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High Power Latent Heat Storages With 3D Wire Structures – Numerical Evaluation Of Phase Change Behavior

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Abstract

Latent heat storage devices use the melting enthalpy of a so-called phase change material (PCM) to store thermal energy. Open porous metals, such as 3D wire structures, allow the design of systems with tailored storage capacity and power. A geometric unit cell was identified, modelled and COMSOL Multiphysics was used to investigate the transient behavior of the PCM melting front within the composite of PCM and 3D wire structure. As a result, the impact of the wire structures material as well as the influence of brazing the inner connections of the wire structure on storage kinetics were analyzed.

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Keywords: Latent Heat Storage; Phase Change Material; 3D Wire Structure; Transient Melt Front; Transient Simulation

1. Introduction

One of the main advantages of latent heat storage devices are the high volumetric storage density and the fact that the energy is stored at a nearly constant (melting) temperature. The main drawback of the most common phase change materials (PCM) is their low heat conductivity and, therefore, the storage power is limited. Open porous metals, such as 3D wire structures, are able to improve the effective heat conductivity of the system significantly. This allows the design of systems with tailored storage capacity and power. PCMs are market available for a wide range of working temperatures between −50 °C up to about 800 °C as shown in Fig. 1. Depending on the used PCM the possible storage capacity varies between 150 MJ/m^3 and 900 MJ/m^3. In the work presented, the main consideration were process heat applications with a temperature range of 130 °C to 350 °C. Therefore, nitrate salts like KNO_3, $NaNO_3$, $LiNO_3$ and their eutectic mixtures are used as PCM. The aim was to develop a simulation model which can be used to design and optimize a latent heat storage in terms of thermal capacity and power. The first step was the definition of a unit cell which was modelled and simulated using COMSOL Multiphysics.

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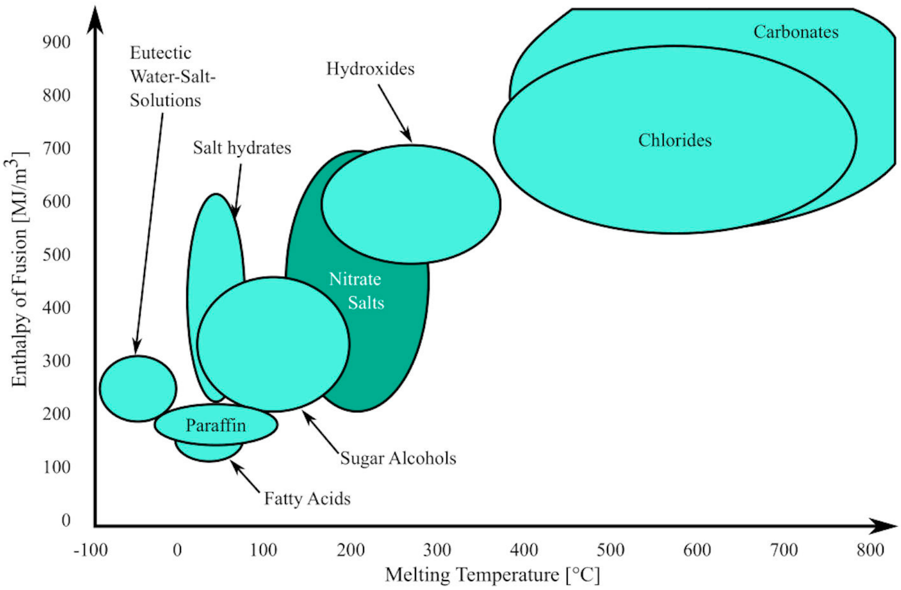

Fig. 1. Properties of available phase change materials (PCM).

2. Geometrical model and simplifications

The main task was the full geometrical modelling of the 3D wire structure in order to get realistic thermal behavior of the metal-PCM-composite. The modelled 3D wire structure is a size 10 strucwire geometry which consists of regular helices combined in one plane and stacked into a 3D structure. The result is shown on the left side of Fig. 2 in front and top view.

Pipes of the size 8x1 fit in the modelled pores and were used as heat carrier tubes. The tubes are separated by 5 pores in both directions. Therefore, the model length and width is fixed to that size. The height of the structure is periodic so the unit cell is one cell high as the red dash lines in the front view in Fig. 2 (left) indicate. By respecting geometric symmetries, the resulting simulation model contains a quarter of the unit cell including wire, PCM and heater tube, as shown in Fig. 2 (right).

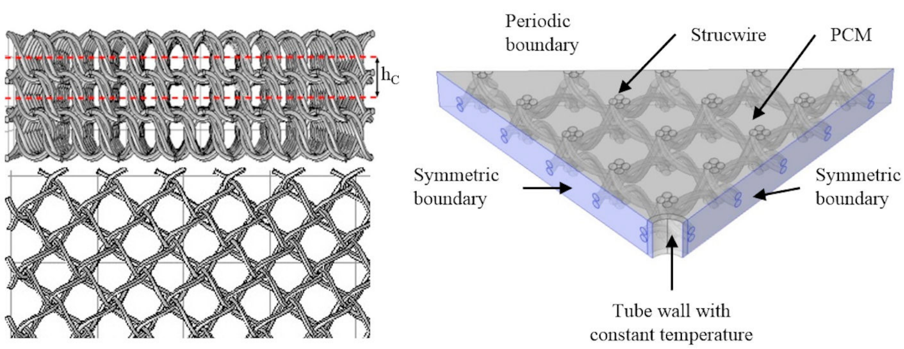

Fig. 2. 3D Model of the strucwire structure (left) and resulting simulation model (right)

The given boundaries are also visible on the right side of Fig. 2. Because of the applied periodic boundaries on top and bottom of the model, the temperature difference inside the fluid flow is neglected and a constant temperature is used as boundary on the inner wall of the heat carrier pipe. Therefore, the temperature field inside the pipes wall is considered as well as the heat transfer from the outer pipe wall into the wire structure and the PCM.