Numerical Modeling of Melting Process of PCMs Including Natural Convection and Turbulence

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Impact of natural convection and turbulence in melting process of two PCMs has been numerically studied, using Fluent.

First study: effect of natural convection in the melting process of a low temperature PCM in a cylindrical enclosure.

Second study: effect of turbulence in the melting process of a high temperature PCM in a parallel flow.

Results of first study shows higher accuracy of the model including natural convection, compared to the experimental data [1].

Results of second study shows higher heat transfer rate and lower temperature gradient due to mixing effect of turbulence.

Background and Motivation

• Latent heat thermal energy storage (LHTES) systems are a promising solution to deliver continuous and cheap electricity through concentrated solar power (CSP) plants.

• Results from experiments or computer models of low temperature PCM provides insight to the thermal behaviour of high temperature PCMs, using dynamic similarity analyses [2].

• Previous studies suggested that PCMs with different Pr number (Pr > 1) show same thermal behaviour in a melting process with natural convection [2,3].

• Design and optimisation of a LHTES system requires knowledge of flow, heat and mass transfer during melting and solidification processes of a high temperature PCM.

Numerical Modeling

• 1st study: 2D axisymmetric grid with fixed temperature, 55°C, at outer surface of cylinder, 32°C at bottom, adiabatic at top.

• 1st study: Laminar melting of wax, Tm = 36°C, Tm = 18.6°C, Ra = 10⁴, time step = 0.05 sec.

• 2nd study: 2D grid of a parallel flow with fixed temperature at HTF inlet, 457°C, symmetry at sides and adiabatic at top and bottom.

• 2nd study: Turbulent melting of NaNO₃, Tm = 306.8°C, Tc, Tm = 150°C, Ra = 10¹⁵, time step = 0.1 sec.

Results

Conclusions

• Ignoring natural convection does not provide accurate results for the purpose of design and/or optimisation of a LHTES system.

• Including turbulence for the cases with Ra > 10¹⁵, provides more accurate results for the purpose of design and/or optimisation of a LHTES system.

References


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