enable heat transfer and recovery, it is necessary that the waste heat source temperature is higher than the heat sink temperature. Moreover, the magnitude of the temperature difference between the heat source and sink is an important determinant of waste heat's utility or "quality". The source and sink temperature difference influences the rate at which heat is transferred per unit surface area of recovery system, and the maximum theoretical efficiency of converting thermal from the heat source to another form of energy (i.e., mechanical or electrical). Finally, the temperature range has important function for the selection of waste heat recovery system designs [6, 7].

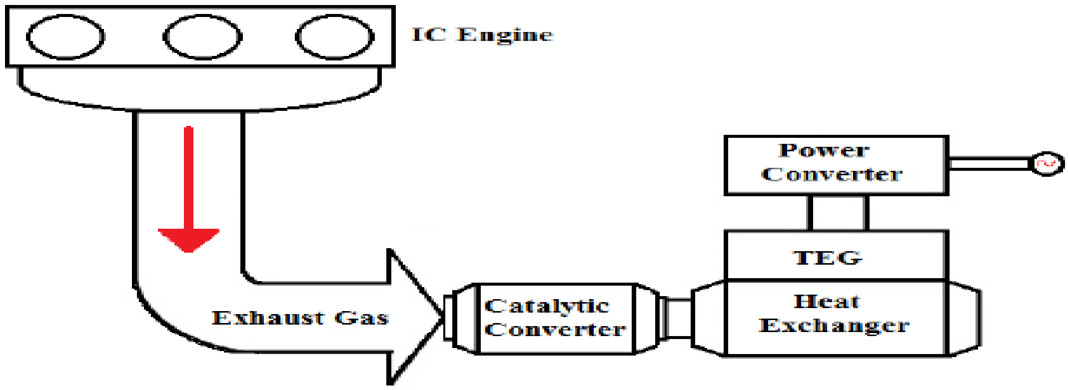


Figure 3: Methodology of arrangement of TEG

Thermoelectric devices may potentially produce twice the efficiency as compared to other technologies in the current market [8].

By using this methodology we can convert waste exhaust gases into electric power. In this the exhaust gases in the pipe provide the heat source to the thermoelectric generator, whereas the sink provided by circulation of cooling water.

1.5 Thermoelectric material

They are divided into three groupings based on temperature ranges:-

- Alloy based on Bismuth in combination with Antinomy, Tellurium and selenium (Low temperature material used up to 450K).
- Based on alloy of Lead (Intermediate temperature materials used up to 850K).
- Fabricated from silicon-germanium alloy (High temperature materials up to 1300K).

Figure 4: A Thermoelectric Module

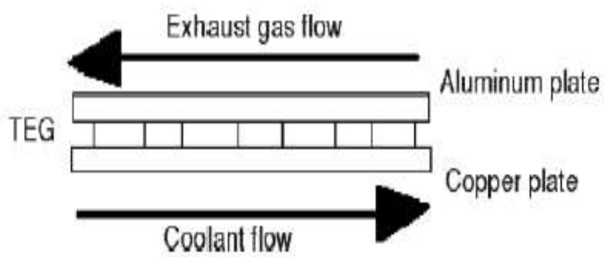


Figure 5: Diagram of TEM sandwiched between hot plate and cold plate.

A single thermoelectric couple is constructed from two 'pellets 'of semiconductor material usually made from Bismuth Telluride (Bi2Te3). One of these pellets is doped with acceptor impurity to create a P-type pellet; the other is doped with donor impurity to produce an N-type pellet. The two pellets are physically linked together on one side, usually with a small of copper, and mounted between two ceramic outer plates that provide electrical isolation and structural integrity. For thermoelectric power generation, if a temperature difference is maintained between two sides of the thermoelectric couple, thermal energy will move through the device with this heat and an electrical voltage, called the See beck voltage, will be created. If a resistive load is connected across the thermoelectric couple's output terminals, electrical current will flow in the load and a voltage will be generated at the load. Practical thermoelectric modules are constructed with several of these thermoelectric couples connected electrically In series and thermally in parallel. Standard thermoelectric modules typically contain a minimum of three couples, rising to one hundred and twenty seven couples for larger devices. A schematic diagram of a single thermoelectric couple connected For thermoelectric power generation and a side view Of a thermoelectric module.

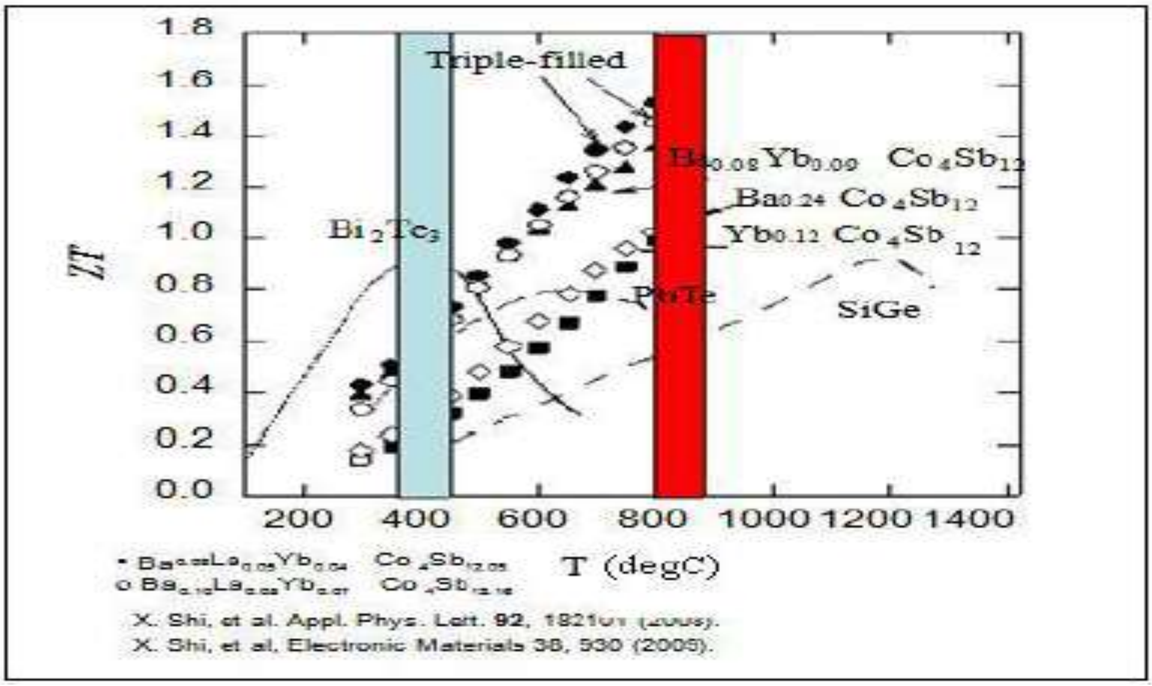
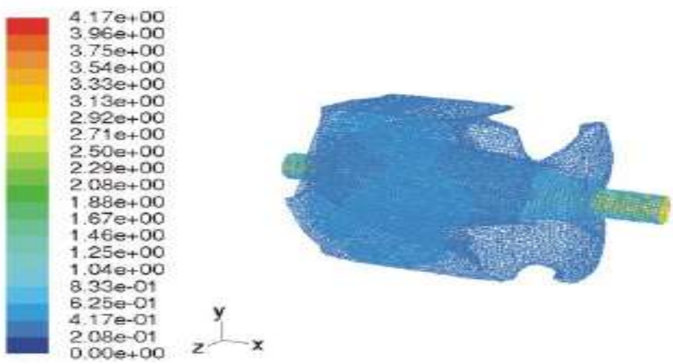


Figure 6: Shows temperature ranges for thermoelectric material [9].



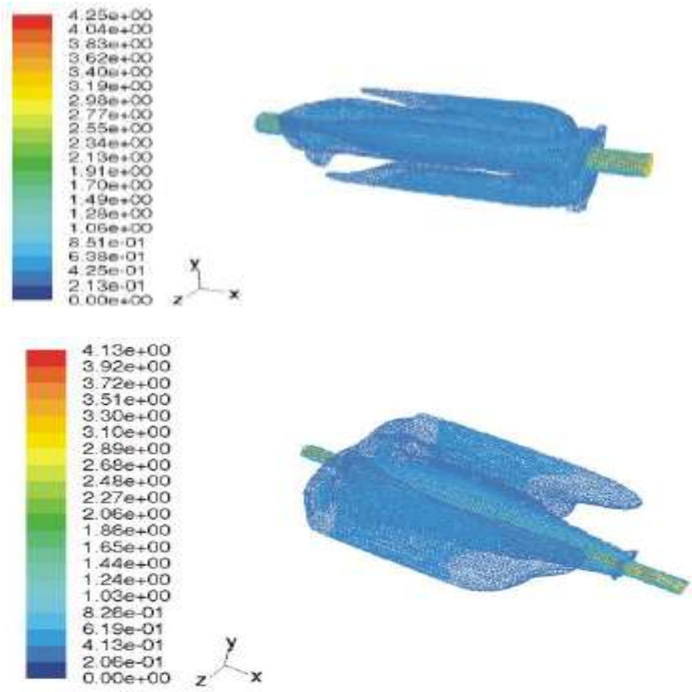


Figure 7: Shows velocity contours of hexagonal , triangular and rectangular models.

III. CONCLUSION

By using Thermoelectric generator, energy can be recovered from a cheaper source but the relative fuel saving may not be in proportion. So there is need of maximizing power generation efficiency of TEG. This can be done by providing large temperature difference between hot and cold side. Moreover cost, space, weight, additional cooling circuit provision, module interface, electronic control and unsteady exhaust flow are practically different issues in implementing TEG. The module size can be reduced with better high temperature module and heat exchanger design.

Three different models of heat exchanger were modeled using CAD and their CFD analysis was done using FLUENT software. The rectangular shaped TEG gave better results as compare to other two models. Therefore Rectangular model was Fabricated and tested on an engine dynamometer. By increasing the power output of an engine we can increase the power produced by the TEG. In the working of the TEM, the temperature drop between hot plate and cold plate place a crucial role. Due to maximum operating temperature of TEM, the maximum temperature on the exhaust side is limited. The efficiency of the modules can be increased by reducing coolant side temperature. Due to space and cost constraints, the total power that could be extracted from exhaust gases was limited. The exhaust energy recovery can be improved by higher temperature resistant thermoelectric module along with better heat exchanger.

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