Review on Thermoelectric Refrigerator System

Prof. Mr. Salunke G.B.1, Mr. Bhadane Sanket Keda2 Mr. Dhus Sudhir Raosaheb3 Ms. Shinde Pallavi Kishor4 Mr. Davkhar Pramod Shankar5

1,2,3,4,5Assistant Professor
1,2,3,4,5Department of Mechanical Engineering
1,2,3,4,5S.C.S.O.E, Shrishivajinagar, India

Abstract— the review paper is focused on simulation of a thermoelectric refrigerator maintained at lower temperature (near about 4°C) as possible as. Air conditioner and Refrigerator are the most energy consuming domestic appliances and for this reason many researchers had performed work to improve performance of the domestic refrigeration systems for cooling. Thermoelectric devices are developed based on Peltier and Seebeck effect which are different from the conventional refrigeration system. Thermoelectric refrigeration is one of the methods which are used for producing refrigeration effect. This paper summarizes the development in thermoelectric materials, thermoelectric refrigeration, and application in domestic appliances.

Key words: Thermoelectric Module, Seebeck Effect, Peltier Effect

I. INTRODUCTION

The applications of thermoelectric coolers are increasing with an increasing demand of cooling in every sector for the past forty years. The TE coolers convert electrical energy into a temperature gradient is a peltier effect. Although the physical principles upon which modern thermoelectric coolers function actually discovered in early 1800s but commercial thermoelectric modules were made available in the year 1960. In 1821, the first important detection relating to thermoelectricity occurred by German scientist Thomas See beck who found that an electric current would flow continuously in a closed circuit made up of two different metals, provided that the junctions of the metals were maintained at two different temperatures. Without actually comprehending the scientific basis for the discovery. See beck, falsely accepting that flowing heat produced the same effect as flowing electric current. Afterwards, William Thomson described a relationship between See beck and Peltier Effect without any practical usage. After studying some of the earlier thermoelectric work, Russian scientists in 1930s, inspired the development of practical thermoelectric modules based on modern semiconductor technology by replacing different metals with doped semiconductor material used in early experiments. The See beck, Peltier and Thomson effects, together with several other phenomena, form the basis of functional thermoelectric modules. TE-coolers can be analyzed by Joule heat, which is called heat rejection (Qh), from TEC hot side larger than the heat absorption (Qa), into TEC cold side.

A. Proposed Approach and Method Implementation

The project implemented a structured system analysis and design methodology approach to achieve the project objectives. Block system analysis with the aid of a straight forward block diagram. Ambient air is blown out by the blower through a duct to the TECs. TECs are sandwiched in between heat sinks. Cold air is blown out from one end of the cold heat sinks. The TECs were powered by a power supply. The cooling system mainly consists of the following modules Card Blower acts as the primary source of air.

1) Duct which conveys the air from the blower to cold heat sinks.
2) One long heat sink is fitted to the hot side of TEC to absorb heat.
3) Six TECs are sandwiched between cold and hot heat sinks.
4) An DC source which is used to power the fans and blower. (Car Battery)
5) DC power supply is used to drive the TECs

II. PRINCIPLE

A. Thermo-Electric Effect

If one connects 2 wires of differently electrically leading materials at the 2 ends and if one applies additionally a voltage, a current flows, which transports heat of one junction point to the other. In the after-effect one junction point becomes cold and the other one warm. For thermoelectric modules materials are applicable with a high electrical conductivity and a small thermal conductivity. A good electrical conductors are also good heat conductors. One obtains the best efficiency with semiconductors.

Fig. 1: A Peltier effect principle

B. Principle Structure

Thermoelectric modules consist of 2 different electrically leading materials. These are alternating electrically interconnected and mechanically arranged in such a manner that the junction points are alternating on one level. Bi2Te3 - based compounds have been widely used in various electronic cooling devices such as infrared detectors, microprocessor chips and thermoelectric cooler for laser diodes, owing to their excellent thermoelectric performance near room temperature. The conversion efficiency of a thermoelectric device is highly dependent on dimensionless thermoelectric figure of merit (ZT) of the materials

\[ ZT = \alpha^2 \frac{\rho}{k} \]

where \( \alpha \), \( \rho \), \( k \) and \( T \) are the Seebeck coefficient, electrical resistivity, thermal conductivity and absolute temperature, respectively. Low conversion efficiency limits the practical applications of the thermoelectric materials. Currently, a lot of work has been done on the fabrication of Bi2Te3-based...
alloys to improve the thermoelectric performance, such as unidirectional solidification (zone melting or the Bridgman method) and powder metallurgy (typically, hot pressing) techniques. The unidirectionally solidified materials present a high figure of merit ZT at room temperature, but their mechanical strength is very poor due to large grain sizes and existence of cleavage planes. On the other hand, although hot-pressed materials display high mechanical strength, unfortunately, the thermoelectric performance is not satisfied. BiTe₃ compound has a rhombohedral structure, which is easy to rupture along the basal plane due to existence of the Te-Te layer parallel to the basal plane, connected by the van-deer Waals bond. The thermoelectric properties are better in the directions parallel to the basal plane than to the c-axis. Mechanical alloying (MA) and hot-extrusion techniques are considered to be an effective way to fabricate Bi₂Te₃-based compounds with oriented fine grains, so as to improve both the thermoelectric and mechanical properties. Recently, our group has fabricated p-type Bi₂Te₃-based bulk materials by MA and hot-extrusion techniques, and the results indicated that the extruded materials have excellent thermoelectric and mechanical performance.

In the present work, the MA and hot-extrusion techniques were applied to preparation of n-type Bi₂Te₃-based bulk thermoelectric materials. The purpose was to clarify the effect of some extrusion conditions on extrusion behaviour, microstructure, and texture, thermoelectric and mechanical properties.

III. CONSTRUCTION

![Fig. 3: Construction of Thermo-Electric Cooler](image)

Main component of Thermo Electric Refrigeration:
- Thermal Cement
- Thermo-Electric Module.
- Fins. (Two Heat Sink)
- M.S. Box
- Fans.
- DC Power Source.

Other sub component required for proper functioning of the Cooler is
- Adaptor
- Infrared Thermometer

A. Thermo-Electric Module

A thermoelectric module is an electrical module, which procreate a temperature difference with current flow. The emergence of the temperature difference is based on the Peltier effect designated after Jean Peltier. The thermoelectric module is a heat pump and has the same function as a refrigerator. It gets along however without mechanically mobile construction units (pump, compressor) and without cooling fluids. The heat flow can be turned by reversal of the direction of current, some benefits of using a TEC are:
- No moving parts so maintenance is required less frequently
- No chlorofluorocarbons
- Temperature control to within fractions of a degree can be maintained
- Flexible shape (form factor); in particular, they can have a very small size
- Can be used in environments that are smaller or more severe than conventional refrigeration
- Has a long life, with mean time between failures (MTBF) exceeding 100,000 hours
- Is controllable via changing the input voltage/ current.

1) thermo-electric module structure

A standard module consists of any number of thermocouples connected in series and sandwiched between two ceramic plates. By inuring a current to the module one ceramic plate is heated while the other is cooled. The direction of the current determines which plate is cooled. The number and size of the thermocouples as well as the materials used in the manufacturing determine the cooling capacity. Cooling capacity varies from fractions of Watts up to many hundreds. Different types of TEC modules are single stage, two stage, three stage, Hoar stage, centre hole modules etc. Single stage will be suitable for a wide range of cooling applications with low to high heat pumping capacities. A thermoelectric cooler has analogous parts. At the cold junction, energy is absorbed by electrons as they pass from p-type (low energy) semiconductor element, to the n-type semiconductor (high energy). The power supply provides the energy to move the electrons. At the hot junction, energy is banish to a heat sink as electrons move from an n-type to a p-type. Figure shows an illustration on the assembly of a Thermoelectric cooler. Common thermoelectric materials used as semi-conductors include bismuth telluride, lead telluride, silicon germanium, and bismuth-antimony alloys of these bismuth telluride is the most frequently used. New high-performance materials for thermoelectric cooling are being actively researched.

2) Parameters of a Thermoelectric Module

Once it is fixed that thermoelectric cooler is to be considered for cooling system, the next step is to select the thermoelectric module or cooler that can satisfy a particular set of needs. Modules are available in great variety of sizes, shapes, operating currents, operating voltages and ranges of heat pumping capacity. The minimum specifications for finding an proper TEC by the designer must be based on the following parameters. The cutaway of a TEC is shown in Figure 4.
D. Fans  
Standard case fans are 80 mm, 92 mm, 120 mm, 140 mm, 200 mm and 230 mm in width and length. As case fans are often the most readily visible form of cooling on a P, and also on heat sinks, decorative fans are widely available and may be lit with LEDs, made of UV-reactive plastic, and covered with decorative grilles. Decorative fans and accessories are popular with case madders Air filters are often used over intake fans, to prevent dust from entering the case and dogging up the internal components. Heat sinks are especially exposed to being clogged up as the insulating effect of the dust will rapidly degrade the heat sink’s dissipating heat.

E. DC Circuit  
The function of DC circuit is Controlling fan speed. To control the speed of fan used MK089 DC motor speed controller. It can control the speed 50% up to full speed. DC motor speed control is normally done by pulse width modulation.

IV. WORKING  
Two unique semiconductors, one n-type and one p-type, are used because they need to have different electron densities. The semiconductors are placed thermally in parallel to each other and electrically in series and then connected with a thermally conducting plate on each side. When a voltage is applied to the free ends of the 2 semiconductors there is a flow of DC current across the junction of the semiconductors causing a temperature difference. The side with the cooling plate absorbs heat which is then moved to the other side of the device where the heat sink is. TECs are typically joined side by side and sandwiched between two ceramic plates. The cooling ability of the total unit is then proportional to the number of TECs in it.

V. ADVANTAGES  
1) Cost: Cost of present HVAC system is very high  
2) Hazardous refrigerant: HFC is quite hazardous for human body and ozon layer which leading to global warming.  
3) Repairing cost: Repairing cost of HVAC system is very high  
4) Maintenance: Proper maintenance is very necessary because this system can affect human body and environment  
5) Simple and fewer parts required.
VI. CONCLUSIONS
We conclude that this system will reduce the operating cost of the cooling system. From construction and working we have conducted the experiment of assembly of thermo-electric refrigerator. The temperature of thermo-electric refrigerator goes on decreases with increase in time. In this way we have completed this review on the Thermoelectric Refrigerator System.

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