Convection and Radiation During Melting of a Phase Change Material: A Simplified Model for Engineering Applications
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**Abstract**

A simplified model for combined natural convection and radiation during melting process of a phase change material (PCM) is presented. First, the simplified model for natural convection during melting is validated using a CFD model, in addition to experimental and numerical benchmark solutions for a test case. Then, the simplified model for both natural convection and radiation is applied to the melting of a fatty acid eutectic filled in glass bricks and validated against lattice Boltzmann-discrete ordinate method (LBM-DOM). Finally, the complete model is applied to study the thermal behavior of a translucent wall; then validated experimentally using a full-scale building located in southern France.

**Numerical study**

![Layout of the INERTRANS wall and PCM filled in glass bricks](Image)

Temperatures and solar radiation for three consecutive days in summer 3, 4, 5 August 2017 from experimental data

For the simplified model:
- a fixed-grid modified “enthalpy” method is used to solve phase change problem
- The absorption solar radiation is divided equally between the nodes representing each layer. Considering N nodes in the PCM cavity, the absorbed solar radiation to be added as a source term to the energy equation at the node P is then given as:
  \[ \frac{\partial \rho C_p T}{\partial t} = \text{absorbed solar radiation} + \frac{\partial}{\partial x} \left( \rho C_p v \frac{\partial T}{\partial x} \right) + \frac{\partial}{\partial y} \left( \rho C_p v \frac{\partial T}{\partial y} \right) + \frac{\partial}{\partial z} \left( \rho C_p v \frac{\partial T}{\partial z} \right) \]
- The nodal optical properties such as the transmissivity and absorptivity of the PCM are evaluated function of the transient liquid fraction.

**Results**

1) Melting of Octadecane with natural convection

2) Melting of fatty acid with natural convection and radiation

3) Application to the TIM-PCM wall

**Conclusions**

- The proposed simplified model is simple to implement and its simulations run significantly faster than those of CFD models and LBM-DOM model. Consequently, it can be easily integrated into an energy simulation tool for yearly performance evaluation,
- During PCM melting process, natural convection has a noteworthy role as it enhances the average fraction of liquid and the position of the melting front,
- Shortwave radiation enhances the average liquid fraction,
- To be closer to reality, natural convection and radiation during melting must be considered.