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Effective thermal conductivity for melting in PCM encapsulated in a sphere

Abstract

Heat transfer in phase change materials (PCMs) contained in spherical encapsulations can be modelled more simply if an effective thermal conductivity can be determined to represent the natural convection occurring within the PCMs. Previous research has shown that natural convection in PCM can be characterised by a constant effective thermal conductivity during the melting process. However, this research did not consider the impact of the increased buoyancy forces with increased temperature difference between the heat transfer fluid flowing around the encapsulation and the PCM. An experimental study was conducted on the heat transfer through a single sphere subject to varying temperature differences. A computational fluid dynamics (CFD) model which ignored buoyancy of the PCM in a sphere was developed. Using this CFD model, the effective thermal conductivity of the liquid portion of the PCM was determined by correlating data from the model against experimental data at various temperature differences with water as the PCM. A suitable relationship for the effective thermal conductivity was developed as a function of the Rayleigh number. This empirical correlation applies to the geometry and PCM used in this study. The study demonstrates the applicability of determining effective thermal conductivity relationships to represent natural convection in PCM thermal storage systems. This correlation can be directly applied to numerical models of PCM storage systems with spheres.

Keywords — Phase change material, thermal energy storage, computational fluid dynamics, effective thermal conductivity