RESEARCH PAPER
Engineering
Volume : 3 | Issue : 7 | July 2013 | ISSN - 2249-555X

Waste Heat Recovery from Exhaust Gases through I C Engine Using Thermoelectric Generator

KEYWORDS Exhaust gases, Seeback effect, Thermoelectric Generators, potential difference.

Ajay Chandravanshi
M. Tech Student in Heat and Power Engineering at Visvesvaraya National Institute of Technology, Nagpur (440010)

Dr. J. G. Suryawanshi
Associate Professor in Mechanical Department at Visvesvaraya National Institute of Technology, Nagpur (440010), Maharashtra, INDIA

ABSTRACT *The temperature of pipe surface of exhaust gases flowing through exhaust gas pipe is very high and it is around 200 oC to 300 oC so a heat exchanger is made, which conducts heat from exhaust pipe to thermoelectric modules, 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. Two setups are prepared to produce power on small scale from waste heat of exhaust flue gases of I C Engine using four Seebeck Thermoelectric Module connecting in series. In second setup heater is used as source of waste heat. Mathematical modelling and C programming of the generator is also done for both the setups.*

INTRODUCTION

Automobiles are an example of high energy usage with low efficiency. 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 10%. 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. [2, 5]

Thermoelectricity utilizes the Seebeck, Peltier and Thomson effects that were first observed between 1821 and 1851. Practical thermoelectric devices emerged in the 1960's and have developed significantly since then with a number of manufacturers now marketing thermoelectric modules for power generation, heating and cooling applications. Ongoing research and advances in thermoelectric materials and manufacturing techniques, enables the technology to make an increasing contribution to address the growing requirement for low power energy sources typically used in energy harvesting and scavenging systems. Commercial thermoelectric modules can be used to generate a small amount of electrical power, typically in the mW or μW range, if a temperature difference is maintained between two terminals of a thermoelectric module. Alternatively, a thermoelectric module can operate as a heat pump, providing heating or cooling of an object connected to one side of a thermoelectric module if a DC current is applied to the module's input terminals. [1, 4]

Thermoelectric Module Construction

A single thermoelectric couple is constructed from two 'pellets' of semiconductor material usually made from Bismuth Telluride (Bi_2Te_3). 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 strip 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 Seebeck 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 is shown in figure 1. [1]

Figure 1: (a) Schematic diagram of a single thermoelectric couple, (b) Side view of a thermoelectric module.

Fabrication of second experimental setup

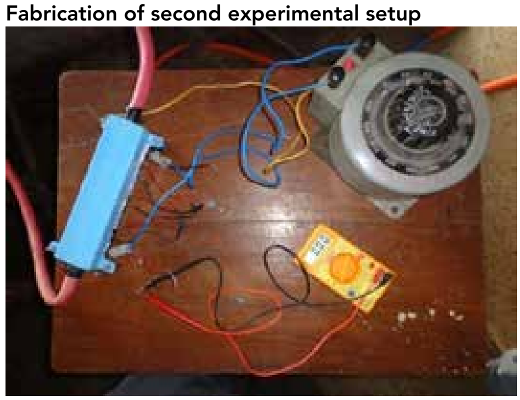

Figure 4: Experiment on Separate setup with heater and Dimmerstate.

Volume : 3 | Issue : 7 | July 2013 | ISSN - 2249-555X

Schematic diagram for second experimental setup

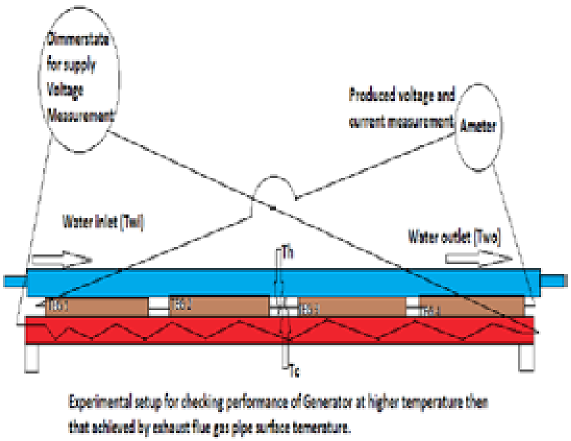

Figure 5: schematic diagrams for second setup

In first setup value of hot side temperature was 82C and available module can work up to 180C, so another setup is prepared in which heater is used to provide hot surface with seat for modules and on other side cold temperature is maintained using a water pipe having same material and cross section as used in first setup. Fabricated separate experimental setup is shown in figure 4 and schematic diagram of second setup is shown in figure 5.

In both the setups the connection of thermoelectric module is in series, so both setups are electrically equivalent.

CONCLUSION

As we know that Engine Power is of order of 8000watts, and it is too high to compare that how much efficiency of engine can be increased using Thermoelectric Technology, because Thermoelectric material are low efficient material and can produce a few watts of power, when surfaces of Thermoelectric generator are subjected to different temperatures, but within a range, according to thermoelectric material properties.

This project is done by using only 4 thermoelectric modules by maintaining the surface temperatures of these modules at different temperatures. Degree of surface contact with heat transferring surface and heat absorbing surface to the module surfaces is neither checked nor measured. In spite of measuring temperatures of module surfaces, temperatures of heat transferring surface and heat absorbing surface are measured, because there should not be space between module surfaces and heat transferring and heat absorbing surfaces and modules should be packed from both the surfaces so heat transferring and heat absorbing surfaces are extended and their surface temperatures are measured. It was not allowed to modify exhaust pipe of engine, so heat of exhaust gases is not taken directly and two intermediate surfaces are used (Hot Side Heat Exchanger) to transfer heat from the surface of exhaust pipe to the surfaces of thermoelectric modules. Modules used have very short range of operating temperature which is from -60C to 180C, and these modules are less efficient, high range modules with high efficiency are available but they are more costly and too expensive as economic point of view.

So it will be beneficial to produce small power from thermoelectric generator, from waste heat, because how much power is produced, that will be extra power, from waste heat and if Thermoelectric modules can be fixed directly on engine exhaust pipe without any intermediate surface than contact resistances between hot side surfaces and cold side surfaces will be decreased and generation efficiency can be increased. Moreover this project is done using only 4 Thermoelectric Modules, if no. of thermoelectric modules can be increased more power can be produced, and from the above project result 24 thermoelectric module will be required to produce 10watts of power, if works on same efficiency, and if efficiency of module is higher than more than 10 watts can be produced. So it depends on thermoelectric modules are high efficient or low efficient. It is a direct energy conversion method so power is produced without any pollution, which can be used to lighten the Head light, Tail Light, Fan in car, AC in car and to charge the batteries.

For waste heat recovery from exhaust gases through I C Engine, 4 thermoelectric modules in series are used having operating temperature range of -60C to 180C and experiment is performed on these. When experiment is performed on engine exhaust pipe, this Thermoelectric Generator gives maximum power of 0.9062 watt, this is low because hot side temperature was low and it was 83C. So to get hot side temperature higher, a separate setup is fabricated and connection of modules was in same arrangement that is series arrangement. In second setup max power produced was 1.72 watts with hot side temperature 178.2C. So it is clear that power can be produced from waste heat of exhaust gases from I C Engine.

We know that Carnot efficiency is the maximum efficiency which can be achieved by any power producing engine and it is 12%, maximum for first setup and 20 .2%, maximum, because Carnot efficiency is low then, generating efficiency will be lower and this is 1.26%, maximum for first setup and 2.78%, maximum, for second setup. So to get higher power and higher efficiency, high range thermoelectric module should be used.

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