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A STUDY OF THE ONSET OF NATURAL CONVECTION DURING MELTING OF PCMS IN A CYLINDRICAL ENCLOSURE

Mohammad Azad[*], Dominic Groulx[*,§] and Adam Donaldson[**]
[*]Department of Mechanical Engineering, Dalhousie University, Halifax, NS, Canada
[**]Department of Process Engg. and Applied Science, Dalhousie University, Halifax, NS, Canada
[§]Correspondence author. Fax: +1 (902) 423 6711 Email: dominic.groulx@dal.ca

ABSTRACT The most beneficial aspect of using phase change materials (PCMs) in thermal energy storage (TES) systems is the high latent heat of fusion of PCMs. However, the inherent disadvantage of using PCMs is their very low thermal conductivities; because of that, most PCM based TES systems have low heat transfer rates in and out of the systems. Efforts have been made in the past to increase the heat transfer rates in PCM based TES systems through: increasing the thermal conductivities of the PCMs by adding conductive nanoparticles to them, or adding metallic matrix and fins to the heat exchangers. Addition of metallic matrix or fins to the heat exchangers increases the heat transfer area and thus increases the heat transfer rate. Addition of nanoparticles to the PCMs hardly enhances the heat transfer rates, at least does not do so economically. However, any improvement in heat transfer rates by addition of nanoparticles to the PCMs or addition of fins and metallic matrix to the heat exchangers comes with reduction in storage volume (and density).

Studies have found that in PCM based TES systems, heat transfer takes place mainly by conduction during the solidification phase, but by convection during the melting phase. Therefore, enhancement of convection heat transfer could play a large role in increasing the overall heat transfer rate during the melting phase of the PCMs. Identification of factors, such as the charging Stefan number, PCM properties, geometry and orientation of the storage system, that influence the onset of natural convection is needed in order to determine the best strategies to increase convection heat transfer rates in TE-based TES systems.

The onset of natural convection was studied numerically during the melting of *n*-octadecane filling the annular space of a horizontal cylindrical enclosure. COMSOL Multiphysics 5.2 was used to model the two dimensional heat transfer process in the system; heating the PCM from the inner surface of the annulus with the outer surface insulated. The PCM was heated at a Stefan number ranging from 0.15 to 0.35 in a progression of 0.05. A second PCM, dodecanoic acid, was also using in the same system under identical conditions. The impact of enclosure geometry, *i.e.*, different aspect ratios (defined as the ratio of the outer to inner surface areas of the annulus), was studied keeping the outer surface area constant. For both PCMs studied, it was found that convection heat transfer rapidly took over the initial conduction heat transfer and that onset of convection was happened sooner at high Stefan numbers and at small aspect ratios of the enclosures. A correlation relating the needed fluid thickness for onset of natural convection as a function of the various parameters (Ste, liquid PCM viscosity, geometric factors) will be created out of the numerical results.