



Fins and turbulence promoters for heat transfer enhancement in latent heat storage systems

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ABSTRACT

One of the serious problems associated with the operation of PCM storage system is the heat transfer in and out of the element containing the PCM. This paper presents the results of an experimental investigation of the effects of radial fins and turbulence promoters on the enhancement of phase change heat transfer external to a horizontal tube submersed in the PCM with the working fluid flowing through it. The experimental measurements were realized on a bare copper tube and an identical copper tube fitted with radial fins. The fins investigated are 40, 60, 120 and 180 mm diameters. A turbulence promoter made of stainless steel wire of 1.0 mm diameter coiled in a helical form with a pitch of 25.0 mm was inserted into the copper tubes. The tests were realized on bare tubes, finned tubes and finned tubes with the turbulence promoter inserted into the finned tubes. The measurements were realized for the working fluid temperatures in the range of $-10\text{ }^{\circ}\text{C}$, to $-25\text{ }^{\circ}\text{C}$ and six values of the mass flow rate ranging from 0.013 to 0.031 kg/s. The position of the phase interface was photographed by a high resolution digital camera and scanned to determine the real interface position by comparison with a precision measuring scale. The results of the phase interface position, velocity of the interface, solidified mass fraction and the time for complete solidification are presented in function of the working fluid temperature, the working fluid mass and the tube arrangements. The results are presented and discussed.

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1. Introduction

The problems of heat transfer with phase change appears frequently in nature and in many practical situations as the solidification of water surface in lakes and rivers, solidification of water in water distribution systems in cold countries, formation of ice on airplane wings, formation of frost and ice in fan coils and finally in latent heat storage systems.

Among the important thermal performance parameters of latent heat storage systems one can include the short time for complete charge and discharge and the high effective storage capacity. The time for complete charge is related to the time for complete phase change of the PCM elements. The high effective storage capacity is related to the well designed arrangement of the PCM elements such that there is as little as possible melt PCM in the storage tank.

These two problems form the main objectives of the present experimental study. To reduce the time for complete phase change two methods were investigated to enhance the heat transfer to and from the PCM elements, that is, attaching fins on the tubes surfaces while the other is by inserting turbulence promoter inside the

tubes. To investigate the problem of increasing the effective storage capacity fins of different diameters were incorporated to the tubes submersed in the PCM. Also by this method it is possible to determine the largest solidified diameter within a specified time.

It is well known fact that problems of heat transfer with phase change have very few analytical solutions for the cases of simple geometry with simple and linear boundary conditions. Approximate methods were developed and applied to a variety of geometries and boundary conditions by many authors as done by London and Seban [1], Murray and Landis [2], Silva [22] and Ismail [23].

During phase change in PCM storage systems, the solid liquid interface moves away from the heat transfer surface and consequently the heat flux decreases due to the increase of thermal resistance of the solidified PCM. To overcome the problem of the decrease of the heat transfer rate a variety of heat transfer enhancement techniques are under investigation such as fins, metal honeycombs, wire meshes and highly conductive particles dispersed in the PCM.

One of the methods used for increasing the rate of energy storage is to increase the heat transfer area by using finned surfaces. To investigate the effects of fins on the rate of solidification and melting, Bathelt and Viskanta [3] studied the solidification problem around a horizontal finned tube. Sparrow

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