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Electronic Cooling Using Heat Pipe With Paraffin Wax As Pcm

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Abstract : Generally, the commercial and industrial electronic devices are required to be operated under less than 80°C. Therefore, there is need to remove heat effectively from these devices under different loading conditions. Phase Change Material (PCM) based heat sinks are emerging as one of effective techniques for removal of heat from the electronic devices. This study has been undertaken to investigate the behavior of PCM for cooling of electronic devices. It includes effect of PCM and their thermal performance under different heat load conditions. Working fluid in heat pipe and PCM both absorb large amount of latent heat, Therefore heat pipe with PCM can store and transfer heat effectively. Temperature difference of 5°C to 29°C was obtained by using heat pipe with PCM for different load conditions.

IndexTerms – Heat pipe, PCM.

1.INTRODUCTION

Energy efficiency plays an important role in curbing global demand of energy. Though global energy needs rise more slowly than in past but still projected to expand by 30% between 2017 and 2040[1]. Electronic industry is one of the most energy consuming sector. The major cause of electronic chip failure is due to temperature rise (55%) as against other factors which are 20% vibration, 19% humidity and 6% dust [2]. In electronic applications, using PCM for thermal control of electronic devices can offer a great advantage by stabilizing the temperature for a long period and improving its life.

Moon, et. al., [3], performed experiments on a miniature heat pipe (MHP) with woven wire wick which was used for cooling a notebook PC. Testing of thermal performance of MHP by reducing its diameter was carried out. Mozumder, et. al., [4], conducted experiment to determine the performance of heat pipe with varying working fluid and fill ratio. Overall heat transfer coefficient was found to be maximum for acetone as working fluid and fill ratio greater than 85% of volume of evaporator shows better result.

Kandasamy et. al., [5], developed a novel PCM based thermal management system for an electronic device and studied the effect of parameters such as heat input, orientation, and various melting/freezing times under cyclic steady conditions. Baby, et. al., [6], performed an experimental investigation of thermal performance of different configurations of PCM based heat sink. The phase change materials used were paraffin wax and n-eicosane. Tan, et. al., [7], conducted experimental study on cooling of electronic devices such as personal digital assistants (PDA's) and wearable computers. In experimentation heat storage unit (HSU) filled with PCM of n- eicosane inside the device was used.

Mesholly, et. al., [8], observed that the thermal conductivity of PCMs is very low, which causes decrease in the effectiveness of heat sinks by slowing down the heat absorption. To overcome this problem, some heat transfer enhancement techniques were employed, such as micro-encapsulation of PCM, dispersed high thermal conductivity particles, incorporating porous matrix and extending fins inside the PCM. Prabhu, et. al., [9], analyzed various phase change materials, their properties and characteristics. It was observed that organic PCMs have high heat of fusion, Inorganic PCMs have high thermal conductivity and Eutectics have volumetric storage density slightly above organic PCMs.

Weng, et. al., [10], described novel heat module with tricosane as PCM for electronic cooling performance under different operating condition. He found that PCM module automatically adjusts the heat transfer rate for cooling electric device, in a manner that is dependent on PCM mass, fan voltage and heater temperature. Kumar, et.al., [11], investigated thermal performance of Nano Embeded Phase Change Material (NEPCM) heat sink assisted by heat pipe for electronic cooling of personal computers. It was found that heat pipe with NEPCM heat sink decreased the temperature of heaters surface plate by 3°C for six hours of application without the help of electronic fan i.e forced convection. Behi, et. al., [12], developed a CFD model and validated the same to assist the model. It was found that the PCM-assisted heat pipe provided up to 86.7% of the required cooling load in the working power range of 50–80 W. Many researchers have already worked on use of PCMs for electronic cooling. Tricosane and n-eicosane are already used by many researchers. This experimental study analyzes use of paraffin wax as PCM used at middle section of heat pipe.

2.EXPERIMENTAL METHOD

The experiment investigates the thermal performance of PCM assisted heat pipe and compares it with the thermal performance of heat pipe under varying heat loads for natural as well as forced convection. The temperature measurement locations for the experimental setup without PCM and with PCM are shown in Figure 1. T_1 is heater temperature. T_2 is temperature after evaporation section. T_3, T_4 and T_5 are temperature at condensation section. T_6 is ambient temperature. T_7, T_8 and T_9 are temperature at evaporation section.

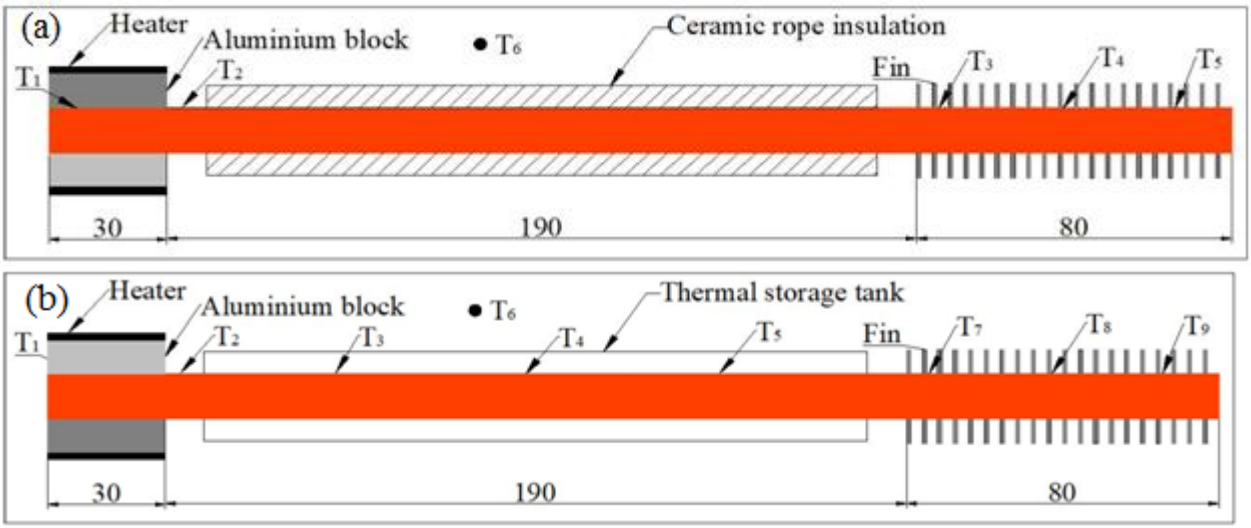

Figure 1 Temperature measurement locations (a) without PCM (b) with PCM

A cylindrical copper heat pipe with operating temperature range of 30°C to 120°C having water as a working fluid is used. The diameter of heat pipe is 12mm with a length of 300mm, evaporator length of 30mm and condenser length of 80mm. Sintered copper is used as wick material in the heat pipe. Circular fins of outer diameter 25mm and thickness of 1mm are attached on the condenser section. Distance between subsequent fins is 3mm. The fin on the condenser section is made of aluminium. There are 20 such fins placed on the condenser section. The different operating conditions for which the observations are taken are shown in Table No. 1 .

Table 1 Operating conditions

Convection type	Operating condition	Heating load	Heating & Cooling cycle
Natural	With PCM	15W, 30W, 45W	10min
	Without PCM	15W, 30W, 45W	10min
Forced	With PCM	30W, 45W, 60W	10min
	Without PCM	30W, 45W, 60W	10min
Forced	With PCM	55W	20min
	Without PCM	55W	20min

Experimental setup of heat pipe without PCM storage tank is shown in Figure 2.

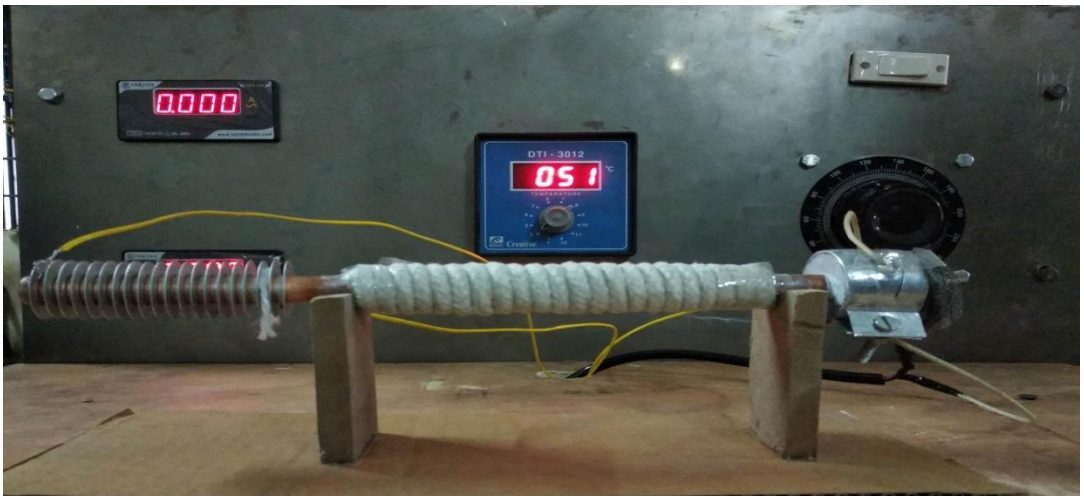

Figure 2 Experimental setup of heat pipe without PCM storage tank

Nozzle heater of 30mm length and 30mm diameter is used for heat supply. K- type thermocouples connected to temperature indicator are used to measure temperature at various locations of heat pipe. Thermocouple T_1 and T_2 are located at the evaporator section whereas thermocouple T_3, T_4 and T_5 are located inside the PCM storage tank. Thermocouple T_7, T_8 and T_9 are located at the condenser section of heat pipe. Thermocouple T_6 measures ambient temperature.

The PCM used is paraffin wax whose melting point ranges from 45°C to 68°C. The storage tank is made of acrylic with maximum storage capacity of 220cc. Surface area of evaporator section is 1130 mm^2. Experimental setup of heat pipe with PCM storage tank is shown in Figure 3.

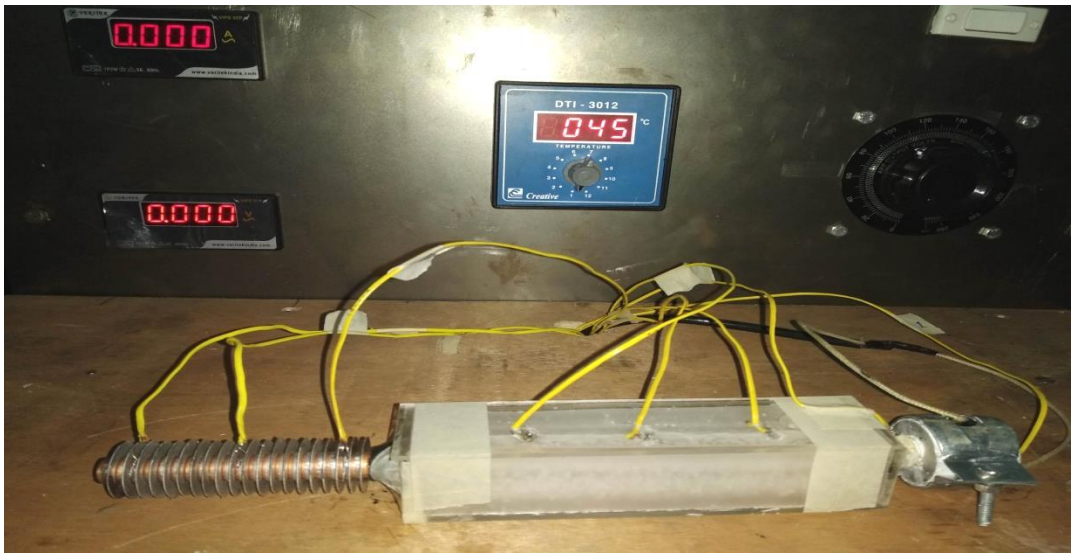

Figure 3 Experimental setup of heat pipe with PCM storage tank

3. RESULTS AND DISCUSSION

3.1 Natural Convection

In case of natural convection heat is not dissipated quickly this results in fast increase in temperature of heater. In case of heat pipe with PCM this increased temperature is used by PCM in middle section of heat pipe. It absorbs heat which in turn helps in maintaining evaporator temperature.

As shown in Figure 4, for 15W there is no considerable difference between both the setups. In first cycle temperature difference is of 6°C. This temperature difference is decreased in subsequent cycles.

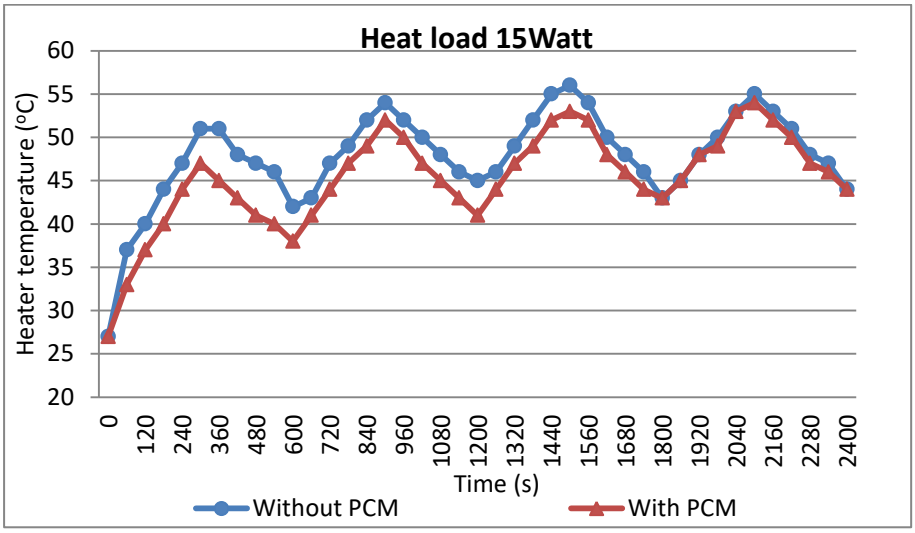

Figure 4 Temperature variations for natural convection at 15W

In case of natural convection without PCM and with PCM for 30W heat load, the temperature difference is nearly constant. For first cycle the maximum peak temperature difference is 11°C. This difference is nearly same for subsequent cycles. In case of 40W heat load nature of graph is same as that of 30W, with the maximum peak temperature difference for first cycle being 14°C. This temperature difference increased and remained in the range of 25°C to 30°C for subsequent cycles as it is seen from Figure 5.

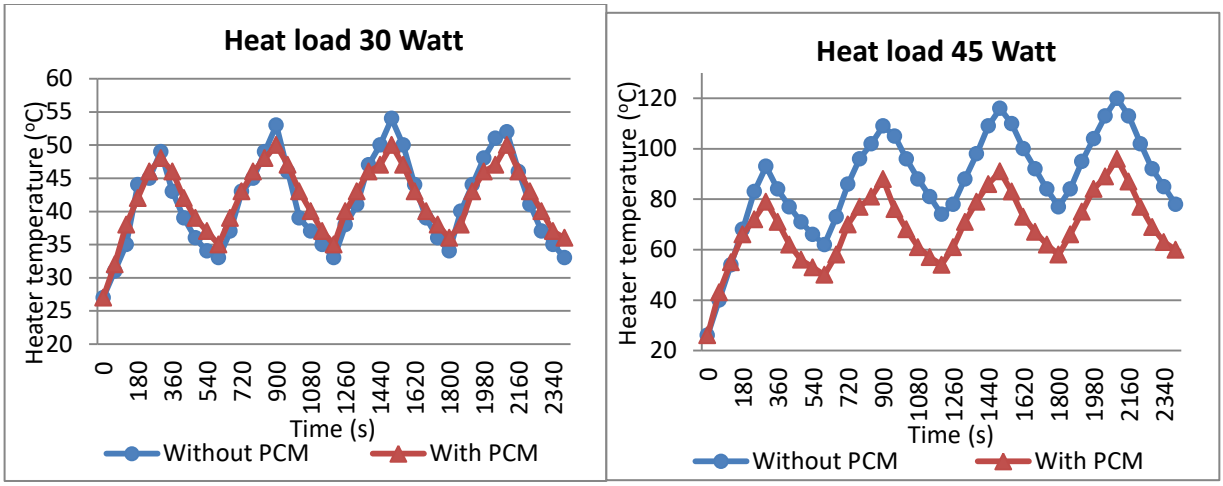

Figure 5 Temperature variations for natural convection at 30W and 45W

3.2 Forced Convection

As shown in Figure 6, in case of forced convection, temperatures attained by heater are less than those in natural convection. There is no considerable difference in heat pipe with PCM and heat pipe without PCM for lower loads such as 30W and 45W, which is only in range of 0°C to 8°C.

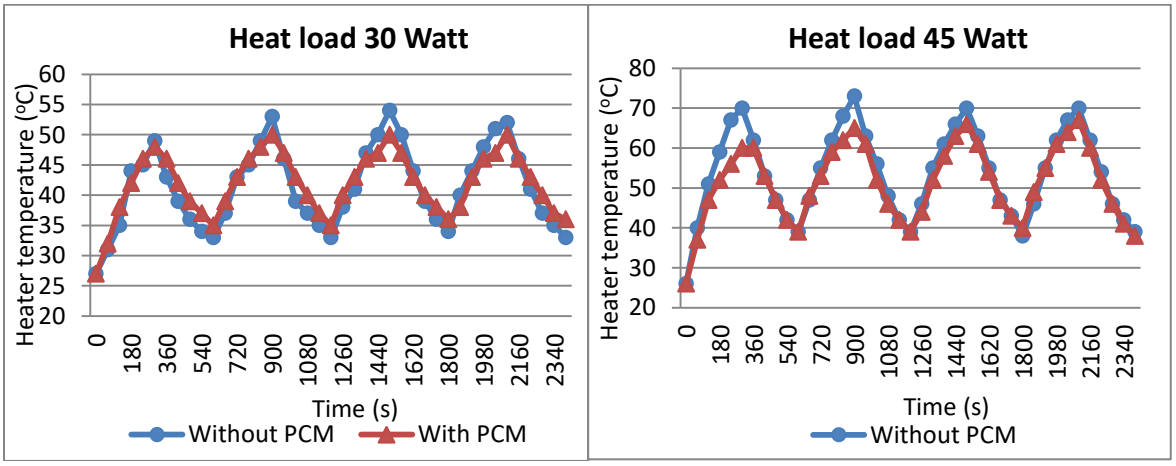

Figure 6 Temperature variations for forced convection at 30W and 45W

In case of heat load of 60W, temperature difference is between 8°C to 13°C. From Figure 7, temperature variation for every cycle is nearly same.

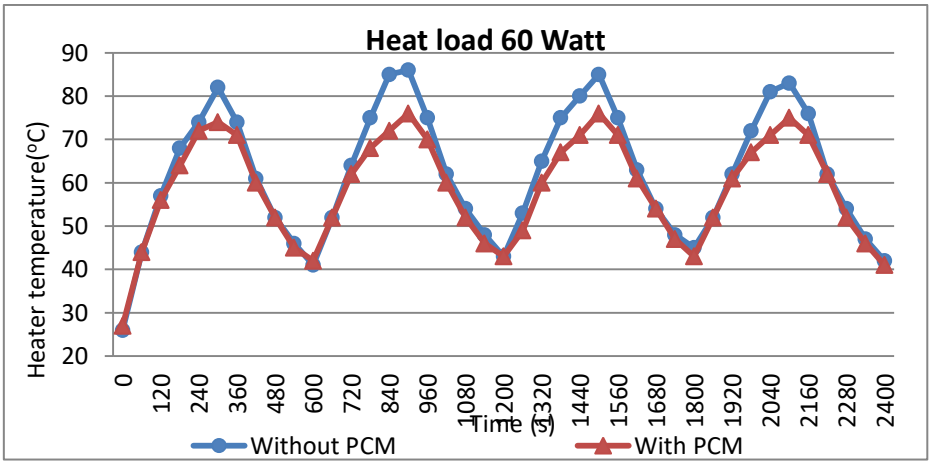

Figure 7 Temperature variations for forced convection at 60W

When heating and cooling cycle is doubled (20 minutes), there is steep increase in heater temperature as shown in Figure 8 which is up to 106°C but heat pipe with PCM gives better performance maintaining temperature difference of 11°C to 17°C at peak value

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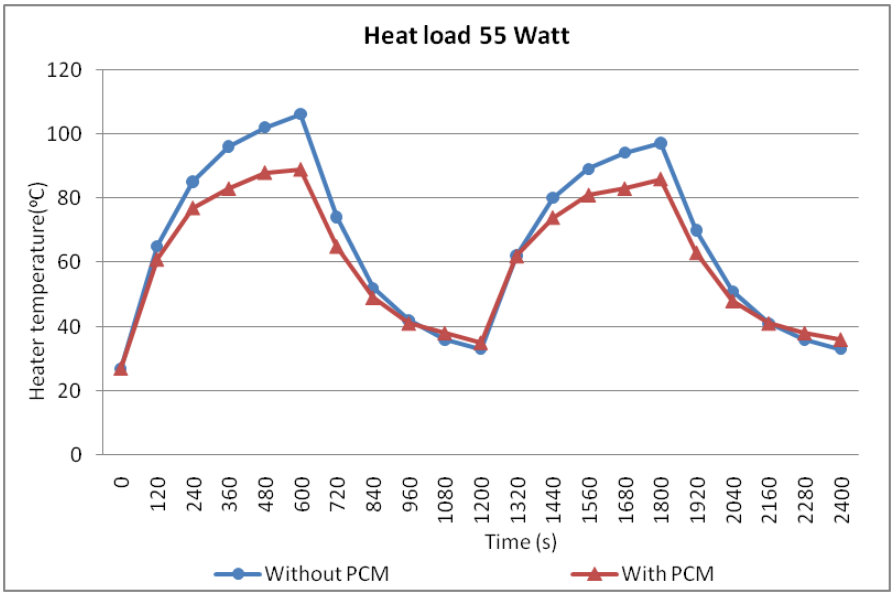

Figure 8 Temperature variations for forced convection at 55W with 20 minutes cycle

4. CONCLUSIONS

When similar experimental conditions are maintained, maximum temperature attained by heater increases with increase in heating load. In case of forced convection, convective heat transfer coefficient at condenser increases which dissipates more amount of heat than that in natural convection. Therefore maximum temperature attained in case of forced convection at 30W (54°C) and 45W (73°C) is less than that in natural convection. (83°C and 120°C)

When PCM is used at middle section, it melts by absorbing latent heat, which decreases heater temperature. Melting of PCM is necessary for getting better result, if heat supplied is less, then PCM will not melt and heat pipe with PCM will give same result as in case of heat pipe without PCM. Therefore in case of 15W natural and 30W forced convection less peak temperature difference is attained between heat pipe with PCM and heat pipe without PCM.

As heat load is increased, more amount of PCM is melted, which absorbs more energy. Therefore in case of 30W, 45W natural convection maximum peak temperature difference is 13°C and 29°C, which is much more than that in 15W natural convection (6°C). Similarly in case of 45W and 60W forced convection maximum peak temperature difference attained is 11°C and 13°C which is more than that attained in 30W forced convection which is 4°C. This is summarized in Table No. 2.

Table 2: Maximum temperature difference attained

Operation model	Heating load (Watt)	Heating-cooling cycle time (minute)	Maximum peak temperature difference at heater with PCM and without PCM (°C)
Natural Convection	15	10	6
	30		13
	45		29
Forced Convection	30		4
	45		11
	60		13
	55	20	17

If heating and cooling cycle time is doubled (20 minutes), it will supply heat for more time which will increase temperature of PCM in storage tank. This helps in more heat removal from heater. In case of 55W forced convection with 20 minutes total cycle time, maximum peak temperature difference attained between heat pipe with PCM and heat pipe without PCM is 10°C. Hence, temperature can be better controlled for longer time by using PCM assisted heat pipe.

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