Applied Thermal Engineering 78 (2015) 556–564

Contents lists available at ScienceDirect

Applied Thermal Engineering

journal homepage: www.elsevier.com/locate/apthermeng

Research paper

Experimental study on solving the blocking for the direct contact mobilized thermal energy storage container

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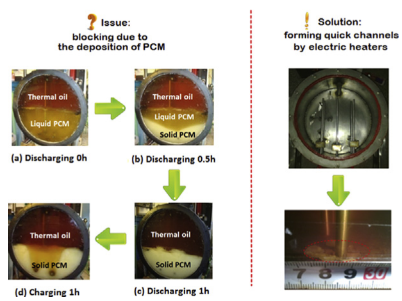
HIGHLIGHTS

- Analyzing the reason of blocking in direct contact M-TES container.
- Designing an option to solve the blocking by using electric heaters.
- Comparing the melting and solidification behaviors of PCM in direct contact M-TES container with and without quick channels.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 18 August 2014
Accepted 1 December 2014
Available online 10 December 2014

Keywords:
Direct contact
Mobilized thermal energy storage system
Blocking
Electric heating
Phase change behavior

ABSTRACT

As a promising technique of the waste heat recovery, the mobilized thermal energy storage (M-TES) can reduce the energy consumption and meet the heat demand for distributed users. With the convective heat transfer in the container, the direct contact M-TES shows a good charging and discharging performance except the blocking by the deposited phase change material (PCM) at the initial stage of the charging process. This paper studied a solution on forming the quick channels (QC) with electric heaters to solve the blocking issue. Phase change behaviors of PCM in the container with and without QC were analyzed and compared. With the QC formed with electric heaters, the charging time at the early and middle stage is obviously shortened compared with that of the experiment without electric heating. However, the solution is not suitable at later stage of charging because of the fading away of QC. The formation of QC takes about 90 s and covers around 5% of the thermal energy stored in the container. The results present that it is a good method to solve the blocking issue for the direct contact M-TES system especially with a low rate of heat release.

1. Introduction

The concern over energy shortage and environmental degradation has propelled the research of the energy saving and environmental protection. As the energy consumption of space heating and domestic hot water are responsible for a great part of

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http://dx.doi.org/10.1016/j.applthermaleng.2014.12.008
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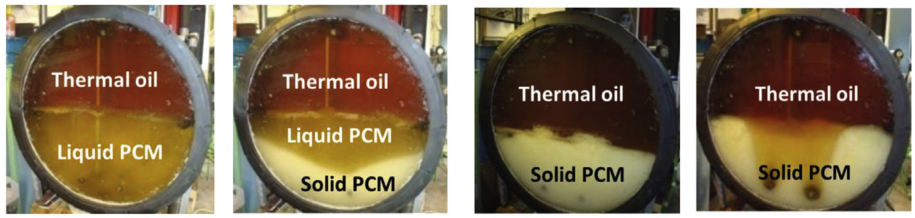
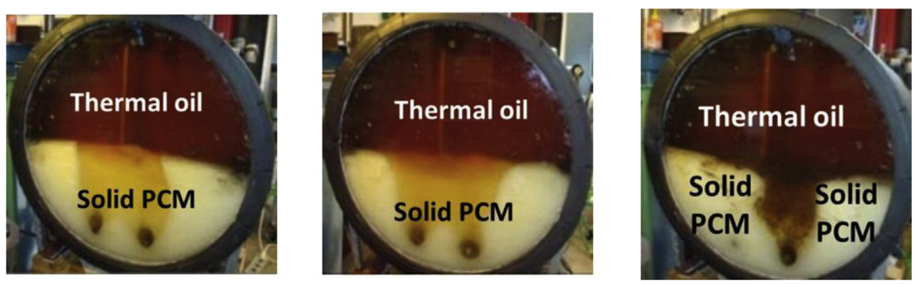


(a) Discharging 0h (b) Discharging 0.5h (c) Discharging 1h (d) Charging 1h

Fig. 1. The formation of the blocking by the deposition of PCM.



(a) F_{oil}=9.2 l/min (b) F_{oil}=15.8 l/min (c) F_{oil}=21.0 l/min

Fig. 2. The melting behavior of PCM with different flow rates of the thermal oil at 1 h charging.

the final energy consumption and CO_2 emissions in many countries [1–5], supplying heat efficiently and environmentally plays an important role in achieving goals set at the conference of the United Nations (UN) climate change [6]. The purpose of the mobilized thermal energy storage (M-TES) system designed as a complement of conventional heating system is to solve the issue encountered when delivering heat to distributed users or emergency heat use.

Thanks to the advantage of the heat transfer without the network limitation and the potential available resource of the industrial waste heat, the M-TES has drawn much attention in recent years. As such, the research for realizing the application of the M-TES technology was carried out. The materials for M-TES system, e.g. form-stable polyethylene glycol/silicon dioxide composites, polyethylene glycol/expanded graphite composites and erythritol, were prepared and tested [7–9]. The lab-scale experiments with the direct and indirect contact container were undertaken to figure out the charging and discharging performance of the M-TES system [10–14]. The optimization of the charging process for the direct contact M-TES container was conducted by modeling and simulating [15]. The combined heat and power (CHP) plant was integrated with the M-TES to seek the appropriate options of system integration [16]. The economic assessment of M-TES system in Sweden was studied [17]. The results showed that it is economically feasible to run the M-TES project locally.

Based on above investigations, the direct contact M-TES container showed a better performance on charging and discharging than that of the indirect contact except the blocking issue caused by the solidification and deposition of PCM. As shown in Fig. 1a, the liquid PCM and the thermal oil separated due to the different density at the initial stage of discharging process. With the heat transfer between the ingoing thermal oil and the liquid PCM, the PCM solidified and deposited at the bottom as shown in Fig. 1b. The whole PCM deposited after 1 h discharging. At the beginning stage of next charging, as shown in Fig. 1d, the thermal oil was blocked by the solidified PCM, which weakened the convective heat transfer in container. The path of thermal oil flow was made at least 90 min in the experiment [13]. The long time of path formation restricted the rapid charging of the M-TES.

In order to improve the melting of PCM at the early stage, the experiment by increasing flow rate of thermal oil was conducted [10]. The melting behavior of PCM with different flow rates of the thermal oil at 1 h charging is shown in Fig. 2. Results indicated that the blocking issue was alleviated by the method. PCM, however, would be easy to be taken out of the container while keeping the increase in the flow rate of the thermal oil. The effluent PCM would block the system circulation loop. As such, more work on solving the blocking issue of the M-TES shall be undertaken further.

The purpose of this paper is to investigate a solution of the blocking issue. The quick channels (QC) formed with electric heaters for the direct contact M-TES container were studied. Results provided insights and guidelines on solving the blocking so as to shorten the charging time and enhance the M-TES efficiency. The remainder of this paper is divided into three sections. Firstly, the concept of M-TES and experimental details were

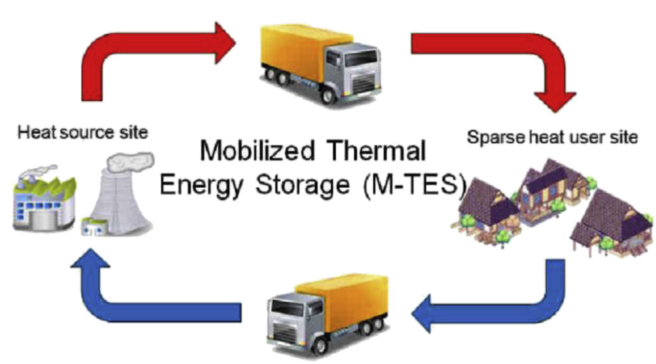


Fig. 3. The schematic diagram of the M-TES system.