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EXPERYMENTAL STUDY ON HEAT STORAGE IN PARAFFIN WAX

BY

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Abstract. The paper presents an experimental study on latent heat storage in a phase change material, namely paraffin wax. Heat storage and discharging processes are analyzed and heat transfer coefficient is determined.

Key words: latent heat storage; phase change material; heat transfer coefficient.

1. Introduction

Using renewable energy sources currently represent a priority in energy production sector. Many studies and research are focused on solar energy, geothermal energy or on recovery heat contained in the gases resulting from combustion processes. Often, heat supply and energy consumption are discontinuous in this type of energy systems, which require energy storage for a period of time. Thermal energy storage, the most common form of energy storage, is currently possible through following procedures: sensible heat storage (SHS), latent heat storage (LHT) and bound energy storage (BES) (Dincer & Rosen, 2010).

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In a latent heat storage system (LHT), energy is stored during melting and recovered during solidification of a phase change material (PCM). Heat input into the PCM changes its phase from solid to liquid by storing the heat as latent heat of fusion. When the stored heat is recovered from a working fluid, the material will change again its phase from liquid to solid (Om Nayak *et al.*, 2011).

In low temperatures domain, paraffin wax is a good heat storage material (Agyenim *et al.*, 2010). Paraffin wax is chemical stabile, noncorrosive and have a high latent heat (Himran & Suonovo, 1994).

Unlike other applications in which paraffin wax is capsuleted (Alkilani & Kamaruzzaman, 2011) or in tubes (Kamal & Mabruk, 2000), in this paper is analyzed heat storage and heat transfer in a large volume of paraffin wax.

2. Experimental Setup

Experimental research aims to analyze the heat transfer from the energy storage medium, the paraffin wax, to the water, which recovers heat from the storage medium. The experimental scheme is shown in Fig. 1.

The main element of the system is the heat accumulator 1, in which the paraffin wax is introduced. Dimensions of the thermal accumulator are: 450 mm length, 160 mm width, 230 mm height.

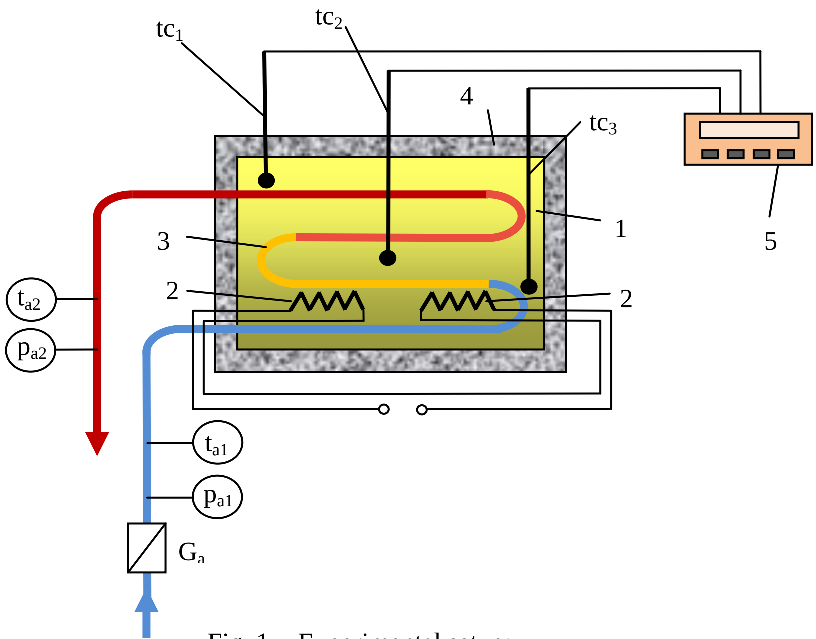

Fig. 1 − Experimental setup:
1 − thermal accumulator; 2 − electric resistances; 3 − water coil;
4 − thermal insulation; 5 − temperatures recorder device.
tc_1, tc_2, tc_3 – thermocouples; ta_1, ta_2 – termometers; pa_1, pa_2 – manometers.

Two electrical resistances are intended to supply the heat required for the wax to store heat by changing the state of aggregation of the solid phase in the liquid phase.

The heat accumulated in the paraffin wax is used for heating water which flows through the coil 3. The coil is made of copper tube with an interior diameter 7 mm. It is placed vertically on the median axis of the thermal battery. It has four horizontal sections, spaced at equal distances between them. The distance from the bottom is 30 mm, and the distance from the top is 80 mm.

For measuring the temperature of paraffin wax were used three calibrated thermocouples. The thermocouples are connected to the indicator device 5. In order to reduce the heat loss from the heat accumulator, it has been provided on the outside with a heat insulation surface 4, made of mineral wool with a thickness of 50 mm, covered with aluminium foil.

Experiments studies the heating of paraffin wax and the heat transfer between paraffine wax and water flowing through the coil mounted inside thermal accumulator. Paraffin wax mass is 11.5 kg. The main thermophysical properties of paraffine vax (Table1) are presented in literature (Ukrainczyk *et al*. 2010).

Table 1
Thermophysical Properties of Paraffin Wax

Property	Unit	Value
Melting range	K	316-329
Density	Kg/m^3	900-970
Specific heat	kJ/kg K	2.0-2.9
Heat of fusion	kJ/kg	190-210
Thermal conductivity	W/m K	0.22-0.24

3. Results and Discussions

Paraffin wax melting process begins at a temperature of 42°C and ends around 55°C. Experiments have shown that the melting of paraffin wax is irregular in the volume. Density decreases in the transition from the solid phase to the liquid phase The liquid phase is an upward movement, accumulate at the top of the vessel. Melting front moves from the top to the bottom of the heat accumulator.

The heating process is represented in Fig. 2. The diagram shows the variation in time of the temperature indicated by the three thermocouple t and the medium temperature t_{med}. It can be seen that between 42°C and 55°C the slope is less. Phase change is done in a temperature range because paraffin wax changes is not a pure substance, it is generally a combination of various hydrocarbons.

The discharging process, during which the water takes the heat stored in paraffin wax, is shown in Fig. 3.

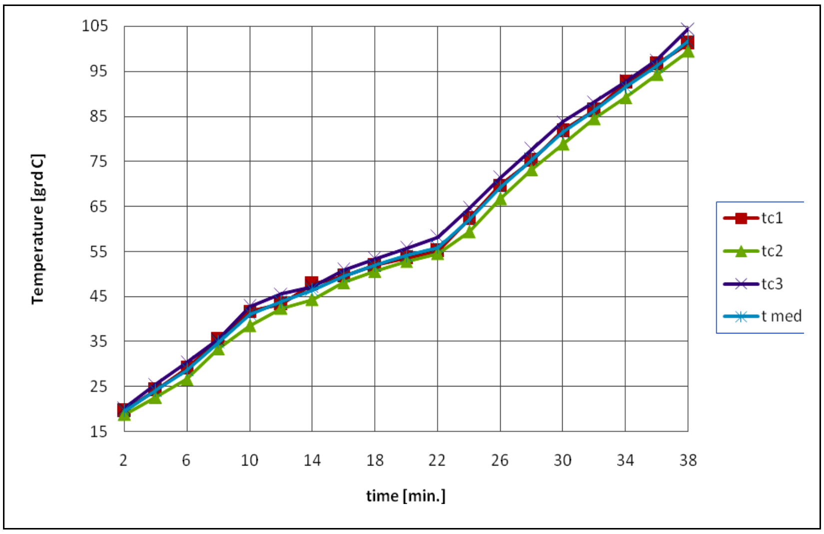

Fig. 2 – Parafin wax temperature in heating process.

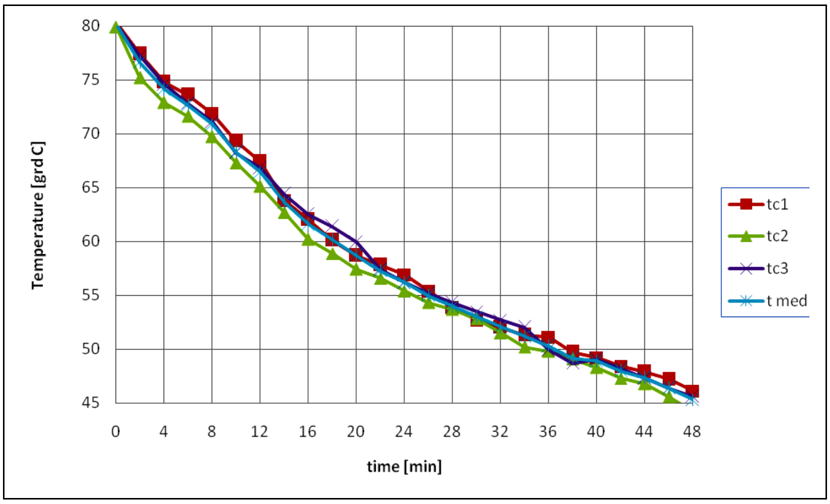

Fig. 3 – Parafin wax temperature in discharging process.

It can be seen that between 80°C and 55°C, when the wax transfers its sensible heat, temperature decrease is faster. Between 55°C and 45° the paraffin wax transfers its latent heat and the rate of temperature decrease is smaller.

The water mass flow has a value of 0.009 kg/s and its inlet temperature was 24°C. In Fig. 4 is represented the variation in time of the outlet water temperature. Variation of heat transfer coefficient is represented in Fig. 5.

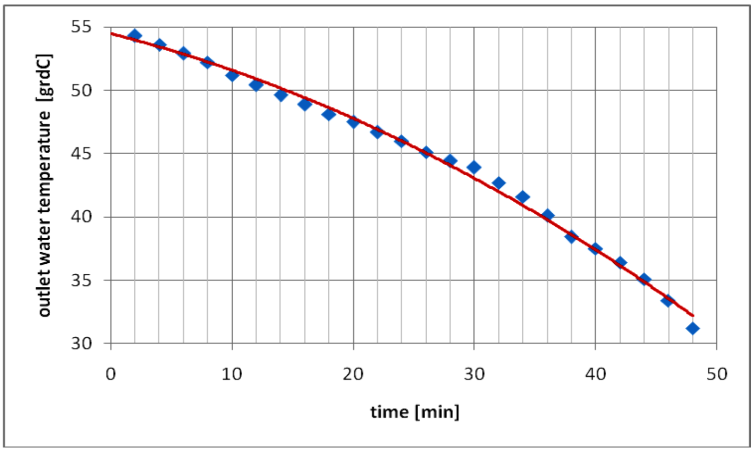

Fig. 4 − Outlet water temperature.

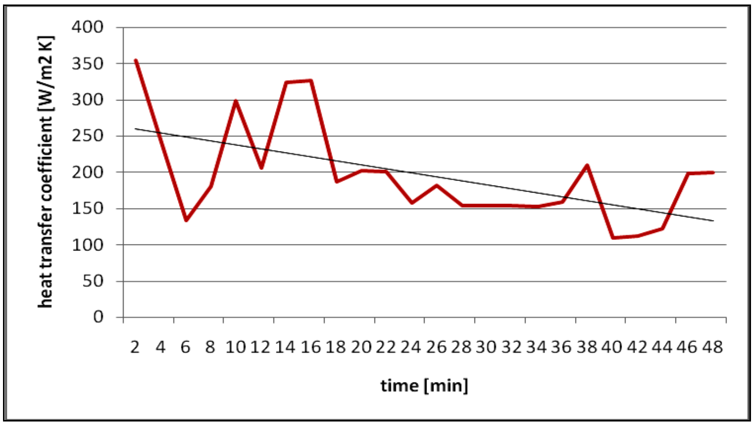

Fig. 5 – Heat transfer coefficient.

Values obtained for heat transfer coefficient is within the range of values indicated in literature (Thirugnanam & Marimuthu, 2013). Heat exchange coefficient decreases over time due to solid wax deposition on the surface of water coil.

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STUDIU EXPERIMENTAL ASUPRA STOCĂRII CĂLDURII ÎN CEARA PARAFINICĂ

(Rezumat)

Stocarea energiei termice se impune în acele sisteme energetice în care aportul de căldură şi energia folosită de consumatori prezintă variaţii mari în timp. Lucrarea prezintă un studiu experimental asupra stocării căldurii într-un material cu schimbare de fază. Materialul ales este ceara parafinică, aceasta prezentând interes practic în domeniul stocării căldurii la un nivel coborât de temperatură. A fost concepută o instalaţie experimentală care a permis studierea procesului de stocare a căldurii în ceara parafinică şi a procesului de transfer de căldură de la aceasta către apă, care reprezintă agentul care preia căldura stocată. Au fost reprezentate variaţiile în timp ale temperaturii cerii parafinice şi apei şi a fost determinat coeficientul de transfer de căldură.