Optimization of Architectured Structures in Building for Harnessing, Storage, and Release of Energy

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Introduction

The problematic of storage and release of thermal energy is an important challenge in various industrial fields. Several systems for thermal energy storage exist like phase change materials (PCMs) and thermochemical storage.

However, thermal conductivity of these chemical compounds is poor. Adding a conductive structure within the PCM is a good way to enhance the efficiency of these systems. Among the possible structure, foams are able to meet the requirements : high porosity and good thermal conductivity.

Variable	Value	Units
k	0,2	[W/(m.K)]
Cp	2	[kJ/(kg.K)]
Lf	215	[kJ/kg]
µ	0,003	[Pa.s]

***Table 1**. PCM - RT28 properties*

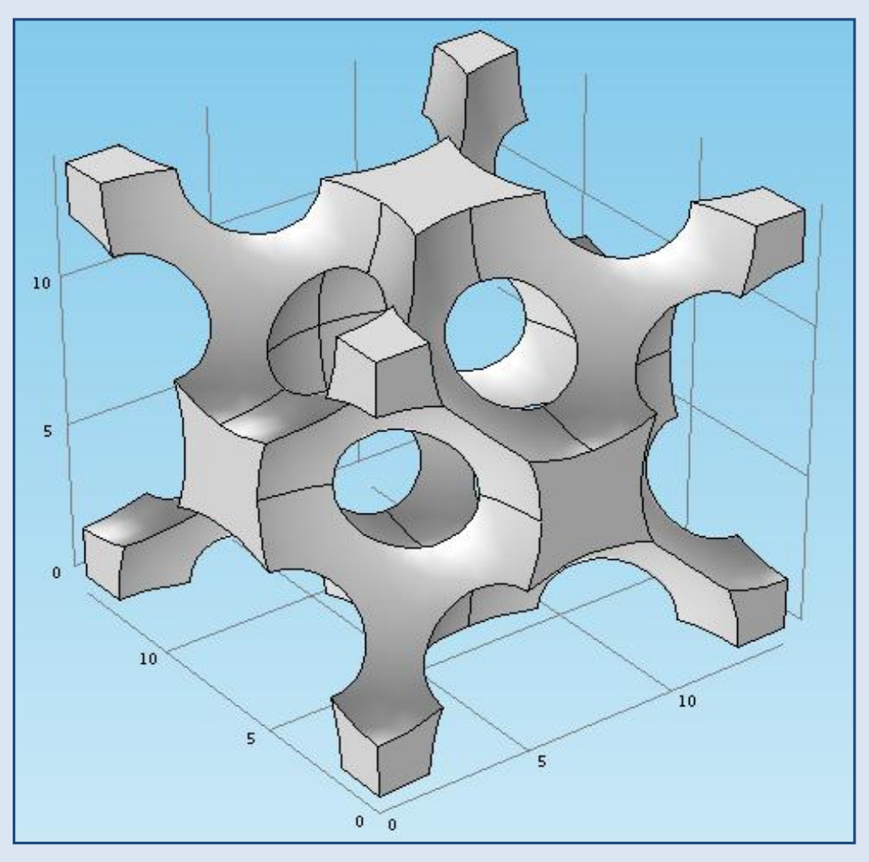


***Figure 1**. Elementary cell foam*

Computational Methods

To model the PCM phase change, using of different functions is a good deal to obtain variations of specific and latent heat, or dynamic viscosity.

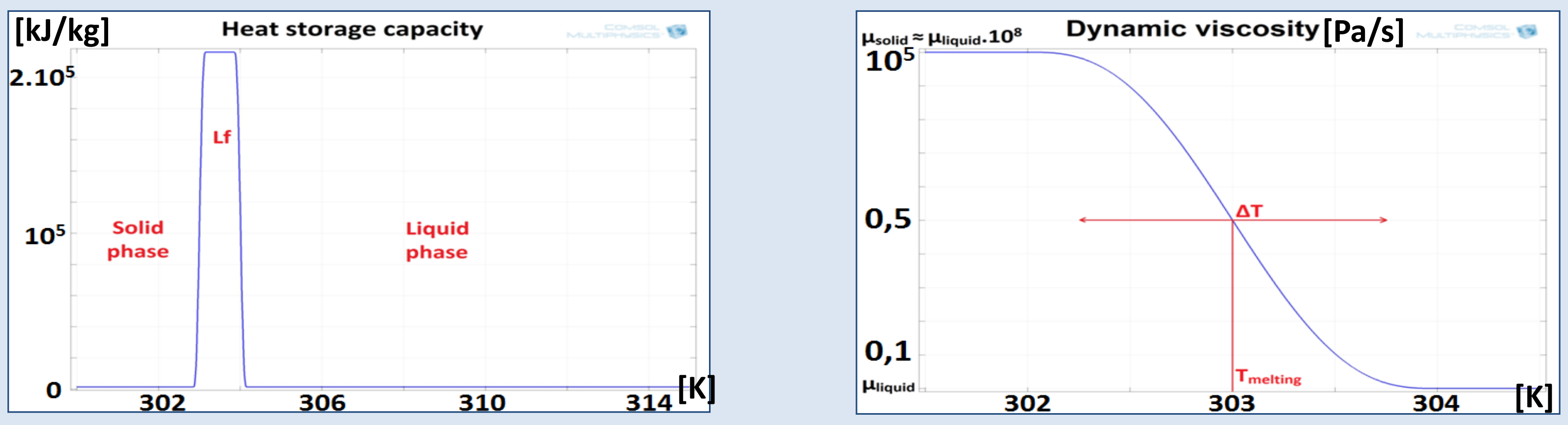


***Figure 2**. Phase change modelisation*

Equation used to simulate heat transfers:

$$\rho.Cp.\frac{\partial T}{\partial t} + \rho.Cp.\boldsymbol{u}\cdot\nabla \mathrm{T} = \nabla\cdot(\mathrm{k}.\nabla\mathrm{T}) + \mathrm{Q} + (\mathrm{Q_{vh}} + \mathrm{W_p})$$

Equation used to simulate flow of natural convection:

$$\rho.\frac{\partial u}{\partial t} + \rho.(u\cdot\nabla u) = \nabla\cdot\left[-p.I + \mu.(\nabla u + (\nabla u)^T) - \frac{2}{3}.\mu.(\nabla\cdot u)I\right] + F$$

$$F = \rho.g.\alpha.\Delta T$$

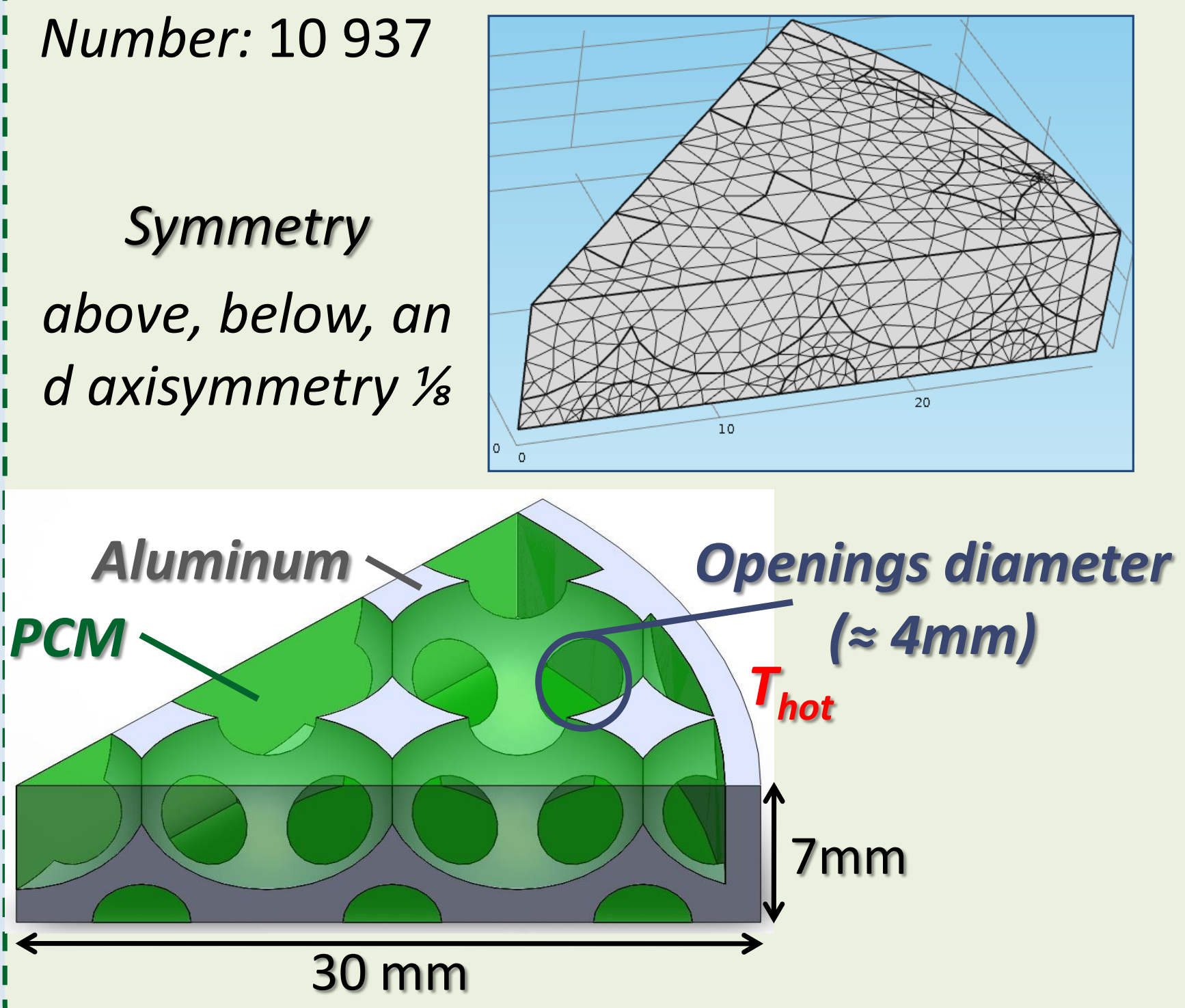
Comsol modules used are "*heat transfer in solids*", "*heat transfer in fluids*", and "*laminar flow*".

Two configurations depending on the studied physics:

Real 3D structure (only conduction)

Mesh element description

Average quality: 0,6682
Type: linear tetrahedral
Number: 10 937



Symmetry

above, below, and axisymmetry ⅛

***Figure 3**. 3D mesh & modelisation*

Simplified 2D structure (conduction & convection)

Mesh element description

Average quality: 0,5827
Type: linear mapped with distribution
Number: 3 680

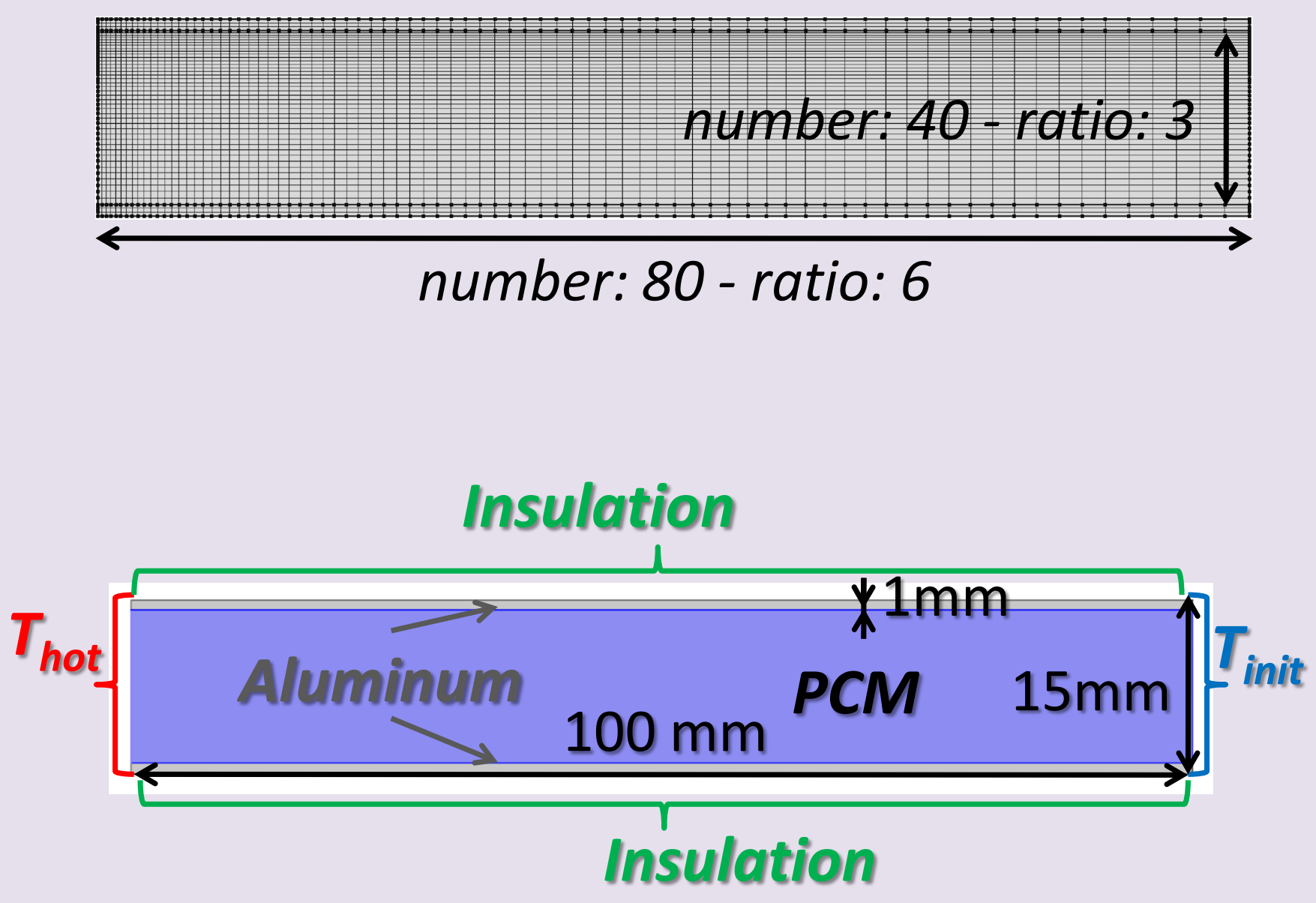


***Figure 4**. 2D mesh & modelisation*

Results

Real 3D structure (only conduction)

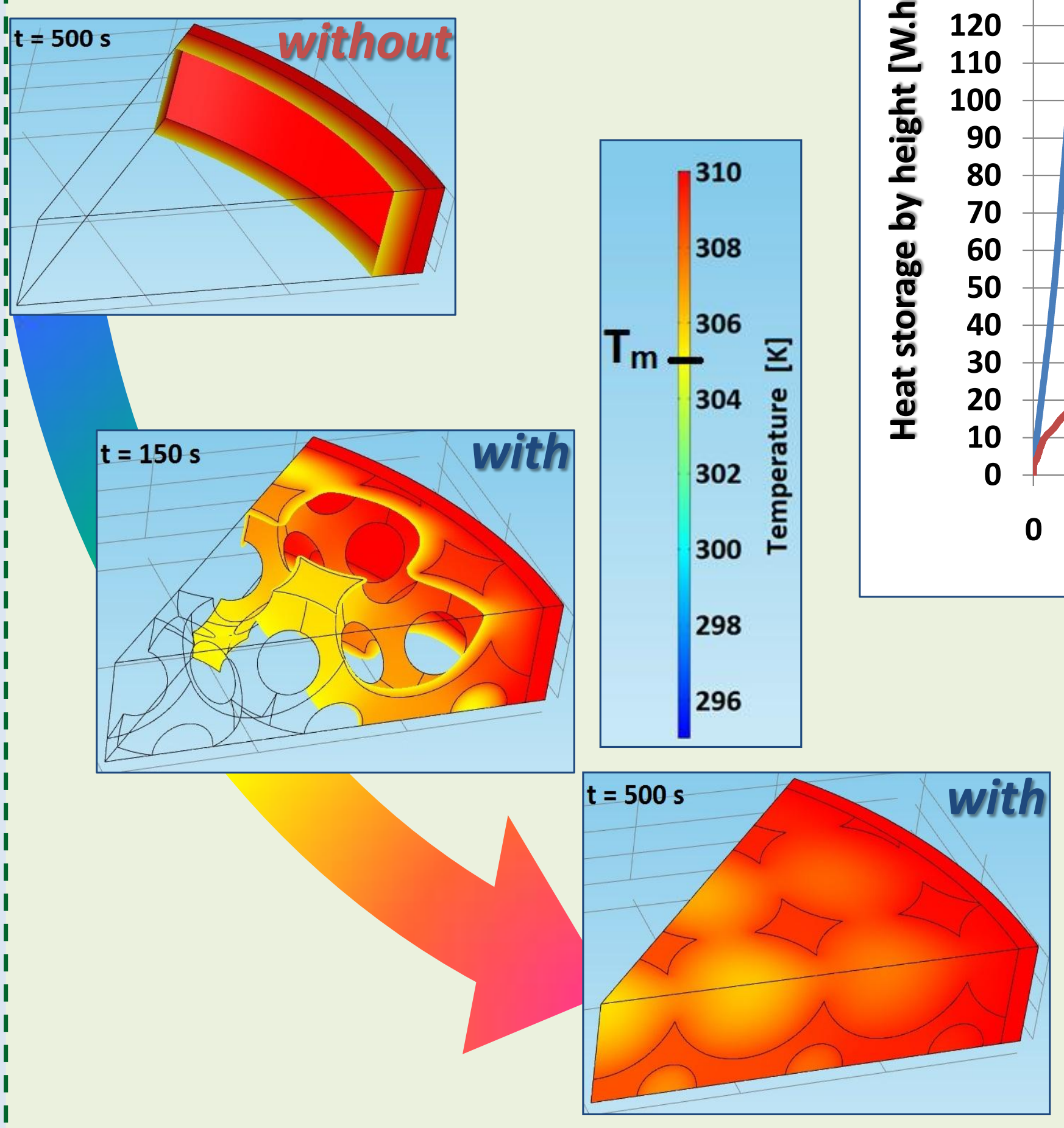


***Figure 5**. with/without metallic foam*

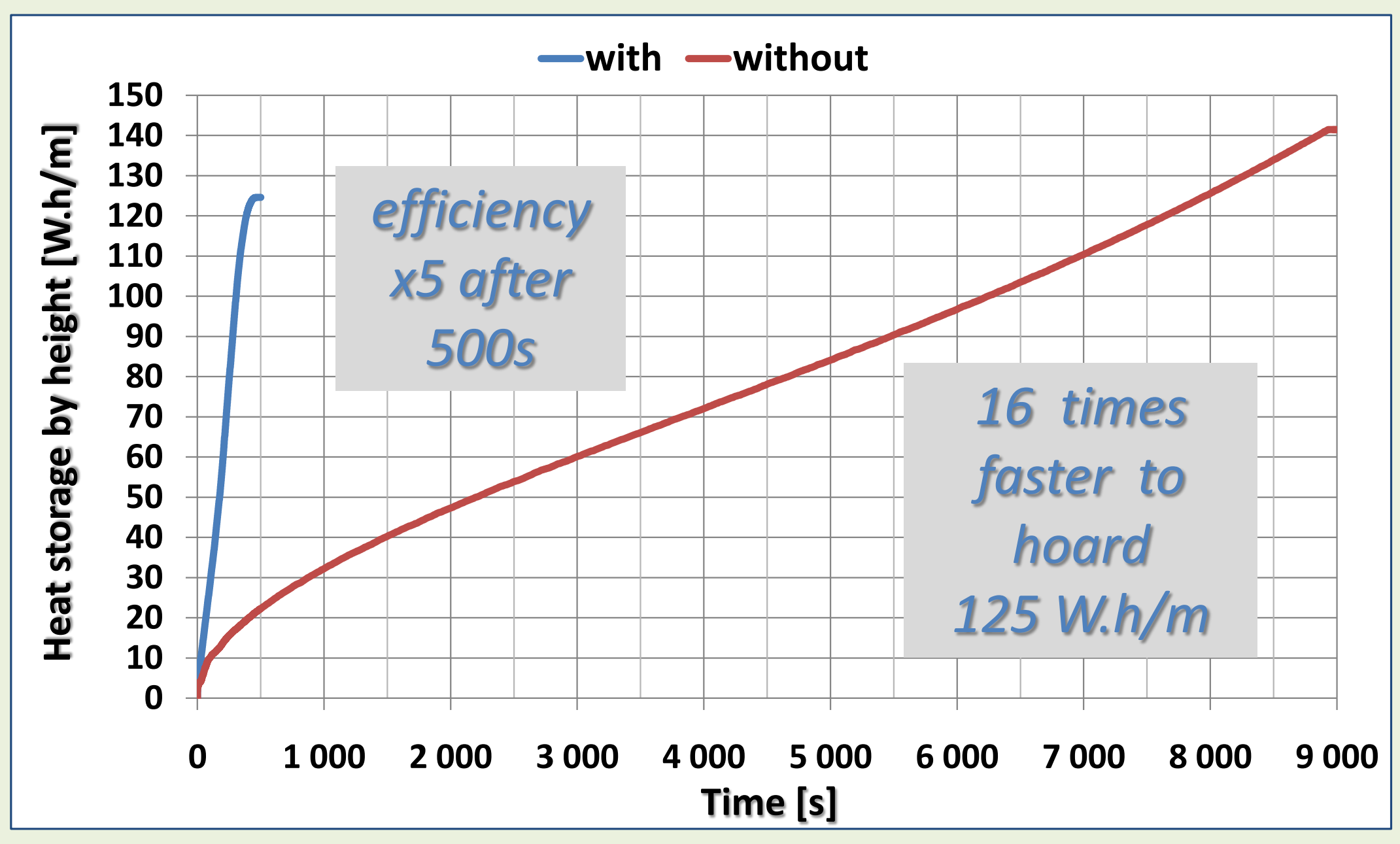
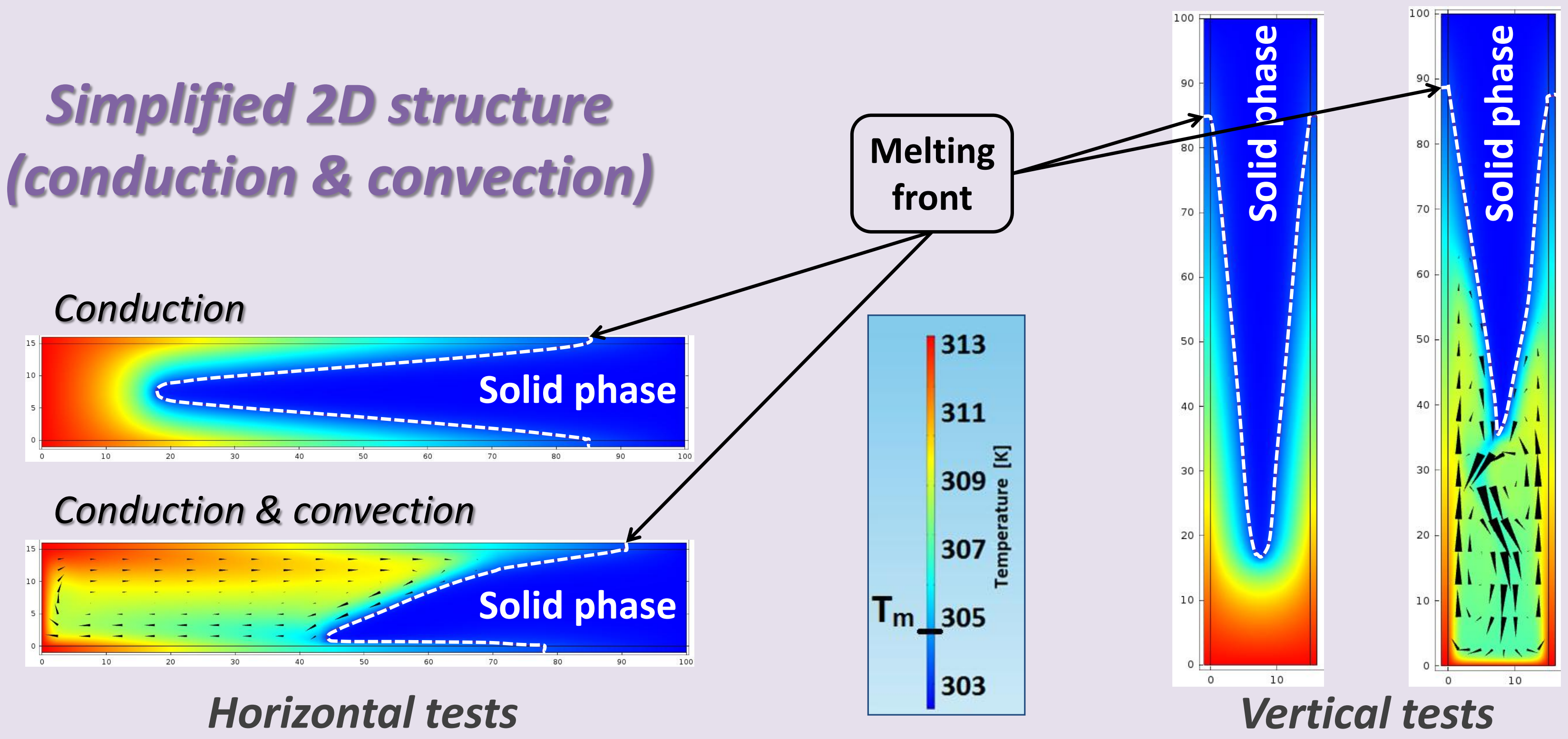


***Figure 6**. Influence of metallic foam*

Addition of metallic foam inside the storage system improve significantly heat transfer efficiency

Simplified 2D structure (conduction & convection)



Horizontal tests *Vertical tests*

***Figure 7**. horizontal & vertical convection simulation*

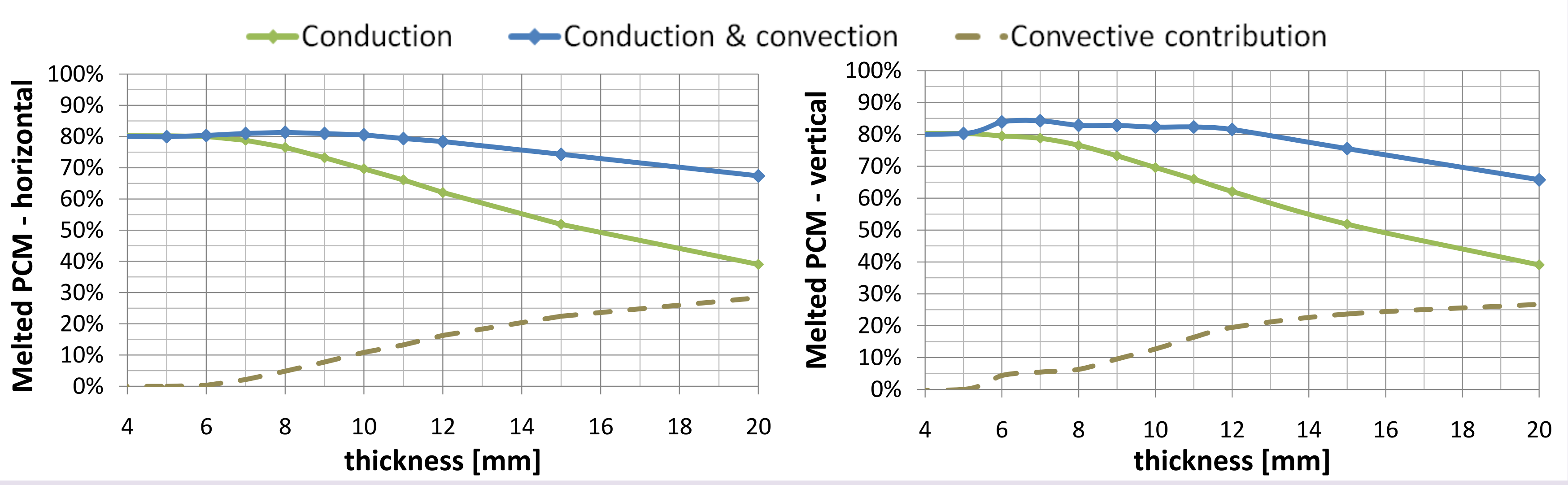


***Figure 8**. Thermal convection effects*

A transition area can be seen around a PCM thickness of 6-10mm.

Horizontal & vertical* convection are almost equivalent

**from bottom to top*

Conclusions

- ✓ Using of metallic foam is evident to obtain a competitive heat storage.
- ✓ Convection transfer is negligible when PCM thickness is small.
- ✓ Direction of ∇T is not a fundamental convection criteria.

Perspectives

- ☐ 3D convection heat transfer on real 3D structure.
- ☐ 3D conduction heat transfer on foams with very small cell.
- ☐ To optimize metallic foam geometry.

References

1. S.D. Sharma, K. Sagara, Latent Heat Storage Materials and Systems : A Review, International Journal of Green Energy.
2. F. Agyenim, N. Hewitt, P. Eames, M. Smyth, A review of materials, Renewable and Sustainable Energy Reviews 14 (2010) 615-628.
3. D. Groulx, Modeling convection during melting phase change material, Excerpt from the proceedings of the 2011 Comsol Conference in Boston.

Excerpt from the Proceedings of the 2014 COMSOL Conference in Cambridge