International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume:06 Issue:05 | May 2019 www.irjet.net p-ISSN: 2395-0072

Integration of Phase Change Material in Helmets

S. Siddesh Shenoy

Mechanical Engineering, B.M.S. College of Engineering, Bangalore, India

***

Abstract – *Helmets play a pivotal role saving human lives in a lot of road accidents. However, discomfort arises in wearing them and hence unfortunately more than half of the accident cases result in death where helmets could have saved lives. Also, during sunny days the heat buildup in the helmet further exhausts the rider. A novel, economical and simple approach is presented in this paper wherein a phase change material (PCM) from a cold storage is placed inside the helmet and when such a helmet is worn the cooling effect is felt. The amount of PCM required is calculated analytically and the time of cooling verified practically. The use of collector improves the cooling distribution from the otherwise localized cooling where the PCM would have been in direct contact with head.*

Key Words: Phase Change material, Heat flux, One dimensional steady state energy equation, Thermal resistance

1. INTRODUCTION

It is a well-known fact that wearing helmets can save a lot of lives. Yet a large number of people do not wear them. Statistical evaluation by Behera C. et al. [1] and UNECE [2] has shown that about half the cases of death in motorcycle accidents have riders not wearing helmets and also, none of the pillion drivers wore a helmet in these cases. A major reason for not wearing the helmet has been cited as the uneasiness caused by the temperature build-up inside the helmet especially in hot and humid conditions especially in tropical countries. The same has been shown in the article by Faryabi J [3]. Shinde A, et.al. [4] approached this problem by making holes in the helmet and analysing the thermal and structural factors. In this paper, another economical approach is presented to the above solution by means of introducing a “cold pack” inside the helmet and method of determining the amount of phase change material (PCM) is presented.

1.1 PCM Integration

The cold pack presented in this paper is a chain of small sachets containing PCM which efficiently stores and releases a large amount of heat i.e. a material of high latent heat capacity. Gel Frost powder is used as the PCM which is a mixture of sodium polyacrylate, paraffin C_{18} and water. It has latent heat capacity of 58.3 W h/kg. The PCM upon removing from a cold storage is placed inside the helmet as shown in figure 1. The collector here is used to contain the PCM material. It is placed in a manner such that it is sandwiched between the inner cushion and the enclosing protective foam beneath the outer shell so that direct contact of the PCM with the head does not lead to drastic localized cooling of the head at places where the scalp is in direct contact with it. Analysis is done by conductive heat transfer equations. Also, due to such an arrangement it offers an all-round cooling effect. Thus, the rider now would feel more comfortable to wear such an embedded helmet than removing it.

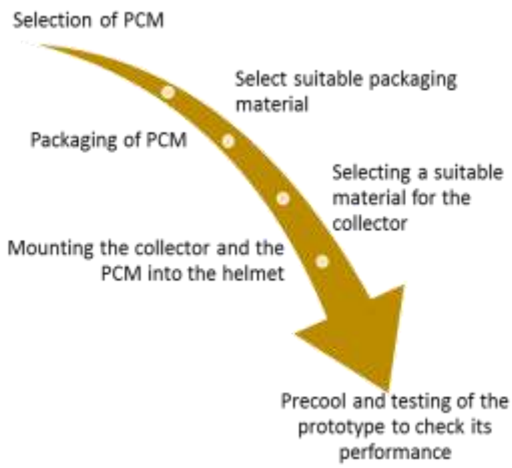

Chart 1- flowchart of PCM integration

Figure 1- PCM in plastic pouches

Figure 2- PCM with collector enclosed in fabric

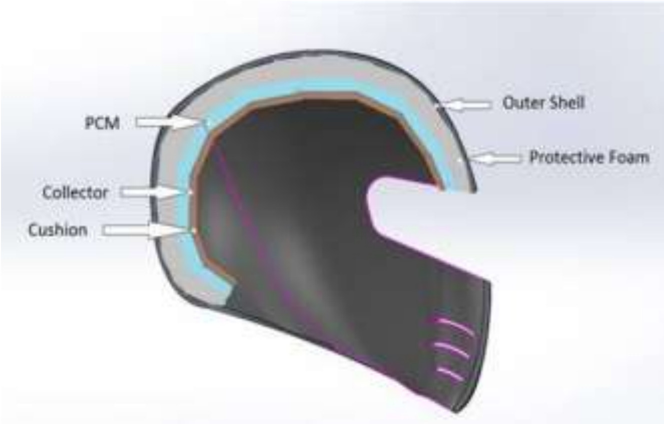

Figure 3- Setup of PCM in the helmet

1.2 Calculations

The cross-section of the helmet is as shown in figure 1. The PCM in the helmet gets heated up by 2 sources, i.e., the hotter air surrounding the helmet (ambient air), and the temperature of the head of the wearer. Generally, the heat generated by the head of the rider is 115 W/m^2, and hence about 15 W of heat is produced for an average size head.

Table -1: Thermal Properties of the helmet material

Material	Thickness (l)	Area (A)	Conductivity (K)
Shell	4 mm	0.0402	52
Foam	19 mm	0.0402	0.012
Cushion	4 mm	0.0289	1.6
Collector	2 mm	0.036	385

The amount of PCM required can be calculated by one dimensional steady state energy equation. The heat flows from the head to the PCM through the cushion and collector. Let us consider this as Q_{int}. Also, PCM gets heated due to the heat flowing from the surroundings to the PCM through the shell and the foam. Let us consider this as Q_{ext}. Now the thermal resistance of each material is calculated.

$$R_{shell}=\frac{l_{shell}}{K_{shell}A_{shell}}=\frac{0.004}{52 \text{ x } 0.0402}=1.912 \text{ x } 10^{-3}K/W$$

$$R_{foam}=\frac{l_{foam}}{K_{foam}A_{foam}}=\frac{0.019}{0.012 \text{ x } 0.0402}=39.38 \text{ K/W}$$

$$R_{cushion}=\frac{l_{cushion}}{K_{cushion}A_{cushion}}=\frac{0.004}{1.6 \text{ x } 0.0289}=0.0865\ K/W$$

$$R_{collector}=\frac{l_{collector}}{K_{collector}A_{collector}}=\frac{0.002}{385 \text{ x } 0.036}=1.443 \text{ x } 10^{-4}\ K/W$$

Thereby the heat flux is given by,

$$Q_{\text{int}}=\frac{T_{surface}-T_{PCM}}{R_{shell}+R_{foam}}=\frac{50-27.5}{(1.912 \text{ x } 10^{-3})+39.8}=0.5652 \text{ W}$$

$$Q_{ext}=\frac{T_{skin}-T_{PCM}}{R_{collector}+R_{cushion}}=\frac{29-27.5}{2.344 \text{ x } 10^{-4})+0.0865}=15 \text{ W}$$

Assuming that all the heat from head and surroundings is absorbed by the PCM for a duration of 1.5 hours, the mass of the PCM required can be calculated as follows.

$$(Q_{\text{int}}+Q_{ext})(\text{working time})=\text{mass of PCM} * \text{latent heat}$$

Latent heat = 58.3 W h/kg.

Therefore, mass of PCM = (15.5652*1.5)/58.3= 400 g = 0.4 kg. The above calculation is considering, rarer extreme case where the ambient air temperature is 50 °C. So, a cooling duration of more than 1 and a half hour hours can be expected. In fact, during trial with the ambient air temperature of 39 °C, the cooling effect was felt for 2 and a half hours.

3. CONCLUSIONS

The calculations presented are after considering, rarer, extreme case where the ambient air temperature is 50 °C. So, a cooling duration of more than 1 and a half hour hours can be expected. During trial with the ambient air temperature of 39 °C, the cooling effect was felt for 2 hours which is more than average duration of a regular motorcycle rider. Thus inclusion of PCM in a helmet is a more economical approach in mitigating the discomforts that the motorcycle rider would otherwise face during hot sunny days.

REFERENCES

[1] Behera C, Rautji R, Lalwani S, Dogra TD, "A comprehensive study of motorcycle fatalities in South Delhi", J Indian Acad Forensic Med. 2009, 31:6–10.

[2] The United Nations Motorcycle Helmet Study, UNECE, New York and Geneva, 2016.

[3] J Faryabi, M Rajabi, S Alirazaee, "Evaluation of the Use and Reasons for Not Wearing a Helmet by Motorcyclists Admitted to the Emergency Ward of Shahid Bahonar Hospital in Kerman", Arch Trauma research article, DOI: 10.5812/atr.19122.

[4] I Khan, A Shinde, S Khandelwal, V Sah et.al.,"Finite element analysis on different materials for motorcycle helmet shell", International Research Journal of Engineering and Technology, Vol:6, Issue:5, May 2019.

BIOGRAPH

S. Siddesh Shenoy
Dept of Mechanical Engineering
B.M.S.C.E.
Bangalore