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Cooling QFP using phase change materials (PCM) heat sink

Daat Research Corp. white paper, May 2018

Encapsulated phase change materials (PCM) are finding an ever wider application in thermal management of electronics and data centers. PCMs have a high fusion capacity and can absorb large amounts of heat when melting and release heat when solidifying. PCM component has been implemented in Coolit and in this white paper we will use it to assess the accuracy of the implemented model. The geometry of PCM objects is specified in Coolit using the new PCM Block component or by importing it from CAD. The PCM physical properties are entered via a dialog and can be general non-linear functions of the temperature.

The first problem is the classic problem with analytical solution [1]. An infinite 100 mm thick slab is initially at 70 ºC. The slab's material properties are: density, $\rho = 790\ kg/m^3$, heat capacity $c_1 = c_2 = 2890$ J/kg/K, $T_{melting} = 55$ ºC, latent heat, L = 173.4 kJ/kg, and thermal conductivity, $k_1 = 0.2$ W/m/K, $k_2 = 0.12$ W/m/K. The subscript 1 is for solid and 2 for liquid phase. At t = 0 sec the surface temperature is changed to 20ºC and we calculate the position (X) of the solidification front as a function of time. Uniform grids with grid cell size 1mm and 8mm were used. Time step for the first grid was 10 seconds and 100 seconds for the second one. Additional tests indicated that the selected time steps yielded time-step independent solutions. Figure 1 shows the Coolit predicted position of the solidification front against the analytical solution [1].

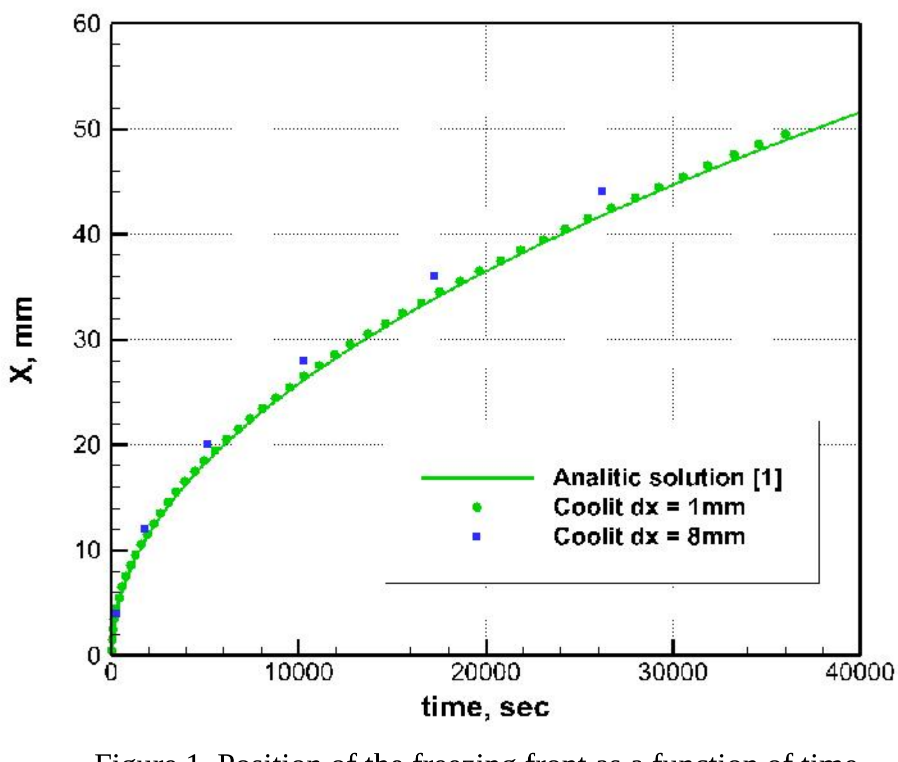

Figure 1. Position of the freezing front as a function of time.

In the second problem we modeled transient cooling of a plastic quad flat package (QFP) using heat sink with PCM. The system had been previously set up and experimentally evaluated in [2]. The setup consisted of a thermally enhanced QFP package, 14 x 14 mm and 64 leads, mounted on top of a printed circuit board (PCB). The die was placed upside on an attached die paddle covered outside with epoxy molding compound. Heat spreader to enhance performance of the QFP package was placed on top of the die. The test is described in more detail in EIA/JESD51-2 standard [3]. We modeled large plate fin heat sink (HS2), 31x31x10 mm with 10 plate fins and filled with molten PCM (paraffin). The input power in this experiment was 4 W.

The QFP die temperature measured in experiment [2] is shown in Figure 2 against results predicted by Coolit. The uncertainty error in experiment was estimated to be within 5% [2]. The 1.1 M grid cell model was calculated with 2 sec time steps.

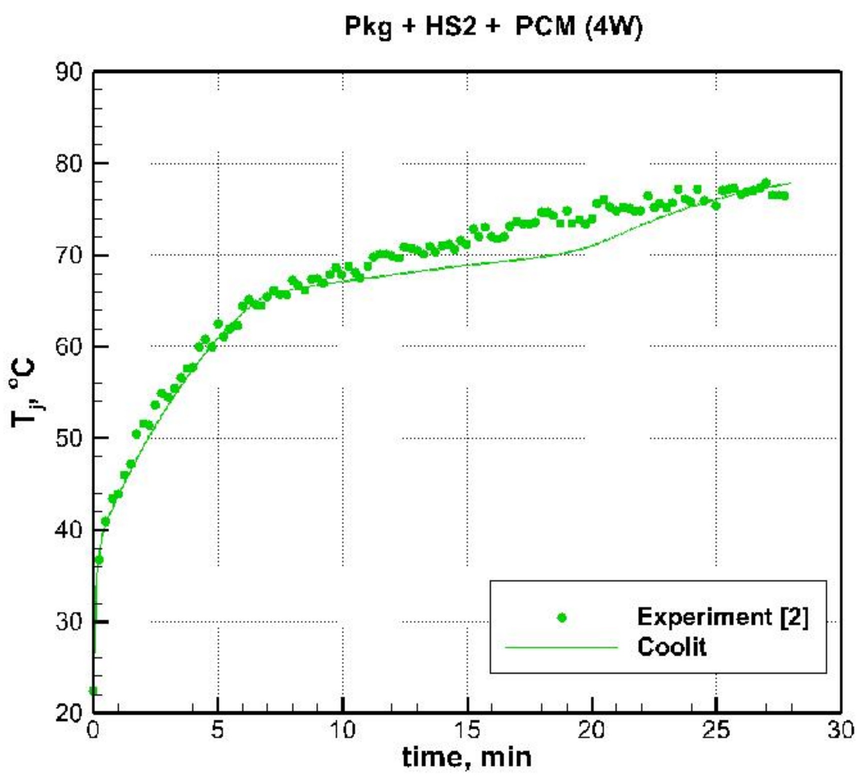

Figure 2. QFP die temperature as a function of time.

References:

1. H.S. Carslaw and J.C. Jaeger, *Conduction of Heat in Solids*, 2nd edn. Clarendon Press, Oxford, p. 285, 1959.

2. R. Kandasamy, X. Q. Wang, A. S. Mujumdar, Transient cooling of electronics using phase change material (PCM)-based heat sinks, Applied Thermal Engineering 28, 2008.

3. EIA/JESD51-2, Integrated circuits thermal test method environment conditions – natural convection (still air).