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Research Article

Performance Enhancement of Refrigeration System using Peltier Module

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Abstract

Thermoelectric refrigeration is based on the Peltier effect, which explains the cooling or heating that occurs when an electric current flows through the joint of two dissimilar materials. The heat emitted by the Peltier modules is discharged into the freezer compartment, which leads to a significant improvement in the coefficient of operation. It helps to reduce power consumption. The thermoelectric module consists of pairs of P-type and N-type semi-conductor which work on Peltier effect. In cooling application, an electrical current is supplied to the module, heat is pumped from one side to the other, and the result is that one side of the module becomes cold and the other side hot. Previous work concludes that large temperature difference on both side of the thermoelectric module affect the performance. Experimentation will be carried out on the refrigerator, for different location of the module. Analysis will be done for same and based on that the appropriate position of module can be found out.

Keywords: *Thermoelectric Refrigeration, Peltier effect, P-type and N-type semi-conductor.*

1. Introduction

Development of air conditioning and refrigeration is one of the greatest engineering achievements of the 20th century. The efficiencies of both living and non-living beings depend to a great extent on the surrounding physical environment. The nature keeps conditions in the physical environment in a dynamic state, at times changing it from one extreme to the other. Temperature, humidity, pressure and air motion are some of the important environment variables that at any location keep changing throughout the year. Adaptation to these unpredictable variations many a times is not possible and thus working efficiently is not feasible either for the living beings or the non-living ones. Thus for a hassle free life, control of the environment is essential. R&AC deals with the techniques to control the environments of the living and non-living subjects and thus provides comfort enabling them to perform better. Air conditioning is the heating, cooling, dehumidification, humidification, ventilation, and sterilization of air. The refrigeration process removes heat from an enclosed space to reduce and maintain the temperature for the contents of that space. While air conditioning regulates the air in a large building, refrigeration solely cools and is generally used in a smaller space. Both innovations make the human population significantly more comfortable and happy.

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Although Refrigeration and Air Conditioning are two different terms they have a few aspects in common. In case of refrigeration, temperature of the space under consideration is maintained at a temperature lower than the surrounding atmosphere along with dehumidification process. Whereas air conditioning is simultaneous cooling or heating with conditioning of air Both Refrigeration and air-conditioning have cooling and dehumidification operations in common. (D. Astrain, A. Martinez, A. Rodriguez, *et al*, 2012; Manoj Kumar Rawat, *et al*, 2013; S.B. Riffat , Guoquan Qiu, *et al*, 2004)

1.1 Importance of R&AC

Which of the appliances in our homes would be the hardest to live without? The most frequent answer to this question was the refrigeration and air conditioning units. R&AC has revolutionized our lives! Taking together, these cooling technologies have altered some of our most fundamental patterns of living. R&AC. R&AC has established its prominence especially in the fields of food preservation and storage, air conditioning, the medical field, transport, industrial processes, electronic equipment cooling, defense equipment and leisure facilities.

- Food Preservation & Storage

Today's advanced food preservation and storage system has replaced the earlier systems comprising of

cold cellars and salting which were expensive and difficult to regulate. Following food requires storage
Storage of Raw Fruits and Vegetables: The growth of bacteria and the rate of enzymatic processes are reduced at low temperature thereby reducing the spoilage and improving the shelf life of the food.

Meat and poultry: These items also require refrigeration right after slaughter during processing, packaging.

Dairy Products: To maintain good quality of milk, pasteurization of ice cream, increasing shelf life of buttermilk, curd and cheese.

Beverages: Production of beer, wine and concentrated fruit juices require refrigeration.

Candy: Use of chocolate in candy or its coating with chocolate requires setting at 5-10^{o}C otherwise it becomes sticky.

- Industrial Field

R&AC is responsible for many developments in industrial world. Few examples are:

Component solidification processes: The car components, the hole punchers, fan blades, containers, hinges, and so many other helpful products are made by solidification process using refrigeration.
Spot Heating and cooling: To heat or cool a confined zone a worker is located.

Chemical processes: Liquefies gases and controls reaction time of chemical processes with refrigeration.
Industrial air conditioning: Controlling air conditions so that they are favorable for processing some objects or materials.

Printing industries: To control humidity in order to avoid problems of static electricity, curling or buckling of paper, ink failure, etc.

Textile: Yarn moves at very high speeds in modern textile plants. Humidity needs to be controlled in order to have good flexibility and strength in yarn.

- Medical World

Refrigeration, especially at very low temperatures, has had an incredible impact on the medical world as well. R&AC has helped to save many lives and proved to be beneficial in the Medical field. Some of the glimpses are presented here:

Control of conditions in hospitals and operating theatres: It is very important to maintain a high air quality and low room temperature to inhibit the bacterial activity and produce a sterilized environment for the patients to recover faster.

Storage and preservation of organs: Dehumidification and low temperature preservation is the only way of stopping the tissue or organ degradation to use store it for use in emergencies.

Clinical treatment: Clinical treatments like spots removal, brain cooling in stroke patients, nose cooling in migraine patients, storing of dental cement etc. essentially require low temperatures.

Safe vaccine storage: Freezing and refrigerating vaccines is necessary for their long time preservation and to protect them from exposure to sunlight, aerial pathogens etc.

Cryosurgery & Cryotherapy: Extremely low temperature is required to destroy abnormal or diseased tissues & to create local anesthesia for removal of damaged tissues.

Blood banks: Blood storage requires separation of RBCs and plasma, and refrigerating them according to the required freezing conditions.

Mortuaries: Dead bodies are kept at freezing temperatures to slow down the decaying process and avoid bacterial growth in them.

- Comfort cooling

Nowadays, comfort is not only a luxury but has become a way of life and R&AC is an essential component when it comes to comfort.

Mobile air conditioning: For comfortable journey, planes, trains, ships, buses are air conditioned.

Residential and official buildings: To provide comfortable conditions for people in summer, living/working spaces have to be cooled and in the winter the same have to be heated.

Sport centers & gyms: Proper ventilation and control of humidity is required to provide comfort during various sport activities and gym workouts.
Swimming pool halls: Swimming pool halls need ventilation, heating and dehumidification for comfort swimming.

- Defense

R&AC is of utmost importance to defense. Some applications of R&AC in defense are

Cooling of infrared detectors: Infrared detectors need cooling so that the sensors in them which detect radiations and convert light do not get 'blinded' or flooded by their own radiation and end up giving pseudo images.

Cooling of weapons: Weapons such as machine guns when cooled to appropriate extents give long-range sustained fire with excellent accuracy. Cooling also increases rate of fire in shotguns.

Cooling of personnel to increase endurance in extreme conditions: Soldiers dealing with extreme fighting temperatures need cooling jackets or other cooling equipment to keep them going.

Cooling of personnel to reduce body core temperature to increase survival rates of injured service personnel: Injured fighters can be helped to survive longer by maintaining their body temperature low.

Seeing these applications we can say that R&AC has become an essential ingredient for maintaining and improving our quality of life.

1.2 Contribution of Conventional R&AC in Ozone Depletion

There are various sources which causes ozone depletion out which conventional R&AC systems has a

major role. R&AC contributes for about 29.6% of the total ozone depletion. This is a considerably large amount which must be reduced in order to protect the ozone layer CFCs and HCFCs used as heat carrier fluids in conventional system deplete ozone layer and increases global warming. Photo dissociation of halocarbon refrigerants in stratosphere causes ozone layer depletion. Following chart shows the contribution of R&AC among other sources in harming the Ozone layer.

- Ozone Layer

Ozone is present in the atmosphere from the ground upto 50 km altitudes and higher. However, most of the ozone is in a region of the atmosphere called the stratosphere, between 15 and 30 km above the surface of the Earth. This ozone rich region is commonly called the 'Ozone Layer'.

Ozone in the stratosphere has a beneficial role as it blocks UV radiation from the sun. Highly energetic UV radiation called UV-C (wavelength 280 nm) is absorbed by the ozone molecules. UV-B radiation (wavelength 280 – 325 nm) is also absorbed. The ozone layer acts as a shield for us from very harmful UV rays. Exposure to UV rays causes skin cancer, damages crops, affects cellular DNA, impairs photosynthesis and harms ocean life. Without the presence of ozone layer living things do not have long time to live on the Earth. (Abel Amare, *et al*)

Ozone is a gas found in the atmosphere consisting of three oxygen atoms: O3. Ozone is formed in the atmosphere when energetic UV radiation dissociates molecules of oxygen, O2, into separate oxygen atoms. Free oxygen atoms can recombine to form oxygen molecules but if a free oxygen atom collides with an oxygen molecule, it joins up, forming ozone. Ozone molecules can also be decomposed by ultraviolet radiation into a free atom and an oxygen molecule. Ozone is thus continuously created and destroyed in the atmosphere by UV radiation coming from the sun. Due to the creation and destruction processes the amounts of ozone molecules created and destroyed are roughly equal, so that the amount of ozone in the atmosphere remains constant.

1.3 R&AC Using Peltier Effect - An Alternative Technology

R&AC has a vast scope. But the conventional technology using the heat carrying fluids viz. refrigerants (CFCs and HCFCs) renders it unsafe and very harmful. Observing the adverse effects of refrigerants, Montreal Protocol was signed and ozone depleting refrigerants are being phased out. CFC phase out has been achieved by the end of 1996 in developed countries and by the end of 2010 in developing countries. Seeing the harmful effects of CFCs HCFCs were introduced as transitional CFCs replacements. Although HCFCs contribution to global warming and ozone depletion is less compared to CFCs, still the contribution is quite remarkable. Hence phasing out of HCFCs came into action eventually. Complete phase out is hoped to be achieved by 2030 in developed countries whereas in developing countries it is expected till 2040. Thus we can see that refrigerants are the root cause of all harmful effects caused by R&AC technology. Hence an R&AC technology without the use of refrigerants has become a necessity in today's world. (Gajendra S. Pache, *et al*, 2014)

Thermoelectric cooling technology proves to be a promising alternative over the conventional R&AC. This technology eliminates the use of refrigerants thereby overcoming the main disadvantage of conventional system i.e. ozone depletion and global warming. Thermoelectric cooling works on the principle of Peltier effect. Heat pumping is done by making electrons passing through conductors of different electron densities. The energy absorbed by the electrons travelling from low energy level to high energy level is responsible for cooling. Heat transfer occurs in the direction of charge carriers. Thermoelectric cooling is analogous to conventional cooling. The two dissimilar conductors replace refrigerant in both liquid and vapour form, cold surface replaces the evaporator surface and hot junction replaces the condenser. This solid-state technology gives many remarkable advantages over traditional RAC. (Gao Min, D.M. Rowe, *et al*, 2006; D. Astrain, J.G. Vian, J. Albizua, *et al*, 2005; S.B. Riffat , Guoquan Qiu, *et al*, 2004)

2. The Thermoelectric Module

The thermoelectric module made of pairs of P-type and N-type semi-conductor thermo element forming thermocouple, which are connected electrically in series and thermally in parallel. The modules are considered to be highly reliable components due to their solid state construction. For most application they will provide long, trouble free service. In cooling application, an electrical current is supplied to the module, heat is pumped from one side to the other, and the result is that one side of the module becomes cold and the other side hot. (Onoroh Francis, Chukuneke Jeremiah Lekwuwa, Itoje Harrison John, *et al*, 2013; S.B. Riffat, *et al*, 2002)

The heat will be absorbed by the cold side of the module. The absorbed heat will be discharge from the hot side of the module. The heat sink usually made of aluminum, is in contact with the hot side of a thermoelectric module. When the Direct Current (D.C) power source is supplied then heat will be rejected by the module's hot side. Heat sink typically is intermediates stages in the heat removal process whereby heat flows into a heat sink and then is transferred to an external medium. Heat transfer through the sink might be natural convection or forced convection.

The current supplied for the Peltier element is actively regulating the temperature of a given object or case. This is done without acoustic and electrical noise,

vibrations and mechanical moving parts. Changing from cooling to heating is possible by changing the direction of the current, without making any mechanical changes.

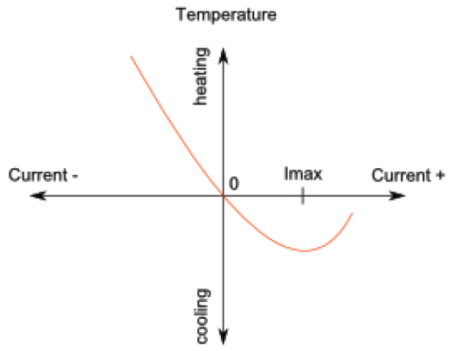

Fig 1: Effect of current on TE module

3. Methodology

The project methodology comprises of the following steps:

1) Selection of Thermoelectric (Peltier) module
2) Design and construction of experimental set up
3) Experimentation
4) Result analysis and conclusion

Selection of Thermoelectric (Peltier) module:
Here we choose a mid-range Peltier Module of low cooling power for our prototype. So, we select TEC12706, with a cooling capacity of 50-60 watts. Thermoelectric module works on the Peltier effect. When current is passed through two dissimilar materials, hot side will be created at one junction and cold side at the other junction.

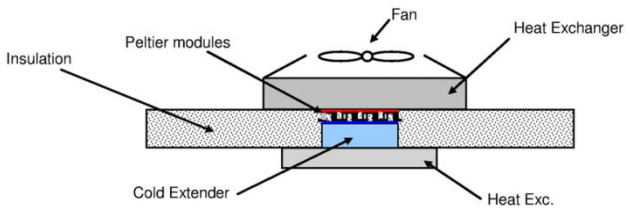

Fig.2 Working Principle of Thermoelectric module

Design and construction of experimental set up

Conventional refrigerator is used for the experimentation. Thermoelectric module is placed in between the wall of the refrigerator such as cold side is inside of the system and hot side towards the outside. The location of the module can be changed as on the top of refrigerator system and in the side wall of the refrigerator system. DC power supply is given to the system.

Experimentation

At initial condition the readings for cooling rate or temperature difference for particular time frame is calculated for refrigerator. These readings are recorded. Same readings will be taken for same refrigeration system under same condition using thermoelectric module. Module will be placed at two different locations, once at top and at side wall of the refrigerator. It will give us different readings of calculations for different location of module.

Result analysis and conclusion

From experimental data we will get different readings for different location of module under same working condition, which on comparison will give idea about the optimum location of the module. Also how much electric energy has been saved can be calculated.

4. Experimental Set Up

For experimental purpose the conventional refrigerator system is taken. Thermoelectric module is connected to the wall of the refrigerator. Cold side of the module is inside that of the container of the refrigerator and hot side is in contact with the surrounding air. Heat will be removed from hot side with help of heat sink. Heat sink is connected on the hot side of the module.

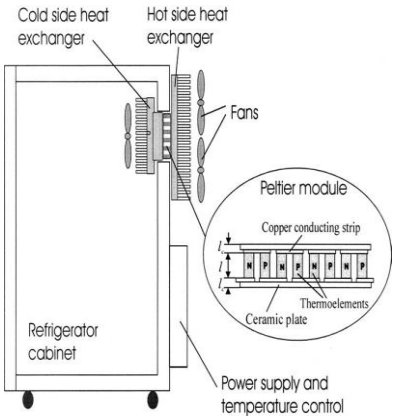

Fig.3 Experimental Set up (Gao Min, D.M. Rowe *et al*, 2006)

Fig.4 Actual model of experimental set up

5. Advantages

- Peltier element is vibration and noise-free.
- Peltier elements are maintenance-free and quick and easy to replace in case of failure.
- It is also possible to reverse the function of the system by reversing the polarity, i.e. a cooling element can be turned into an efficient heating element.
- Heat transport can be controlled by current input/voltage.
- They are small and lightweight even when combining several modules in one element. Compact size makes them useful for applications where size or weight is a constraint.
- Temperature control to within fractions of a degree can be maintained.
- Able to operate in any orientation.
- Amount of flammable and environmental harmful refrigerant reduces.
- The module has long life (100,000 Hrs - 200,000 Hrs).

Conclusions

Thermoelectric module can be used with refrigeration system to get more cooling rate. Though the thermoelectric module have low efficiency, when used with the refrigerator the overall efficiency of the system will increase.

The module can be used with required favorable condition to get maximum efficiency.

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