Experimental analysis of three different cases of air cooled thermoelectric refrigeration system, module TEC-12715

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Abstract

Thermoelectric refrigeration system uses peltier effect to produce hot and cold ends at each of its junctions. Cold end is kept inside the cabinet to produce cooling effect inside that cabinet. Thermoelectric device can work either as a refrigeration system or as heat pump. This work presents an analysis of variation of temperature with respect to time for water cooled thermoelectric assembly. Here TEC-12715 thermoelectric module was used for cooling the refrigeration cabinet. The current was varied from 5A to 11A and time was noted for temperature to drop from ambient temperature to 10-15°C.Results showed that maximum decrease in temperature of polystyrene cabinet was observed when I=0.5Imax.

INTRODUCTION

On applying a direct current of suitable magnitude within a thermoelectric circuit temperature difference is noticed at each of the junctions.One end absorbs heat and becomes cold while the other end rejects heat and becomes hot.For system to work as refrigeration system cold end is kept inside the volume which is to be cooled.For system to work as heat pump, the hot end is kept inside the volume which is needed to be kept warm

We generally use thermoelectric refrigeration system when cooling load on the system is less.For example, in designing a refrigeration system having capacity less than 1 TR (tones of refrigeration) thermoelectric refrigeration can be used.Mostly we use refrigeration system based on vapor compression system.

Thermoelectric refrigeration works on the principle of peltier effect.Now the question arises what is peltier effect actually When two junctions are created by joining two different metals and a battery is connected to the circuit, one end is observed to be hot and other end is observed to be cold.This effect is known as peltier effect.A single-stage thermoelectric module can achieve a temperature difference up to 70 °C following categories such as TEC-12706,TEC-12709,TEC12712,TEC-12715 and so on.Appropriate TEM is selected according to the application we have.Here TEC denotes thermoelectric 127 denotes no of P-N couples, 06 or 09 is the current in ampere.

For the design of a typical thermoelectric module one needs to have the knowledge of size of TEM, no of couples within a TEM, contact resistance between thermoelectric elements and copper plates.Increase in thermal resistance due to junction should also be taken care of.Moisture is very harmful for a TEM, therefore a good quality moisture resisting element is used for protecting TEM from moisture.

LITERATURE REVIE

Reviews on Different research Works

A detailed literature survey was done for understanding the topic more effectively and precisely

Manoj kumar Rawat et al[1] designed and developed an experimental thermoelectric refrigerator having a capacity of 1 Litre.Outer casing was made up of MS sheet.For thermal insulation polyurethane foam sheet has been provided inside the box to prevent reversal of heat flow.A thin copper sheet (0.4 mm) was fixed inside the box for uniform distribution of temperature.Four numbers of super cool make thermoelectric cooling modules (I_{max}=4 A, V_{max}=7.8 A & Q_{max}=19 W) were selected on the basis of active and passive heat removal from thermoelectric refrigeration cabinet.Cold side of TEM mounted on refrigeration cabinet and hot side of module was fixed on heat sink.A black anodized heat sink fan assembly with a thermal resistance of 0.5°C/W. has been used for each module to enhance heat removal rate.The performance of single TEM was evaluated at 0.5I_{max}, 0.25I_{max} and 0.75I_{max}.Optimum performance was obtained at I=0.5I_{max}.That means temperature reduction at cold side of module was maximum when I =0.5I_{max} (i.e. I= 2 A).So at this optimized current of 2A four cases were studied.In first case performance of thermoelectric refrigeration was evaluated without any heat load inside the refrigeration cabinet.In 2nd case 50 ml of water was taken inside the cabinet. In 3rd case 75 ml of water was taken inside the cabinet.In 4th case 100 ml of water was taken inside the cabinet.A temperature reduction of 11°C was observed without any heat load and 9°C with 100 ml of water inside the cabinet when the ambient temperature was 23°C in first 30 minutes.COP was found out to be 0.1 for 100 ml heat load condition.

D Astrain et al[2] designed a TSF device based on thermosyphon with phase change which distributes the heat from the hot side of peltier pellet to the whole surface of finned heat sink.Here heat dissipation from hot side of thermoelectric module was optimized resulting in increase of COP of thermoelectric refrigeration system.The thermosyphon system consisted of prismatically closed chamber with a fluid inside it. In the bottom part of the back face ,hot side of the peltier pellet is placed in touch with a chamber surface.The heating effect produced by hot side of peltier plate is utilized to vaporize the liquid contained in the close chamber.Vapor on reaching the top side of container condenses on coming in contact of vertical fins and it again comes down in the container.This way self feed cycle continues.

TSF spreads the heat from little hot surface (peltier pellet) over a big surface.Using TSF reduces the thermal resistance between hot side of Peltier pellet and chamber containing fluid.Outer part of TSF containing vertical fins was optimized used CFD software FLUENT.Two models in 3D were implemented, one for natural convection through fins, other through the forced convection through the fins.For the model of natural convection spacing between fins was varied, length of fins and width of fins was also simultaneously varied .Four different heat flows were taken.For model of forced convection through the vertical fins mass flow rate of air was varied.Temperature of air was kept constant at 293 K same as the ambient one.Spacing between the fins and height of fins was also varied.Here aim was to minimize the thermal resistance $R_{disp.}$

$$R_{disip} = \frac{T_{w2i} - T_a}{Q_H} \quad (2.1)$$

R_{disip} was obtained with the help of FLUENT simulations

Application of TSF was observed in thermoelectric domestic refrigerator

Two prototypes were built, one with traditional finned heat sink and other with phase change TSF device.An increase in COP was clearly observed when TSF was used in place of traditional finned heat sink.Comparison was made between the COP of heat sink with TSF incorporated it and traditional finned heat sink and it was found that COP of heat sink with TSF was greater than COP of traditional heat sink

K V Mali et al[3] designed a thermoelectric refrigerator with an interior volume of 5 liters' to maintain a temperature in the range of 5°C to 25°C and retention for next half an hour.High impact polystyrene was used to build the outer casing as it has low thermal conductivity which decreases the heat transfer through the cabinet.The components of air cooler were as follows an internal heat sink, a thermoelectric module and an external heat sink.The amount of heat transferred to internal heat sink was found out to be 33 W.The test was conducted at different ambient temperatures 21°C, 15°C, 32°C and 43°C.The temperature varied from 5°C to 15°C with temperature within TEC as less than 1°C.The retention time for low temperature was calculated as per test procedure.6 A of current was needed for thermoelectric module.Battery providing this amount of current is very huge and bulky, much the bigger than air cooling cabinet.

EXPERIMENTAL SETUP AND METHODOLOGY

3.1. Description of the experimental system

We have studied 3 different cases namely single stage air cooled thermoelectric refrigeration system,2 stage air cooled thermoelectric refrigeration system & single stage water cooled thermoelectric refrigeration system.

Single stage air cooled system consists single thermoelectric module TEC-12715,an aluminium plate of 2 mm thickness having a size of 17cmx17cm,an intel air cooled air cooled heat sink with TDP of 130W,a temperature sensor with an accuracy of ±0.3°C,two switch mode power supply,nitrile insulation tape,polystyrene sheet with a thickness of 1.8cm.A CAD model of single stage thermoelectric refrigeration system was drawn in autodesk inventor.Fig 3.1 shows the CAD model of single stage thermoelectric refrigeration system.

Experimental setup of single stage air cooled thermoelectric refrigeration system consists of all the components mentioned in above fig.Refrigeration cabinet is made of polystyrene material.Inner dimensions of polystyrene cabinet is 15cmx15cmx15cm with a thickness of 1.8cm.Polystyrene has a low thermal conductivity,thus it decreases the transfer of heat from surrounding to the enclosed space within the cold cabinet.Above the cabinet an aluminum plate is mounted with the help of nitrile tape.Thermoelectric module is sandwiched between the heat sink and aluminum plate.It is fastened to the aluminium plate and the heat sink with the help of screws and nuts.Thermal grease is applied on both sides of thermoelectric module to decrease the contact resistance.Fig.3.2 shows the experimental setup of single stage air cooled thermoelectric refrigeration system.

2 stage thermoelectric refrigeration system consists of 2 thermoelectric modules,aluminium plate of 2mm thickness having a size of 17 cmx17cm,a polystyrene cabinet with a thickness of 1.8cm with inner dimensions of 15cmx15cmx15cm,a temperature sensor with accuracy of ±0.3°C,switch mode power supply,nitrile tape for insulation purpose,an intel heat sink with TDP of 130W and an AC outlet.Fig 3.3 shows the arrangement of various parts used in 2 stage thermoelectric refrigeration system with the help of a CAD model.

Experimental setup of 2 stage air cooled thermoelectric refrigeration system is depicted in fig 3.4.It consists of polystyrene cabinet with it's top portion open.Aluminium plate is attached to the top portion of cabinet with the help of nitrile tape.Thermocouple lead of temperature sensor is placed inside cabinet to measure the temperature of cabinet.Both the thermoelectric modules are placed above the aluminium plate.Thermal grease is applied at each of the junctions to lower thermal contact resistance.Air cooled heat sink of intel make with TDP of 130W is placed at the top of both the thermoelectric modules.Assembly is tightened with the help of screws and nuts.

depicts the CAD model of single stage water cooled thermoelectric refrigeration system.This CAD model was made in autodesk inventor.The single stage water cooled thermoelectric refrigeration system consists of a thermoelectric module TEC-12715,nitrile tape for insulation purposes,polystyrene sheet with 1.8cm thickness,a temperature sensor with thermocouple,a hollow water jek with one inlet and one outlet for chilled water flow,a reservoir,a chilled solution of ethylene glycol with water,an aluminium plate of 2mm thickness and size of 15cmx15cm,a water pump with reservoir,a bakelite plate of dimensions same as that of aluminium plate and switch mode power supply for powering TEM and water pump.

depicts the experimental arrangement of single stage water cooled thermoelectric refrigeration system.It's CAD model depicts the way in which different parts of this system are assembled together.First of all a polystyrene cabinet of inner dimensions 15cmx15cmx15cm was built.Thickness of this polystyrene cabinet was 1.8 cm.Top portion was left open for keeping the aluminium plate on it.Thermocouple leads were placed inside the polystyrene cabinet for measuring temperature of polystyrene cabinet.Dimensions of the aluminum plate were 17cmx17cm.Aluminium plate was fixed to the polystyrene cabinet with the help of nitrile tape.Thermoelectric module was kept on aluminium plate with thermal grease on its both sides.Cooling water jek with one water inlet and water outlet was fixed on top of thermoelectric module.A bakelite plate of dimensions same as that of aluminium plate was fixed on the top of water cooling jek.Above the bakelite plate a heat sink coupled with CPU fan was placed on it.Whole assembly from aluminium plate to the heat sink was fastened with the help of screws and nuts.Water pump used in domestic desert coolers was used to force chilled water through the water jek.This chilled water flowing through the water jek takes away the heat generated at the hot side of TEM.

Experimental Procedure

We have studied three different cases namely:

Ist Case: single stage air cooled thermoelectric refrigeration system

2nd Case:2 stage air cooled thermoelectric refrigeration system

3rd Case:single stage water cooled thermoelectric refrigeration system

CONCLUSION AND FUTURE SCOPE

Thermoelectric refrigeration system is a good alternative to conventional vapor compression refrigeration systems because here no refrigerant is used.So, there is hardly any chance of leakage of refrigerant into environment.Thermoelectric system is a solid state device since it does not consists of any movable parts such as compressor etc.Therefore we can say that thermoelectric system is a reliable system with very less chances of permanent failure

REFERENCES

[1] Sujith G “Design and Fabrication of Thermoelectric Refrigerator with Thermo siphon System” International Journal of Scientific Engineering and Applied Science(IJSEAS)-Volume-2,Issue-4,April 2016 ISSN:2395-3470

[2] Sreerekha Vadi, V kulkarni “Performance Analysis of Thermoelectric cooler” Discovery The International Daily Journal, ISSN 2278-5469

[3] Manoj kumar Rawat, Himadri Chattopdhyay “A review on developments of Thermoelectric Refrigeration and air conditioning Systems: A Novel Potential Green Refrigeration and air conditional Technology” International Journal of Emerging Technology and Advance Engineering Volume 3 Special issue: ICERTSD 2013,Feb 2013,pages 362-367

[4] D Astrain, J G Via ”Increase of COP in the thermoelectric refrigeration by the optimization of heat dissipation”,www.elsevier.com/apthermeng 23(2003) 2183-2200

[5] Mayank Awasthi, KV Mali “Design and Development of Thermoelectric Refrigerator” International Journal of Mechanical Engg and Robotics Research Vol 1, No 3 Oct 2012