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POWER GENERATION FROM WASTE HEAT ENERGY (THERMO-ELECTRIC POWER GENERATION)

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Abstract: In conventional method of electricity generation, we generate energy by combustion of fuels present in nature. Combustion of fuels produce thermal energy which is converted into mechanical energy and then to electrical energy. But this combustion of fuels produces various harmful gases in atmosphere, greenhouse effect, global warming, etc and also there is limited resources. To Overcome this problems, different methods have been under development. In the recent years of power generation, various development of power generation from different sources other than fossil fuel have been done in this area.

In this paper, we will discuss about Thermo-electric Power Generation i.e. direct conversion of heat energy to electrical energy by using Thermo-electric generators. Due to their distinct advantages, Thermoelectric power generators have emerged as a promising alternative green technology. Thermoelectric power generation offer a potential application in the direct conversion of waste heat energy into electrical energy where it is unconditional to consider the input of the thermal energy. The application of this optional green technology in converting waste-heat energy directly into electrical power can help in improving the net efficiency of any energy conversion systems.

Keywords: Thermoelectric generator, Seebeck effect, waste-heat recovery, alternative green technology, direct energy conversion, thermocouple, thermal shield, thermoelectric materials, thermo electric module, thermal fin.

I. INTRODUCTION

In present situation of electric power generation, we are mainly dependent on naturally occurring resources of fuels either Renewable or Non-renewable source of energy. Other source of electricity generation is either have very low production or very high cost of installation, making them difficult to adapt. But Thermoelectric power generation, as an alternative source of power generation from heat energy to increase the net efficiency of any system and also the cost is very low as compared to other green technology. Following its small and compact design and its high converting efficiency, it is more desirable to be used in the electric power generation process.

During various energy conversion processes, alorge amount of thermal energy is wasted in the form of "Heat Energy". This heat is released in the atmosphere without any proper utilization. This research in pointed to utilize this form of waste heat to generate power for further use. This enhancement in the system by adding Thermoelectric generators in the combination with system can be used to improve the overall efficiency of provided energy system. This enhancement of system can improve aprrox 4 to 8 percent of total efficiency of system. Also, no extra input of energy is needed as it utilize the waste heat released itself from the system.

Thermo-electric Generator (TEG) is a solid-state device, also known as Seebeck device, used to convert Thermal (heat) energy directly to electrical energy according to "Seebeck effect". TEG works when there is a temperature difference between two media across the generator. TEG takes heat from one medium and converts it into electrical energy. The temperature difference between media develop a 'Seebeck Voltage' across the generator due to which TEG operates and produces electricity. When this device is connected in a circuit, a DC current start to flow through it because of Seebeck Voltage in TEG. The amount current in the circuit is dependable on the range of potential difference in the TEG device. Usually the current is in very less, about milliampere. Combination of generators together can increase the amount of generation of electric power.

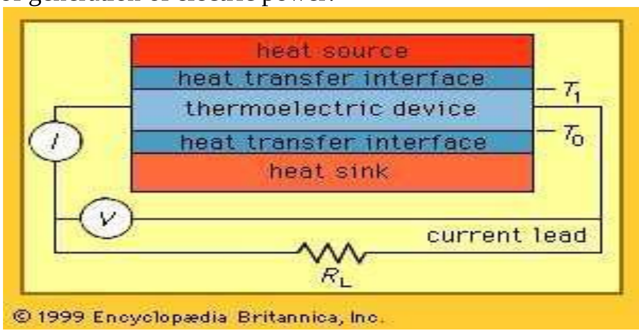

Fig.1 Thermo-electric Generation.

Seebeck Effect: In the year 1821, a German physicist, Thomas Johann Seebeck discovered the Seebeck effect. The Seebeck effect is a phenomenon in which a temperature difference between two dissimilar electrical conductors or semiconductors produces a voltage difference between the two substances. When heat is applied to one of the two conductors or semiconductors, heated electrons flow toward the cooler one.

The voltages produced by Seebeck effect are small, usually only a few microvolts (millionths of a volt) per kelvin of temperature difference at the junction. If the temperature difference is large enough, some Seebeck-effect devices can produce a few millivolts (thousandths of a volt). Due to this voltage, thermo-electric devices act as a Thermo-electric Generator (TEG).

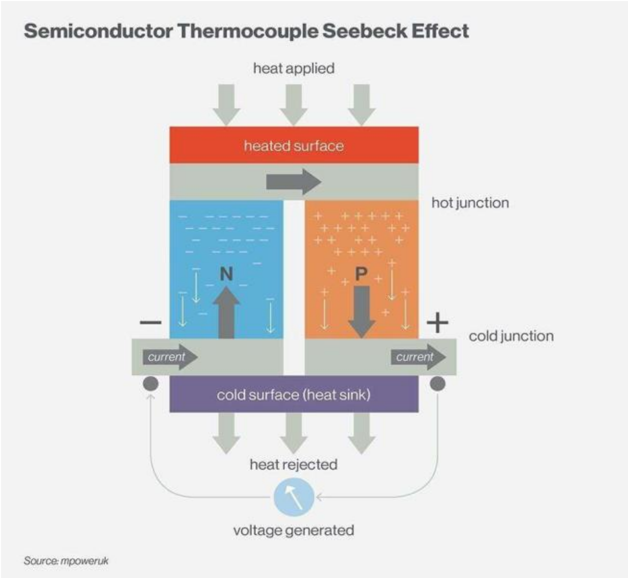

Fig.2 Seebeck Effect.

There is a Seebeck effect in junctions between different metals, the effect is small. A much larger Seebeck effect is achieved by use of p-n junctions between p-type and n-type semiconductor materials, typically silicon or germanium. The figure 2 shows p-type and n-type semiconductor legs between a heated surface (heat source) and a cold surface (heat sink) with an electrical power load of resistance RL connected across the low-temperature ends. A practical thermoelectric device can be made up of many p-type and n-type semiconductor legs connected electrically in series and thermally in parallel between a common heat source and a heat sink.

II. COMPONENTS OF TEG

Thermoelectrical generator is consist of following parts-

- Thermoelectric Module
- Thermoelectric shield
- Thermal Fin
- Copper electrode

Thermoelectric Module:

It is semiconductor which is highly doped by pollutants to increase the electric conductivity of the semiconductor. Semiconductor of this module has electric conductivity ranges between 200µV/K to 300µV/K. Semiconductor to be used as module has to operate on high temperature. Some of the good thermoelectric module semiconductors are Bi2Te3, CaMnO, Ca3Co4O9, Sb2Te3, and PbTe. For 100K temperature difference and 200 modules it produces 4.2% efficiency and 15volts, it is commercially available TEG. CaMnO3 bulks were prepared by a solid-state reaction. They show metallic behaviour at temperatures higher than about 400 K and electrical resistivity Ω is lower than 12 mΩcm at 1000K in air. For CaMnO3, S value reaches -130 muV/K at 973 K. Both thermoelectric properties are dominated mainly by crystallographic structure. It generates 3.9% efficiency 2.6 V for 200 modules and 100K temperature difference. This TEG is prefer for High operating temperature. We have Ca3Co4O9 semiconductor for high temperature withstanding property. Ca3Co4O9 has some good thermo electric properties. It can withstand 800ºc. Seebeck property 206µV/K, Electrical resistance 11.6 mΩcm. figure of merit ZT=0.23. Thermal conductivity 1.2Wm-1K-1. This property taken for 880K. This TEG generates 4.2 % efficiency 4.2 volts for 200 modules and 100K temperature difference.

Thermoelectric Shield:

It is a material which protects the modules damage due to high Temperature. Mostly Ceramics material for this which is Al2O3. It also transfers temperature to the modules from hot side. It should be thick.

Thermal Fin:

It is used here for increase the thermal gradient value. When we increase the Thermal gradient value it increases the seebeck voltage generated by TEG. This FIN also transfers the heat from Thermoelectric Module. It is made by Aluminium metal. When we include Thermal fin it increase the efficiency of the TEG.

Copper Electrode: This electrode helps in creating a potential difference between the surfaces and maintain the flow of electrons in the circuit.

III. PERFORMANCE CALCULATION FOR TEG.

The performance of the Thermo Electric can be calculated by-

$$Z = \alpha^2 / kR$$

Where,

Z - is the thermoelectric material figure-of merit
α - is the Seebeck coefficient
k - total thermo electric conductivity
R- is the electric resistivity

This figure of merit can be multiply by $\overline{T}$ thermoelectric module.

$$Z\overline{T} = \alpha^2 \overline{T} / kR$$

Here,

$$\overline{T} = \frac{T_H + T_L}{2}$$

Where, T_H- Temperature at Hot end.
T_L- Temperature at cold end.
Seebeck coefficient,

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

Where,
ΔV is voltage difference
ΔT is Temperature Difference

Limited by the second-law of thermodynamics, the ideal (absolute maximum) efficiency of a thermoelectric power generator operating as a reversible heat engine is Carnot efficiency,

$$\eta = \frac{W_e}{\dot{Q}_H}$$

$$\eta_{Carnot} = 1 - \frac{T_L}{T_H}$$

The maximum conversion efficiency of an irreversible thermoelectric power generator can be estimated using

$$\eta = \eta_{Carnot}\left[\frac{\sqrt{1+Z\overline{T}}-1}{\sqrt{1+Z\overline{T}}+T_L/T_H}\right]$$

Here,
ZT- Figure of Merit.

IV. CONCLUSION

Current method to produce electricity by hydro-electric plant first convert kinetic energy to mechanical energy and then into electrical energy. By the other means of electricity generation by burning of fuels causes release of harmful gases in environment and also other harmful effect.
The resources present in nature is in the limited and cannot be used extensively. So, the need of other green technology lead to development of Thermoelectric Power generation. The system gives the best economical pollution free, required energy solution to the people.
The combination of TEG can be used to generate high power according to the requirement. This work can be used for many applications in urban and rural areas where power availability is less or totally absence. By making this system generates and charge 12v which is capable to recharge a mobile. it avoiding dependency of grid supply. This is a Promising technology for solving power crisis to an affordable extent.

V. ADVANTAGE, DISADVANTAGE AND APPLICATION

Advantage:
It is clean, noise less system. Cost of installation and maintenance is less. Power generation from TEG is a Non-conventional system. No fuel is required to operate as it operates on waste heat from the system. Easy to maintain and compact in size. It act as a promising technology for solving power crisis to an affordable extent. Simple in construction. Pollution free. Reduces transmission losses. It has wide areas of application. It can be used at any time when it necessary. Less number of parts required.

Disadvantages:
Improper variation of temperature gradient difference may damage the TEG. It has a very complex design.

Application:
Thermoelectric Generators are basically used in where the power production is less. In automobile vehicle produce heat that can be used for generating electricity by using TEG. Recharge the battery where ever waste heat is obtained. Self-charging battery by fixing the TEG at radiator or two-wheeler silencers pipe.

VI. SCOPE OF THE FUTURE WORK:

By using proper heat sink material help to increase the output voltage. Using long proper heat sink material is to avoid the heat in between the gap of fins. By addition of the more TEG in SERIES is to increase the voltage.

Waste heat micro level can be used to generate power at low level or for specific less power required devices. It can help in following forms:

Domestic waste heat application:
We all know that we use thermal energy in our daily life for cooking food and various other uses. The after the process is released in atmosphere. All these heat goes wasted. By the application of this power generation process in the system can help in generation of energy from the heat wasted during the house hold usage.

Waste heat from Exhausted gases of Automobiles:

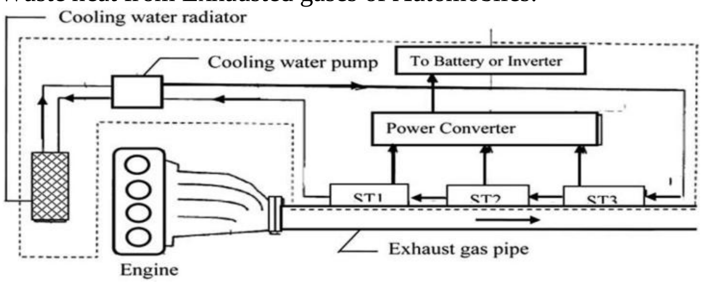

Fig. 3 Diagram to show application of Thermoelectrical power generation to Automobile Exhaust Gases.

Gases exhausted from various automobiles in use are released at very high temperature. The high temperature of these gases as waste heat energy can also be used to generate power from them by the application of TEG in the system.

Industrial waste heat application:
On a daily scale of Industrial use, a large amount of heat goes wasted in atmosphere. After the application of Thermoelectric power generation application to the industrial equipment producing heat can be utilized to produce power by waste heat of the industry.

VII. CURRENT AND FUTURE USE:

Recently, an increasing concern of environmental issues of emissions, in particular global warming and the constraints on energy sources has resulted in extensive research into innovative technologies of generating electrical power and thermoelectric power generation has emerged as a promising alternative green technology. In addition, vast quantities of waste heat are discharged into the earth’s environment much of it at temperatures which are too low (i.e. low-grade thermal energy) to recover using conventional electrical power generators. Thermoelectric power generation offers a promising technology in the direct conversion of waste-heat energy, into electrical power. In this paper, a background on the basic concepts of thermoelectric power generation is presented and recent patents of thermoelectric power generation with their important and relevant applications to waste-heat energy are reviewed and discussed. Currently, waste heat powered thermoelectric generators are utilized in a number of useful applications due to their distinct advantages. These applications can be categorized as micro- and macro-scale applications depending on the potential amount of waste heat energy available for direct conversion into electrical power using thermoelectric generators. Micro-scale applications included those involved in powering electronic devices, such as microchips. Since the scale at which these devices can be fabricated from thermoelectric materials and applied depends on the scale of the miniature technology available. Therefore, it is expected that future developments of these applications tend to move towards nano technology. The macro-scale waste heat applications included: domestic, automobiles, industrial and solid waste. Currently, enormous amounts of waste heat are discharged from industry, such as manufacturing plants and power utilities. Therefore, most of the recent research activities on applications of thermoelectric power generation have been directed towards utilization of industrial waste heat. Future developments in this area might focus onto finding more suitable thermoelectric materials that could handle higher temperatures from various industrial heat sources at a feasible cost with acceptable performance. Another future direction is to develop more novel thermoelectric module geometries and configurations. The developments of more thermoelectric module configurations by developing novel flexible thermoelectric materials will make them more effective and attractive in applications where sources of waste heat have arbitrary shapes.

REFERENCES

[1] P Pradyumnan& Swathikrishnan, Indian journal of pure & Applied physics, Vol.48, February 2010,pp.115-120
[2] Natkrita Prasoetsopha, Supree Pinitsoontorn, Vittaya Amornkitbamrung, Department of Physics, Faculty of Science, Khon Kaen University, Khon Kaen 40002,
[3] D. Flahaut, T. Mihara and R. Funahashi, N. Nabeshima, K. Lee, H. Ohta and K. Koumoto, JOURNAL OF APPLIED PHYSICS 100, 084911 (2006)
[4] Riffat SB, Ma X. Thermoelectrics: A review of present and potential applications. Appl Therm Eng 2003;23: 913-935.
[5] Omer SA, Infield DG. Design and thermal analysis of two stage solar concentrator for combined heat and thermoelectric power generation. Energy Conversion & Management 2000; 41: 737-756.
[6] Yadav A, Pipe KP, Shtein M. Fiber-based flexible thermoelectric power generator. J Power Sources 2008; 175: 909-913.
[7] Jinushi T, Okahara M, Ishijima Z, Shikata H, Kambe M. Development of the high performance thermoelectric modules for high temperature heat sources. Mater Sci Forum 2007; 534-536: 1521-1524.
[8] D. Flahaut, T. Mihara and R. Funahashi, N. Nabeshima, K. Lee, H. Ohta and K. Koumoto, JOURNAL PHYSICS 100, 0=184911 (2006)
[9] Il-Ho Kim1, Soon-Mok Choi, Won-Seon Seo and Dong-Ik Cheong, Kim et al. Nanoscale Research Letters 2012, 7:2
[10] Driss Kenfaui, Guillaume Bonnefont , Daniel Chateigner , Gilbert Fantozzi ,Moussa Gomina, Jacques Guillaume Noudem, Materials Research Bulletin 45 (2010) 1240–1249

