Review on Application of Thermoelectric Peltier Module in cooling and power generating Technology

Swapnil S. Khode, Pratik Kale, Chandrakant Gandhile

***Abstract*— Now a days, thermoelectricity phenomenon has used in various sector. It come from the concept of thermocouple, which gives concept of obtaining a potential difference by maintaining two junction at different temperature and vice versa. This phenomenon of getting potential difference or getting temperature difference is used in power generation and refrigeration and air conditioning respectively which helps to minimize the pollution caused by conventional systems. It is because it direct convert temperature difference into voltage gradient without using any mechanical systems. The purpose of this paper to review on various application of thermoelectric phenomenon by using peltier module technology. In this paper, we have also mention development on thermoelectric module based devices.**

***Index Terms* — Thermoelectric, Peltier Effect, Thermoelectric module, Applications.**

I. INTRODUCTION

The thermoelectric phenomenon deals with the conversion of thermal energy into electrical energy and vice-versa. When operating as an energy-generating device the thermoelectric device is termed a thermoelectric generator (TEG). The source of thermal energy manifests itself as a temperature difference across the TEG. When operating in a cooling or heating mode the thermoelectric device is termed a thermoelectric cooler (TEC). Similarly, the thermoelectric device produces heating or cooling that takes the form a heat flux which then induces a temperature difference across the TEC. Thermoelectric devices are solid-state mechanisms that are capable of producing these three effects without any intermediary fluids or processes. They have no moving parts, reducing their susceptibility to mechanical failure while allowing for prolong periods of operation with minimal maintenance. Additionally, this allows quiet cooling operations compared to conventional compressor-based refrigeration systems and produce no pollutants or environmentally detrimental byproducts. These criteria make thermoelectric devices highly attractive for a multitude of applications. For power generation applications thermoelectric devices are used in automobiles as exhaust gas waste heat recovery devices where thermal energy is scavenged along the exhaust line of a vehicle and converted into useful electricity [1]. Space exploration robotic rovers utilize TEGs to convert heat energy released from the decay of radioisotopes to electricity [2]. Solar thermoelectric generators capture incoming sunlight and convert solar thermal energy into electricity using thermoelectric principles [3] [4]. On the other hand, thermoelectric devices are widely implemented for heating, ventilation and air-conditioning (HVAC) purposes in vehicles. These take the form of thermoelectric air-conditioners and climate controlled seats that may potentially replace conventional compressor-based air-conditioning systems in automobiles [5]. Due to their high manufacturability and ability to be miniaturized thermoelectric devices are suitable candidates for controlling temperature sensitive equipment such as surgical tools and fiber-optic lasers in telecommunication applications [6]. These TECs can also be embedded into microprocessors to achieve precise temperature control as well as hot spot mitigation when physical space around the microprocessor is limited [7].

Manuscript received January 06, 2015.

Swapnil S. khode, B.E (Final mech).J.D.I.E.T, Amravati University. City -Yavatmal, Country -India, Mobile No:9763183670. Research work in portable thermoelectric air cooler system, as an alternative for conventional HVAC system.

Pratik kale ,B.E (Final mech).J.D.I.E.T, , Amravati University City -Yavatmal, Country -India, Mobile No:8055850382.

Chandrakant Gandhile, B.E (Final mech).J.D.I.E.T, , Amravati University City -Yavatmal, Country -India, Mobile No: 8390560581.

II. THERMOELECTRIC PHENOMENON

Governing Effects

The discovery of the thermoelectricity began in 1821 when a German physicist, by the name of Thomas Johann Seebeck, discovered that an electromotive potential (or electrical voltage) was produced in a circuit of two dissimilar metals when one of the junctions of circuit was heated or at a higher temperature than the other junction (refer to Figure 1) [8]. The proportionality of the electrical potential to temperature difference was governed by the Seebeck coefficient, which is an inherent property of the circuit of two dissimilar metals. The relationship between voltage and temperature difference is(1.1) where is the voltage across the junctions of the circuit, is the Seebeck coefficient and is the temperature difference across the junctions of the circuit. In Figure 1 the temperature difference across the circuit is expressed as , where and are the hot and cold junctions, respectively. represents the direction of current in the circuit that is generated due to a potential difference. Figure

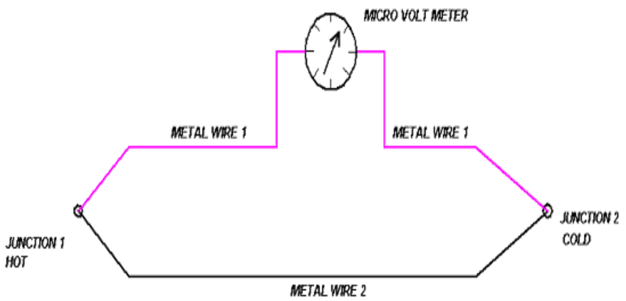

Fig: 1.Seeback effect

III. How it Works

When two conductors are placed in electric contact, electrons flow out of the one in which the electrons are less bound, into the one where the electrons are more bound. The reason for this is a difference in the so-called Fermi level between the two conductors. The Fermi level represents the demarcation in energy within the conduction band of a metal, between the energy levels occupied by electrons and those that are unoccupied.

When two conductors with different Fermi levels make contact, electrons flow from the conductor with the higher level, until the change in electrostatic potential brings the two Fermi levels to the same value. (This electrostatic potential is called the contact potential.). Current passing across the junction results in either a forward or reverse bias, resulting in a temperature gradient. If the temperature of the hotter junction (heat sink) is kept low by removing the generated heat, the temperature of the cold plate can be cooled by tens of degrees (Fig2).

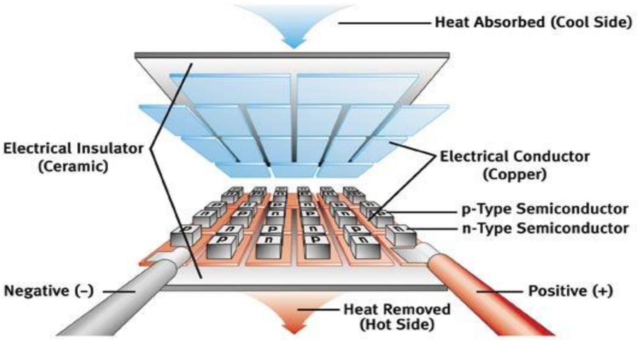

Fig.2 TEC Construction

IV. FEATURES OF THERMOELECTRIC MODULE

Some of the more significant features of the thermoelectric modules are:

Fig3: Peltier module

1.No moving parts: - A thermoelectric module works electrically without any moving parts so they are virtually maintenance free.

2.Small size and weight: - The overall thermoelectric cooling system is much smaller and lighter than a comparable mechanical system. In addition, a variety of standard and special sizes and configurations are available to meet strict application requirements.

3. Ability to cool below ambient: - Unlike a conventional heat sink whose temperature necessarily must rise above ambient, a thermoelectric system attached to that same heat sink has the ability to reduce the temperature below the ambient value.

4.Precise temperature control: - With an appropriate closed-loop temperature control circuit, thermoelectric module can control temperatures to better than +/-0.1˚C.

5.High Reliability: - Thermoelectric modules exhibit very high reliability due to their solid state construction. Although reliability is somewhat application dependent, the life of typical thermoelectric system is greater than 200,000 hours.

6.Electrically Quite Operation: - unlike a mechanical refrigeration system, thermoelectric modules generate virtually no electric noise and can be used in conjunction with sensitive electronic sensors. They are also acoustically silent.

7.Operation in any Orientation: - Thermoelectric modules can be used in any orientation and in zero gravity environments. Thus they are popular in many aerospace applications.

8.Convenient Power Supply: - Thermoelectric modules operate directly from a DC power source.

9.Spot Cooling: - With a thermoelectric module it is possible to cool one specific component or area only, thereby often making it necessary to cool an entire package or enclosure.

10.Ability to Generate Electric Power: - When used 'in reverse' by applying a temperature differential across the faces of a thermoelectric refrigeration system, it is responsible to generate a small amount of DC power.

11.Environmental Friendly: - Conventional refrigeration system cannot be fabricated without using chlorofluorocarbons or other chemicals that may be harmful to environment. Thermoelectric devices do not use or generate gases of any kind.

Another benefit to thermoelectric devices is that they convert thermal energy directly into electricity, or vice-versa. Direct conversion eliminates losses associated with multiple energy conversion processes. Direct conversion also means there is no need for additional equipment or materials, making for a simplified device. Thermoelectric energy conversion is done in the solid state. As such, the devices have no moving parts that can wear out.

V. APPLICATIONS

A. Applications of thermoelectric devices as Power generation-

A thermoelectric power generator is a solid state device that provides direct energy conversion from thermal energy (heat) due to a temperature gradient into electrical energy based on "Seebeck effect". The thermoelectric power cycle, with charge carriers (electrons) serving as the working fluid. The major drawback of thermoelectric power generator is their relatively low conversion efficiency (typically ~5%). This has been a major cause in restricting their use in electrical power generation to specialized fields with extensive applications where reliability is a major consideration and cost is not. Applications over the past

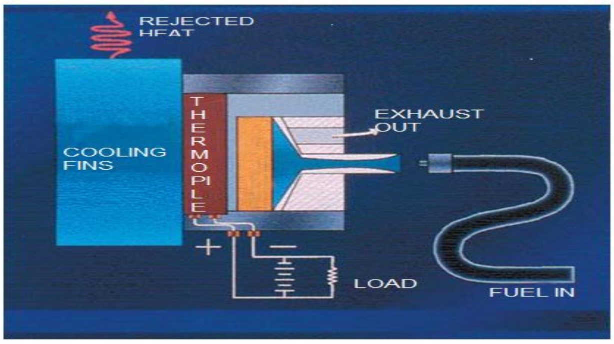

Fig: 4 TEG power generator

decade included industrial instruments, military, medical an aerospace and applications for portable or remote power generation.

B. Solar thermoelectric generation –

The growing demand for energy throughout the world has caused great importance to be attached to the exploration of new sources of energy. Among the unconventional sources, solar energy is one of the most promising energy resources on earth and in space, because it is clean and inexhaustible. Applications of solar thermoelectric generator are attractive. The use of the sola thermoelectric generator usually combines a solar thermal collector with a thermoelectric generator, which delivers the electric energy.

Thermoelectric power generation is based on a phenomenon called “Seebeck effect” discovered by Thomas Seebeck in 1821. When a temperature difference is established between the hot and cold junctions of two dissimilar materials (metals or semiconductors) a voltage is generated, i.e., Seebeck voltage. A schematic diagram of a simple thermoelectric power generator operating based on Seebeck effect is shown in Fig. (6). As shown in Fig. (6), heat is transferred at a rate of *QH* from a high-temperature heat source maintained at *TH* to the hot junction, and it is ejected at a rate of *QL* to a low-temperature sink maintained at *TL* from the cold junction. Based on Seebeck effect, the heat supplied at the hot junction causes an electric current to flow in the circuit and electrical power is produced. Using the first-law of thermodynamics (energy conservation principle) the difference between *QH* and *QL* is the electrical power output *W e* . It should be noted that this power cycle intimately resembles the power cycle of a heat engine (Carnot engine), thus in this respect a thermoelectric power generator can be considered as a unique heat engine.

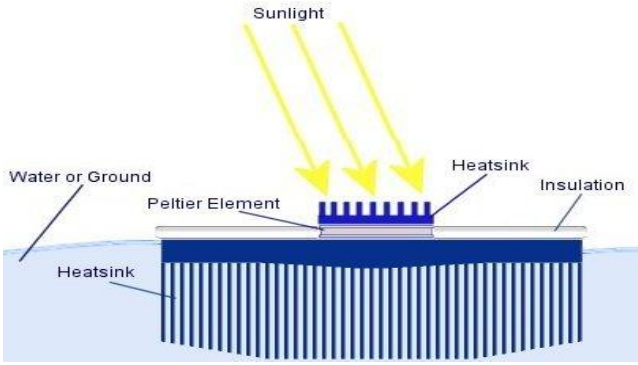

Fig. 5: Basic working of the Solar thermoelectric generation system.

C. Application of thermoelectric devices as cooler-

Thermoelectric cooling is a form of solid-state refrigeration; it has the advantage of being compact and durable. A thermoelectric cooler uses no moving parts (except for some fans), and employs no fluids, eliminating the need for bulky piping and mechanical compressors used in vapor-cycle cooling systems.Such sturdiness allows thermoelectric cooling to be used where conventional refrigeration would fail. Thermoelectric devices also have the advantage of being able to maintain a much narrower temperature range than conventional refrigeration. They can maintain a target temperature to within ±1° or better, while conventional refrigeration varies over several degrees. Unfortunately, modules tend to be expensive, limiting their use in applications that call for more than 1 kW/h of cooling power. Owing to their small size, if nothing else, there are also limits to the maximum temperature differential that can be achieved between one side of a thermoelectric module and the other. However, in applications requiring a higher ΔT, modules can be cascaded by stacking one module on top of another. When one module's cold side is another’s hot side, some unusually cold temperatures can be achieved [1].

D. Solar Water Condensation Using Thermoelectric Coolers-

A solar water condensation system is built using a TE cooler, solar panels, heat exchange unit and an electronic control unit. The system is self powered and can be used in isolated and desert areas to condensate water from the surrounding humid air. Applying the system in high humidity see area produced 1L of water per hour which can be used mainly for irrigation. The economical advantage of this kind of system is still obscure due to the relatively high installation cost. This system would be a long-term cost saving system since the energy source is free and the solar sub-system generally requires little maintenance. The development and production of such equipment is a future business possibility.

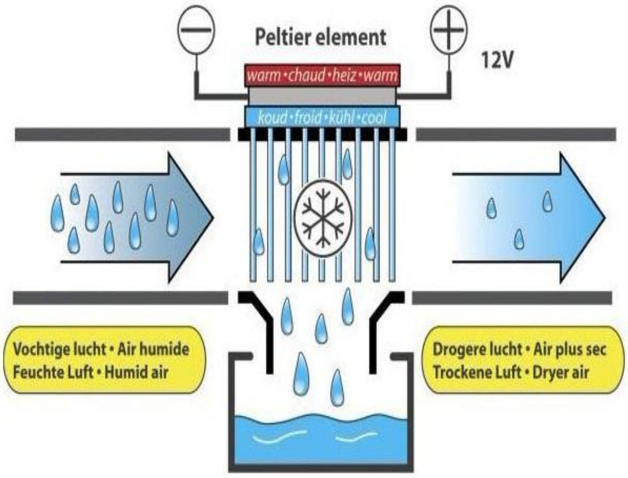

Fig. 5: Basic diagram of the built water condensation system

E. For medical application-

Thermoelectric cooling is widely used in many areas of science and technology, in particular, in medicine. It is well known in medical practice that temperature effects are an important factor in treatment of many diseases of the human organism. To achieve low temperatures, systems with liquid nitrogen are used, which limits their use in hospitals significantly. In most cases such devices are bulky, without proper temperature control and thermal modes reproduction. Therefore, the use of thermal effects on the patient is confronted with some difficulties and is reduced mainly to the application of ice or hot water. The use of thermoelectric cooling can solve this problem, because it has several advantages, if compared to conventional techniques of thermal effects. Fundamental research on the application of thermoelectric cooling in medicine confirms the possibility of its practical application in such areas of medicine as cryotherapy, cryosurgery, ophthalmology, traumatology, neurosurgery, plastic surgery, gynecology, urology, oncology, dermatology etc [5]. In dermatology thermoelectric devices are used for cryomassage procedures (stimulation of metabolism, smoothing of wrinkles) for the treatment of pyoinflammatory processes, freezing out warts, hardening of individual parts of human body and other medical procedures. Therefore, the development and improvement of thermoelectric medical devices for skin diseases treatment is of current importance.

VI. CONCLUSIONS

This paper describes use of Thermoelectric technology in different sector, which are as follows.

1. Thermoelectric technology has been used practically in wide areas recently. The thermoelectric devices can act as coolers, power generators, or thermal energy sensors and are used in almost all the fields such as military, aerospace, instrument, biology, medicine and industrial or commercial products.

2. Still thermoelectricity not used more widely because the coupling between the electrical and heat currents is weak in most materials, and the overall energy conversion efficiency is therefore very low. Therefore, researchers are working hard to discover new p- and n-type semiconductors, which can do this more efficiently.

ACKNOWLEDGMENT

The authors thank Prof. P. S. Ghawade for their stimulating discussion.

REFERENCES

[1] B.J. Huang, C.J. Chin and C.L. Duang:- A design method of thermoelectric cooler, International journal of Refrigeration, 23 (2000), pp.208-218.
[2] S.B. Riffat, Xiaoli Ma, Thermoelectrics: a review of present and potential applications, International Journal of Applied Thermal Engineering 23 (2003), pp. 913–935.
[3] S.Ghamaty and N.B.Elsner, Si/SiGe Quantum well Thermoelectric materials and devices for waste heat recovery from vehicles and industrial plants, International symposium on Nano- Thermoelectrics : June 11-12, 2007, Osaka, Japan.
[4] Velimir Jovanovic, Saeid Ghamaty, Daniel Krommenhoek, John C. Bass, High coefficient of performance quantum well thermoelectric nano cooler, ASME, July 8-12,2007, pp.1-7.
[5] L.I. Anatychuk, R.R. Kobylyansky, Yu.M. Mocherniuk, Thermoelectric Device for skin treatment, Journel of Thermoelectricity no.4, 2009, pp.86-92.
[6] Jan-Willem Bos, Thermoelectric Materials: efficiencies found in nanocomposites, Education in Chemistry, March 2012, pp.15-18.
[7] The where and why thermoelectricity by G.F.Boesen, C.J.Phetteplace, L.J.Ybarrondo.
[8]Buist, RJ & Streitwieser, GD March 16-18,1988, The thermoelectricly cooled helmet, The Seventeenth International Thermoelectric Conference, Arlington, Texas.
[9] Bulat, L & Nekhoroshev, Y 2003, Thermoelectric cooling-heating unit for thermostatic body of pickup refrigerated trucks, 22nd international conference on thermoelectrics.
[10] Goldsmid H. (1986). *Electronic Refrigeration.*London:Pion.
[11]Goldsmid H.(1964). *Thermoelectric Refrigeration.* New York:Plenum
[12] Harrington, SS 2009, Thermoelectric air cooling device, Patent Application Publication, US Patent Number 5623828.
[13]Harvie, MR 2005, Personal cooling and heating system, Patent Application Publication, US Patent Number 6915641.

.

Swapnil S. khode, B.E (Final mech).J.D.I.E.T, Amravati University. City -Yavatmal, Country -India, Mobile No:9763183670. Research work in portable thermoelectric air cooler system, as an alternative for conventional HVAC system.

Pratik kale ,B.E (Final mech).J.D.I.E.T, , Amravati University City -Yavatmal, Country -India, Mobile No:8055850382.

Chandrakant Gandhile, B.E (Final mech).J.D.I.E.T, , Amravati University City -Yavatmal, Country -India, Mobile No: 8390560581.