Energy for the factory

Optimization of heat storage through the use of phase change material

Graduate

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Objective: This bachelor thesis examines the use of phase change materials (PCM) to stabilize industrial heating systems. The background to this is the process heat supply for chocolate production at Lindt & Sprüngli, where a lack of storage facilities causes significant temperature fluctuations in the 70 °C network. Conventional water storage tanks can dampen such fluctuations, but they require large volumes and space reserves that are not available in established factory structures. PCMs have the ability to store heat predominantly as latent heat during the solid-liquid phase transition. This process is almost isothermal, which allows for the uniform release or absorption of energy. The aim of the work is to experimentally verify this property, quantify the smoothing potential of PCMs in comparison to water, and derive dimensioning parameters for industrial implementation.

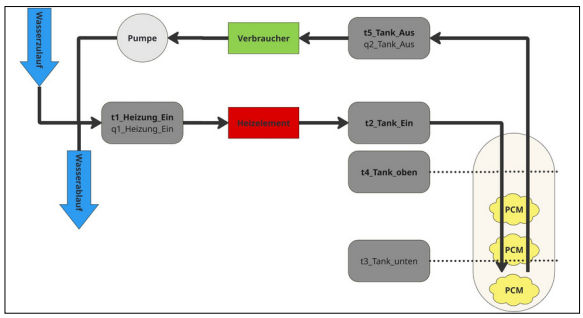
Approach: First, theoretical training was provided on thermal storage principles, heat transfer mechanisms, and the material properties of relevant PCMs. An orientational simulation was used for preliminary analysis to identify control variables such as temperature windows, heat flow, and PCM mass. Since the simulation could only reproduce transition phenomena to a limited extent, a practical laboratory setup was designed and implemented. The test bench consists of a storage tank that can be filled with either water or macro-encapsulated PCM elements. An electric heating rod was used to generate defined temperature cycles between 40 °C and 55 °C, which simulate typical fluctuations in factory operation. A constant volume flow ensured reproducible conditions. The primary measured variables were inlet and outlet temperatures, from which the smoothing factor can be calculated. Various storage states were investigated: pure water storage, water storage with a small amount of PCM, and water storage with a higher PCM content. HeatStixx L capsules from kraftBoxx filled with ATS 50 (inorganic salt hydrate) from Axiotherm were used as the material.

Result: The measurements clearly show that PCM can significantly dampen temperature fluctuations compared to pure water storage systems. While water storage systems achieve smoothing exclusively through their sensitive heat capacity, PCM creates a slight plateau in the temperature curve, which effectively cushions fluctuations in the melting temperature range. Depending on the PCM mass used, the amplitude of the outlet temperature could be reduced by up to 55%. The investigations also confirmed that the geometry and packing density of the PCM elements, the thermal conductivity of the material, and the flow pattern in the tank are decisive factors for the achievable smoothing.

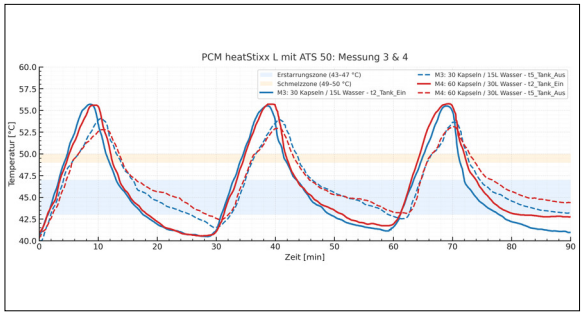
The results clearly show that PCM heat storage systems could represent a compact, technically feasible, and energy-efficient solution for stabilizing industrial heating systems in the future. They contribute to increasing process quality and supply security, reducing energy losses, and lowering CO_2 emissions in the long term. They can thus make an important contribution to the decarbonization of industrial production processes.

Capsules with salt hydrate PCM (ATS50) in a lab tank: absorb heat at phase change and release it when required
Own presentment

Flow chart of lab setup: fluctuating inlet temperature is stabilized in the tank by PCM, yielding a smoothed outlet
Own presentment



Measurements with PCM (ATS50) in the tank: phase change visible, plus significant reduction in temperature fluctuations
Own presentment



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