International Journal of Mechanical and Industrial Engineering

Volume 1 | Issue 2 Article 4

October 2011

Cooling of Motorcycle Helment Using Phase Change Material

S. Vaitheeswaran
Sri Sairam Engineering College, Chennai, India, ssvaithy@gmail.com

C. Suresh Kumar
Sri Sairam Engineering College, Chennai, India, suresh151290@gmail.com

S. Santhosh
Sri Sairam Engineering College, Chennai, India, S.Santhosh@gmail.com

S. Sathish Kumar
Sri Sairam Engineering College, Chennai, India, S.SathishKumar@gmail.com

Recommended Citation
Vaitheeswaran, S.; Kumar, C. Suresh; Santhosh, S.; and Kumar, S. Sathish (2011) "Cooling of Motorcycle Helment Using Phase Change Material," *International Journal of Mechanical and Industrial Engineering*: Vol. 1 : Iss. 2 , Article 4.
DOI: 10.47893/IJMIE.2011.1020
Available at: https://www.interscience.in/ijmie/vol1/iss2/4

Cooling of Motorcycle Helment Using Phase Change Material

S. Vaitheeswaran[1], C. Suresh Kumar[2], S. Santhosh, S. Sathish Kumar
3rd year, B.E. Mechanical Engineering, Sri Sairam Engineering College, Chennai, India
[1]ssvaithy@gmail.com, [2]suresh151290@gmail.com

Abstract--Human life is so precious and valuable, that it should not be compromised under any cost. In a latest survey, it is mentioned that nearly 62% of mortality in road accidents occur due to head injury, where the rider has not worn a helmet. It is not that people are very negligent about their lives on road, but that they experience dozens of discomforts by wearing helmets. But the most common discomfort is that, heavy sweat occurs due to excessive heat formation.

This project mainly focuses on absorbing this heat produced inside the helmet. To achieve this, a suitable Phase change material (HS 22) is encapsulated inside an aluminium packet. Also 6 holes of 6mm diameter are drilled on the front and rear sides of helmet. This allows fresh air (reaction air coming opposite to riding direction) to continuously flow in and out of the helmet so that the heat produced in the helmet is instantaneously tapped out. During summer season, the inlet air itself will be hot which will be absorbed by the PCM. The PCM fuses taking its latent heat of fusion from the packet surface and cools it. Thus continuous cooling is achieved till the entire PCM fuses. After the ride, the PCM rejects the heat and again solidifies.

Factors like position of PCM in the helmet, volume, latent heat of fusion, etc. are carefully adjusted to achieve effective forced convective heat transfer and thus cooling for a minimum drive of 1.5 hours at an utmost ambient temperature of 45^{0}C. This ventilation system is practically feasible, very economical and will surely promote the riders to wear helmets. This project has been successfully completed as our 3rd year project.

Keywords--Helmet, phase change, latent heat, evaporative cooling

I. INTRODUCTION

The problem of excessive heat and sweat formation due to wearing of helmet has been remaining as an unsolved problem. This has reduced the usage of helmet which in turn imposed serious safety hazards for the two wheeler riders. It's high time to find an effective and economic solution for this problem. This paper seeks a practical solution for this problem using Phase Change materials.

II. OBJECTIVES

The chief objectives of this project are,

- To remove the heat produced inside helmet by letting fresh air to enter by providing suitable vents.
- Cover these vents with movable lids to prevent water seepage during rain.
- To drive away the hot air present inside the helmet to allow fresh air to enter.
- To absorb heat present in the incoming air (if any) using a Phase Change Material (PCM) by allowing forced convection to take place.

III. BASIC DESIGN

The design of helmet initially made pictorially and a theoretical stress analysis was carried out. The various views of the helmet were taken and based on this design the fabrication work has been carried out. The views of the design from various directions are presented in fig.1 and fig.2.

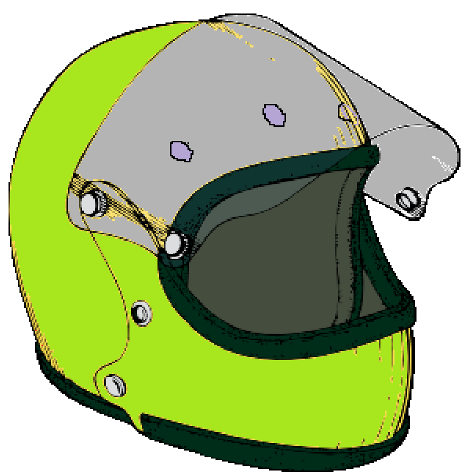

Figure 1 Isometric view of the prototype

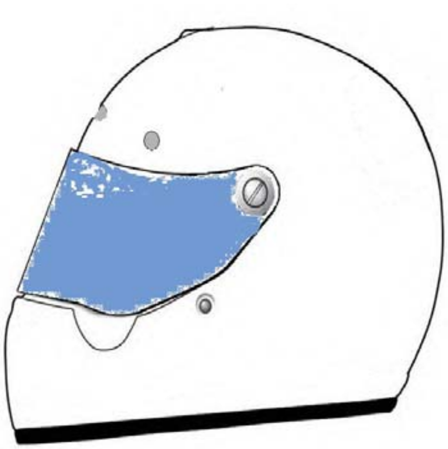

Figure 2 Side view of the prototype

IV. STEPS IN FABRICATION

The following steps were involved in the fabrication of the prototype:

- PCM selection
- PCM preparation
- PCM mounting
- Hole drilling
- Anti-hydraulic lid

A. *PCM selection*

The phase change materials are selected based on their melting point and the operating temperature range.

The table 1 shows the list of commercially available PCMs of which HS29 was selected.

B. *PCM preparation*

The PCM was initially bought in the inactive state from a Chemical industry and then it was heated at a using a water bath at a temperature of 50^{0}C until the inactive crystals of PCM completely melts. Then it was kept in a cold water bath for solidification. This process made the PCM active.

TABLE 1 COMMERCIALLY AVAILABLE PCMS WITH THEIR PROPERTIES

Properties	Appearance (Colour)	Contents	Phase Change Temp. (^{0}C)	Operating range (^{0}C)	Density (kg/m^3) Liquid	Latent Heat (kJ/kg)	Congruent Melting	Sub Cooling	Flammability	Stability	Max. operating Temp(^{0}C)	Qty per kWh (kg)
HS 37N	Light white / Grey /Blue	Inorganic Salts	-37 to -39	-45 to -32	--	60 (minimum)	Yes	No	No	**	~ 50	--
HS 26N	Light Blue to Dark	Inorganic Salts	-25 to -26	-31 to -20	1200	205	Yes	No	No	**	~ 50	18
HS 23N	Light white/grey	Inorganic Salts	-22 to -24	-29 to -17	1180	200	Yes	Low	No	~ 2000	~ 50	18
HS 7N	Light white/grey	Inorganic Salts	-7 to -5	-12 to 0	1120	230	Yes	Low	No	~ 2000	~ 50	16
Frost	Light Blue to Dark	Inorganic Additives	-1 to +1	-5 to 5	1010	290	Yes	No	No	**	~ 50	12
HS 08	Colorless to Blue	Organic Mixture	8 to 9	2 to 13	1050	190	Yes	No	Yes	**	~ 80	19
HS 11	Colorless to Blue	Organic Mixture	10 to 11	5 to 16	1060	260	Yes	No	Yes	**	~ 80	14
HS 22	Grey / brown	Inorganic Salts	21 to 23	16 to 28	1540	185	Yes	Low	No	~ 3000	~ 80	19
HS 24	Grey / brown	Inorganic Salts	23 to [illegible]	18 to 30	1540	185	Yes	Low	No	~ 2000	~ 80	19
HS 29	Grey / Brown	Inorganic Salts	27 to 29	22 to 34	1550	190	Yes	No	No	~ 5000	~ 80	19
HS 32	Light White to Grey	Inorganic Salts	30 to 32	25 to 37	---	165	Yes	No	No	**	~ 80	20
HS 34	Light White to Grey	Inorganic Salts	32 to 35	27 to 40	1850	150	Yes	Low	No	~ 2000	~ 80	25
HS 58	Light White to Grey	Inorganic Salts	55 to 59	52 to 64	1290	250	Yes	Low	No	~ 1000	~ 90	15
HS 89	Light White to Grey	Inorganic Salts	87 to 89	82 to 94	1540	180	Yes	No	No	~ 1000	~ 105	20

C. *PCM mounting, Hole drilling and Anti-hydraulic lid*

The PCM is mounted inside the helmet using a specially made wire mesh to allow free flow of air. The wire mesh is positioned such that the PCM packet can be kept in or taken out whenever required. The holes were drilled using HSS tool very accurately to 6mm diameter. The anti hydraulic lid has been made to protect the seepage of water during rainy season through the holes. This lid is not shown in figure 1 or figure 2 but it is present in the prototype.

V. DESIGN CALCULATIONS

A. *Stress analysis*

A theoretical stress analysis has been made to check whether the strength of the helmet has been reduced due to the drilling of the holes. The helmet was considered to undergo an impact load when falling from a height. The helmet has been considered as a hollow spherical shell and its strength without holes was initially found. Then the same calculation has been repeated by subtracting the area of the holes. In all the cases the stress induced due to impact load was found to be less than the safe stress of the helmet material which is usually polystyrene.

- Specifications:

- Circumference of the helmet = 860mm
- Outer radius of the helmet, R = 136.87mm
- Thickness of the plastic casing, t = 4mm
- Inner radius of the helmet, r = R – t
  = 132.87mm
- Surface area under impact load,
  a = 2*π* R^2
  = 2* 3.14 * (0.136^2)
  = 0.1177 sq. m.
- Height of fall, h = 1.60 m
- Length of object exposed to impact,l= 0.004m
- Load acting on the helmet under impact is,
  P = W (1+ (1 + (2Hae / W * l)) $^{.5}$)

B. Stress analysis for full helmet

- Normal load, w = 200 N
- Young's modulus of polystyrene,
  E = 2.5 * 10^9 N/m^2
- Therefore,

P = 200 (1 + (1 + (2 * 1.60 * 0.1177 * 2.5 * 10^9/ 200 * 4 * 10^{-3}))$^{.5}$)
= 6.86 * 10^6 And

- Stress σ_1 = P / a = 6.86 * 10^6 / 0.1177
  = **58.28 M Pa**

C. Stress analysis for drilled helmet

- Diameter of the drilled hole, d = 6mm
- No. of Holes drilled, n = 6
- Remaining area, A_1 = a – (d * t * n) sq. m
  = 0.1177 – (0.006*0.004*6)
  = 0.1175 sq. m
- Impact load P = W (1+ (1 + (2H*A_1*e / W * l)) $^{.5}$)
  = 200 (1 + (1 + (2 * 1.60 * 0.1175 * 2.5 * 10^9/ 200 * 4 * 10^{-3}))$^{.5}$)
  = 6.85 * 10^6 N
- Stress, σ = P / A_1 = 6.85 * 10^6 / 0.1175
  = **58.34 M Pa**
- But, the permissible yield stress value of polystyrene, [σ] = **70 M Pa**
- Therefore, σ < [σ] and σ_1< [σ]

Hence, **the design is safe.**

D. Time of cooling effect

Another calculation has been done to calculate the minimum time for which the PCM can give its cooling effect. A peak temperature of 45^0C is assumed and the calculation is shown below.

Specifications

- PCM employed: HS 29
- Operating temperature: 29°C
- Enthalpy: 205kJ/kg
- Density: 1550kg/m^3

Assumptions

- The bag containing Phase change material is assumed as a flat plate
- Ambient temperature 45°C
- Temperature of PCM 29°C

Data

- Mean film temperature is 37°C
- The length of the bag exposed is 10cm
- Velocity of air is 35 Km/hr

Properties

For air at 37°C, from HMT data book,

- Kinematic viscosity, ν=16.96*10^{-6} m/s
- Thermal conductivity, k= 0.02756 W/m k
- Prandtl number, Pr = 0.669.
- Reynold's number,
  Re = (U_∞ * L)/ ν
  = (9.7222*0.1)/ (16.48*10^{-6})
  = 58993.932

So,

- Coefficient of heat transfer,

h = 0.662*(k/L)*$Re^{0.5}$ $Pr^{0.333}$
= 0.662*(.02756 /0.1)*$(58993.932)^{0.5}$ * (0.669)
= 29.646 W/m^2 K.

- Heat transferred
  Q_t = hAΔT = 29.646*5*10^{-3}*16
  = 2.372W
- Heat absorbed by PCM

$Q_p = mC\Delta T$
$= 200*10^{-3}*205*10^3*16 =$

S.no.	Time (mins)	Temperature inside the helmet (^{0}C)
1	05	35
2	10	34.5
3	15	34
4	20	34
5	30	32.5
6	40	31

656000J

- Cooling time = 656000/2.372
  = 1.5 hrs

Thus the PCM will have excellent cooling

S.No.	Speed (km/hr)	Temperature inside the helmet (^{0}C)
1	30	35
2	35	34
3	40	32
4	45	31.5
5	50	31.5
6	55	30.5

effect for a minimum drive of 1.5 hours

VI. Testing And Results

A practical test was conducted by riding a bike using our prototype and the temperature reduction inside the helmet was note. Two types of tests have been conducted. In one test for a constant time period of 30 minutes, the bike was rode at different speeds and the temperature change was noted. The results are shown in table 2. In the other test for a constant speed of 35km/hr, the time interval was varied and the results are shown in table 3.

TABLE 2 Temperature distribution at constant time of t=30 minutes

TABLE 3 Temperature distribution at constant speed of 35km/hr

VII. Practical Application & Cost

- This project is practically viable as all the parts are already available.
- The cost of the helmet would rise by Rs.50-Rs.100 and may decrease further by mass production

VIII. Advantages

- No electric power is required
- This is very simple in construction.

IX. Conclusion

After doing these suitable modifications in the helmet, we're sure that the helmet will no longer be a symbol of discomfort but would conversely promote the riders to wear it.

Acknowledgment

[1] We thank Prof. A. Rajendra Prasad, Dean (R & D), Head, Department of Mechanical Engineering, Sri Sairam Engineering College for guiding us in this project.
[2] We also thank Prof. Daddathreyan, Director, CFCT, IITM Research Park for guiding us in the design.
[3] We like to thank Mr. Vijayaramnath, Assistant Professor, Department of Mechanical Engineering, Sri Sairam Engineering College for assisting in the stress analysis.

References

[1] R.J. Buist, G.D. Streitwieser, (1988) The thermoelectrically cooled helmet, in Proceedings of the Seventeenth International Thermoelectric Conference, Arlington, Texas, pp. 88–94.

[2] L.F. Cabeza, H. Mehling, H. Hiebler, F. Ziegler, (2000) Heat transfer enhancement in water when used as PCM in thermal energy storage, Applied Thermal Engineering 22,pp. 1141–1151.

[3] B. Zalba, J.M. Marin, S.V. Belen, L.F. Cabeza, (2002) Free-cooling: an application of PCMs in TES, in: IEA, ECES IA Annex 17 3rd Workshop, Tokyo, Japan, pp.122-180

[4] N. Leoni, C. Amon, (1997) Transient Thermal Design of Wearable Computers with Embedded Electronics Using Phase Change Materials, ASME HTD-Vol. 343, pp. 49–56.

[5] B.V. Antohe, J.L. Lage, D.C. Price, J.L. Weber, (1996) Thermal management of high frequency electronic systems with mechanically compressed microporous cold plates, in: Thermal Management of Commercial and Military Electronics, Proceeding of ASME National Heat Transfer Conference, pp. 179–186.

[6] R.A. Wirtz, N. Zheng, D. Chandra, (1999) Thermal management using dry phase change materials, in: Proceeding of Fifteen IEEE Semiconductor Thermal Measurement and Management Symposium, San Diego CA, pp. 74–82.

[7] Pluss polymers official website.

[8] R.T.Ryan, (1994) Helmet materials and strength of helmets, journal vol.12, pp.121-125

[9] F.L.Tan, (2000) International journal on helmet cooling system using PCM,vol. 44, pp.23-32.

[10] Bicycle Helmet Safety Institute, Bicycle Helmet Cooling, an article on www.bhsi.org, last revised on 2005.

[11] K.C. Paarsons, Taylor and Francis (1993) Human Thermal Environments, pp.149-187

[12] Fresh Air Systems Technologies, Helmet Conversions and Airflow Improvement, an article on www.fastraceproducts.com