EXHAUST HEAT RECOVERY IN I. C. ENGINE BY USING THERMO ELECTRIC GENERATOR

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ABSTRACT:

The increasingly worldwide problem regarding rapid economy development and a relative shortage of energy, the internal combustion engine exhaust waste heat and environmental pollution has been more emphasized heavily recently. Higher depletion rate and increasing price of fossil fuels have motivated many researchers to harness energy from the waste heat from internal combustion engines, and thus improve the overall efficiency. Traditionally, only 30 to 35 percent of energy is being utilized to run the vehicles and accessories mounted on the engine and left amount of energy is wasted in various ways like in the form of exhaust and cooling of engine components resulting in to entropy rise and serious environmental pollution.This paper proposes and implements a waste heat recovery system using a thermoelectric generator (TEG) designed for four stroke I.C. engine. The system converts the waste heat from the exhaust manifold into electrical energy using a TEG. The experimental results demonstrate that the proposed system recovers considerable amount of waste heat which can be used to power some auxiliary automobile devices and other applications like mobile charging.

I. INTRODUCTION:

Growing demand for energy consumption has become a major problem facing the world today. It is estimated that globally, only one third of all energy usages were utilized while the remaining is rejected as waste heat. A large part of global energy usage is consumed in the form of thermal energy. This has triggered off an intriguing challenge for scientists and engineers to utilize the waste heat from the industry.

Access to energy in the right form, at the right time, and at the right place is a premise for our society to continue to prosper. Accordingly, with the stipulated population growth and increase in welfare, the power production must continue to grow, however in appropriate ways. The power supply for a modern society must deal with production, storage and distribution and must come from diverse sources. Moreover, for the society to be sustainable the sources of energy supply must eventually be renewable. Reusing a waste, such as waste heat, is considered a conditional renewable energy source. Furthermore, meeting the future need of power supply requires that we also deal with the concept of energy quality. Electric energy is for instance of greater value than thermal energy. Heat at high temperatures is of greater value than at lower temperatures. Heat on demand is of greater value than intermittent and distributed heat. Thermoelectric generators represent a scalable and robust technology to convert waste-heat to high quality electricity.

II. PROBLEMDEFINITION:

In the operation of internal combustion engine around 65 to 70% of energy is lost in the form of heat energy. This heat causes problems like knocking, jamming, thermal stresses and failure of some parts of I. C. engine. Most of the heat is dissipated through exhaust.

Although heat is poor source of energy, but this heat can be converted into useful form of energy like electrical energy. The transformed electrical energy can be used in some applications like charging of mobile, ipods, bluetooth headsets.

On highway there is a necessity of led lights on number plates. These led lights can work on battery but glowing the LEDs on battery causes extra load on battery as there is already a load of headlight, taillight, side indicators, digital displays etc.

III. DESCRIPTION OF THE EQUIPMENT:

1. PELTIER MODULE:

A thermoelectric (TE) module, also called a thermoelectric cooler or Peltier cooler, is a semiconductor-based electronic component that functions as a small heat pump. By applying a low voltage DC power to a TE module; heat will be moved through the module from one side to the other. One module face, therefore, will be cooled while the opposite face is simultaneously heated.

Both N-type and P-type Bismuth Telluride Bi2Te3 thermoelectric materials are used in a thermoelectric cooler

Figure 1Peltier Module

2.HEAT SINK:

A heat sink is a passive heat exchanger that transfers the heat generated by an electronic or a mechanical device into coolant fluid in motion. As per the importance of the heat sink are concerned, it protects the thermoelectric module from damage by emitting excess heat into the surrounding and helps in maintaining temperature difference across the thermoelectric module. The heat sink is made up of aluminum due to high conductivity and light weight.

Figure 2Heat sink

3.THERMAL GREASE:

Thermal grease (also called thermal gel, thermal compound, thermal paste, heat paste, heat sink paste or heat sink compound) is a viscous fluid substance, originally with properties akin to grease, which increases the thermal conductivity of a thermal interface by filling microscopic air-gaps present due to the imperfectly flat and smooth surfaces of the components; the compound has far greater thermal conductivity than air (but far less than metal). In electronics, it is often used to aid a component's thermal dissipation via a heat sink.

Figure 3 Thermal Grease

3. BOOSTER CIRCUIT:

This is based on the theory that inductor holds current and passes in opposite direction. This is a DC to DC converter and it has a poor efficiency of 60-80%. So we can't use it for a large project. We can use it for low power consuming models like 12 V and 3 V models which requires 250 mA current. We have to spend 650 mA with 80% efficiency. In this circuit we are going to put DC pulse of around 2V through TEG and amplifying to 5 V as output. We need to fallow the below for expected voltage range. 6 V to 12 V at 1 A: 80 turns of 24swg wire in a 0.5 mm ferrite core.

6 V to 12 V at 500 mA: 60 turns of 36swg wire in a 0.5 mm ferrite core.

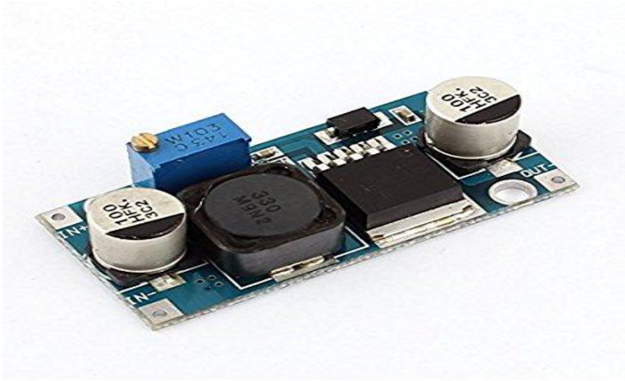

Figure 4Booster Circuit

5. CLAMP AND BOLTS:

Clamps and bolts are used to mount heat sink and Peltier plate assembly on exhaust pipe of bike.

Figure 5 Clamp and bolts

III. METHODOLOGY:

A. IDENTIFYING THE PROBLEM:

In the operation of internal combustion engine around 65 to 70% of energy is lost in the form of heat energy. This heat causes problems like knocking, jamming, thermal stresses and failure of some parts of I. C. engine. Most of the heat is dissipated through exhaust.

B. SEEKING FOR POSSIBLE SOLUTION:

There are some methods of heat recovery from exaust gases of I. C. engine like piezoelectric generation, thermionic generation, thermo-photovoltaic generation, thermoelectric generation, rankine cycle, stirling cycle, refrigeration, mechanical terbo-compounding But these methods are complex in design, bulky in size and high in cost. On vice versa thermoelectric generation is easy to design, compact and low in cost. Hence we selected thermoelectric generation method to recover exhaust heat of I. C. engine. There 16 are two modules in thermoelectric generation method known as thermoelectric cooler (TEC) and thermoelectric generator (TEG)

C. MATERIAL SELECTION

There are many materials with higher thermal conductivity for our application viz. Silver (K=406 W/m^2K), Copper (K=385 W/m^2K), Aluminium (K=205 W/m^2K) & Gold (K=314 W/m^2K). Now from adequate thermal conductivity and cost point of view Copper would be most suitable for our application.

D. PROTOTYPE MANUFACTURING:

1. FACING OPERATION:

Facing is the act of cutting a face, which is a planar surface, onto the work piece. Within this broadest sense there are various specific types of facing, with the two most common being facing in the course of turning and boring work (facing planes perpendicular to the rotating axis of the work piece) and facing in the course of milling work (for example, face milling). Other types of machining also cut faces (for example, planning, shaping, and grinding). Facing operation was performed on lathe machine to reduce the length from 148mm to 145mm. 26

2. DRILLING OPERATION:

The purpose of spot drilling is to drill a hole that will act as a guide for drilling the final hole. The hole is only drilled part way into the work piece because it is only used to guide the beginning of the next drilling process. Spot drilling of 14 mm diameter was performed on the block.

3. BORING OPERATION:

Boring is the process of enlarging a hole that has already been drilled (or cast), by means of a single-point cutting tool (or of a boring head containing several such tools). Boring is used to achieve greater accuracy of the diameter of a hole, and can be used to cut a tapered hole. Boring can be viewed as the internal-diameter counterpart to turning, which cuts external diameters. Boring was carried out to enlarge the diameter from 10mm to 38mm. 4.6.4 Grinding operation Grinding is the machining process of using rotary thin cutters to remove material from a work piece to finish it. It covers a wide variety of different operations and machines, on scales from small individual parts to large. It is one of the most commonly used processes in industry and machine shops today for machining parts to precise sizes and shapes. We used grinding blade to cut the block diagonally.

4. DRILLING AND TAPPING:

Taps and dies are tools used to create screw threads, which is called threading. Many are cutting tools; others are forming tools. A tap is used to cut or form the female portion of the mating pair (e.g., a nut). A die is used to cut or form the male portion of the mating pair (e.g., a bolt). The process of cutting or forming threads using a tap is called tapping, whereas the process using a die is called threading. We did the tapping on the block to mount the block on exhaust heat pipe and also to mount fins on the block.

5. BRAZING:

Brazing is a metal-joining process in which two or more metal items are joined together by melting and flowing a filler metal into the joint, the filler metal having a lower melting point than the adjoining metal. Brazing was carried out to join the mounting plates to the fins.

E. DESIGN OF FIN:

We are designing the fin to maintain the temperature difference. So that the heat dissipation rate from the surface will be increased.

We got the standard fin pattern from market. This fin pattern is generally used in heat sink of computer CPU processor. This pattern is having dimension as follows:

Length of fin = 4mm

Thickness of fin = 0.5mm

Width of fin = 6.4mm

We are going to calculate heat transfer coefficient by using force convection and the heat flow rate through the fin. The properties of the ambient air are as follows:

At the ambient air temperature 27°C=300K

Density (ρ) = 1.1614Kg/m^3

Viscosity (μ) = 1.846x10^{-5} N s/m^2

Thermal conductivity (k) of air = 2.63x10^{-2} W/m K

Thermal conductivity (k) of Aluminum = 247 W/m K

Velocity of air (U) = 11.11 m/s

Prandtl number (Pr) = 0.707

The air flow on the fin by the forcely while bike moving with the speed, so the convection on the fin is forced convection. The convection coefficient is changed. It is calculating by forced convection method.

Consider fin is plate on which the convection is take place. Using the formula for convection on the plate, is given as,

$$Nu = 0.664\ (Re^{0.5} \cdot Pr^{0.33}) \quad (1)$$

Where, Nu = Nusselt number,

Re = Reynolds number,

Pr = Prandtl number.

We know that,

$$Re = \frac{\rho\ U\ L}{\mu} \quad (2)$$

$$\therefore Re = \frac{1.1614 \times 11.11 \times 6.44 \times 10^{-3}}{1.846 \times 10^{-5}}$$

$\therefore$ Re = 4500

Also,

Pr = 0.707

By substituting above value in equation (1), we get

Nu = 39.79

We know that,

$$Nu = \frac{h\ L}{K} \quad (3)$$

$$\therefore h = \frac{Nu \times K}{L} \quad \therefore$$

$$h = \frac{39.79 \times 2.3 \times 10^{-2}}{6.44 \times 10^{-3}}$$

$\therefore$ h = 162.5 W/m^{2}K

This heat transfer coefficient is obtained by forced convection.Assuming the fin is having finite length and tip is not insulated, the heat transfer from the fin is given by,

$$Q = \sqrt{h\ P\ K\ A}\ (T_s - T_a)\ \tanh(mL) \quad (4)$$

Firstly let's find the perimeter (P) of the fin cross-section

P = 2 (w + t)

= 2 (6.44 + 0.5)

= 13.88 mm

The cross-section area (A) of the fin,

A = (W x t)

= (6.44 x 0.5)

= 3.22mm^2

Now,

$$m = \sqrt{\frac{h\ P}{K\ A}} \quad (5)$$

$$= \sqrt{\frac{162.5 \times 13.88 \times 10^{-3}}{247 \times 3.22 \times 10^{-6}}}$$

$\therefore$ m = 52.186

$\therefore$ mL = 52.186 x 4 x 10^{-3}

$\therefore$ mL = 0.2087

Substituting above values in equation (ii), Q $=\sqrt{h\ P\ K\ A}\ (T_s - T_a)\ \tanh(mL)$

$$\therefore Q = \sqrt{162.5 \times 13.88 \times 10^{-3} \times 247 \times 3.22 \times 10^{-6} \times 40 \times \tanh(0.2087)}$$

$\therefore$Q= 0.3485W

It is heat flow rate from single fin. We are using 27 fins on each side, so the total is heat flow rate is given by,

Q = 2 x 27 x0.3485

= 18.82 W

It is the total amount of heat dissipated by fin pattern. So we will be getting temperature difference of 40°C.

F. EXPERIMENTAL SETUP:

Sr. No.	Parameters	Values
1.	Engine Displacemnts	149.01 cc
2.	Engine Type	4-stroke, single cylinder, DTS-i air cooled engine
3.	Max. Power	15.06 bhp @9000rpm
4.	Max. Torque	12.5 N-m @6500rpm
5.	Transmission	5-speed normal
6.	Kerb Weight	143 kg

Table 1 Specifications of bike used (pulsar 150)

Figure 6 Experimental setup

G. CONDUCTING EXPERIMENT:

We first conducted experiment on TEC which resulted in low output voltage as compare to TEG. TEC also got damaged after experimenting three to four times.

H.REACHING TO THE CONCLUSION:

We came to some conclusion which is discussed in further chapter.

IV. RESULTS ANDDISCUSSIONS:

Experiment is performed from 7:00am to 8:00am in summerseason.The results of actual experimental setup on a bike (Pulsar 150) are given in Table 2Observation Table of actual setup

Sr. No.	Distance(km)	Time(min)	Voltage(V)
1	0.00	0.00	0.00
2	0.30	0.07	0.40
3	0.50	1.09	1.04
4	0.60	1.42	1.25
5	0.75	2.13	1.68
6	1.10	2.52	2.03
7	1.20	2.61	2.94
8	1.70	3.79	3.42
9	2.00	5.22	3.65
10	2.50	5.50	4.00
11	3.20	7.08	4.54
12	3.90	8.05	4.85
13	4.80	9.58	5.05
14	6.10	11.09	5.30
15	6.90	13.09	5.40
16	7.50	14.51	5.55
17	8.50	15.76	5.70
18	9.90	16.94	6.03
19	10.80	18.58	6.20
20	11.70	20.07	6.35

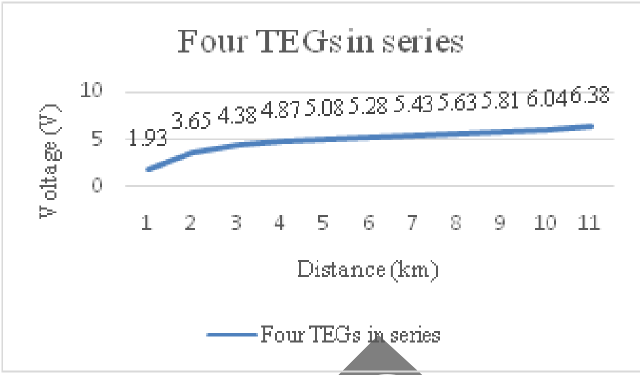

Figure 7 Graph of performance of four TEGs in actual setup

V.CONCLUSION:

In this project we have successfully fabricated an exhaust gas heat recovery power generator. Thus the eco-friendly power generation method can be implemented for domestic and commercial use at an affordable cost. The efficiency of the engine will be increased because waste surface heat of the silencer is drawn out to convert it into electrical energy. The main objective of this project is to convert the recovered heat to useful electric energy. This objective has been successfully accomplished in this paper. The output could be increased by connecting a number of TEGs in series, so that the voltage gets added up leading to increased power. Test conducted on TEC resulted into lower output. It also got damaged after using it 4-5 times whereas TEG gives better output than TEC and has more life as compared to TEG. As distance travelled increases thevoltage output also increases.

REFERENCES:

1) Rathod Mahesh M., *Engineering Heat and Mass Transfer,* Laxmi Publication, Second Edition, [PP1125].
2) Rajput R. K., Heat and Mass Transfer, S, Chand, Revised Edition, 2014, [PP214,413].
3) ShrutikaKarpe, *"Thermoelectric Power Generation Using Waste Heat of Automobile",* International Journal Of Current Engineering and Technology, E-ISSN 2277 – 4106, P-ISSN 2347 – 5161, 2016.
4) Jonas Coyet, Fredrik Borgstrong, "*Waste Heat Recovery System with New Thermoelectric Material",* Master Thesis, LIU-IEI-TEK-A-15/02289-SE, June 2015.
5) Harshvardhan M. V., Prashanth K. P., Venkatesha B. K., "*Conversion of Waste Heat Energy from Internal Combustion Engine using Thermoelectric Generator",* ISSN:23489510, International Journal of Core Engineering & Management", Volume 3, Issue 4, July 2016.
6) Ajay Chandrawanshi, Dr. J. J. Suryawanshi, *"Waste Heat Recovery From Exhaust Gases through I.C. Engine using Thermoelectric Generator",* International Journal of Applied Research, Volume 3, Issue 7, july 2013.