Energy Ville

Empowered by: KU Leuven, VITO, imec & UHasselt

Topology and Parameter Optimisation of PCM Storages

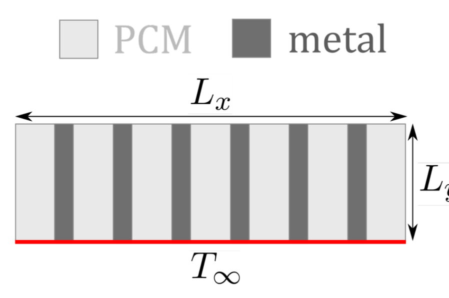
GeoWatt – Activity 1 - Innovation for 4th Generation Thermal Networks: from Component to System Level

Description

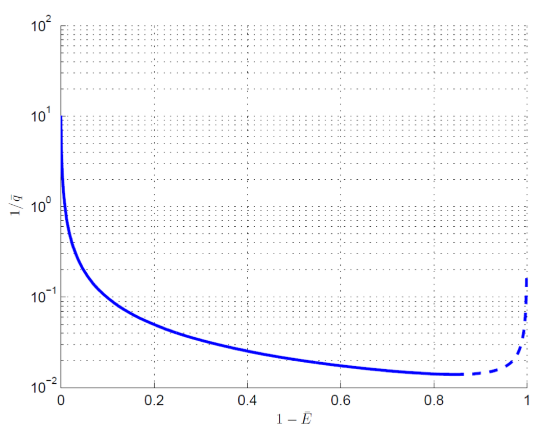
The low Phase Change Materials (PCMs) thermal conductivity limits the charging and discharging process of latent heat storages. Highly conductive metal fin structures tend to enhance the heat transfer, therefore considerably reducing charging and discharging times. By tuning the shape of the PCM domain towards high aspect ratios, the heat extracted from a hot flow is enhanced due to reduced thermal diffusion lengths. **Optimisation of fin distributions** leads to designs with increased fin density towards the exit of the channel. Increased fin density locally improves the charging potential.

Charging Limits

Introducing highly conductive metal fins in the PCM storage increases the overall heat transfer. The performed study used a constant temperature wall as heat source. A uniform fin distribution was found to have the **best charging performance**. Moreover, for a given metal volume fraction, introducing more and thinner fins increases the charging power. In the limit of infinitely thin fins, charging performance reaches its limit value. These limits are shown in Figure 1.



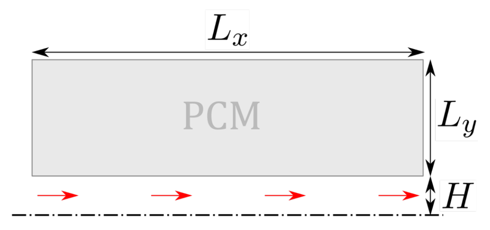
Highly conductive fins in a PCM domain heated by a constant wall temperature source



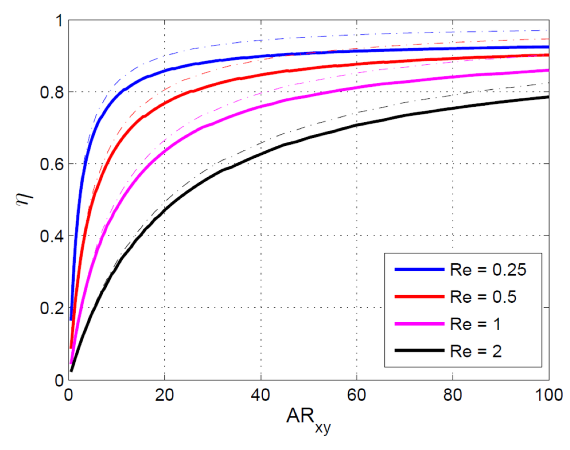
charging limits for infinitely thin fins showing the inverse power density vs. metal volume fraction.

Finite Inlet Power Charging

By **including a heat transfer fluid,** more realistic designs were studied. A hot water flow was used to charge the PCM, with a constant input power. The input power is created by a constant mass flow rate combined with a fixed temperature difference with respect to the melting temperature of the PCM. Higher PCM aspect ratios result in a higher charging performance as is seen in Figure 2. The thinner the PCM layer, the smaller the thermal diffusion lengths and therefore the higher the charging power.



A PCM domain heated by a hot water flow with finite input power

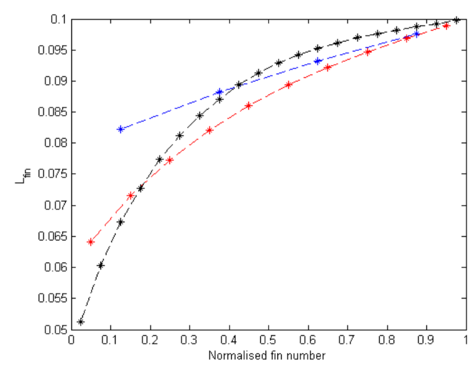


normalised charging power vs. PCM domain aspect ratio $(AR\_xy=L\_x/L\_y)$ *for different input powers* $(\dot{Q}\_in \sim Re)$.

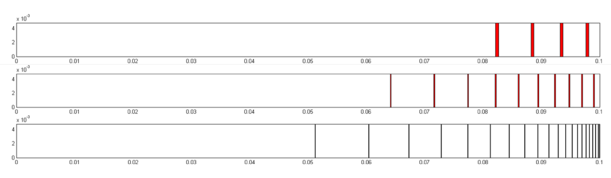
Fin Spacing Optimisation

Due to the limited input power and limited convection of the heat transfer fluid, the PCM does not melt uniformly. Therefore, uniform fin distributions can be outperformed by new designs with irregular fin distributions.

An **adjoint-based optimisation** strategy was used to optimise the performance of PCM storages by optimally spacing the highly conductive fins in the PCM domain. The optimised fin distributions show a trend towards closer fin spacing, i.e. a higher fin density, towards the exit of the heat transfer fluid channel. Figure 3 shows examples of optimised fin distributions. It is observed that optimal fin distributions strongly depend on the fin widths. More fins with smaller widths are favoured over few and wide fins.



Optimised fin distribution for three cases (4, 10 and 20 fins) for the same input power, domain size and metal volume fraction: fin positions vs. normalised fin number



optimal fin distributions

References

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[2] Peremans B., Blommaert M., Diriken J., Baelmans T. (2018). Design procedure for energy efficient latent heat storages with heat transfer fluid channels and finite inlet power. Proceedings of the 16th International Heat Transfer Conference, IHTC-16. International Heat Transfer Conference. China, 10-15 August 2018, Abstract No. IHTC16-23248.

[3] Peremans B., Blommaert M., Baelmans T. (2018). Optimization of metal fin distributions in latent heat storages. Proceedings of the 6th International Conference on Engineering Optimization, EngOpt 2018. Engineering Optimization Conference. Portugal, 17-19 September 2018 Abstract.

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