

# Natural Convection Driven Melting of Phase Change Material: Comparison of Two Methods

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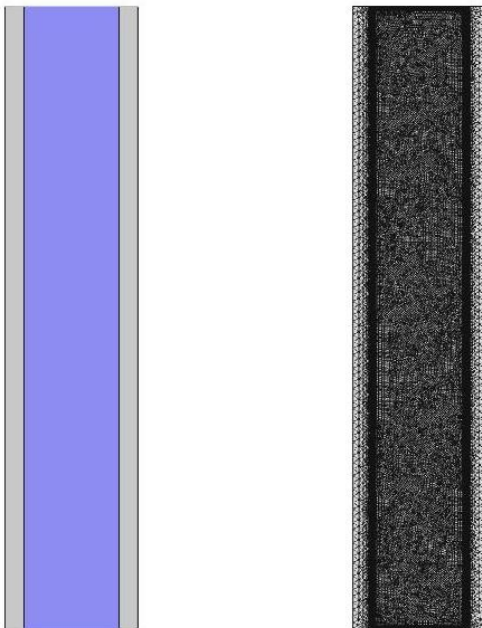
## Abstract

Numerical study of PCM phase change is complicated due to the transient and non-linear characteristics of the process. It was observed that ignoring natural convection in mathematical modeling results in the PCM taking longer to reach its maximum temperature [1]; for that reason, natural convection has to be accounted and simulated for in order to properly describe the physics encounter in the phase change process, especially during melting [2]. In this work, two different methods to simulate for natural convection in the liquid melt are used to solve the same problem in order to draw conclusions on each method and compare one from the other. A simplified two-dimensional model was created in COMSOL Multiphysics 4.3 in order to simulate melting in a LHESS inside a rectangular box having a length ( $L$ ) = 20mm and a height ( $H$ ) = 132mm, with aluminum sides (Figure 1). The PCM simulated for is Rubitherm RT25 having a melting temperature of 300K over a 1K melting range; with an initial temperature equivalent to the environment temperature of 293K. And the heat source for the simulation was taken to be equivalent to solar incident radiation on one side of the system ( $q'' = 1000 \text{ W/m}^2$ ); with convection heat transfer from both sides of the system ( $H_{\text{front}} = 10 \text{ W/m}^2\text{K}$ ,  $H_{\text{back}} = 5 \text{ W/m}^2\text{K}$ ). The first method used defines the viscosity of the PCM in the following way: in the liquid phase, the viscosity is equal to the liquid PCM actual viscosity; for the temperature below the melting point, the viscosity takes a huge value (106), in essence forcing the PCM to remain stationary, i.e., solid [3]. The second method achieves the same result by modifying the buoyancy term in the Navier-Stokes' momentum conservation equation using an additional term to force the velocity field to be zero when the PCM is solid [4]. Figure 2 and Figure 3 present a typical result for this simulation. Figure 2 shows the temperature in the system at four different times (30, 60, 90 and 120 minutes); the white contour line represents the solid-liquid interface on that figure. It is interesting to note that natural convection in the liquid melt is extremely well capture in the system; and the impact of the back aluminum wall is also clearly visible, speeding up the melting process once enough PCM has melted to expose the top portion of the wall. Figure 3 presents the velocity in the liquid melt for the same four times; in that case, a blue contour line is used to show the solid-liquid interface position. It can be observed that the largest velocities are found around every solid surface as expected (two walls and the PCM solid-liquid interface). Simulations are still underway using both methods. The preliminary results suggest that the second method, from Biwolé et al. [4], is more stable and requires less time to perform the same simulation.

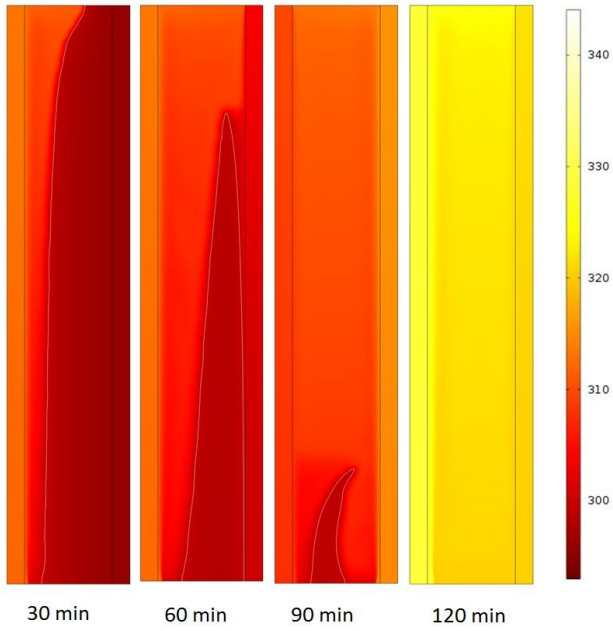
## Reference

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2. Murray R., Desgrosseilliers L., Stewart J., Osbourne N., Marin G., Safatli A., Groulx D., White M.A. (2011) "Design of a Latent Heat Energy Storage System Coupled with a Domestic Hot Water Solar Thermal System", *Proceedings of the World Renewable Energy Congress - WREC 2011*, Linköping (Sweden), 8 p.
3. Murray, R., Groulx, D. (2011) "Modeling Convection during Melting of a Phase Change Material", *Proceedings of the COMSOL Conference 2011*, Boston (USA), 7 p.
4. Biwole, P., Eclache, P., Kuznik, F. (2011) "Improving the Performance of Solar Panels by the Use of Phase-Change Materials", *World Renewable Energy Congress 2011*, Linköping (Sweden), 8 p.

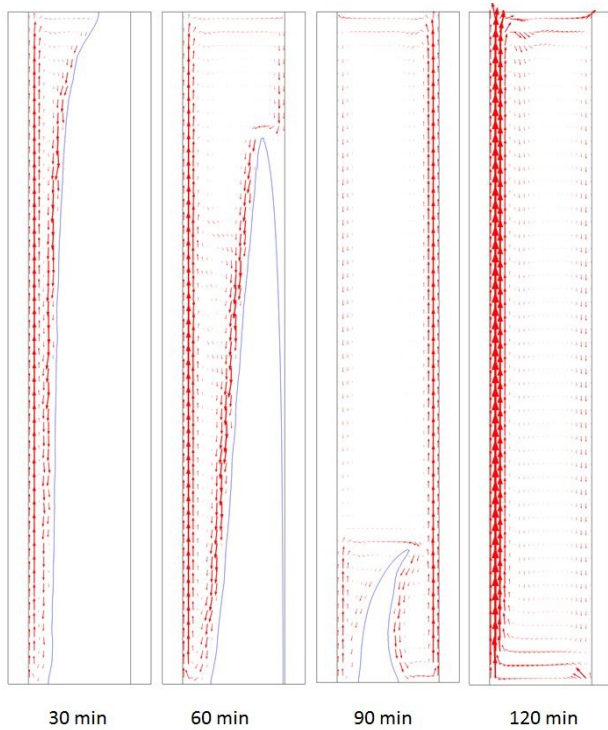
## Figures used in the abstract



**Figure 1:** Geometry used (left) and typical fine mesh (right)



**Figure 2:** Temperature surface plot during melting after 30, 60, 90 and 120 minutes. The solid-liquid melting interface is shown in white.



**Figure 3:** Velocity arrow plot during melting after 30, 60, 90 and 120 minutes. The solid-liquid melting interface is shown in blue.