Abstract

The aim of the doctoral thesis is to increase the thermal conductivity of low-temperature organic phase change materials (PCM) by adding nano-admixtures to them. In addition, the doctoral thesis also focuses on determining the impact of admixtures on the ability to store thermal energy of the tested materials, as well as assessing the possibility of using nano-enhanced phase change materials (NEPCM) in energy storage in practice. The analysis of current achievements in the field of thermal energy storage using PCMs has shown that the limitation in the implementation of latent heat thermal energy storage (LHTES) is the low thermal conductivity of PCMs (especially organic). The low conductivity prolongs the charging and discharging time of the storage, and consequently eliminates the possibility of using LHTES in some heating and cooling installations. Actions taken so far to intensify heat transfer through the proposals for various LHTES designs also result in a reduction of the amount of accumulation material in the energy storage. As a result, research was carried out to increase the thermal conductivity of PCM directly by adding admixtures with high thermal conductivity. As previous research have shown, adding nanomaterials to PCMs allows for a potential increase in their thermal conductivity but this effect is not always achieved. Moreover, based on previous research presented in the literature, it is difficult to predetermine or predict the impact of individual nanomaterials and their mass fraction on the thermal conductivity and other thermophysical properties of selected groups of chemical compounds being phase change materials. Therefore, individual tests are required for each case. In addition, only a few articles have paid attention to the problem of the stability of NEPCM, which may be an obstacle to their use in energy storage. This problem requires further scientific activities. Therefore, in the doctoral thesis, research was undertaken to determine the characteristics of thermal conductivity and heat capacity of selected low-temperature organic PCMs with admixtures, taking into account the weight content of the additives (nanoparticles). Research was also carried out to determine the stability of nano-enhanced PCMs (NEPCM) and their applicability in energy storages.

The first chapter is an introduction, explaining the need for energy storage and presenting a short description of thermal energy storage technology, as well as justifying the need for development of energy storage using phase change materials.

The second chapter presents the current state of knowledge on the properties of phase change materials and their use for energy accumulation, shows the application areas and the design solutions of latent heat thermal energy storages, and identifies limitations, challenges and present directions of research on the improvement of phase change materials and latent heat thermal energy storage systems.

Chapter three presents the aim, thesis and scope of the doctoral dissertation.

The fourth chapter describes the methodology adopted in the doctoral thesis for experimental research on the thermophysical properties of base and nano-enhanced phase change materials,

justifies the selected measurement methods, presents the experimental stands and dedicated measuring instruments used during the research.

Chapter five presents the results of experimental research of the thermophysical properties of selected base low-temperature phase change materials named RT22 HC and RT28 HC. It compares the measurements of heat capacity and phase transition temperature using three different methods (T-history and DSC – the author's own experimental tests, 3LC – manufacturer's tests), as well as the author's own results of thermal conductivity measurements using two methods (hot wire and tubular Poesngen apparatus), to precisely determine the properties of the tested phase change materials before adding admixtures to them.

Chapter six discusses the method of preparing phase change materials with selected admixtures (graphene or titanium dioxide nanoparticles with SDBS surfactant) and the results of own experimental tests of their thermophysical properties. It presents the effect of admixtures on improving the thermal conductivity and shows the dependence of the thermal conductivity coefficient of the nano-enhanced phase change materials on the weight fraction of the admixtures. It also describes the impact of the used admixtures on the stored energy, showing the heat capacity dependence on the weight fraction of the admixtures and the relationship between the thermal conductivity coefficient of nano-enhanced phase change materials and their heat capacity, which allows determining the appropriate content of the investigated admixtures.

The seventh chapter discusses visual tests of the suspension stability in the nano-enhanced phase change materials, showing the problem of sedimentation of the nanoparticles.

Chapter eight focuses on presenting a new method of counteracting the effects of sedimentation of nanoparticles from the nano-enhanced phase change materials – the use of the bubbling process is proposed and its effectiveness is studied. Moreover, in this chapter, guidelines for energy storage with nano-enhanced phase change materials are elaborated and a new design of energy storage is proposed.

The ninth chapter is a summary presenting the most important research results and conclusions from the research work carried out, detailing the contribution of the author of this doctoral thesis to the state of knowledge and defining the scope of work to be carried out in the future.