THERMAL STORAGE AND HEAT DISCHARGE EFFICIENCY OF AN AIR-PCM-WATER HEAT EXCHANGER

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Introduction

Reducing the use of fossil fuels is one of the biggest challenges of the current energy transition. Since thermal needs correspond to up to 80% of the building energy consumption, using solar energy to heat buildings could provide key improvements in energy efficiency. However, while PhotoVoltaic (PV) panels can provide a high average power, their power is too low during high thermal demands, which makes energy storage essential. We propose to use Phase Change Materials (PCM) [1, 2, 3, 4] to store thermal energy during periods of high solar power and reuse it when the renewable power becomes insufficient. As heat pumps have a high Coefficient of Performances (COP) for low temperature heating, the use of PCMs with a low fusion temperature is preferred. In that respect, we built new air-water heat exchangers containing PCM layers between both circuits, with fusion temperature between 23 and 25°C. In this document we report the measured storage capacity as well as the charge and discharge powers of such a PCM heat exchanger with dimensions of 0.8 x 0.5 x 0.25m.

Heat exchanger design and measurement setup

The design of the storage module is represented in Figure 1. It is a plate heat exchanger traditionally used for heat transfer between 2 water circuits. The plates separate different sectors belonging to the water circuit, the air circuit or the PCM layers. One water, two air and three PCM elements correspond to a basic cell, displayed below in the side view, which is repeated 20 times in the exchanger. This exchanger contains 18kg of PCM "Rubitherm RT25HC" with a fusion temperature of 25°C, that can be thermally charged by a water flow and discharged by an air flow.

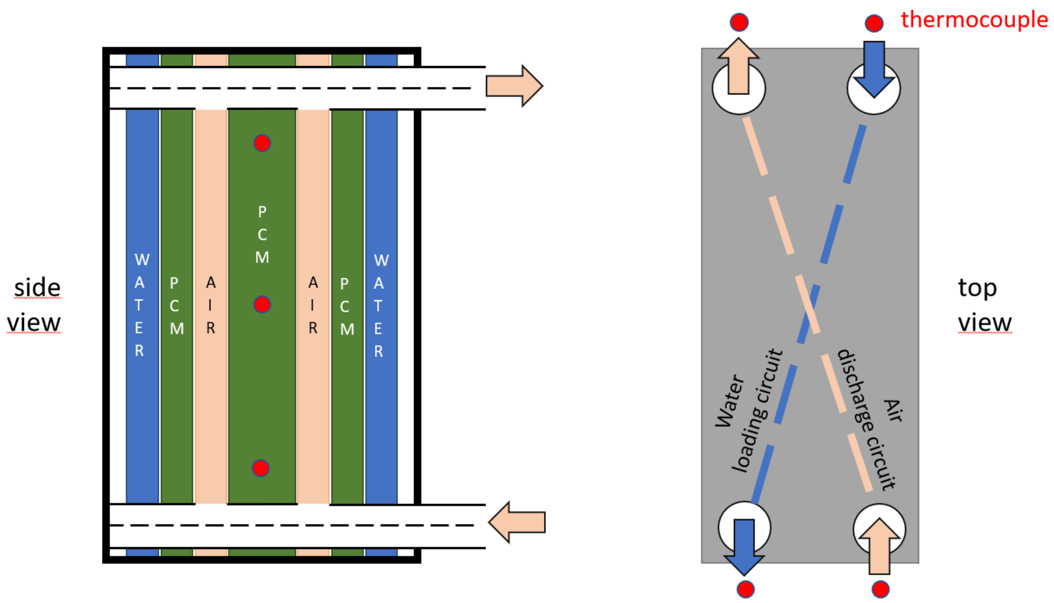

Figure 1: Heat exchanger structure with the side view showing the elements of a basic cell and three thermocouples (in red) to measure the PCM temperature. The top view shows the water and air circuits and the temperature sensors located in both circuits before and after the heat exchanger.

The temperature dependence within the PCM layers has been investigated with the help of three thermocouples located at different positions along the air flow as shown in Figure 1. To measure the charge and discharge powers, air flow and water flow meters have been used. The temperature

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difference between the entrance and exit of the heat exchanger was measured with thermocouples located at these points for both circuits.

Measurement results

The hot and cold loads were performed by a water flow of 0.17 l/s. The water heat load from 20°C to 40°C was completed in less than an hour with a loading power of 2KW. The air heat discharge realized with an air flow of approximatively 70m^3/h and a temperature of nearly 21°C lasts about 6 hours by starting with a PCM heat exchanger at 40°C. The large temperature difference causes a high power of 600W at the beginning of the discharge which stabilizes at 175W after 2 hours. The integration of the whole discharge from 40°C to 21°C gives a total thermal energy storage of 1.5KWh. The temperature dependence of the PCM during the discharge is shown in Figure 2a) for 3 locations. Close to the air entrance the PCM refreshes quickly. At the middle, it remains liquid and stable at 25°C for up to three hours and at the end, the PCM remains liquid for about 5 hours.

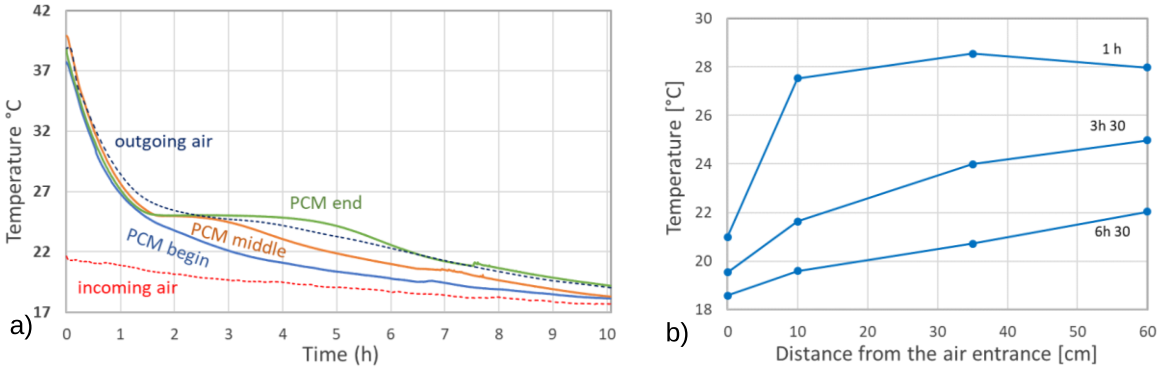

Figure 2: a) Temperature evolution during 10 hours of a heat discharge for the PCM at the beginning, middle and end of the air flow and for the incoming and outgoing air.
b) PCM temperature profile after 1 hour, 3 ½ and 6 ½ hours.

The temperature profile in the PCM layers is displayed in Figure 2b) at the beginning, in the middle and at the end of the discharge. We can notice the sharp temperature increase in the first 10 cm and almost no increase for the rest of the distance at the beginning of the discharge. During the discharge, the sharp rise in temperature near the air inlet slowly disappears, and an almost constant rise in temperature is achieved after 6 ½ hours.

In the same way a cold discharge has been measured. An air flow of 40°C was directed towards the heat exchanger with PCM layers at 10°C. The exchanger was discharged in 3 hours with an average discharge power of 750W and a peak power of 1KW after 15min. The cold storage capacity was also measured to be 1.5kWh. Due to its relatively small dimensions, this storage capacity can be considered as very promising for a use in standard buildings. An apartment of 8 radiators could have by that way 12kWh of hot or cold storage. As shown by previous simulations [5], this storage can drastically increase the energy autonomy of buildings equipped with solar power from mid-February to the end of November.

Referenzen

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