Available online at www.sciencedirect.com

ScienceDirect

Energy Procedia 61 (2014) 2399 – 2402

Energy Procedia

The 6th International Conference on Applied Energy – ICAE2014

# Thermoelectric Cooling Device Integrated with PCM Heat Storage for MS Patients

X. Li[a], S. Mahmoud[a], R.K. Al-Dadah[a]*, A. Elsayed[a]

[a]*School of Mechanical Engineering, University of Birmingham, Edgbaston, Birmingham, United Kingdom. B15-2TT*

**Abstract**

Most Multiple Sclerosis (MS) patients are sensitive to temperature resulting in wide range of symptoms including fatigue and intention tremor. Published work showed that cooling the upper limbs can reduce the severity of these symptoms thus improving the quality of lives of MS patients. Currently available cooling devices are large, heavy and power intensive. This work aims to develop a compact light weight wearable upper limb cooling device that can be used to reduce the skin temperature to 10°C and for duration of 20 minutes. This work combines the heat pumping ability of thermoelectric devices together with the heat storage capability of PCM materials. Experimental work was carried out to investigate the performance of three different PCM materials. Results showed that PCM-OM37 with power input of 3W can deliver the required temperature of 10°C for duration of 20 minutes highlighting the potential of this proposed technology.



Peer-review under responsibility of the Organizing Committee of ICAE2014

*Keywords: Thermoelectric cooler; Phase change material, Multiple Sclerosis*

## 1. Introduction

Around 80% of multiple sclerosis (MS) patients are heat sensitive, they experience symptom exacerbation associated with heat stress resulting from exercise and/or exposure to elevated environmental temperatures. Such symptom exacerbation can be a limiting factor for most of the normal daily life physical activities [1]. Published studies showed that cooling individuals with MS can alleviate such symptoms like fatigue and intention tremor [2]. Various cooling technologies were introduced for MS patients to wear during their normal daily life routines; but they proved to be bulky, heavy and power intensive [3-4].

Thermoelectric coolers (TEC) are solid-state active heat pumps that use the Peltier effect to transfer heat from one side of the device to the other, without refrigerant fluid circulation but they are power intensive and heat has to be removed efficiently from the device hot side otherwise the cooling

* Corresponding author. Tel.:+44 (0) 12141435.
E-mail address: aldadark@adf.bham.ac.uk



Peer-review under responsibility of the Organizing Committee of ICAE2014
doi:10.1016/j.egypro.2014.12.014

**Nomenclature**

| Abbreviation | | Symbols | |
|---|---|---|---|
| PCM | Phase Change Material | $T_{melt}$ | melting temperature ( °C ) |
| TEC | Thermoelectric Cooler | $T_{Max}$ | max temperature ( °C ) |
| | | $T_{min}$ | minimum temperature ( °C ) |

device will stop functioning [5]. Phase change materials (PCMs) have a high heat storage density and have the advantage over other heat storing mediums like water or rock in terms of the melting temperature. Most PCMs have melting temperature that suit wide range of applications in particular the low temperature ones [6]. This work exploits the PCM heat storage capability to dissipate the heat from the hot side of the Peltier cooling device to develop an effective, compact, light weight and wearable upper limb cooling system that can be used to alleviate symptoms associated with heat stress for MS patients. In order to achieve such requirement, the cooling device should be capable of delivering a cooling temperature of around 10$^{o}$C for duration of 20minutes.

## 2. Experimental setup

Fig 1 shows the layout of the experimental facility. It consists of two containers with one filled with PCM as the heat storage part and another filled with water simulating part of the upper limb of the MS patient, three Peltier devices sandwiched between these two containers, DC power supply to control the power input to the Peltier devices, thermocouples, Pico data logger and a desktop. Fig 2 shows a cross section through the PCM, Peltier devices and water illustrating the internal details of the cooling device. The PCM and water containers are made of Aluminum rectangular sections with dimensions of 160mm in length, 30mm in width, 17.5mm in height and 2.5mm in wall thickness. Wire EDM process was used to machine a footprint to locate the hot and cold sides of the Peltier devices to ensure good mechanical and thermal contact with both containers. Also a thermal paste was used to enhance the thermal contact. The Peltier devices used are of 9mm x 9mm cross section with capability of 2.8 W cooling capacity. The PCM was fitted with six thermocouples located at mid height of each container. Also, the water container was fitted with two thermocouples. All the thermocouples used are of the T type thermocouples with uncertainty of ±0.3$^{o}$C. Three different PCM materials were used namely PCM-OM37, PCM-OM46 and PCM-HS34 with their properties given in Table 1. The Peltier devices, working as a heat pump, transferred heat from the cold side (water container) to the hot side (PCM Container) with power input from the power supply. Firstly, the PCM container was filled with one type of PCM and the Peltiers were activated for a duration of 30 minutes and then switched off until the PCM cools down to the ambient temperature (the room temperature is 16$^{o}$C). This test was carried at three different power levels (3W, 6W, 9W). This procedure was repeated with the other two PCMs.

Table 1. Properties of PCM

| PCM Type | $T_{melt}$ ($^{o}$C) | Density (kg/m$^3$) | Specific heat (J /kg K) | Thermal conductivity (W/mK) | Latent heat (KJ/kg) |
|---|---|---|---|---|---|
| PCM-OM37 | 37 | 880 | NA | NA | 218 |
| PCM-OM46 | 46 | 860 | NA | NA | 245 |
| PCM-HS34 | 34 | 1850 (liquid) 1980 (solid) | 2344.6 | 0.47(liquid) 05-0.6(solid) | 150 |

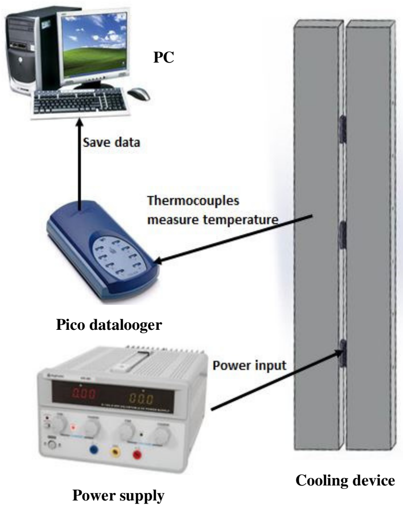



Fig. 1. Experiment Setup

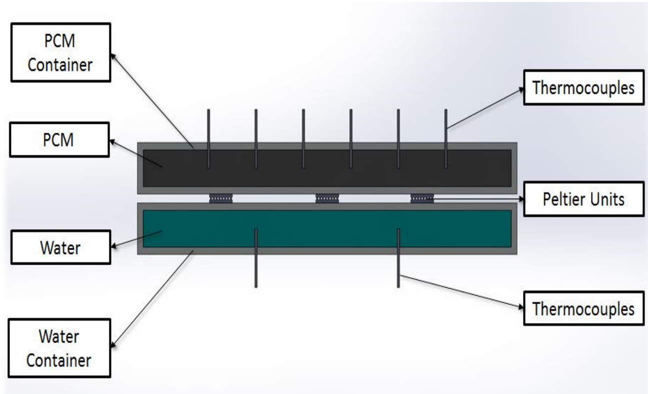



Fig. 2. Cross section of cooling device

## 3. Results and Discussion

The objective of this investigation is to determine the effect of power input and the PCM type on the performance of the cooling device in terms of temperature levels and duration. Fig 3 shows the temperature variation with time for the water and PCM-HS34 at three different power levels. It can be seen that with power of 3W, the water was cooled down to 10°C for a period of 18 minutes. With power of 6W, the water temperature dropped to 8°C for a period of 12 minutes. As for the 9W power input, the water temperature dropped to 8°C but then started to increase due to the complete melting of the PCM material caused by the higher amount of heat rejected to the PCM. Also the time required to cool the PCM to ambient conditions increases from 24minutes for power input of 3W to 52minutes at 9W. Fig 4 shows the temperature variation with time for the three selected PCMs at the three power inputs. It can be seen that for 3W power supply, the PCM-OM37 produces cooling water temperature of 10°C for a period of 23 minutes and it takes 20 minutes to cool down. However, the PCM-OM46 produces cooling water temperature of only 16°C. Therefore it can be concluded that the PCM-OM37 with power input of 3W is the most suitable for this application since it can achieve the 10°C target with the reasonable duration of 23 minutes, cools down to ambient within 20 minutes and lowest power requirement. This could be attributed to the PCM-OM37 favorable thermal properties shown in table 1.

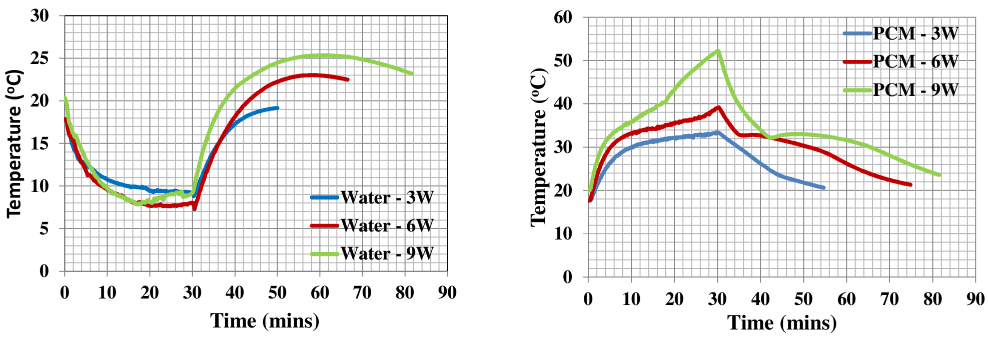



Fig. 3. Temperature trends of cooling system filled with PCM-HS34 at various power inputs

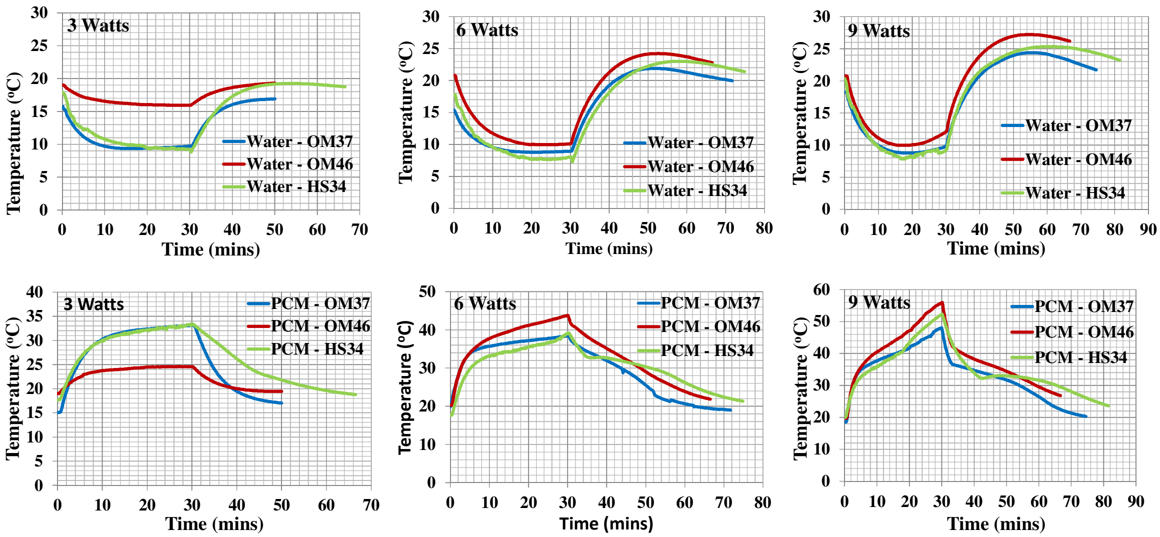



Fig. 4. Temperature trends of cooling system filled with different PCM at 3W, 6W and 9W

## 4. Conclusions

There is a need for compact light weight wearable cooling device that can be used by MS patients to alleviate the adverse symptoms like fatigue and intention tremor caused by incresaed ambient temperatures or physical activities. This work investigated the use of thermoelectric coolers combined with PCM materials to cool the upper limb surface temperature to 10$^{o}$C for duration of 20 minutes. Results showed that PCM-OM37 with power input to the peltier devices of 3W have the potential to achieve such requirements. The longer cooling time can be attributed to its higher latent heat and its fast rate of cooling is caused by the lower density hence lower mass.

## References

[1] Meyer-Heim A, Rothmaier M, Weder M, Kool J, Schenk P, Kesselring J. Advanced lightweight cooling garment technology: functional improvements in thermosensitive patients with multiple sclerosis, *Mult Scler* 2007; **13**: 232.

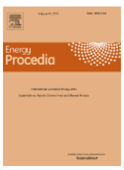
[2] Koch M, Mostert J, Heersema D, J. Tremor in multiple sclerosis, *J Neurol.* 2007; **254(2)**: 133–145.

[3] Grahn D A, Murray J, Heller H G. Cooling via one hand improves physical performance in heat-sensitive individuals with Multiple Sclerosis: A preliminary study. *BMC Neurology* 2008, **8**:14.

[4] Feys P, Helsen W, Liu X, Mooren D, Albrecht H, Nuttin B, Ketelaer P. Effects of peripheral cooling on intention tremor in multiple sclerosis. *J Neurol Neurosurg Psychiatry* 2005;**76**:373–379.

[5] Hamidreza N, Woodbury, KA. Optimisation of a cooling system based on Peltier effect for photovoltaic cells, *J. Solar Energy* 2013;**91**:152-160.

[6] Sharma A, Tyagi V V, Chen C R, Buddhi D. Review on thermal energy storage with phase change materials and applications, *Renewable and Sustainable Energy Reviews* 2009;**13:**318–345.




## Biography

Xingjian Li is a BEng final year student at the School of Mechanical Engineering of the University of Birmingham after completing two years at Huazhong University of Since and Technology (2010-2012).