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A passive thermal energy storage system for laptop cooling using phase change material

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Abstract

The main problem with laptop computers is overheating of its components which may affect the performance and stability of the components. The objective of this research work was to develop and test the effectiveness of thermal energy storage system for cooling of laptop to overcome overheating problem and to improve the comfort level of the users while using laptop on their lap. The proposed TES system contains phase change material HS-207, a mixture of hydrated salts (Manufactured by Green High Tech Energy Limited, India) that reduces the temperature of components of the laptop and protect user's lap from overheating. It was found in this study that, under general utilization situation, the temperature of core 1 & core 2 of the processor and hard disk of the laptop could increase to 50°C, 41°C and 42°C respectively. The proposed TES system could bring down the temperature of core 1 & core 2 and hard disk by up to 10°C, 4°C and 5°C respectively. The rate of heating of components was decreased appreciably upon using TES system. The rate of heating of core 1, core 2 and hard disk was decreased by 65.44%, 51.92% and 54.67% respectively while using TES system.

Keywords: laptop computer, overheating; cooling; phase change material, thermal energy storage.

Abbreviations

TES	Thermal energy storage
PCM	Phase change material

Introduction

Due to the consumer demand advancement in processor speed of the laptop is increased rapidly which lead an increase in heat generation which may affect the performance and stability of the components, sometimes it lead to hardware fatality and system crash. In traditional laptop cooling system metal heat pipes and fans are used to control the heating rate of the laptop components. The use of fans has disadvantage as they need more space and extra power to operate [1]. The compression of laptops will not allow more fans, or increased fan size to control the temperature and hence need an external cooling system.

TES is a process to conserve huge amount of thermal energy in different forms that can be utilized further for many applications [2]. TES is a good choice to control the temperature of the laptop because it has many advantages like high storage capacity, low cost and hazard free nature [3]. There are different TES systems are available [4-6]. Thermal energy may be stored in the form of sensible heat or latent heat [7]. Latent heat storage in PCM is much effective than sensible heat storage due to their low cost [8]. PCMs are an excellent choice for thermal management as they don't require any power. PCMs are the materials used to store latent heat energy during phase transition at a constant temperature [9-12]. The biggest advantages of PCMs are they have high thermal storage capacity and have a constant phase change temperature.

The most popular PCM used are hydrated salts, paraffin waxes and their eutectics [13]. Hydrated salts are the most common PCMs that have been studied on a large scale because of their extensive use in latent heat storage systems. The advantages of hydrated salts are (i) high latent heat of fusion per unit volume (ii) small change in volume during melting and freezing, and (iii) high thermal conductivity relative to paraffin waxes [14]. Hydrated salts are not very corrosive and toxic.

In 2015, Mohammed A. Bou-Rabee et. al., studied the thermal behavior inside laptop computers and tested the performance of a new cooling system. The proposed system was found to be able to reduce the GPU's temperature by 6°C [15]. In 2011, Russell et al., prepared a notebook computers cooling pad using PCM (a paraffin wax manufactured by Shell, with a melting temperature of around 27°C) and reported an increase in the comfort operation time extended to 5.5 hours ± 0.2 hours of the laptop by more than four times [16]. In 2010, Randeep Singh et. al., investigated two different designs of miniature loop heat pipes to control the temperature of notebook computers. The miniature loop heat pipes can serve as a potential replacement for the mechanically actuated liquid cooling system and passively operating conventional heat pipes for high-heat flux applications [17].

Although, ample research work has been done in the field of PCM over the last few years, still limited research was concerned with the passive cooling of laptops. In the present work, a passive TES system for laptop cooling was developed and tested to protect user's lap from excess heat and to control the temperature of the components of laptop to improve their life.

Experimentation

Construction of TES system

A DELL Vostro dual core processor laptop was used in this study. 1mm thick stainless steel sheet was used to construct a 32cm×22cm×1cm TES system for laptop cooling. The system was filled with PCM HS-207 a mixture of hydrated salts (Manufactured by Green High Tech Energy Limited, India).The melting temperature of PCM HS-207 is 30°C.

Thermophysical properties of PCM HS-207

The thermophysical properties like the phase change temperature and the latent heat of fusion of PCM HS-207 were investigated by differential scattering calorimetry (DSC) [Mettler Toledo]. The accuracy and temperature precision of the instrument was ±0.2K and ±0.02K respectively. Figure 1 represents the DSC curve of PCM-HS207. The peak represents the solid-liquid phase change temperature [18].

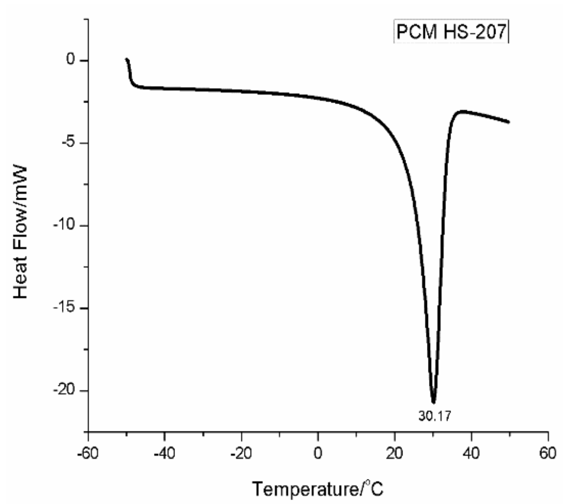

Figure 1: DSC curve of PCM-HS207

Thermal cycle testing of PCM-HS207

The thermal cycle testing was carried out to investigate the change in phase change temperature and latent heat of fusion of PCM-HS207 for a large number of thermal cycles which defines the stability of the PCM [19] and life of system. For thermal cycle testing melting and freezing of PCM-HS207 was repeated for many times. The DSC analysis for 350 cycled PCM-HS207 was performed.

Results and discussion

The phase change temperature and latent heat of fusion of non-cycled and 350 cycled PCM-HS207 were determined by using DSC and listed in table 1.

Table 1: Thermophysical properties of non cycled and 350 cycled PCM HS-207

Sample	Phase change temperature,° C	Latent heat of fusion, KJ/Kg
Non cycled PCM-HS207	30.1706	238.0617
350 cycled PCM-HS207	30.1706	232.9914

From the experimental results, it was observed that after 350 thermal cycles, the phase change temperature of the PCM-HS207 had no change and the latent heat of fusion was decreased by

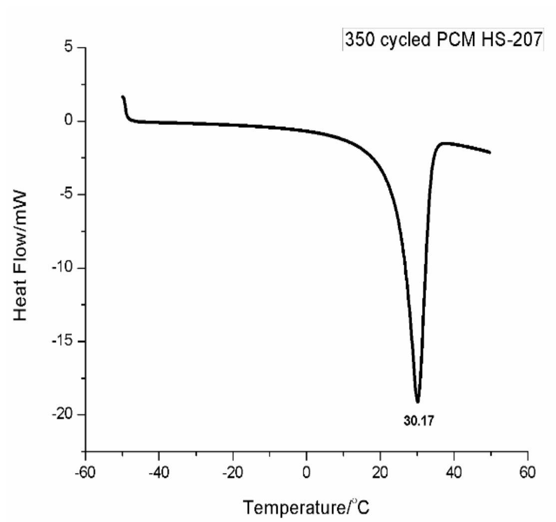

Figure 2: DSC curve of 350 cycled PCM-HS207

5.073 KJ/Kg. From the above results we may conclude that PCM- HS207 maintains a good thermal stability [20] even after 350 accelerated thermal cycles. Figure 2 shows the DSC curves of 350 cycled PCM-HS207.

Heat transfer analysis of laptop

The effectiveness of heat transfer by the TES system was tested by placing the TES system at the bottom of the laptop. The temperature of components of the laptop, i.e., core 1 & core 2 of the processor and hard disk was measured by using CPUID HW Monitor Software. During the experiment PCM HS-207 absorbed heat as latent heat of fusion from components of the laptop at a constant temperature and changes its phase from solid to liquid, which is called charging of the PCM. When temperature fell PCM changes its phase from liquid to solid by releasing absorbed heat, which is called discharging of the PCM.

Heat transfer analysis of components of laptop is summarized in table 2 and rate of heating of components is described in table 3. As shown in table 2, maximum temperature of components was higher when cooling of laptop was occurs due to its own cooling system, i.e. without using TES system and the temperature was lower when using TES system. Maximum temperature of core 1, core2 and hard disk was decreased by 4 °C, 5°C and 10°C respectively upon using TES system.

We may conclude from table 3 that the rates of heating of components were decreased appreciably upon using TES system. The rate of heating of core 1, core 2 and hard disk were decreased by 65.44%, 51.92% and 54.67% respectively upon using TES system. We may conclude from the above results that the passive TES system prepared in this research work is very effective to control the temperature of components of the laptop which results an improvement in user's comfort level while using laptop on their lap.

Table 2: Heat transfer analysis of components of laptop

Components	Condition	Initial temp., °C	Maximum temp., °C	Time., min
Core 1	Without using TES system	28	41	60
	Upon using TES system	28	37	115
Core 2	Without using TES system	28	42	90
	Upon using TES system	28	37	120
Hard disk	Without using TES system	29	50	70
	Upon using TES system	29	40	80

Table 3: Rate of heating of components of laptop

Component	Rate of heating, °C/min	
	Without using TES system	Upon using TES system
Core 1	0.217	0.078
Core 2	0.156	0.075
Hard disk	0.300	0.136

Figure 3, 4 and 5 shows the temperature measurement with time of core 1, core 2 and hard disk of the laptop, without using TES system and by using TES system filled with PCM HS-207.

We can see in figure 3 that the maximum temperature of core 1 reached at 41°C in 60 minutes without using TES system and maximum temperature of core 1 reached at 37°C in 115 minutes while using TES system. It is clear from the above results that upon using TES system, the maximum temperature of core 1 was decreased by 4°C and also the time to reach at maximum temperature was increased by 55 minutes.

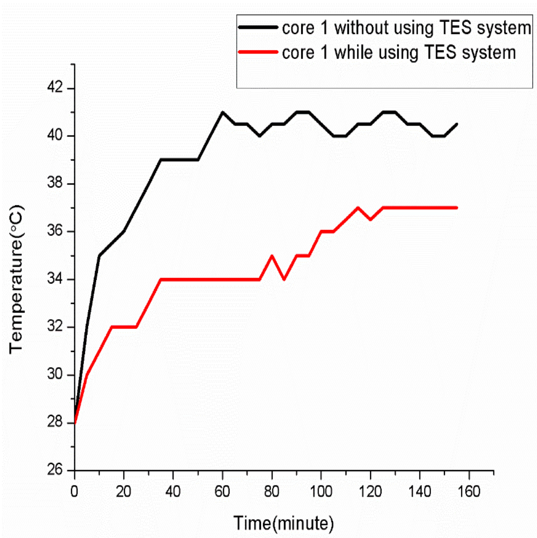

Figure 3: Temperature measurement of core 1 of the processor

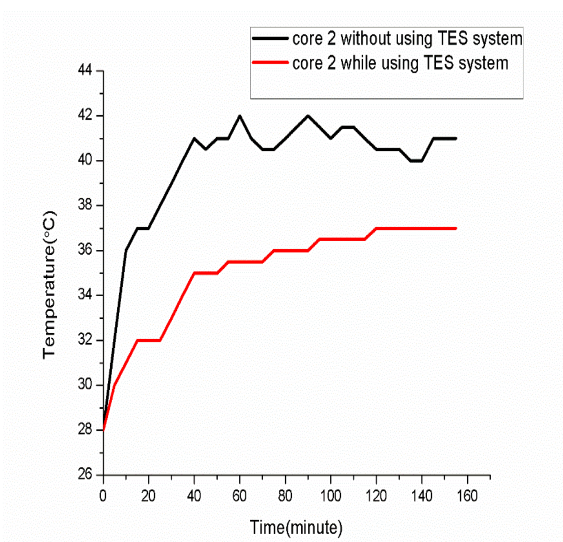

Figure 4: Temperature measurement of core 2 of the processor

From figure 4 it is clear that the maximum temperature of core 2 was 42°C reached in 90 minutes without using TES system and maximum temperature was 37°C reached in 120 minutes while using TES system. It is clear from the above results that upon using TES system, the maximum temperature of core 2 was decreased by 5°C and also the time to reach at maximum temperature was increased by 30 minutes.

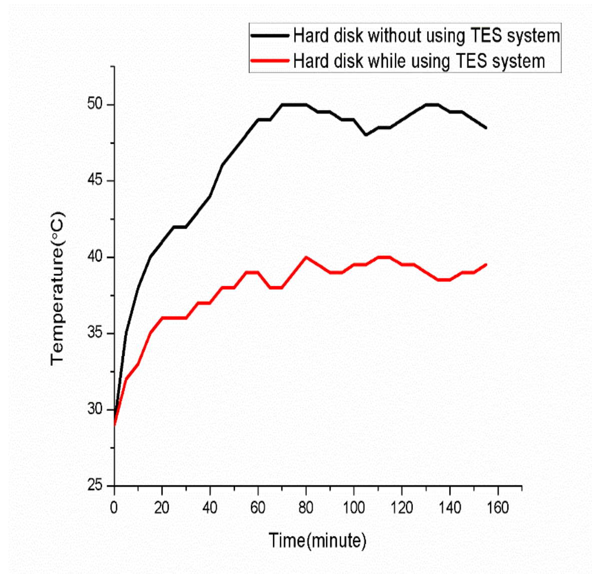

Figure 5: Temperature measurement of hard disk of the laptop

Also from figure 5 it is clear that the maximum temperature of hard disk was 50°C reached in 70 minutes without using TES system and maximum temperature was 40°C reached in 80 minutes while using TES system. It is clear from the above results that upon using TES system, the maximum temperature of hard disk was decreased by 10°C and also the time to reach at maximum temperature was increased by 10 minutes.

Conclusion

A passive TES system for laptop cooling was developed and tested to control the temperature of the components of laptop and to protect user's lap from excess heat. The maximum temperature of components of laptop, i.e., core 1, core 2 and hard disk was decreased by 4°C, 5°C and 10°C respectively upon using TES system. The rate of heating of components was decreased appreciably upon using TES system. The rate of heating of core 1, core 2 and hard disk was decreased by 65.44%, 51.92% and 54.67% respectively while using TES system. The above results concluded that the performance and stability of components of laptop may be increased by lowering their operating temperature and there was an improvement in user's comfort level while using laptop on their lap, while using TES system.

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