International Journal of Core Engineering & Management (ISSN: 2348-9510)
Special Issue, NCETME -2017, St. Johns College of Engineering and Technology, Yemmiganur

WASTE HEAT UTILISATION BY THERMO ELECTRIC CONVERSION

[1]N. PRADEEP KUMAR, [2]M.M. RAVICHAND, [3]RAVITEJA M G, and [4]SOMANATH.H
[1]Assistant Professor, Dept. Of Mechanical Engineering, NIT, Raichur.
Email: jesun335@gmail.com
[2.3.4] B.E. Scholar, Dept. Of Mechanical Engineering, NIT, Raichur.
Email:m.m.ravichand@gmail.com

Abstract

As the world is currently running in fuel crisis it is a wise approach to recover the useful energy from the exhaust gases. Our project aims to utilize heat rejected through exhaust gases to generate electricity which can charge the battery. In internal combustion engines out of the total heat supplied to the engine in the form of fuel, approximately, 30 to 40% is converted into useful mechanical work; the remaining heat is expelled to the environment through exhaust gases and engine cooling systems, resulting in to entropy rise and serious environmental pollution, so it is required to utilized waste heat into useful work. The recovery and utilization of waste heat not only conserves fuel (fossil fuel) but also reduces the amount of waste heat and greenhouse gases damped to environment. The study shows the availability and possibility of waste heat from internal combustion engine, also describe loss of exhaust gas energy of an internal combustion engine. The temperature of pipe surface of exhaust gases flowing through exhaust gas pipe is very high and it is around 200°C to 300°C so a heat exchanger is made, which conducts heat from exhaust pipe to thermoelectric modules (TEC-MODULE), one surface of these modules is in contact with the surface of hot side heat exchanger and other is in contact with the surface of cold side heat exchanger and thus potential difference is created and power is produced due to Seebeck effect. The results shows the efficiency of conversion is less, but can be improved by using better insulation system and proper design.

Index Terms: Thermoelectric effect, Seebeck effect, TEC-MODULE, IC-engines, Exhaust system.

I. INTRODUCTION

Automobiles are an example of high energy usage with lower efficiencies. Out of the total heat supplied to the engine in the form of fuel, approximately, 30 to 40% is converted into useful mechanical work. Roughly 75% of the energy produced during combustion is lost in the exhaust or engine coolant in the form of heat. By utilizing a portion of the lost thermal energy to charge the battery instead of using an alternator the overall fuel economy can be increased by about 5%. Depending on the engine load the exhaust temperatures after the catalytic converter reach about 300-500 degrees Centigrade. Thermoelectric generators are ideal for such applications as they are small, with no moving parts, and relatively efficient at these temperatures. Thermoelectric technology can be used to generate electrical power from heat, temperature differences and temperature gradients, and is ideally suited to generate low levels of electrical power in energy harvesting systems. Thermoelectricity utilizes the Seebeck, Peltier and Thomson effects that were first observed between 1821 and 1851.

The recovery and utilization of waste heat not only conserves fuel, usually fossil fuel but also reduces the amount of waste heat and greenhouse gases damped to environment. It is imperative that serious and concrete effort should be launched for conserving this energy through exhaust heat recovery techniques. Such a waste heat recovery would ultimately reduce the overall energy requirement and also the impact on global warming.Waste heat is heat, which is generated in a process by way of fuel combustion or chemical reaction, and then "dumped" into the environment even though it could still be reused for some useful and economic purpose.

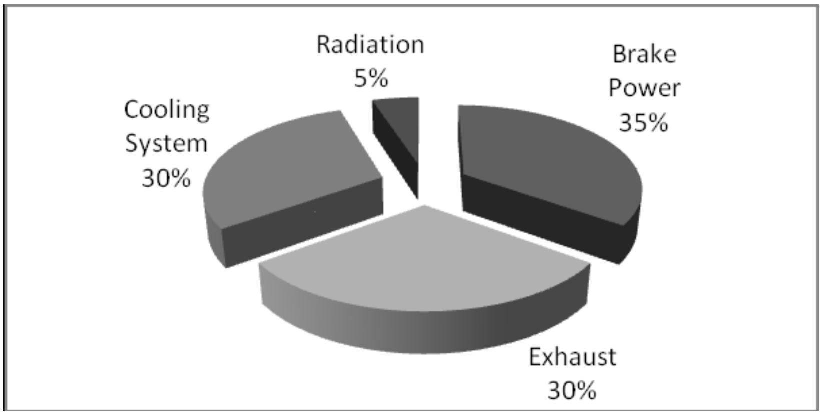

Figure 1: Total Fuel Energy Content in I. C. Engine

Benefits of 'waste heat recovery'
1. Direct Benefits: Recovery of waste heat has a direct effect on the combustion process efficiency. This is reflected by reduction in the utility consumption and process cost.

2. Indirect Benefits:
a) Reduction in pollution: A number of toxic combustible wastes such as carbon monoxide (CO), hydrocarbons (HC), nitrogen oxides (NO_x), and particulate matter (PM) etc, releasing to atmosphere. Recovering of heat reduces the environmental pollution levels.
b) Reduction in equipment sizes: Waste heat recovery reduces the fuel consumption, which leads to reduction in the flue gas produced. This results in reduction in equipment sizes.
c) Reduction in auxiliary energy consumption: Reduction in equipment sizes gives additional benefits in the form of reduction in auxiliary energy consumption.

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: (1) Where Q, is the heat loss (kJ/min); **m** is the exhaust gas.

Electrons on the hot side of a material are more energized than on the cold side. These electrons will flow from the hot side to the cold side. If a complete circuit can be made, electricity will flow continuously. Semiconductor materials are the most efficient, and are combined in pairs of "p type" and "n type". The electrons flow from hot to cold in the "n type", while the holes flow from hot to cold in the "p type." This allows them to be combined electrically in series.

Seebeck coefficient or the thermo power, represented by 'S', of a material measures the magnitude of an induced thermoelectric voltage in response to a temperature difference across that material. If the temperature difference ΔT between the two ends of a material is small, then the thermopower of a material is defined approximately as

$$S = -\frac{\Delta V}{\Delta T}$$

A thermoelectric voltage of ΔV is seen at the terminals. The negative sign indicates the flow of electrons and positive sign means flow of holes.

Figure of merit Z for thermoelectric devices is defined as

$$Z = \frac{\sigma S^2}{\kappa}$$

Where **σ** is the electrical conductivity, **κ** is the thermal conductivity, and **S** is the Seebeck coefficient. The dimensionless figure of merit ZT is formed by multiplying Z with the average temperature.

$$\bar{T} = \frac{(T_2 + T_1)}{2}$$

A greater ZT indicates a greater efficiency, subject to certain provisions, particularly that the two materials in the couple have similar Z. ZT is therefore a method for comparing the potential efficiency of devices using different materials. Values of 1 are considered good; values in the 3–4 range are essential for thermoelectric to compete with mechanical devices in efficiency. To date, the best reported ZT values are in the 2–3 range.

Efficiency of a thermoelectric device for electricity generation is given by **η**, defined as,

$$\eta = \frac{\text{energy provided to the load}}{\text{heat energy absorbed at hot junction}}.$$

II. LITERATURE

Large quantity of hot flue gases is generated from internal combustion engine etc. If same of this waste heat could be recovered, a considerable amount of primary fuel could be saved. It is depends upon mass flow rate of exhaust gas and temperature of exhaust gas. The internal

International Journal of Core Engineering & Management (ISSN: 2348-9510)
Special Issue, NCETME -2017, St. Johns College of Engineering and Technology, Yemmiganur

combustion engine energy lost in waste gases cannot be fully recovered. However, much of the heat could be recovered and losses be minimized by adopting certain measures. There are different methods of the exhaust gas heat recovery namely for space heating, refrigeration and power generation. The mass flow rate of exhaust gas is the function of the engine size and speed, hence larger the engine size and higher the speed the exhaust gas heat is larger. So heat recovery system will be beneficial to the large engines comparatively to smaller engines. The heat recovery from exhaust gas and conversion in to mechanical power is possible with the help of Rankine, Stirling and Brayton thermodynamic cycles, vapour absorption cycle.

These cycles are proved for low temperature heat conversion in to the useful power. Engine exhaust heat recovery is considered to be one of the most effective means and it has become a research hotspot recently. For example, Doyle and Patel have designed a device for recovering exhaust gas heat based on Rankine cycle on a truck engine. The commissioning experiment of 450 kilometers showed that this device could save fuel consumption by 12.5%. Cummins Company has also done some research on waste heat recovery on truck engines, and the results showed that engine thermal efficiency could improve by 5.4% through exhaust heat recovery. James C. Conklin and James P. Szybist have designed a six-stroke internal combustion engine cycle with water injection for in-cylinder exhaust heat recovery which has the potential to significantly improve the engine efficiency and fuel economy. R. Saidur et al Rankine bottoming cycle technique to maximize energy efficiency, reduce fuel consumption and green house gas emissions. Recovering engine waste heat can be achieved via numerous methods. The heat can either be reused within the same process or transferred to another thermal, electrical, or mechanical process. Hau xuewjun et al has studied the analysis of exhaust gas waste heat recovery and pollution processing for diesel engine. They analyzed total effect of waste heat on pollution or environment. Waste heat can be utilized for some useful works and it is reduces pollution. The diesel engine exhaust gas waste heat recovery rate increase with increasing diesel engine exhaust gas emission rate.

III. EXPERIMENTAL SETUP & METHODOLOGY

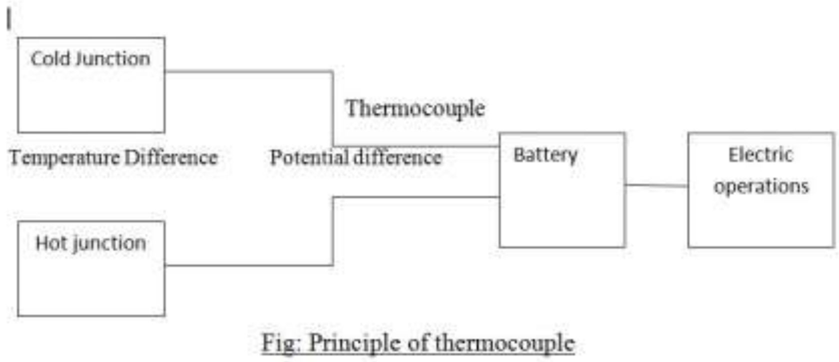

Figure 2: Principle of thermocouple

Hot side is made of a steel box which is connected to the exhaust pipe in one end while the other end is connected to the pipe that helps to exit the flue gas from the box to the atmosphere. For cold side we are using a galvanized steel box that can be filled with cold water. Use of cold water instead of atmospheric air increases the temperature gradient between the two junctions of the thermocouple (two side of TEC-Module) i.e. higher temperature difference resulting into higher voltage or power output. As galvanized iron is not affected by water and its corrosion we choose it over other materials. Thermal grease (also called thermal gel, thermal compound, thermal paste, heat paste, heat sink paste, thermal interface material, grey goo, or heat sink compound) is a kind of thermally conductive (but usually electrically insulating) adhesive, which is commonly used as an interface between heat sinks and heat sources (e.g., high-power semiconductor devices). The grease gives a mechanical strength to the bond between the heat sink and heat source, but more importantly, it eliminates air (which is a thermal insulator) from the interface area.

Components used

a. An IC Engine in operating condition
b. A thermocouple or TEC Module
c. A hot side that is not hotter than TEC module Maximum temperature
d. One cold side (efficient heat sink)
e. Thermal paste to maximise temperature difference
f. Rechargeable battery
g. Base plate that adds stability
h. Small springs and bolts

WORKING SPECIFICATIONS

a. Max. Operating Temperature: 138°C
b. Do not exceed Imax or Vmax when operating module.
c. Please consult HB for moisture protection options (sealing).
d. Life expectancy: 200,000 hours

Table 1: performance specifications

Hot side temperature (°C)	25	50
Q_{max} (watts)	50	57
Delta T_{max} (°C)	66	75
I_{max} (amps)	6.4	6.4
V_{max} (volts)	14.4	16.4
Module resistance (ohms)	1.98	2.30

The set up for the project is illustrated in the following figure

Figure 3: Experimental setup

IV. RESULT AND DISCUSSION

Following results were obtained by conducting experiment on a tractor engine at idle condition running at 850rpm, using a single TEC-Module.

Table 2: output for single module at different temperature

Hot junction temperature (℃)	Cold junction temperature(℃)	Temperature difference(℃)	Voltage (V)	Current (A)
59	8	51	1.96	2.9
62	9	53	2.00	2.9
66	9	55	2.04	3.0
69	9	60	2.06	3.0

From the above table it is observed that as the temperature difference between the hot and cold junction increases, voltage and current is also increased to a maximum of 2V and 3Amp at 69^{0}C of hot junction temperature. Beyond this temperature, cold junction temperature started increasing and there is no much temperature difference between the two junctions.

V. CONCLUSION

From the results, by using a single TEC module the electricity generated cannot be sufficient to charge an automobile battery. By using multiple TEC module we can achieve more power generation. It is estimated that 25 thermoelectric module will be required to produce 150watts of power.

Further work can be done by choosing better conducting material to increase the hot junction temperature and to reduce the cold junction temperature, so as to obtain maximum potential difference.

REFRENCES

[1] T. Endo, S. Kawajiri, Y. Kojima, K. Takahashi, T. Baba, S. Ibaraki, T. Takahashi, “Study on Maximizing Exergy in Automotive Engines,” SAE Int. Publication 2007-01-0257, 2007
[2] J. Vazaquez, M.A. Zanz-Bobi, R. Palacios, A. Arenas, “State of the art of thermoelectric generators based on heat recovered from the exhaust gases of automobiles,” Proceedings of 7th European workshop on thermoelectric, 2002.S.
[3] Mohsin J. Dadi Imran M Molvi,.Alpesh V Mehta, “The Most Efficient Waste Heat Recovery Device: A Gamma Type Stirling Engine,” International Journal of Advanced Engineering Technology, Vol.3, 2012, pp189-19
[4] Vijay Chauhan, “A Review Of Research In Mechanical Engineering On Recovery Of Waste Heat In InternalCombustion Engine,” International Journal Of Research In Engineering & Applied Sciences, Volume 2, Issue 12 (December 2012) pp 2249-3905.N.
[5] Ramesh Kumar, AnkitSonthalia, And Rahul Goel, “Experimental study on waste heat recovery from an internal combustion engine using thermoelectric technology,” thermal science, 2011, vol. 15, no. 4, pp. 1011-1022.
[6] HouXuejun and Gao Deli. “Computational Models Analysis of Diesel Engine Exhaust Waste Heat Recovery,” International Conference on Ecology, vol.7, 2012.
[7] Alpesh V. Mehta, “Waste Heat Recovery Using Stirling Engine,” International Journal of Advanced Engineering Technology, Vol.3, 2012. pp 305-310.
[8] Kwankaomeng S, And Promvonge P, “Investigation on A Free-Piston Stirling Engine and Pneumatic Output,” The First TSME International Conference on Mechanical Engineering 20-22 October, 2010, UbonRatchathani.
[9] “Heat recovery from automotive engine” Applied Thermal Engineering, vol.29, 2009 pp439–444.