

# PCM/HYBRID FOAM SYSTEM IN TEMPERATURE CONTROL APPLICATION

Mohammad Almajali, Khalid Lafdi, and Paul Prodhomme

University of Dayton Research Institute, Dayton, OH 45469

## Introduction

Phase change materials (PCMs) are used in energy heat storage due to their high heat capacity. However, the thermal conductivity of PCM is still very low and offsets the benefit of using PCM in such application. Therefore much work has been placed to improve the thermal conductivity of PCM in different ways [1-3]. Researchers found that the best way to improve the thermal conductivity of the PCM is to infiltrate it inside foam that has higher relatively thermal conductivity such as carbon foam [4, 5]. The present work dealt with a study on the phase change process of the PCM/foam composite under constant heat load. The study will be conducted based on copper-coated carbon foam and uncoated carbon foam. The use of coated material would make the study of the phase change process of PCM/foam composite more efficient.

## Experimental

The thermal control for the composite of PCM/foam system samples were analyzed under constant load. The experimental setup basically included four important components; test rig, vacuum chamber, data acquisition system and an electronic circuit controller for test rig. The test rig design consisted of three subassemblies; top plate with actuator and heater subassembly, coolant plate with sample holder subassembly and actuator guide subassembly (Fig. 1).

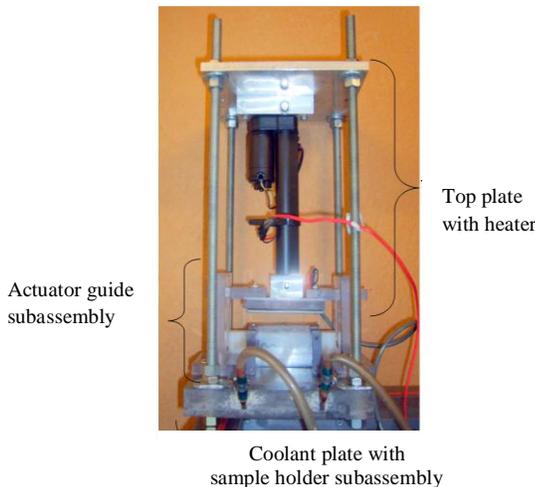


Fig. 1 Details of test rig subassembly

Two open cell carbon foam samples with a size of (7.5 cm X 5 cm x 5 cm) were used. One of these samples was coated

for a total period of one hour with copper using electroplating technique. The initial temperature of both the TC composite samples was approximately 22-24 °C. Since all the tests were performed under a vacuum condition of 100 to 150 torr, for each case the two samples to be analyzed were subjected to the following boundary conditions: the right and left boundaries of the sample were assumed under adiabatic conditions and the lower boundary was in contact with the coolant plate which was maintained at approximately 22 °C with water flow at a rate of 2 liters/min.

The basic idea was to maintain an equal temperature difference of 10 °C between the melting points of the selected PCMs with respect to the coolant boundary. The top of heater boundary was subjected to a uniform heat load. The two samples were first subjected to a uniform heat flux of 10 W and the temperature histories for thermocouples at different locations for the two samples were recorded till the steady state was approached. Figure 3 illustrates the sample under the considered load showing the thermocouples locations.

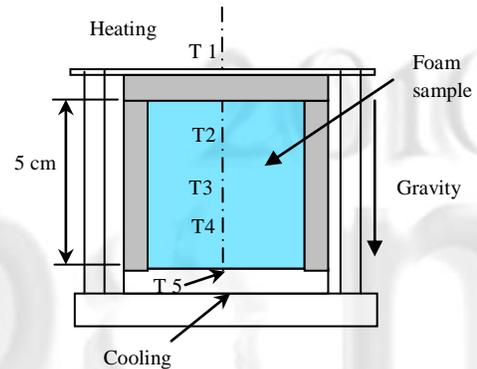


Fig. 2 Thermocouples locations on the sample

## Results and Discussion

The temperature histories for thermocouples at different locations for the two samples were recorded till the steady state condition was approached. The discussion will be carried out to compare the phase change process between the coated and uncoated foams and to evaluate their temperature control ability. Figures 4 and 5 present the transient temperatures for the composites with uncoated foam and copper coated foam, respectively.

The initial temperature of the composite was close to the ambient temperature (23 °C) for both composites. When the heat was applied to the system, the temperature started to increase rapidly within the first 40 seconds till the steady state condition was approached. However, the steady state condition was reached after 6 minutes for the composite contains uncoated foam and before 4 minutes for the composite with coated foam. The highest temperature was detected at the top side of the composite, where the heat was applied, and the lowest temperature was detected at the bottom side, where the surface was cooled. In between these two

extremes, the temperature decreases as going from the top side to the bottom. This is valid for both composites (coated and uncoated).

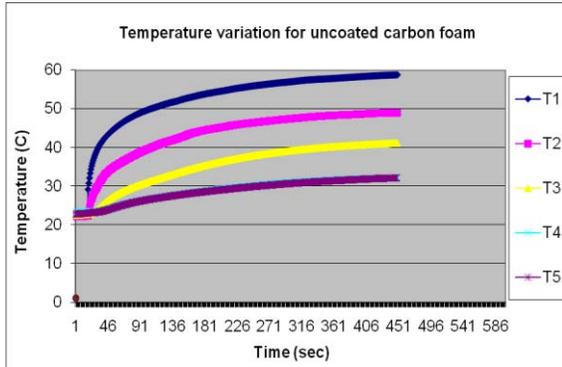


Fig. 3 Temperature histories for uncoated composite

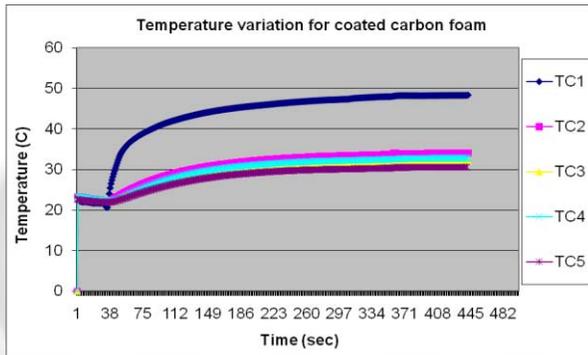


Fig. 4 Temperature histories for coated composite

At steady state condition; the temperature at the upper side of the composite, containing copper coated foam, is lower than the composite, containing pristine foam. While at the lower side of the sample, there was no difference. Copper coating has a significant influence on the PCM/foam system. The added copper coating inside the foam decreased the porosity of the foam from 96% to only 90-91%. This change in porosity affected both the thermal conductivity and the permeability of the foam. The thermal conductivity was increased from 5.6 W/k.m for the uncoated foam to nearly 11 W/k.m for the foam coated with copper for period of one hour. Copper also has higher surface energy than carbon that can improve the permeability.

The experiments for both composites were conducted under the same condition on the samples that have the same size (thickness and area). So when applying Fourier law for the two composites at steady state condition, the thermal conductivities for both systems, uncoated and coated, can be expressed, respectively, as follow:

$$K_1 = \frac{Q\Delta L}{2A(T1-T2)} \tag{1}$$

$$K_2 = \frac{Q\Delta L}{2A(TC1-TC2)} \tag{2}$$

Since the temperature difference between the hot and cold side decreased from 30 °C for the uncoated foam to 18 °C for the coated foam, the thermal conductivity increased more than 1.67 times. During the transient state, the heat transferred faster in the coated foam due to the improvement in the thermal conductivity. The duration time elapsed corresponding to two measured temperatures (30 °C and 26 °C) was calculated. These calculations were taken for the inside composites only at three thermocouples locations (Table 1). Apparently, the heat is transferred faster in the coated composite than the uncoated one.

Table 1. Duration for Transient at Different Locations

Composite	Time for 30 °C (Sec)		Time for 26 °C (Sec)	
	T2 to T3	T3 to T4	T2 to T3	T3 to T4
Uncoated	57	132	22	42
Coated	27	33	14	20

### Conclusions

Copper coated carbon foam and pristine carbon foam were infiltrated with wax material. This system didn't only improve the heat capacity of carbon foam, but it also enhanced the thermal conductivity of the wax. Using coated foam made the system even more conductive and it can withstand 22% power than the uncoated foam. In addition to the advantage of heat transfer performance, coated foam has compensation in strength. For energy heat storage application this system can dissipate and absorb the heat quickly.

### References

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