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 ($Pr \gg 1$) 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, $T_m \sim 36$°C, $T_h - T_m = 18.6$°C, $Ra \sim 10^8$ 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 Na NO_3, $T_m \sim 306.8$°C, $T_h - T_m = 150$°C, $Ra \sim 10^{12}$, time step=0.1 sec.

Results

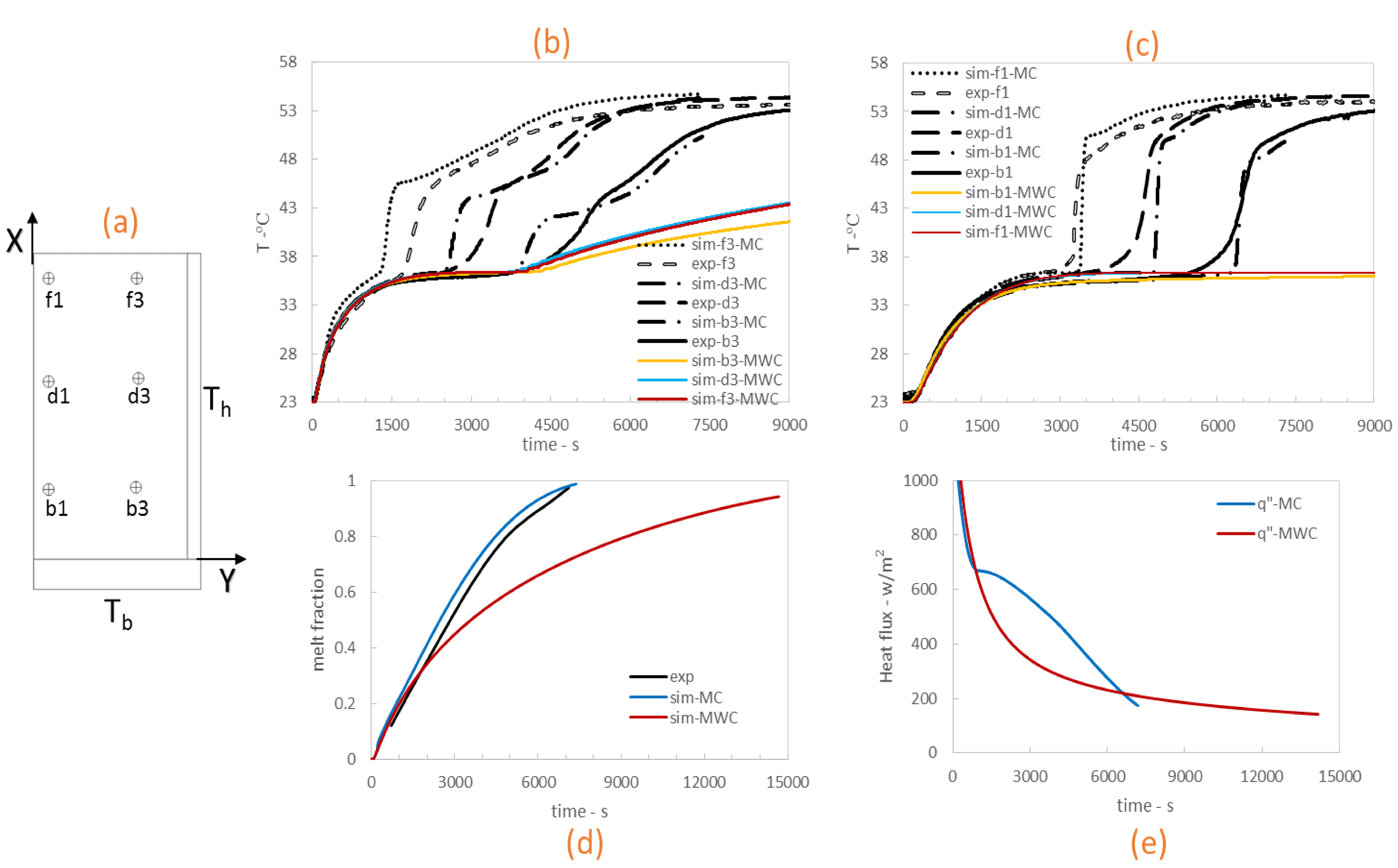

Figure 1: 1st study : Profiles comparison

a) Half geometry sketch, b) Predicted temperature evolution at points, f3, d3, b3, (MC) and (MWC) compered with experimental data, c) Same as b but for the thermocouple location at f1, d1, b1, d) Melt fraction, e) Heat flux

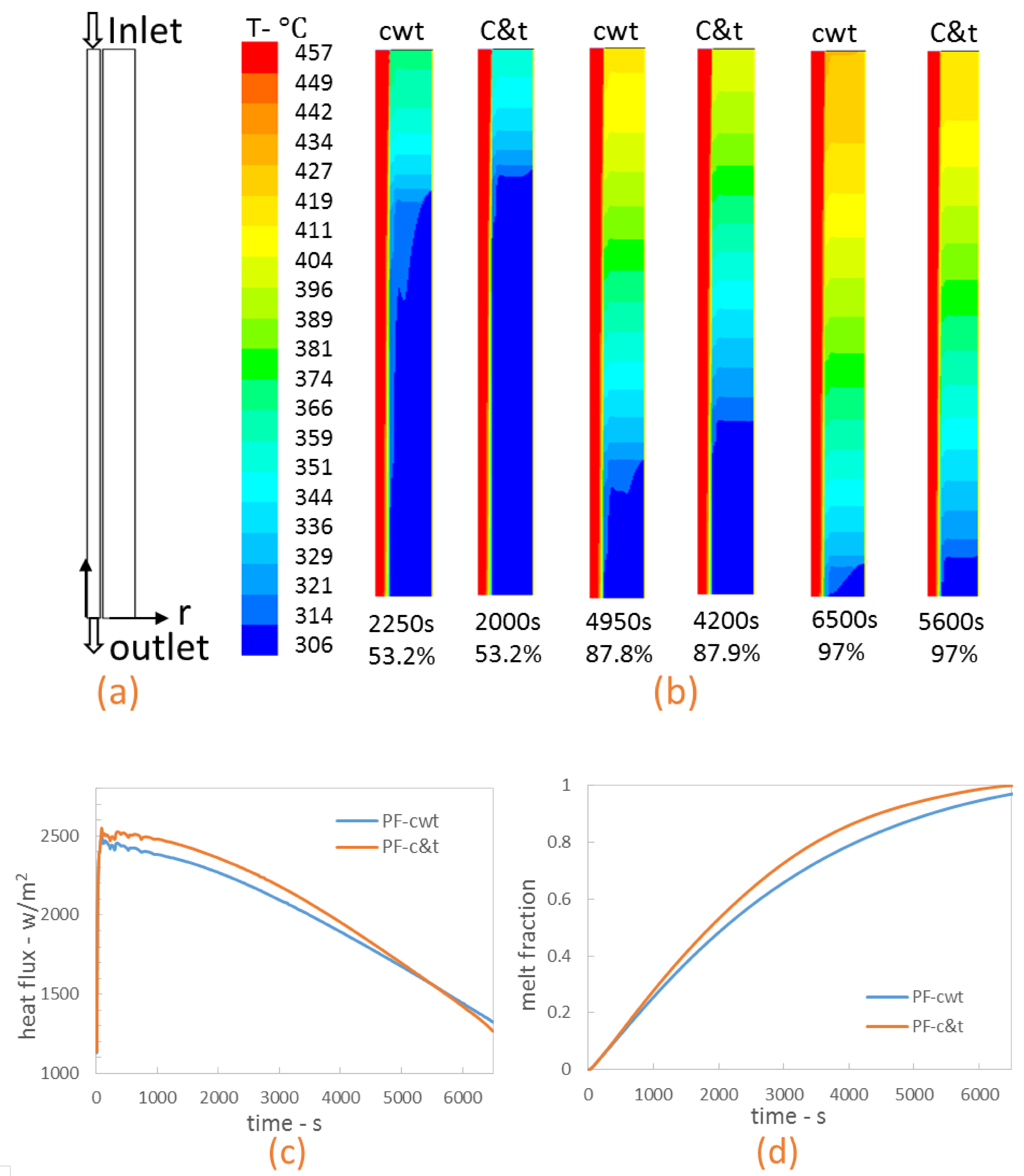

Figure 2: 2nd study : Contours and profiles comparison

a) Half geometry sketch, b) Temperature contours including convection and turbulence (c&t) and convection without turbulence (cwt), c) Heat flux, d) melt fraction

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 $Ra > 10^{11}$, provides more accurate results for the purpose of design and/or optimisation of a LHTES system.

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