

Abstract

The growing demand for energy and human activities harmful to the environment make it necessary to transform energy generation towards renewable energy sources. The energy transformation requires the use of energy storage, including latent heat thermal energy storage (LHTES), which can store e.g. heat from solar collector installations or a waste heat, and then use it to support heating/cooling systems of buildings, increasing the share of renewable energy and reducing greenhouse gas emissions. Organic phase change materials (PCMs), which are typically used as storage materials in LHTES, provide chemical and thermal stability, but have low thermal conductivity, which limits heat transfer rates. This limitation may excessively extend charging/discharging time of the storage and may result in incomplete usage of the material's potential for energy accumulation in the case of sources that are relatively short-operating (e.g. solar radiation energy), and also makes it difficult to use the full thermal capacity to meet the heating/cooling load demand of buildings. Although methods to improve heat transfer are used (fins, fin-and-tube heat exchangers, encapsulated PCM, porous materials filled with PCM), they are not satisfactory, as they require increasing the mass and volume of the storage, or reducing the amount of PCM in the LHTES. To obtain a better thermal response without substantially limiting the amount of PCM in storage, direct improvement of the thermal conductivity of PCM is used by adding nanomaterials (carbon-based, metals or metal oxides nanoparticles) to it. The result is new materials: nano-enhanced phase change materials (NEPCMs). However, NEPCM research indicates that although they improve thermal conductivity, a problem of sedimentation of nanomaterials from NEPCM in the liquid appears after some time due to the difference in the density of the "base" PCM and the nanomaterials. The stratification in NEPCM changes the existing thermophysical properties and eliminates their usefulness in LHTES. To counteract this issue, methods such as addition of surfactants, pH optimization or sonication are used. However, they do not completely eliminate this problem and do not work after several cycles of phase transitions. Chemical methods (surfactants, pH optimization) maintain the suspension in the liquid, but the phase change can destroy the forces governing the suspension and prevent its further stability. In addition, the use of surfactants reduces the latent heat capacity and thus the ability of the material to accumulate energy. On the other hand, sonication breaks down agglomeration of particles, but has an optimized duration, which, if exceeded, can cause the opposite effect - re-agglomeration of particles. For this reason, it is necessary to develop a method that effectively prevents sedimentation effect and works even after a phase transition. Therefore, the question arises: are there other methods to stop the sedimentation of nanoparticles from NEPCM and their effects, even after many cycles of phase change?

In the context of the above considerations and problems, scientific goal of the project is to research the use of the bubbling process to maintain NEPCM stability (prevent sedimentation of nanoadditives from NEPCM in the liquid state) and improve heat transfer in LHTES. The implementation of the project will allow to propose a new method to prevent the sedimentation of nanomaterials, which may be used in the future to maintain the stability of NEPCMs and other colloidal solutions. The key in the implementation of the project is to check whether bubbling process will effectively ensure the stabilization of NEPCM during many cycles of phase change? As part of the project, NEPCM samples- RT22 HC material doped with graphene nanoparticles (in short GNPs, with a mass fraction of 1%) and a surfactant (SDBS) will be prepared. The prepared NEPCM samples will be used in tests aimed at determining the sedimentation rate of nanoparticles from NEPCM based on theoretical analysis (based on Stokes' law) and in experimental tests using the phase interface reading method. The results of the research will allow to determine the sedimentation rate of nanoparticles before and after the application of bubbling process. Injection nozzles of our own design will be prepared, which will allow to assess how the parameters characterizing the bubbling process (such as: air flow rate, size and number of bubbles) will reduce the sedimentation rate of nanoparticles and re-mixing the nanomaterials with the PCM. To answer the question: what impact will the bubbling process have on heat transfer in latent heat thermal energy storage, experimental measurements of a self-designed heat accumulator will be made on a laboratory scale. The heat accumulator design will allow to initiate the bubbling process. Measurements during charging/discharging (heating/cooling) of the prepared heat accumulator will be carried out to determine its thermal and flow characteristics. Based on the experimental research carried out in the project, a numerical model will be created that will enable mapping the behavior of nanoparticles during the flow of bubbles through the PCM, as well as the behavior of the LHTES with NEPCM during its charging and discharging. Research carried out as part of the project will provide knowledge about the intensification of heat transfer in the LHTES with the bubbling process and NEPCM, and the efficiency of its storage after many heating/cooling cycles. It is expected that the research carried out in the project will contribute to improving the thermal and transient response of the LHTES. In the future, the impact of the research results on creation of new LHTES storage designs, increasing the usage of renewable energy sources and meeting the climate goals is also expected.