A COLD STORAGE PCM HEAT EXCHANGER FOR DAILY SUMMER FREE COOLING WITH COLD NIGHT AIR

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Introduction

As thermal needs correspond to up to 80% of the building energy consumption, thermal storage can be a key solution to decrease their dependance on nonrenewable energy. It can increase the building thermal autonomy in winter and in summer. By ventilating Phase Change Materials (PCM) [1] [2], [3] with the cold air of summer nights, PCM can be solidified to store cold. During the day, ventilating the PCM melts it and refreshes the ambient air [4].

We developed in this respect half meter high aluminum PCM containers allowing important temperature stratification in the vertical direction. By placing thin horizontal metallic plates in the PCM container and air flow channels around it, heat transfer occurs between the PCM and the ambient air as soon as an air flow is blowing. We present here this PCM heat exchanger structure with the results of the first measurement of heat/cold storage charge and discharge power as well as a method to determine the load level of the thermal battery.

Air-PCM heat exchanger structure and testbed

The storage module is shown in Figure 1, and comprises two 50cm-long extruded cells, each with a capacity of 1.86 liters of PCM. The containers filled with Crodatherm 21 are surrounded by strips for air flow heating/cooling. The temperature profile along the vertical axis is studied for both PCM and air zones with 7 and 9 thermocouples, respectively. Two flow meters were installed before and after the heat exchanger to measure 4flow and exclude air leaks. The flow was generated by a "helios" radial fan preceded by heater for the hot loads. For cooling loads, outside ambient air was drawn in. The charging and discharging powers were determined by multiplying the air mass flow rate: $\dot{m}$, the air specific heat: $c_{p\ air}$,= 1.005 J/gK and the difference between the inlet and outlet air temperature.

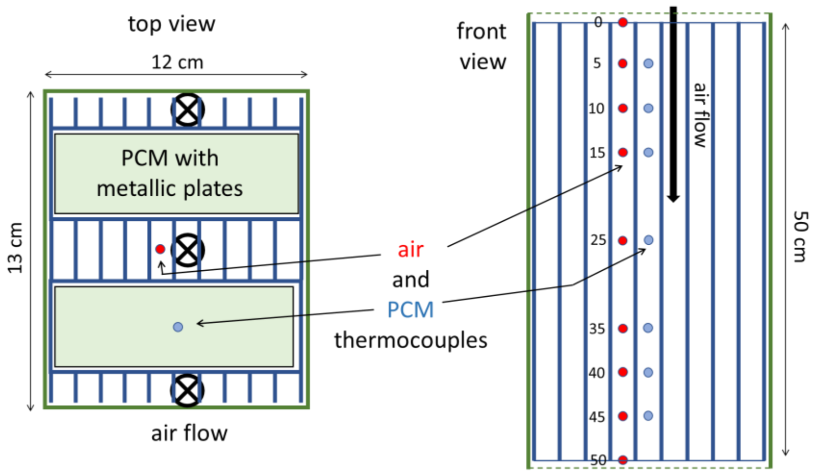

Figure 1: Heat exchanger structure with the top view showing the two cells with their PCM and air flow zones. Heat transfer is ensured by thin metal fins spaced 6mm apart in the PCM zones and by aluminum strips in the air zones. The front view shows a cross-section of the heat exchanger in the air zone with the precise position of each air (red) and PCM (blue) thermocouple (the latter being situated in the PCM zone). The numbers indicate the distance in cm from the air inlet.

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Measurement results

The PCM heat exchanger was successively ventilated with hot and cold air flows of 32 m³/h to perform thermal cold and hot dis/charges. Figure 2 shows a cold discharge starting with PCM materials at around 14°C and carried out with an input air at 30°C. An average cooling power of 78W was obtained for 3.5 hours, corresponding to an energy storage of approximatively 0.25 kWh. The temperature evolution is shown in Figure 2a) for seven positions in the PCM and in the air flow. The melting position progresses slowly at the beginning and accelerates at the end of the cold discharge: one hour was necessary to melt PCM at 5cm from the flow entrance, while total PCM fusion was obtained after 2.6h at 25cm and 3.2h at 45cm. While temperature stratification is important in the PCM zones due to the melting process, the temperature rise is very gradual in the air. We observe a nearly linear increase at 25cm between 21°C and 30°C which can be used to determine the charge level of the thermal battery.

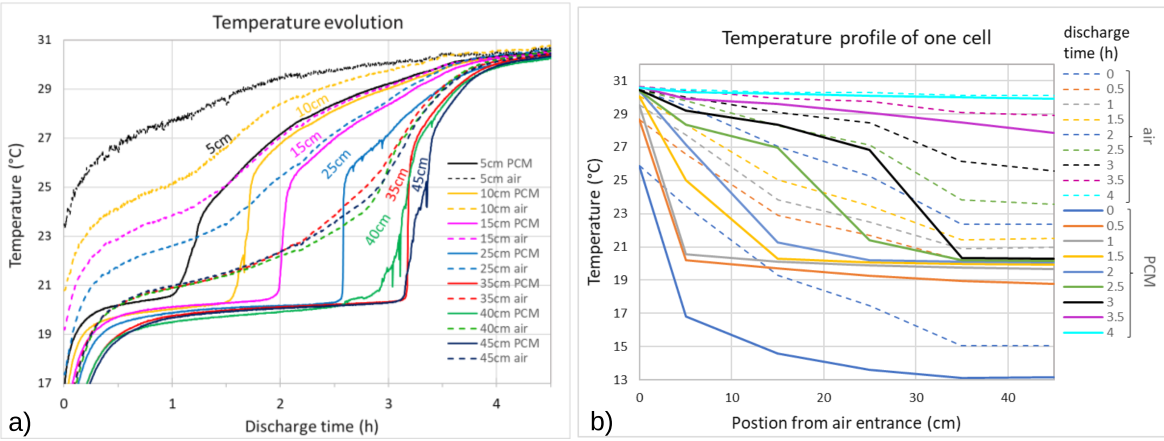

Figure 2: a) Evolution of the temperature during 4.5 hours of a cold discharge for different vertical positions in the PCM container and along the air channels.
b) PCM and air flow temperature profiles from the beginning to the end of the discharge process.

The temperature profile in the PCM and in the air is displayed in Figure 2b). A rapid decrease in temperature is observed where the PCM is completely liquid with a stabilization below 21°C afterwards. After 1½h discharge, a warm front move towards the end of the heat exchanger reaching it after 3.2h. The air profile follows the PCM profile but with gentler slopes. The cooling efficiency of the PCM remains high until less than 15cm remains solid. At that point, the thermal battery can be considered empty and need recharging.

Heat discharge (or cold loads) was measured by ventilating the PCM at 14°C at the same flow rate. The PCM totally solidified after 5h with 1½h needed to solidify the first 5 cm. If the fusion temperature of 21°C is optimal to refresh building in summer, cold nights are necessary to solidify it completely. If the outside air temperature is at 18-19°C, other PCMs such as the Crodatherm 24W could be used, as they have already shown complete solidification in 5 hours [4], [5].

Referenzen

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