Design of an Automated Thermal Cycler for Long-term Phase Change Material Phase Transition Stability Studies

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Abstract

Phase change materials (PCMs) are capable of storing and releasing large amounts of thermal energy when transitioning between solid and liquid phases, a characteristic that has major implications in thermal energy storage systems. This is due to the high latent heat of fusion required for a PCM to fully melt or solidify. When subject to long-term use however, questions are raised regarding the performance of PCMs after a large number of phase transition cycles have occurred. An automated thermal cycler would allow for frequent, long-term phase change cycling of PCMs for experimental analysis.

The thermal cycler assembly, shown in Fig. 1, consists of an aluminum block housing which is heated and cooled through a discreet ON/OFF control system. Heat enters the system through two high power cartridge heaters, and is removed from the system through four thermoelectric cooling assemblies. The aluminum block houses eight vials containing individual PCM specimens. The controller heats the block housing to a maximum allowable temperature, maintaining this temperature for a specified time to allow the PCM samples to melt completely. A similar procedure is followed with a minimum allowable temperature for cooling (i.e., fully solidifying the PCM samples).

When performing thermal analysis in the COMSOL Multiphysics® software (using the Heat Transfer in Solids interface), an eighth model of the thermal cycler is utilized to minimize computation time. This model and its corresponding tetrahedral mesh plot are shown in Fig. 2. Heat flux and/or temperature boundary conditions are applied to the curved segment along the corner edge of the aluminum block; as this is the location of the cartridge heaters.

With the controller maintaining the housing temperature at either a maximum or minimum value, COMSOL is used to predict the time required for the PCM to fully change phase. The latent heat of transition is simulated in COMSOL as an effective specific heat capacity using a Gaussian distribution about the transition temperature, see Fig. 3. The specific heat capacity increases over a selected temperature range, such that the integral over this temperature range is equal to the latent heat of fusion of the PCM. Fig. 4 shows the COMSOL temperature results at various points in and around the PCM sample while phase change occurs. It requires approximately 6 minutes to fully melt a 5 g sample of PCM (melting temperature of 60 °C) with general fatty acid

properties.

A full length paper will compare experimental phase change timings to those predicted by COMSOL for various PCM specimens. The technique of using a Gaussian expression for specific heat capacity will also be further validated for 3D models.

Figures used in the abstract

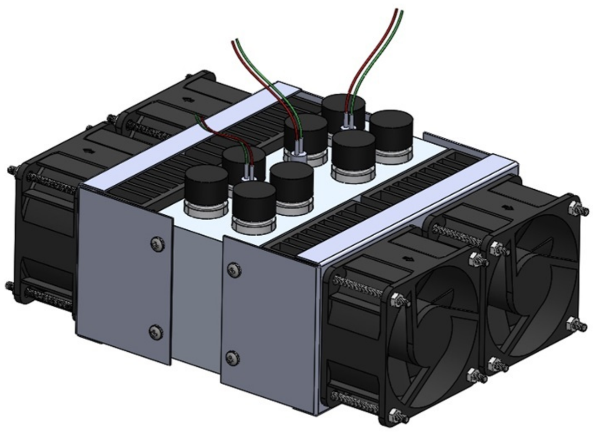

Figure 1: Thermal cycler assembly.

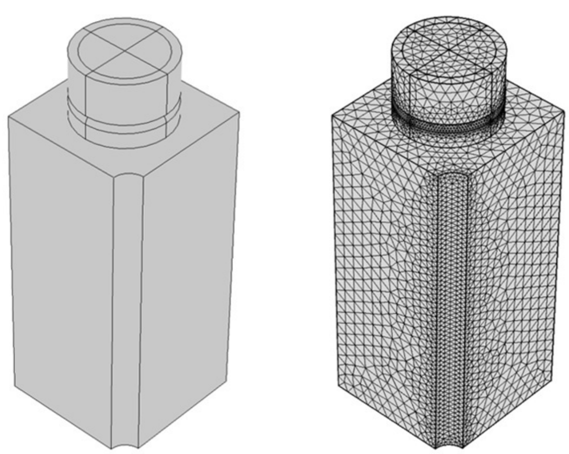

Figure 2: Eighth model (and mesh plot) used in COMSOL thermal analysis.

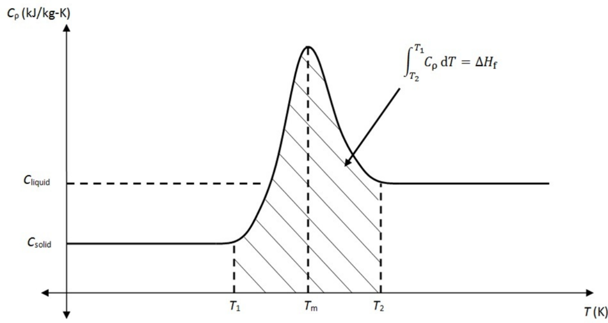

Figure 3: Gaussian representation of specific heat at constant pressure during phase change.

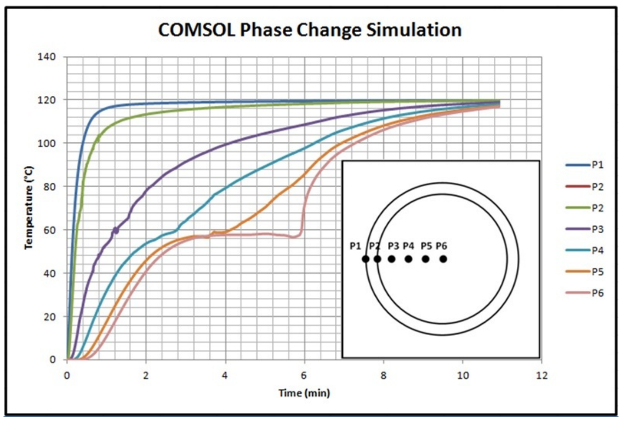

Figure 4: Temperature plot of PCM during solid to liquid phase change.