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Design of Helmet Cooling System Modules and their Comparison

Mangesh. P. Panchbhai[1], Parthsarthi Prashant Pethkar[2], Aniket Balasaheb Korde[3], Parag Ashok Rane[4]
[1]*Assistant Professor,* [2, 3, 4] *U. G. Scholar, Mechanical Engineering, K.K.W.I.E.E.R, Nashik,*

Abstract: ***Now-a-days Helmet is a hot topic as well as very much important for safety of the rider, often reason for not using Helmet is the uncomforting feel due to the higher temperature than that of the Surrounding which leads to suffocation as a result the Helmet use is avoided by many of the peoples. The helmets present in the market are too traditional and uncomfortable for the rider to wear it for a longer time period. There has been significant period till the previous development of helmet. It does not provide enough cooling to the human head. So to overcome this problem we had develop the cooling system for motorbike helmet, our aim is to Compare and select the best module by taking various parameters into consideration from two modules viz: Peltier Module Helmet cooling system and Phase Change material Helmet cooling system***
Keywords: (Uncomfortable, Suffocation, Peltier Module, Phase Change material, compare)

I. INTRODUCTION

The Helmet is the most essential equipment when it comes to safety factor. There are several helmet available with various modified Designs and in wide varieties but maximum of the designs fails to provide the comfort to the rider by providing the cooling effect, as many surveys in India and certain other countries clearly stated that major reason of not wearing the helmet is discomfort caused due to the heat issues.

This heat is mainly caused due to high insulation properties of the liner in Helmet which results into the low heat transfer and this may also result into distraction of the rider during the long rides.

This Paper mainly focusses on to overcome this problem caused, there are two effective methods which can provide the cooling effect which are the Peltier Module and Phase Change Material Module.

The Peltier Module works on principle of Peltier effect and the following equation can be stated

$Q = (\mu 1 - \mu 2)^* I$

Where μ1 is Peltier coefficient of conductor 1 and μ2 is Peltier coefficient of conductor 2 and I is the current from 1 to 2.

The Phase Change Material works on the Principle of a heat transfer through conduction and provides cooling to the rider. The Phase change Material changes it phase from one to another. The PCM powder is packed into bag and is placed between the head and Liner of the Helmets, when the helmet inner temperature increases and is larger than melting temperature of PCM the phase change process occurs which nearly takes 25 to 30 minutes.

Furthermore this two modules will operated and test in same conditions and various parameters such as safety, cost, weight and maintenance will be compared.

II. METHOD

A. Peltier Effect: [1]

Peltier Effect and Seebeck Effect features a reverse phenomenon with reference to one another, whereby thermal energy is absorbed at one dissimilar metal junction and discharged at the other junction when an current is flowed within the circuit (circuit).

The circuit is modified to desire a configuration that accompany the Peltier Effect, a phenomenon opposite that of the Seebeck Effect. If a voltage (Ein) is applied to terminals T1 and T2 respectively, an electrical current (I) will flow within the circuit. As a results of the present flow, a small cooling effect is obtained at thermocouple A (where heat is absorbed), and a heating effect (QH) will occur at junction B (where heat is expelled). Note that this effect could even be reversed whereby a change within the direction of electrical current flow will reverse the direction of heat flow.

Joule heating, having a magnitude of I2 x R (where R is that the electrical resistance), also occurs within the conductors as a results of current flow. This Joule heating effect acts con to the Peltier Effect and causes a net reduction of the available cooling.

The Peltier effect are often expressed mathematically as,

$QC \text{ or } QH = \beta \times I = (\alpha T \times I)$

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Where:

1) β is that the Peltier coefficient between the 2 materials A and B in volts.
2) I denotes current flow in amperes.
3) QC and QH are the rates of cooling and heating, respectively, in watt

B. Phase Change Material: [2]

Phase change effect (PCE) is extremely attractive due to its high storage density with small temperature swing. It's been demonstrated that for the evolution of a heat of transformation storage system during a building fabric, the choice of PCE plays an important role additionally to heat transfer mechanism within the PCE. Thermal energy storage within the walls, ceiling and floor of the buildings could even be enhanced by encapsulating or embedding suitable PCEs within these surfaces. Either they will capture solar power directly or thermal energy through natural convection. While the rise within the thermal storage capacity of building may result into increase of human comfort by decreasing the frequency of internal air temperature swings so as that indoor air temperature is closer to the specified temperature for a substantial period of your time. This technique provides a valuable solution for correcting the difference between the availability and demand of energy. Heat of transformation storage could also be a replacement area of study and it received more attention during early 1970s and 1980s. Many phase change materials has been studied and tested for various practical uses by many scientists.

C. Heat Calculation

1) Radiation Heat Flow

The radiation is emission or transmission of energy within the shape of waves or particles through space or medium. This includes

a) Electro-Magnetic radiation like radio waves micro waves light x-ray and gamma ray.
b) Particle radiation like (Alpha) α, (Beta) β and (Gamma) γ, radiation.

Thermal radiation could also be an immediate results of the random movements of atoms and molecules in matter. Since these atoms and molecules are composed of charged particles (protons and electrons), their movement results in the emission of electromagnetic radiation, which carries energy far away from the surface.

The Stefan–Boltzmann law describes the potential to be radiated from a black body in terms of its temperature. Specifically, the Stefan–Boltzmann law states that the general energy radiated per unit area of a black body across all wavelengths per unit time is directly proportional to the biquadrate of the black body's thermodynamic temperature T:

$j^* = \sigma T4$

The constant of proportionality σ is named as Stefan–Boltzmann constant the worth of the constant is

Where,

k is that the Boltzmann constant,
h is Planck's constant,
c is that the speed of light during a vacuum.

The Stefan-Boltzmann equation, which describes the speed of transfer of energy, is as follows for an object during a vacuum

For radiative transfer between objects, the equation is:

$Q = \in(Ta4 - Tb\ 4)$

Where,

Q is that the heat flux,
ε is Emissivity of head =0.98
A is that the area of the head, considering radius of head 10cm= 4πr2=0.125664 m2
σ is that the Stefan–Boltzmann constant,
Thead is temperature of human head= 37°C= 310K
T is human comfort
Temperature= 25°C= 298K
=0.98 x 0.125664 x 5.67 x 10-8[3104 — 2984]
=7.42watts

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2) *Convection heat Flow:* Heat convection occurs when bulk flow of a fluid carries heat in conjunction with a flow of matter within the fluid. The flow of fluid may force by external forces or sometimes by buoyancy forces caused due to thermal energy expands the fluid thus influencing its own transfer. The latter process is typically called natural convection. All convective process also move heat partly by diffusion. Another quite convection is forced convection. During this fluid is forced to flow by use of pump, fan or other mechanical means. The convection heat transfer is given by Newton's Law, Q= h A (Thead - T) Where, h= convective heat transfer coefficient= 50 W/m2 °C (for air)

Q2= 50 x 0.125664 x (310 - 298)
=75.4watts

3) *Metabolic Equivalent of Task [5]:* The metabolic equivalent could even be a physiological measure expressing the energy cost of physical activities and is stated because the ratio of rate during a specific physical activity to a refere 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 capable the speed of energy produce per unit area of a mean 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

D. Selected Components of Peltier Module Helmet Cooling System

1) *Electric Fan:* [7] 12V 0.9 A DC,

CFM =104

2) *Heat Sink:* [6] L*B*H=10*8*3=240 cm3

Material =Aluminum
k=200 W/mk
Thermal resistance = 1.4 ºC/W
No.of fins=13

3) *Peltier Module [4]*

Heat content to be removed Q = 104.76 W (Approx. 105 W)

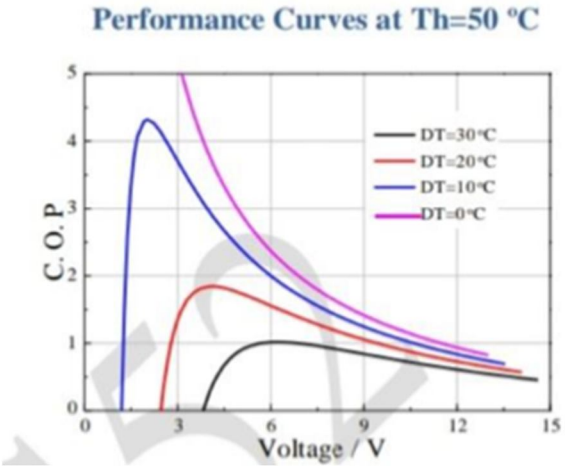


Fig 5.1: Voltage vs. C.O.P

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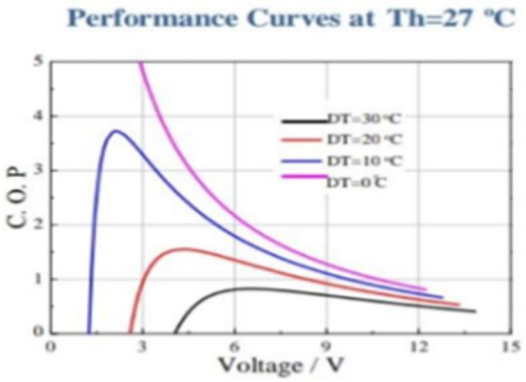


Fig 5.2: Voltage vs. C.O.P

From the above Graphs,
COP of Peltier module = 0.9
COP = (Heat to be Removed)/ (Capacity of Peltier)
0.9 = 105/ (Capacity of Peltier Module)
Therefore, Capacity of Peltier Module = 116 W
Hence 130 W capacity Peltier Module is chosen

4) Li-Po (Lithium Polymer) 3S rechargeable battery [8]

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:

a) Peltier module = 3.8A
b) Blower (Hot side) = 0.9A
c) Blower (Cold side) = 0.2A
d) 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 are often used for 27 minutes after fully charging once.

E. Manufacturing of PCM Material [3]

Manufacturing of Cacl2.6H2O

1) Preparation of CaCl2.6H2O

a) Step 1: Place the limestone within the cup. Use enough limestone the fill the cup about 1/4 full. Placed on the gloves.
b) Step2: Add a 1/4 of a cup of hydrochloride acid to the limestone.
c) Step 3: The hydrochloride acid will start to bubble because it dissolves the limestone. Gently swirl the cup to combine the contents and ensure the reaction goes to completion. If all of the limestone dissolves add slightly bit more.
d) Step 4: once the answer stops bubbling, filter off the solids by pouring the answer through the paper into the second cup. The salt is dissolved within the filtered solution.
e) Step 5: Use the recent plate to gently heat the second beaker containing the salt solution. The solid left after the water evaporates is solid salt.
f) Step 6: Repeat an equivalent process until required amount of pcm is ready

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2) Reaction: Formation of salt from the reaction of carbonate and acid

CaCO3(s) + 2HCl (l) → CaCl2(s) + H2O (l) + CO2 (g)↑

During this reaction one mole of carbonate (CaCO3) react with two mole of acid (HCl) to make one mole of salt (CaCl2), one mole of water (H2O) and one mole of CO2 (CO2).

3) Hydrolysis: Salt is one among the promising salt hydrates for thermo chemical heat storage for common building applications. A reversible chemical gas-solid reactions are often consistent with that involves CaCl2, according to the de/re-hydration reaction

CaCl2 · xH2O(s) + heat ↔ CaCl2 · (x−y) H2O(s) + yH2O (g).

Reaction	Δ*h* [kJ/mol *salt*]
$CaCl_2+H_2O \rightarrow CaCl_2.H_2O$	71.6
$CaCl_2.H_2O+H_2O \rightarrow CaCl_2.2H_2O$	51.9
$CaCl_2.2H_2O+2H_2O \rightarrow CaCl_2.4H_2O$	117.1
$CaCl_2.4H_2O+2H_2O \rightarrow CaCl_2.6H_2O$	120.7
$CaCl_2.4H_2O+2H_2O \rightarrow CaCl_2.6H_2O$	361.3

Table I: Reactions



Fig 3: Phase change materials

III. EXPERIMENTAL RESULT

A. Testing Condition

Initial Helmet Temperature = 34

Average Vehicle = 40 kmph

Date of Experiment = 17/03/2020

1) Peltier Module

Time (Min)	Helmet Temperature (Celsius)
0.5	34
1	33.7
1.5	33.2
2	32.1
2.5	31.5
3	30.7
3.5	29.1
4	28.8
4.5	28.4
5	28
5.5	27.6
6	27.3
6.5	26.9
7	26.5
7.5	26.3

Table II. Peltier Module test results

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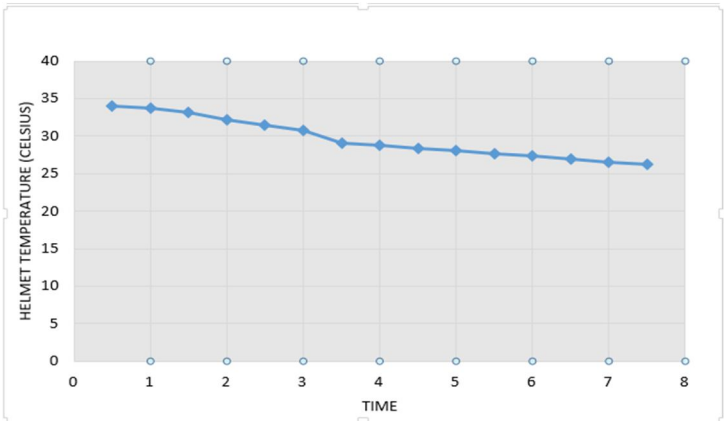


Fig 4: Temperature vs. Time graph of Peltier Module

2) Phase Change Material Module

Time	Temperature
1	34
3	33.8
5	33.5
7	33
9	32.7
11	32.5
13	32.3
15	32
17	31.7
19	31.3
21	30.8
23	30.3
25	29.8
27	29.4
29	29
30	29

Table III: PCM module test result

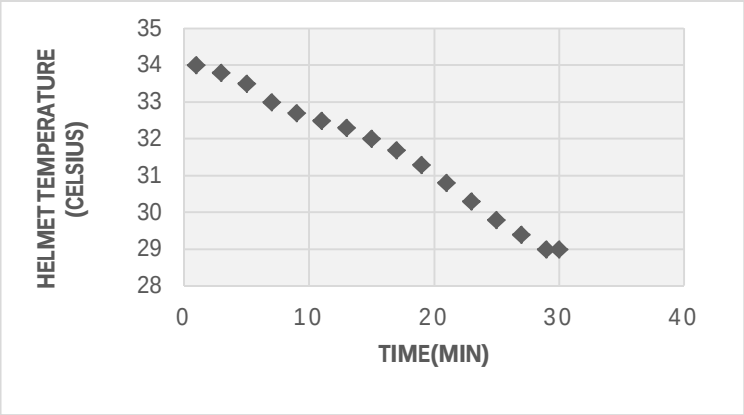


Fig 5: Temperature vs Time graph of PCM Module

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B. Outcomes

1) The Cooling Effect can be rapidly provided by Peltier Module as compared to the Phase Change Material Module.
2) The Peltier Module takes Nearly 7.5 minutes to drop the temperature by 7.7ºC.
3) The PCM module takes nearly 30 minutes to cool down the temperature from 34ºC to 29ºC.
4) The PCM module provides the cooling effect for longer Period time.

IV. CONCLUSION

From the above research following points can be made:

A. The Peltier Module weighs nearly 400 Grams more than the PCM module.
B. The Peltier Module has a Running time of Nearly 30 minutes and PCM module can provide cooling for 1.5 to 2 hrs.
C. The Peltier Module has a Cut of nearly 3*3 cm2 for the setup of Peltier Module on the Helmet and on other hand PCM module is 100% safe as Compared, Since it do not have any cuts.
D. The Peltier Module is approx. 3 times Expensive than the PCM module Thereby it can concluded that Phase Change Material Module is more Effective and Useable from the certain above observations.

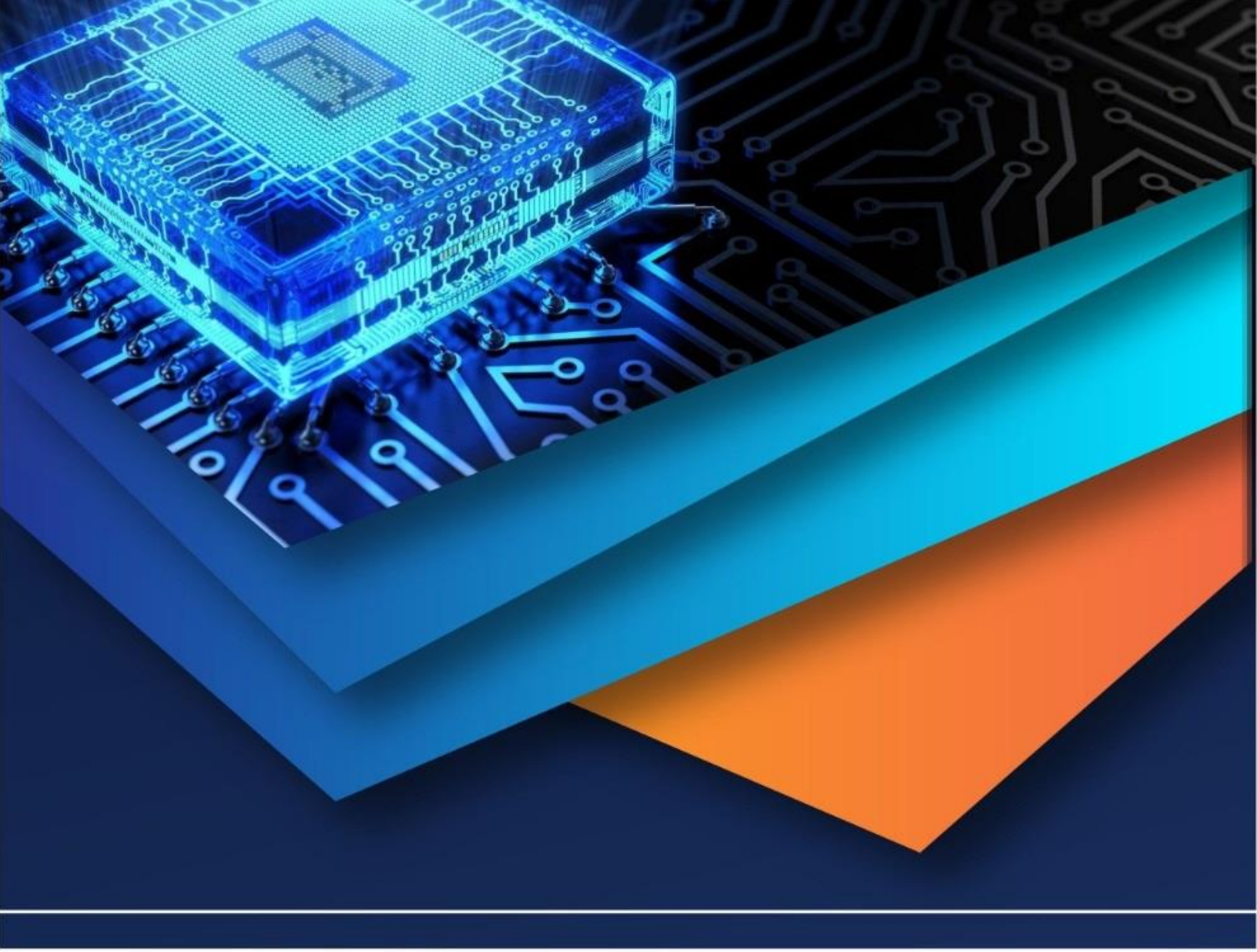
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