World Academy of Science, Engineering and Technology
International Journal of Mechanical and Mechatronics Engineering
Vol:12, No:07, 2018

Analyzing the Heat Transfer Mechanism in a Tube Bundle Air-PCM Heat Exchanger: An Empirical Study

Authors : Maria De Los Angeles Ortega, Denis Bruneau, Patrick Sebastian, Jean-Pierre Nadeau, Alain Sommier, Saed Raji

Abstract : Phase change materials (PCM) present attractive features that made them a passive solution for thermal comfort assessment in buildings during summer time. They show a large storage capacity per volume unit in comparison with other structural materials like bricks or concrete. If their use is matched with the peak load periods, they can contribute to the reduction of the primary energy consumption related to cooling applications. Despite these promising characteristics, they present some drawbacks. Commercial PCMs, as paraffines, offer a low thermal conductivity affecting the overall performance of the system. In some cases, the material can be enhanced, adding other elements that improve the conductivity, but in general, a design of the unit that optimizes the thermal performance is sought. The material selection is the departing point during the designing stage, and it does not leave plenty of room for optimization. The PCM melting point depends highly on the atmospheric characteristics of the building location. The selection must relay within the maximum, and the minimum temperature reached during the day. The geometry of the PCM container and the geometrical distribution of these containers are designing parameters, as well. They significantly affect the heat transfer, and therefore its phenomena must be studied exhaustively. During its lifetime, an air-PCM unit in a building must cool down the place during daytime, while the melting of the PCM occurs. At night, the PCM must be regenerated to be ready for next uses. When the system is not in service, a minimal amount of thermal exchanges is desired. The aforementioned functions result in the presence of sensible and latent heat storage and release. Hence different types of mechanisms drive the heat transfer phenomena. An experimental test was designed to study the heat transfer phenomena occurring in a circular tube bundle air-PCM exchanger. An in-line arrangement was selected as the geometrical distribution of the containers. With the aim of visual identification, the containers material and a section of the test bench were transparent. Some instruments were placed on the bench for measuring temperature and velocity. The PCM properties were also available through differential scanning calorimeter (DSC) tests. An evolution of the temperature during both cycles, melting and solidification were obtained. The results showed some phenomena at a local level (tubes) and on an overall level (exchanger). Conduction and convection appeared as the main heat transfer mechanisms. From these results, two approaches to analyze the heat transfer were followed. The first approach described the phenomena in a single tube as a series of thermal resistances, where a pure conduction controlled heat transfer was assumed in the PCM. For the second approach, the temperature measurements were used to find some significant dimensionless numbers and parameters as Stefan, Fourier and Rayleigh numbers, and the melting fraction. These approaches allowed us to identify the heat transfer phenomena during both cycles. The presence of natural convection during melting might have been stated from the influence of the Rayleigh number on the correlations obtained.

Keywords : phase change materials, air-PCM exchangers, convection, conduction
Conference Title : ICHTFF 2018 : International Conference on Heat Transfer and Fluid Flow
Conference Location : Zurich, Switzerland
Conference Dates : July 30-31, 2018