Air Cooled Helmet using Peltier Effect

Amar Sadanand Shetty[1], Samant M Singh[2]
[1](Department of Mechanical Engineering, University of Mumbai, Mumbai
Email: shettyamar777@gmail.com)
[2] (Department of Mechanical Engineering, University of Mumbai, Mumbai
Email: samants300@gmail.com)

ABSTRACT

This paper deals with the development of cooling system for motorbike helmet using thermoelectrical technology. In this context, "Peltier cooling helmet" that works on thermoelectrical refrigeration, aims to supply cooling by victimization thermoelectrical effects instead of the prevailing typical ways like 'vapour compression cycle' or the 'vapour absorption cycle'.

The system consists mainly of a heat sink, electric fan and thermoelectric module. When electrical voltage is applied to the thermoelectric module, it will create a temperature difference across the thermoelectric module, which is being used to utilize electricity to pump heat out. The prototype had been fabricated and mounted onto a bike helmet. Experiments are conducted on the prototype to analyse the performance of the cooling system. The numerical and experimental results showed a good agreement and indicated that the temperature inside the helmet was reduced from 32.7°C to 26.3°C in approximately 7.5 minutes.

Keywords: *Cooling helmet, Peltier effect applications, heat removal.*

1. INTRODUCTION

Peltier Effect: Peltier found there was associate degree opposite development to the Seebeck result, whereby thermal energy might be absorbed at one dissimilar metal junction associate degreed discharged at the opposite junction once an electric current flows within the closed circuit. The circuit is changed to get a distinct configuration that illustrates the Peltier result, a development opposite that of the Seebeck result. If a voltage (Ein) is applied to terminals T1 and T2, associate degree electrical current (I) can flow within the circuit. As a results of this flow, a slight cooling effect (QC) will occur at thermocouple junction A (where heat is absorbed), and a heating effect (QH) will occur at junction B (where heat is expelled) as seen in Fig. 1. Note that this result could also be reversed whereby an amendment within the direction of electrical current flow can reverse the direction of heat flow.

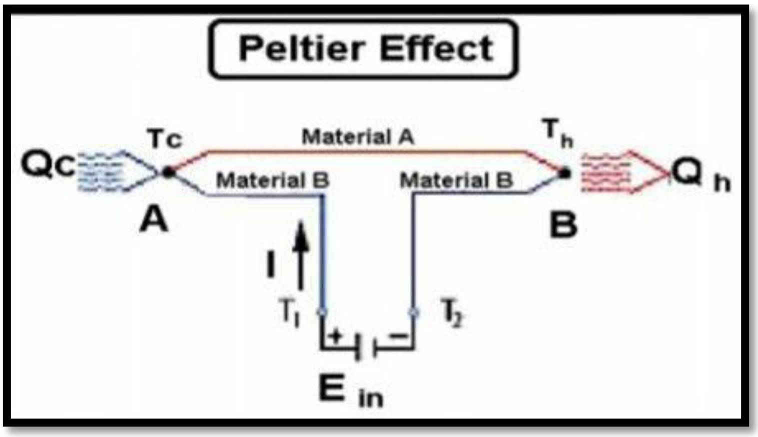

Fig. 1 Peltier Effect

Human body comfort: Thermal comfort is that the condition of mind that expresses satisfaction with the thermal setting and is assessed by subjective analysis (ANSI/ASHRAE Standard 55). The human body are often viewed as an engine wherever food is the input energy. The body can generate excess heat into the environment, so the body can continue to operate. The heat transfer is proportional to temperature difference. In cold environments, the body loses more heat to the environment and in hot environments the body does no exert enough heat. Both the hot and cold eventualities causes discomfort. Maintaining this standard of thermal comfort for occupants of buildings or different enclosures is one amongst the vital goals of HVAC (heating, ventilation, and air conditioning) design engineers. Most people will feel comfortable at room temperature; colloquially a range of temperatures around 20 to 22 °C (68 to 72 °F), but this may vary greatly between individuals and betting on factors like activity level, clothing, and humidity. There are six primary factors that directly have an effect on thermal comfort that may be sorted in 2 categories: Personal factors - as a result of their characteristics of the occupants and,Environmental factors - that are conditions of the thermal setting. The former are metabolic rate and cloth covering level, the latter are air temperature, mean radiant temperature, air speed and humidity. Even if all these factors may vary with time, standards usually refer to a steady state to study thermal comfort, just allowing limited temperature variations.

2. DATA ANALYSIS AND METHODOLOGY

2.1 Total Heat Flow Estimation

2.1.1 Radiation Heat Flow

The Stefan-Boltzmann law describes the power radiated from a black body in terms of its temperature. Specifically, the Stefan-Boltzmann law states that the total energy radiated per unit surface area of a black body across all wavelengths per unit time (also known as the black-body radiant emittance) is directly proportional to the fourth power of the black body's thermodynamic temperature T:

$$j^* = \text{Ï}ƒT^4$$

For radiative transfer between two objects, the equation is as follows:

$$Q = \epsilon\sigma(T_a^4 - T_b^4)$$

Where,

ξ is the emissivity of human head=0.98,

A is the surface area of the human head, considering radius of human head 10cm=$4\pi r^2$ =0.125664 m^2

σ is the Stefan–Boltzmann constant,

T_{head} is temperature of human head= 37°C= 310K

T is human comfort temperature= 25°C= 298K

$$Q1= \varepsilon\ A\ \sigma\ [T_{head}—T]$$

$$= 0.98 \times 0.125664 \times 5.67 \times 10\text{-}8[3104 - 2984] =7.42\text{watts}$$

2.1.2 Convection heat flow

The convection heat transfer is given by Newton's Law,

$Q= h\ A\ (T_{head} - T)$

Where,

h= convective heat transfer coefficient= 50 W/m2 °C (for air)

Q2= 50 x 0.125664 x (310 - 298)

=75.4watt

2.1.3 Metabolic Equivalent of Task

The metabolic equivalent is a physiological measure expressing the energy cost of physical activities and is defined as the ratio of metabolic rate during a specific physical activity to a reference metabolic rate, set by convention to 3.5 ml O2 kg-1 min-1 or approximately,

1 MET= 1 kcal/kg*h

=4.184 kJ/kg*h

=1.16222 W/kg

Still, another definition of 1 MET= 58.2 W/m2, which is equal to the rate of energy produced per unit surface area of an average person seated at rest.

For, riding bike 3MET energy is consumed,

Q3= 3 x 58.2 =174.6 W/m2
=174.6 x 0.125664
=22 watts
So, total heat to be removed,
Q= Q1 + Q2 + Q3
=7.42 + 75.4 + 22
=104.76 watts

2.2 METHODOLOGY

2.2.1 Electric fan and Heat sink

Air velocity (distance travelled per unit of time) is usually expressed in Linear Feet per Minute (LFM).
For 12V DC 0.9A fan,
CFM= 104 and corresponding LFM= 1200
Refer Fig. 2,

Fig. 2 Graph of Thermal Resistance vs Heat Sink Volume

Volume of heat sink required = 15 inch^3
=245.8 cm^3
So, LxBxH= 15 x 8.5 x 2 = 255 cm^3
Thus, Properties of Heat Sink-

- Length of heat sink = 15cm
- Breadth of heat sink = 8.5 cm
- Height = 2cm
- Material- Aluminium (k= 200W/mK)

We know from above,
Peltier hot side temperature (Tmax) = 85°C
Ambient temperature T= 30°C
Heat to be removed is approx. 105W

Thermal resistance (R) = Tmax- T /Pd
=85 - 30 / 105
=0.53°C/W

The number of fins can be found out from the graph below in Fig. 3,

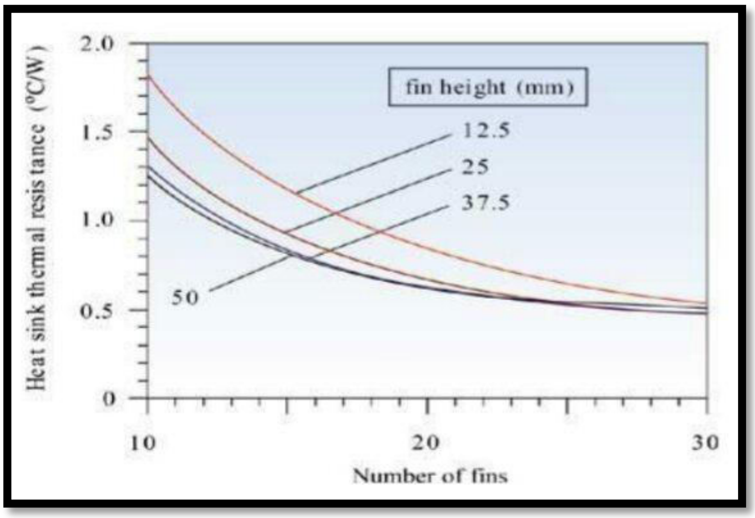

Fig. 3 Graph of Thermal Resistance of Heat Sink vs Number of fins

2.2.2 Battery

Li-Po (Lithium Polymer) 3S rechargeable battery
Voltage - 11.1V
Current - 2200mAh
Capacity - 25C
Weight- 158g

Maximum continuous current supply= 2200 x 25
=55000mA
= 55A

Time duration of continuous current supply= 60minutes/25C
= 2.4minutes

Thus, Li-Po battery provides continuous supply of 55A for 2.4 minutes.
Current consumption:

1. Peltier module = 3.8A
2. Electric fan (Hot side) = 0.9A
3. Electric fan (Cold side) = 0.2A
4. Temperature control (Thermostat) = 0.06A

Thus, total current consumption = 5A (approx.)
Hence, Li-Po battery can provide current for, 55/5 = t/2.4
t = 55 x 24/ 5
t = 26.4 minutes

Since, total current required is approx. = 5amps, the battery can be used for approximately 27 minutes after fully charging once.

2.3 Efficiency of Peltier module:

Taking 160ml (0.352 lbs) of water of temperature = 29.2°C and cooling it inside a closed polystyrene box.
Ambient temperature = 33.2°C

Time (minutes)	Temperature (Celsius)
5	28.2
10	27.7
15	27.5

Input power = VI
=10.14 x 7.6
= 77.06 J/s
Input Energy = 77.06 x 900
= 69354
Temperature change = 91.76F (33.2°C) – 81.5F (27.5°C)
= 10.26F
British Thermal Unit = lbs x F x 1BTU/lbf
=0.352 x 10.26 x 1
=3.611 BTU
=3.611 x 1055
= 3809.60Joules

η = BTU/ Input energy
= 3809.6/69357.6
= 0.05
= 5.4%

Thus, it is found that the efficiency of Peltier module used is 5.4%

3. DESIGN ANALYSIS AND RESULT

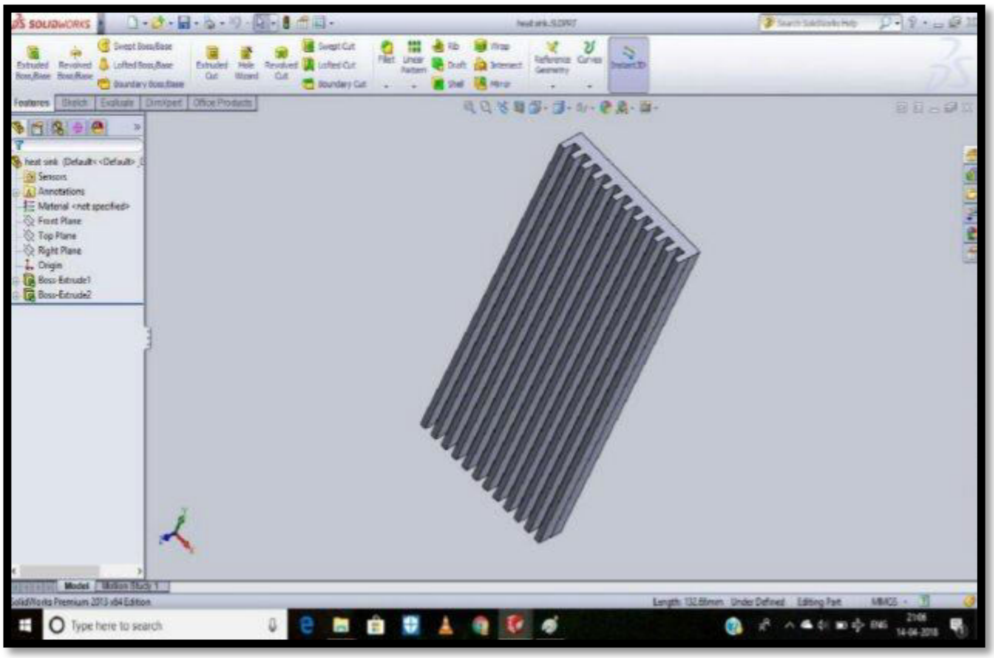

Fig. 4 Heat sink design

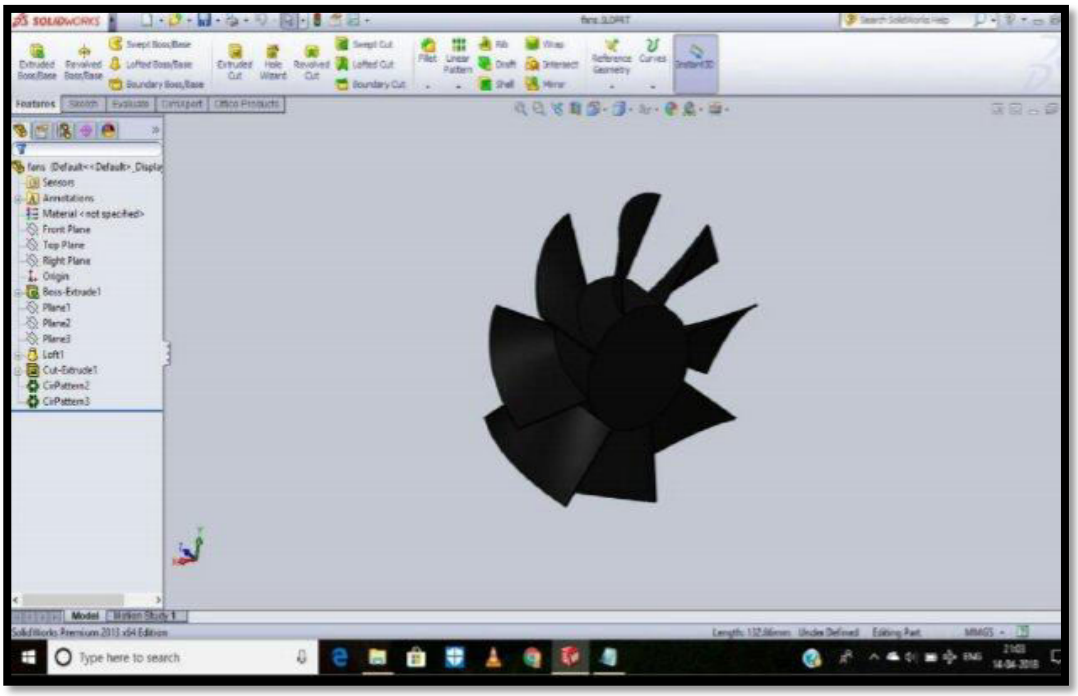

Fig. 5 Heat removal electric fan design

Sr. No	Time (minutes)	Helmet Temperature (Celsius)
1.	0.5	32.7
2.	1	32.4
3.	1.5	32
4.	2	31.6
5.	2.5	31.2
6.	3	30.8
7.	3.5	30.4
8.	4	30
9.	4.5	28.6
10.	5	28.2
11.	5.5	27.7
12.	6	27.3
13.	6.5	26.9

14.	7	26.5
15.	7.5	26.3

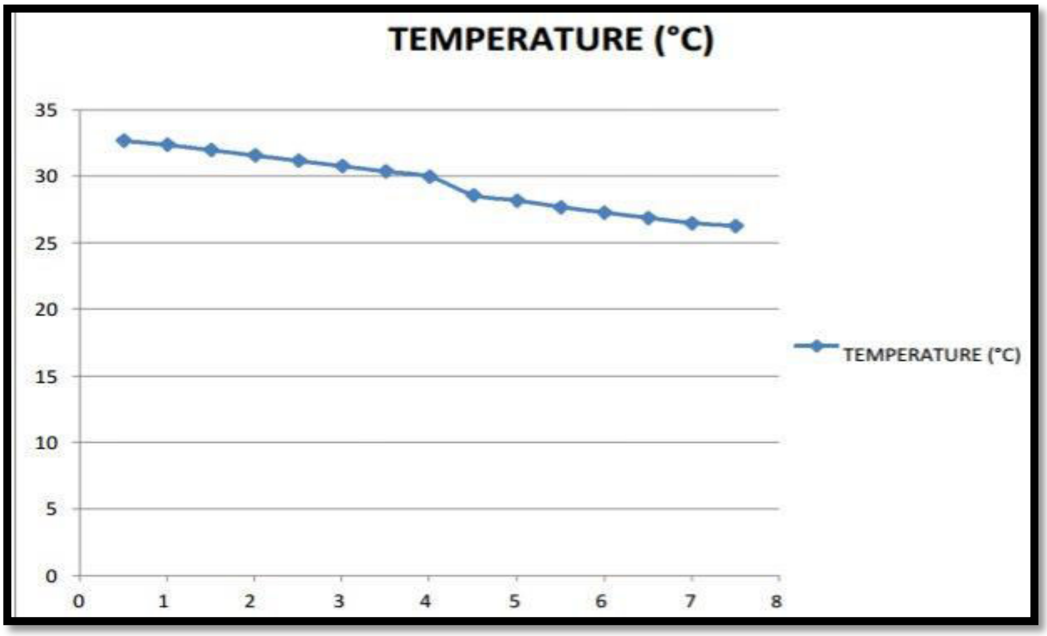

Fig. 6 Helmet inner temperature vs Time variation

4. PROTOTYPE

Fig.7 Side view of model

Fig. 8 Bottom view of model

5. OUTCOME

- The prototyping of a cooling system based on thermoelectricity for a motorcyclist helmet is done.
- The targeted cooling performance is achieved and future enhancements are going to be carried out to enhance the cooling performance of the model. This will embody the employment of upper power thermoelectric module.
- This can be a really effective answer in the main for the individuals living in high temperature zones.

6. References

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