JP Journal of Heat and Mass Transfer

http://www.pphmj.com
http://dx.doi.org/10.17654/HM015030747
Volume 15, Number 3, 2018, Pages 747-768 **ISSN: 0973-5763**

THERMODYNAMIC MODEL OF A PHASE-SHIFTING DEVICE OPERATING WITH A PHASE CHANGE MATERIAL

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Abstract

A thermodynamic model of a “heat wave” phase shifter operating with phase change material (PCM) has been developed and experimentally investigated. The work started by building a physical model and developing numerical algorithms set up to simulate its thermal behavior. Parameter studies reveal its operation characteristics and demonstrate a remaining potential for further improvements. This new phase shifter is a short term PCM heat storage device which uses the

Received: March 29, 2018; Accepted: May 20, 2018

Keywords and phrases: phase change materials, PCM, continuous phase transition, phase shifter, passive cooling.

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daily variation of the outside air temperature to indirectly cool the interior of a building. Besides sensible heat storage and phase shifting an important influence of the latent heat of the PCM is observed that originates from the high latent heat thermal inertia of the PCM. This latent heat greatly increases the heat storage capacity and, as a consequence, the phase shift of the "heat wave", compared to a device working solely with a material showing only a sensible heat capacity. To maximize the phase shifters efficiency it is important to operate the PCM in its full range between the solid (cold) and the liquid (hot) phase. Finally, a 45 % increase of the phase shift compared to only sensible heat storage could be achieved. In this article, the derivation of this and similar results are outlined in detail.

1. Introduction

In ancient times, e.g. in the Roman empire, mainly the water/ice transition was used to cool and preserve food [1]. Then it was found that with additives, e.g. alcohol, glycol, etc., certain properties of water/ice may be positively influenced, e.g. its discontinuous first-order phase transition could be changed to a continuous phase change that instead of a point-wise transition now shows an enlarged melting temperature range [2]. Furthermore, the (mean) melting point could be shifted to a lower temperature. This then led to the discovery and development of further other phase change materials, that show the melting/freezing phenomenon also above the freezing point of water, which are roughly classified into organic materials (eutectics, mixtures, paraffin's, fatty acids, etc.) and inorganic materials (eutectics, mixtures, hydrated salts, etc.) [3]. The first category has the advantage of being non-corrosive and the second one to usually be less flammable, which is an important feature demanded from PCM's introduced into building elements [4].

Today, phase change materials and their operation are studied by a broad community of scientists.

First, there are the material scientists, involving chemists who are developing such materials with the practical objective of increasing the