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Research Article

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Thermal Comfort of Riding Helmet with the Incorporation of Phase Change Material in a Novel Encapsulation Position - A Comparative Study

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Abstract

Aim: The primary goal of this study is to evaluate the thermal comfort of a typical riding helmet by incorporating commercial phase change material (PCM) (CR+28).

Method: In this project, CR+28 with a latent heat of 180 kJ/kg was employed, with a thermal conductivity range of (0.5 - 1.1) W/m-K, and a phase transition temperature range of 26 to 28 °C. Standard riding helmets were used for group 1, while group 2 consisted of standard riding helmets with CR+28 incorporated as a sustainable PCM. There were 20 samples in each group, with the sample size calculation performed using G-power with a power of 80%, $\alpha = 0.05$ per set, resulting in a total sample size of 40.

Results: The addition of CR+28 to the helmet increased thermal comfort by 9.19% when compared to the standard riding helmet without CR+28. According to statistical t-test analysis, there was a significant difference in the mean-variance of thermal comfort between group 1 and group 2, with a p-value of 0.001 ($p < 0.05$).

Conclusion: Within the constraints of this study, it is evident that the addition of CR+28 significantly boosts thermal comfort inside the helmet.

Keywords

Thermal comfort, Sustainable phase change material, Helmets, Novel encapsulation, Energy storage systems, Solar cooling

Introduction

In this experiment, the standard riding helmet and helmets encased in salt hydrate PCM will be compared. Salt hydrate PCM which absorbs and releases enough heat during the phase transition to allow for the analysis of internal thermal temperature using a resistance temperature detector (RTD) sensor [1]. More of a problem is the temperature discomfort that cyclists experience in a variety of environmental circumstances. The external surface of the helmet is exposed to direct solar insulation, which is more intense during the day and can be partially mitigated by installing an internal cooling system. The inside of the helmet gets hotter because of the tightly packed interior space between the wearer's head and the helmet. This internal heat pressure may have an effect on the head, resulting in hair loss. Applications for PCMs include solar cooling and solar power plants, photovoltaic energy systems, the space industry, waste heat recovery systems, food and pharmaceutical product preservation, and household hot water [2].

Over the last 5 years around 1260 papers and roughly 1670 papers based on PCM are listed on Google Scholar and Science Direct, respectively. With nanographene/paraffin composites, the influence of PCM encapsulated in helmets

to enhance heat transfer [3]. Researchers have looked into adding nanoparticles like copper oxide, aluminum oxide, and titanium dioxide to PCMs to improve the thermal comfort of helmets [4]. The essential impact of PCMs, to design a helmet model by cooling technology with PCM has been investigated [5-7].

It has been noticed that limited studies have been done on PCM with novel encapsulation techniques. This study explained how to improve the thermal comfort of a riding helmet by addition of PCM. The study has been conducted to compare the thermal comfort of standard riding helmet and riding helmet with PCM.

Materials and Method

The Institute of Mechanical Engineering, Saveetha Industries, Saveetha School of Engineering, Saveetha Institute of Medical and Technical Sciences, Thandalam, Chennai (Tamil Nadu, India), performed the sample preparation and encapsulated PCM samples according to the specifications. The two groups that contributed to this study to ascertain thermal comfort were the standard riding helmet and the standard riding helmet with PCM. The thermal comfort qualities of a standard riding helmet and a helmet with PCM were compared in the investigation. With one repeat in each group for comparative purposes, a total of 40 experiments were conducted on each sample or group to assess the thermal comfort by injecting phase change material. G-power was determined to be 80% while carrying out samples on each group of 20 sizes.

The standard riding helmets are taken as a group 1 (Control). Normally it has four layers, including an outside layer, fibre shell which readily absorbs solar heat, expanded polystyrene, and an inside headband. Styrene monomer is used to make expanded polystyrene. The inside headband is made up of several different materials or fabrics. Keep the helmet in one place without any disturbance. Measure the inside temperature of the helmet every 15 min to examine thermal comfort by using an RTD sensor. Repeat the process and note down the readings every 15 min for 20 samples in each group.

The riding helmet with PCM at their latent heat of 180 kJ/kg and thermal conductivity ranges from (0.5 - 1.1) W/m-K as a group 2 (Experimental). In figure 1, PCM was poured into pouches. In figure 2, the pouch was inserted between the expanded polystyrene and inner headband after pouring PCM. In figure 3, the inserted PCM pouch was inserted into the helmet. In figure 4, measure the inside temperature of the helmet every 15 min to determine the thermal comfort of the helmet. Repeat the process every 15 min and take up the reading for every 20 samples in each group.

A salt hydrate PCM (CR+28) at a latent heat of 180 kJ/kg has a phase transition temperature of 26 - 28 °C and a thermal conductivity ranging from 0.5 - 1.1 W/m-K, respectively. A RTD is used to measure resistance changes as its temperature changes. By using this RTD to analyze the interior temperature changes of normal helmets and helmets with PCM, the interior heat temperature of group 1 and group 2 samples can be found. The interior heat temperature was measured using

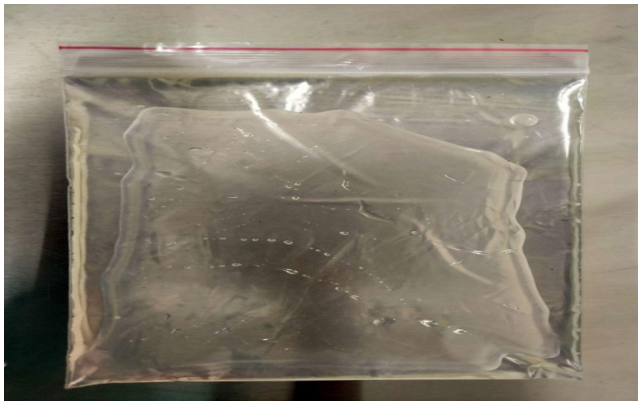


Figure 1: PCM pouch.



Figure 2: PCM placed between expanded polystyrene and inner headband.



Figure 3: PCM placed inside the helmet.



Figure 4: Measuring inside temperature.

RTD for group 1 and group 2. The interior temperature is determined using the formula T is R*(T1 - T0) + T0, where T = temperature, R = RTD sensor, T is formulature of the environment, T1 is Temperature of the object.

Statistical analysis

For use in data management, data analysis, mathematical modeling, and other statistical tasks, IBM developed the statistical programs SPSS (Statistical Package for the Social Sciences). The t-test is used in the thermal comfort assessment created for the research samples using the SPSS statistical analysis program. The descriptive table, as well as the Bonferroni studies, are all carried out using the statistical programs SPSS. In this study, the dependent variable is thermal comfort and weightage percent of PCM is independent variables. The study also provides mean statistics, significance levels, and standard deviation data [3].

Results

Table 1 shows the thermal comfort of a standard riding helmet without PCM and riding helmet with PCM. Table 2 shows the group statistics of thermal comfort in standard riding helmet without PCM and riding helmet with PCM. Table 3 shows the independent samples test of thermal comfort. Table 4 shows the descriptives of the thermal comfort as standard riding helmet without PCM and riding helmet with PCM. As a result, the thermal comfort is recorded in the two group's tables.

Discussion

According to the research, the PCM with helmet has higher thermal comfort more significantly than the PCM without helmet. To simplify the process, the descriptive table shows the mean, standard deviation, standard error, etc., to make the steps easier to understand. It makes it possible to quickly calculate thermal comfort for analysis. Previously, the study on the PCM used in football helmets to increase thermal comfort [8]. Another work on novel PCM on storage tanks to maintain the thermal comfort energy in HVAC systems [9].

Table 1: Thermal comfort of standard riding helmet with PCM and without PCM.

S.No.	Inside temperature after 30 min with PCM	Inside temperature after 30 min without PCM
1	33.96	36.95
2	33.98	36.98
3	33.94	36.97
4	33.99	36.95
5	34.01	36.99
6	34.03	37.02
7	34.02	37.08
8	34.04	37.11
9	34.05	37.16
10	33.95	37.17
11	33.97	37.19
12	34.13	37.22
13	34.17	37.32
14	34.11	37.33
15	34.06	37.25
16	34.1	37.28
17	34.12	37.29
18	34.14	37.34
19	34.16	37.42
20	34.09	37.41

Table 2: Group statistics of thermal comfort in standard riding helmet without PCM and with PCM.

Group		N	Mean	Std. deviation	Std. error mean
Thermal comfort	Inside temperature with PCM	20	34.051	0.07319	0.016366
	Inside temperature without PCM	20	37.1695	0.154595	0.034569

This study shows the applications and advantages of PCM to improve thermal energy comfort [10]. The effect of novel PCM contained in helmets has been researched using nanographene/paraffin composites [3]. PCMs may benefit from the addition of nanoparticles like copper oxide,

Table 3: Independent samples test of thermal comfort in standard riding helmet without PCM and with PCM.

		Levene's test for equality of variances		T-test for equality of means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean difference	Std. error difference	95% CI of the difference	
									Lower	Upper
Thermal comfort	Equal variance assumed	13.81	0.001	-81.53	38	0.000	0.001	-3.118	0.0382	-3.1959
	Equal variance not assumed			-81.53	27.1	0.000	0.001	-3.118	0.0382	-3.1969

Table 4: Descriptives of the thermal comfort as standard riding helmet without PCM and with PCM.

	N	Mean	Std. deviation	Std. error	95% CI for Mean		Minimum	Maximum
					Lower bound	Upper bound		
Inside temperature with PCM	20	34.051	0.07319	0.01637	34.0167	34.0852	33.94	34.17
Inside temperature without PCM	20	37.1695	0.1546	0.03457	37.0971	37.2418	36.95	37.41
Total	40	35.6103	1.58362	0.25039	35.1038	36.1167	33.94	37.41

aluminum oxide, and titanium dioxide to increase thermal comfort in helmets [4]. It has been researched how PCMs are fundamental to designing a helmet model using cooling technology and novel PCM [5]. The addition of a cutting-edge novel will increase the thermal comfort of the energy storage system's thermal conductivity [11, 12].

In figure 5, it is observed that the helmet has 9.19% more thermal comfort than the helmet without PCM and also has a significance value around p = 0.001 which is p < 0.05. As an outcome, a composite with a substantially more thermal comfort by adding novel PCM on the helmet was generated.

The long-term objective of this research is to keep objects and materials cold by cooling telephones, switching boxes, and clothing, as well as by protecting them from the heat of the sun and higher temperatures. So, PCM has the ability to change the material phases. Other limitations of PCMs include their limited phase change temperature, restricted thermal conductivity, cost and availability, deterioration and cycle, and volume change during phase change.

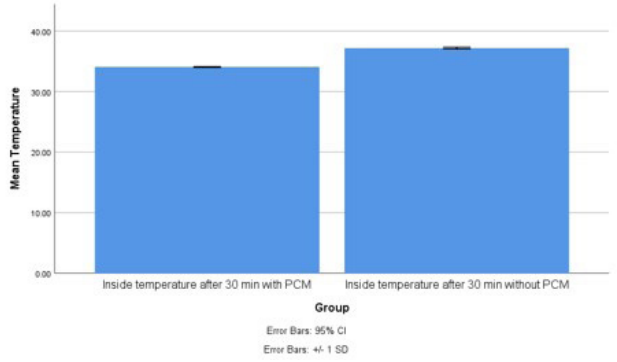


Figure 5: Mean thermal comfort is compared with and without PCM. The mean value shows that the thermal comfort of a helmet with PCM had a maximum value of 9.19% more than the helmet without PCM with +/-1 standard deviation. X-axis means PCM temperature at different times and Y-axis means mean temperature.

Conclusion

The innovative encapsulating PCM boosts the thermal comfort of the helmet. In comparison to PCM without helmet, addition of PCM on helmet increased thermal comfort by over 9.19%. The thermal comfort of the helmet with PCM was significantly influenced by a unique encapsulation approach. The space industry, solar cooling, photovoltaic electricity systems and PCM may be used in these fields due to its improved thermal comfort.

Acknowledgements

None.

Conflict of Interest

None.

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