AUTOMOBILE EXHAUST ENERGY UTILISATION FOR SIMULTANEOUS COOLING AND HEATING WITH PELTIERMODULES

S. Raahila Parveen[1] ,Dr. D.R. Srinivasan[2]

PG Research Student, Refrigeration and Air Conditioning, Department of Mechanical Engineering, JNTUA College of Engineering, Anantapur, A.P, India.[1]

Assistant Professor, Department of Mechanical Engineering, JNTUA College of Engineering Anantapur, A.P, India[2]

ABSTRACT :

There has been an industrial revolution from the 19th century that has given a multifold increase in energy consumption. This has resulted in the over-exploitation of natural energy resources. Consequently, it has led to a rapid rise in pollution levels with energy costs rising abnormally. Industrialists and researchers have been focusing on alternative sources of energy that can minimize the use of conventional energy resources thereby reducing energy costs. Waste heat recovery is one of the promising methods as one the energy sources that can be employed as it is abundantly available in the exhaust gases emitted from industries, automotive engines, braking mechanisms of automobiles, etc. It is estimated about 30 to 40% of energy can be harnessed from these exhaust gases by employing the principle of Peltier modules. This energy can be utilized to generate power that can be further utilized for both heating and cooling purposes. The present work exhibits the potential where waste heat from an internal combustion engine can be utilized to create hot and cold chambers in an automobile. The Peltier effect serves as the basis for cold chamber configuration which relies on a low temperature in the chamber that can be attained by Peltier semiconductors. Designing an automobile with a unique configuration that offers benefits for carrying hot and cold products, a reduction in silencer costs etc makes this idea innovative.
Keywords: Turbine, Dynamo, Battery, Thermoelectric plate, Hot and Cold Chamber

I. INTRODUCTION :

Around the world, internal combustion engines are the main consumers of fossil fuels. About 30 to 40 percent of the total energy used to heat the engine's fuel is lost through evaporation in the environment. It is necessary to use waste heat for productive purposes since it is released into the air through exhaust gases or engine cooling systems, causing an increase in entropy and major environmental problems that contribute to pollution. In the end, such waste heat recovery could lessen both the need for overall energy and the effect on global warming. Over the past century, the internal combustion engine has emerged as the main source of power for automobiles. Currently, to reduce fuel consumption, engine designs are becoming more sophisticated due to high gasoline prices and worries about reliance on foreign oil. The see-beck effect states that if these junctions are already at different temperatures, an electric potential will form in a thermocouple. The temperature gradient that exists here between the hot junction and the cold junction affects the electric potential that is generated. An electric current in a closed circuit can be driven by this electric potential. Metal alloys like platinum, which produce a ton of microvolts per degree of temperature difference, are used to make conventional thermocouples. Modern semiconductor thermocouples that do solid-state energy conversion, made from p-type and N-type organic semiconductors, are probably less well known. In some applications, these devices can produce numerous microvolts for every degree of temperature change, which is usable electrical power. Semiconductor devices' thermoelectric generator modules can generate thermoelectric power in applications for green energy technology. They are made up of several coupled thermocouple elements. The potential for waste heat recovery from engine exhaust to reduce fuel consumption without raising emissions is well acknowledged by researchers, and recent technology developments have made these systems practical and affordable. On the other hand, CO, HC, and NO that particulate matter have been the main subjects of laws on exhaust emission levels. One of the best solutions to these issues is power efficiency on the engine, which can increase the engine's energy consumption efficiency and lower emissions.

II. Literature Survey:

A thermoelectric material needs to have both hot and cold sides to produce any thermoelectric effects. Usually, excess heat makes it simple to reach the hot side. However, convective heat transfer towards the surroundings is frequently the extent of passive cooling. Effective passive cooling to widen the temperature gradient is crucial because the thermo-electric voltage is inversely proportional to the difference in temperatures between the warm and cold sides. A thermoelectric material requires have both hot and cold sides to produce any thermoelectric effects. Usually, excess heat makes it simple to reach the hot side. However, convective heat transfer towards the surroundings is frequently the extent of passive cooling. Effective passive cooling to raise the temperature difference is crucial because the thermo-electric voltage is related to the temperature differential between the warm and cold sides. A thermoelectric material must have both hot and cold sides to produce any thermoelectric effects. Usually, excess heat makes it simple to reach the hot side. However, convective heat transfer towards the surroundings is frequently the extent of passive cooling. Effective passive cooling to widen the temperature gradient is crucial because the thermo-electric voltage is inversely proportional to the difference between the hot and cold sides. Every energy-consuming industry relies on the waste heat recovery system to collect heat. This waste heat is transformed into beneficial work done as electric energy via Thermo-Electric Module. The resulting electric energy has several promising advantages, including (a) energy storage in DC batteries, (b) powering a range of loads in the residential, commercial, but also industrial sectors, and (c) power export to the grid, earning valuable revenues, (d) maintaining the plant's economic growth, and (e) being an environmentally friendly system. Waste Heat Recovery (WHR), one of many renewable energy technologies, has recently received a lot of attention from the commercial, residential, and industrial sectors. The See beck effect, as defined by Satoshi Ishii and Asuka Miura, is the production of electrical voltage caused by the placement of a conductor in such a temperature gradient. The See beck coefficient, S, which itself is governed by the rate of scattering and the density of both the conduction electrons and is defined as the proportion of the induced electric voltage towards the temperature difference, serves as a measure of its efficiency. By joining two conductors with various See beck coefficients, a thermocouple is created that can be used, for instance, in thermal electric-power generators as well as for temperature detection.

a. Possibility of Heat Recovery and Availability from I.C. Engine

Waste heat is produced during a process through the burning of fuel or a chemical reaction, and it is then released into the environment even though it may still be employed for beneficial and cost-effective purposes. The heat of the excess heat gases and the flow rate for exhaust gases both have an impact on this heat. Take a combustion engine as an example, which loses between 30 and 40 percent of its energy as waste heat through the exhaust. Temperatures in the exhaust gases coming out of the engine can reach 400–500°C. These gases are therefore highly heated and released as exhaust emissions. the internal combustion engine's overall energy distribution. Compression ignition or spark ignition engines still power a lot of automobiles. CI engines, commonly referred to as diesel engines, have a broad range of uses and are distinguished as energy converters by their great efficiency. The various engines and associated power rangers are displayed in the table below. The efficiency of a diesel engine is typically around 35%, while the remaining input energy is squandered. The mean heating power obtainable through waste heat is estimated to be roughly 23kW for a typical and average driving cycle, compared to 0.8–3.9kW of cooling capacity. The exhaust from combustion engines can serve as a significant heat source that may be used in a variety of ways to provide extra power and enhance overall engine efficiency. This is because the wasted energy makes up about two-thirds of input energy and is for the benefit of better fuel economy.

Table 1. Various Engines and their Outputs

S. 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 agricultural tractors and construction machines	150	
3	water air cooled engine	35-150	
4	earth moving machinery	520-720	
5	Marine applications	150-220	
6	Trucks and road engines	220	

III. Experimentation :

In this project, the turbine that is connected to the DC generator receives exhaust fumes from the engine. Continuous electricity can be generated from the dynamo as it rotates under the force of exhaust fumes, and this power was stored in the battery. The Peltier effect is how the Thermos electric plate functions. When DC is applied with the help of a battery, a pellet array with negative and positive charge carriers absorbs heat energy through one substrate and finally releases it to the substrate on the other side. As a result of the heat energy being absorbed throughout this process, a chilly surface was produced. The opposite surface receives the heat energy that was absorbed and becomes warm. In which the heat energy is lost, the opposite side cools.

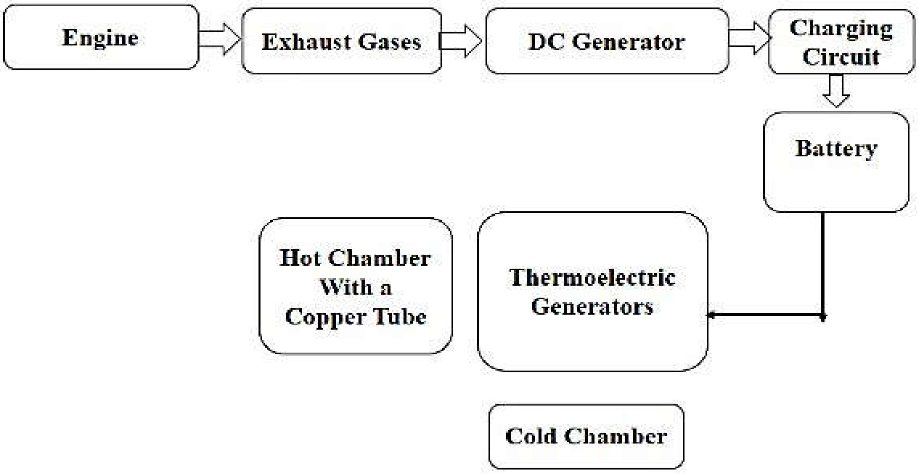

Fig.1: Block diagram of Waste Heat Recovery System

a) Waste heat from engines

Because of combustion, waste heat or unneeded heat can be produced and then released into the environment, but it can also be recycled for modestly useful and cost-effective uses. Four sources of unneeded heat from a rotary engine are available during a cross-engine run period: exhaust gas, engine jacket cooling water, or turbocharger cooling are released into the atmosphere.

b) Persistent problem :

Due to COVID, the number of two-wheeler vehicles is increasing in the world. However, due to the depletion of fossil fuels, the previous rail design is becoming ineffective and unacceptable. According to the research, the efficiency of current internal combustion engines is capped at 40%, with the remaining 60% of the fuel's energy being wasted. In the meantime, the engines' exhaust gases contribute to global warming. In-depth investigation and experimental work on waste heat recovery from cars utilizing thermoelectric modules were developed in response to future concerns.

c) Objectives :

- The thermoelectric in a two-wheeler that can generate electricity is being designed in this project.
- Find the best location for the thermoelectric modules to provide the engine with its best performance.
- Cutting back on environmental pollutants
- Blends of biodiesel are utilized to reduce engine load and performance and lower pollutant levels.

d) Scope and Delimitations :

This study during the project covers

- Designing of the thermoelectric module
- Generating power for the project model while a 1.5-volt fan is running, and voltage is being displayed on a multimeter.
- For using the thermoelectric module setup, a subsequent computation is made.
- The ambient conditions were acceptable when the readings were being recorded.

IV. METHODOLOGY DESIGN

We already knew that waste heat or exhaust heat from the engine occurs because of the power supply when passenger vehicles move at a large speed in a variety of road conditions. There is a lot of waste heat or exhaust heat produced by generator vans as well, therefore we are installing thermoelectric modules there to show how this waste heat may be converted into useful heat. The initiative focuses on turning waste heat into usable energy. This concept has been used in high-powered two-wheeler engines and generator vans. On the two-wheeler, we mounted thermoelectric modules and focused IC engines. Iron is used to supply the heat source, and a fan is employed to create the cooling effect. We demonstrate by turning on a 1.5 V fan, but we have also set up a multimeter to display the number of volts generated.

Fig.2: Experimentation setup

DESIGN CALCULATIONS :

1. **Engine Specifications:**

Bore Diameter of the Engine = 80MM

Stroke Length of Engine = 100MM

Speed Of Engine = 1500RPM

Temperature Of Exhaust Gases = 200

2. **Fabrication Dimensions:**

Hot Chamber Box = 10MM * 10MM * 10MM

Cold Chamber Box = 7MM*7MM *7MM

Copper Tube in Hot Chamber = 8MM DIAMETER.

Nozzle = 19MM TO 9MM

The diameter Of Connecting Pipe to the Engine Exhaust = is 25.4MM

Diameter Of Turbine = 100MM

Dc Generator Capacity = 12v 5AMPS

Temperature At Entry of Hot Chamber = 110

Temperature At Exit of Hot Chamber = 70

3. **Cold Chamber Performance:**

Ambient Temperature = 26℃
Power Input = 60w
Input To Fans = 0.14 Amps Cooling Time.

4. **Calculations:**

The velocity of exhaust at the outlet of

Engine = Distance moved by piston per rotation*Rotations per second

= 2* stroke length*RPM/60

= 2*0.1*1500/60

= 5 m/s

Using the continuity equation,

$A_1V_1 = A_2V_2$

$\pi/4 * 0.08^2 * 5 = \pi/4 * 0.0254^2 * V_2$

$V_2 = 49.6$ m/s

A_1 = Area of cylinder

V_1 = Velocity of exhaust at the exit of cylinder

A_2 = Area at the exit of the nozzle

V_2 = Velocity at the exit of the nozzle

Turbine

Force exerted by jet in direction of motion of the plate.

f_x = mass {final velocity – initial velocity}

$f_x = m\{(v-u)-0\}$

$= \rho av(v-u)$

$= 1.249 * \pi/4 * 0.0254^2 * 49.6 * (49.6-5.235)$

= 1.35 N

ρ = density of exhaust gas

a = area of the nozzle

v = velocity of exhaust gas

u = velocity of blades

Output: Work done by series of plates = $f_x * u = \rho av(v-u) * u$ watts

= 1.35*5.235

= 7.10 w

Input:

Kinetic energy of jet per second = ½ mv2 = ½ ρav*v2

= ½ * 1.249*π/4 * 0.02542*49.62*49.6

= 38.61 w

Efficiency of turbine

$= \frac{work\ done\ by\ series\ of\ plates}{kinetic\ energy\ of\ jet\ per\ second}$

$= \frac{7.10}{38.61}$

= 19.39%

DC Generator:

Voltage : 12V

No load current: 2amps

Maximum load current: 5amps

Torque : 5kg-cm at 12V

= 0.5 kN-m

Power output = V*I = 12*5 = 60 watts

Power input = T*W = $\frac{2\pi NT}{60}$

$P_{output} = \frac{2\pi NT}{60} = \frac{2*\pi*1000*5}{60} = 52.35$ watts

Efficiency $\eta = \frac{Poutput}{Pinput} = \frac{52.35}{60} = 87.25\%$

Cold Chamber:

Density of air (ρ) = 1.204 kg/m^3

The viscosity of air (μ) = $1.8205*10^{-5}$

Thermal conductivity of air (k) = 0.025596

Discharge Q = 200CFM = $\frac{200*(0.3048)^3}{60}$ = 0.0944 m^3/sec {1 feet = 0.3048 m}

Q = A*V = 4*7*7*v

= 4*7*7*0.0944

Velocity of air V = 0.0185 m/s

Cold chamber box=7mm * 7mm*7mm

$R_e = \frac{\rho v D_h}{\mu}$:

$D_h = \frac{4A}{\rho} = \frac{4*7*7}{4*7} = 7$

R_e = 85.64i.e., laminar

So,

$N_u = \frac{hD}{k} = 3.66$ (for a constant surface temperature)

$h = \frac{3.66*3}{7*0.3048}$

h = 4.5 w/m^2k

Total cooling rate

$hA\Delta T = Q = 4.5*4*7*7*(23-4)$

= 16.785 watts

Q = V*I

Maximum power = 60 watts

Coefficient of performance = 16.785/60

=0.27797

Hot Side:

$\rho = 1.204\ kg/m^3$

$\mu = 1.8205*10^{-5}$

k = 0.025596

Q = 200CFM = $\frac{200*(0.3048)^3}{60}$ = 0.0944 m^3/s {1 feet = 0.3048 m}

Q = A*V = 4*10*10*v

= 4*10*10*0.0944

V = 0.03776 m/s

$R_e = \frac{\rho v D_h}{\mu}$:

$D_h = \frac{4A}{\rho} = \frac{4*10*10}{4*10} = 10$

R_e = 249.72 i. e, laminar

So,

$N_u = \frac{hD}{k}$ = 3.66 (for a constant surface temperature)

$h = \frac{3.66*3}{15*0.3048}$

h = 3.602 w/m^2k

Total cooling rate

hAΔT = Q = 3.602 * 4 * 10 * 10 * (65-23)

= 60.52

Q = V*I

Maximum power = 60 watts

Coefficient of performance = 60.51/60 = 1.002

Hot Chamber

Dimensions of hot chamber:10*10*10 cm

Material of tube section: copper

Thermal conductivity of copper :

401 W/mK

Diameter of copper tubes:8 mm

The temperature at the entry of the hot chamber: 110

The temperature at the exit of the hot chamber: 70

Amount of heat transfer to the chamber from exhaust gases: M*C_p*change in temperature

M = mass of exhaust gases

= density of exhaust gases*discharge

= density of exhaust gases*C/S area of tube section*velocity of exhaust

C_p = specific heat of exhaust gases

Change in temperature = temperature difference between entry and exit of the hot chamber

Heat transfer to the chamber from exhaust gases = ρ*C/S area*velocity of exhaust* C_p*ΔT

= 1.249*0.7854*0.08^2*49.6*1.063*(110-70)

= 13.2406 W for 1 min running

V. RESULTS AND DISCUSSION

Four experiments were conducted for this study to examine the voltage that the thermoelectric generator produces when there is a temperature differential between the hot and cold sides. The TEG motorcycle's Kirloskar engine exhaust system has been employed in all experiments to provide heat on the hot side. Waste heat from the motorcycle is utilized in each experiment.

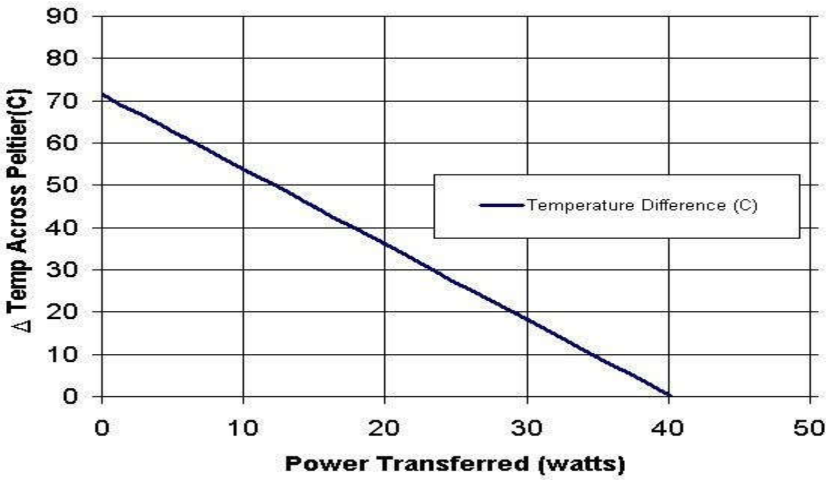

Fig.3: Power Vs Temp of Peltier plates

a) During Engine ramp :

When the motorcycle's throttle is opened for the engine ramp experiment, the voltage quickly rises to 10 minutes and 0.81 V at a temperature difference of less than 10°C. The engine's increased intake of fuel and air is causing the voltage to rise quickly, which will boost combustion and discharge a lot of waste heat into the exhaust system.

b) During Motorcycle Running :

When measuring the voltages for this experiment, the motorcycle was moving at a steady 60 km/hr. The maximum voltage of 0.92V is produced as time passes because the engine's combustion rate increases and more waste heat is emitted into the exhaust system. The voltage rises gradually as time passes.

c) During engine stop :

Data was collected for the final trial right after the motorcycle's engine was shut off. As a result, there is no longer any combustion taking place inside the engine system, where voltage is now falling over time.

VI. CONCLUSION :

The experimental investigation was carried out to utilize the energy available in automobile exhaust gas and following conclusions are drawn below. The initial temperature of the exhaust gas entering the nozzle is 110°c and power generated is 60 watts. As the temperature of exhaust gases is varying from time to time, the analysis was extended for different temperatures i.e., 110°c -90°c power generated is 52.35 watts, 90°c -70°c power generated is 57.67 watts and so on. The heat transfer in hot chamber is found to be 13.24 watts/min and at the cold chamber with Peltier semiconductor has lowest temperature of 15°c. The overall efficiency is 87.25% with 0.92 V as highest voltage at 60km/hr. speed. On an average 15% of expenditure on fuel can be saved by this arrangement. As a result, there is significant decrease in usage of fuel consumption there by reducing pollution.

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