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Energy accumulation using encapsulated phase change materials with recycled material components

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Abstract

Phase change materials (PCM) are often used for solar energy accumulation. PCMs have large latent heat capacity, which is why they are suitable for energy storage. Solar radiation is cyclic, so it is important for storage materials to have quick response time, when the temperature of the environment is changing. An advantage of PCMs is that they allow to accumulate not only sensible, but also latent energy during phase change, however PCM also has a problem - low thermal conductivity, which needs to be improved. To improve energy accumulation, PCM can be mixed with materials that have better thermal conductivity, for example metals or graphite, but these composite materials can be expensive. To reduce costs of encapsulated PCM spheres, recycled materials can be used.

There are several publications on energy related calculations, but none of them involve energy accumulation using encapsulated PCM together with recycled material components. In this research experiments are carried out with recycled graphite powder and steel spirals from a local industrial enterprise which has these materials as waste, to see how recycled components affect energy accumulation for encapsulated PCM.

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Keywords: solar energy; PCM; sphere; paraffin wax; thermal accumulation; graphite

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1. Introduction

World energy demand is incessant and from the attention to climate change prevention in the last decade not only in Europe, but all over the world, we can conclude that renewable energy sources have one of the highest development potentials [1]. Solar energy systems is among these renewables, which has optimization and energy efficiency enhancement potential [2, 3]. Sharma et al. [4] say that solar energy is dominating among other renewable energy sources and it plays a significant role in world energy politics.

One widely known solar accumulation method is use of encapsulated phase change materials (PCM) [5]. PCMs are used because of their wide work temperature range and they can accumulate not only physical energy, but also latent energy which is also known as "hidden" energy. Latent energy is energy which is used to change phase of the material, for example, from liquid to solid. A common PCM is paraffin wax, because it is relatively cheap, easily accessible, not toxic and can have several work cycles, but its biggest drawback is low thermal conductivity λ=0,2 [5]. Thermal conductivity can be enhanced by adding composite materials with higher thermal conductivity, for example graphite powder or metallic details [3, 4]. There are several publications where metal or graphite powder are added to PCM with the aim to enhance thermal conductivity of the material, but these composite materials can be expensive [8]. That is why it is important to find a good alternative, to reduce costs of encapsulated PCM with good thermal conductivity. In a world where resources are limited, it is crucial to expand the life cycle of everything we have. In experiments with spherically encapsulated PCM, graphite powder and metallic parts are taken as waste materials from a local enterprise which specializes in graphite brush production. Since this enterprise has no use for these materials, it is interesting to experiment with these materials in solar energy accumulation field and have its lifecycle expanded, making the end product (encapsulated PCM with better thermal conductivity) more sustainable.

2. Methods

2.1. Experimental materials and runs

In the experiment paraffin was used as a PCM and it was encapsulated in 4 spheres (diameter 5 cm) – paraffin mixed with graphite powder (graphite mass in sphere is 5 % ± 1 %), paraffin mixed with steel spirals (mass 10 % ± 1 %), paraffin mixed with burned steel spirals (mass 10 % ± 1 %) and clean paraffin. Some steel spirals were burned for one hour in 550 ºC temperature. This was done to burn off all industrial oils and other materials that may influence thermal conductivity of the material. When spheres with different material combinations were made, spheres were put in a water tank, which was heated to 58 ºC (melting temperature of paraffin 58 ºC). The length of the experiment is 130 minutes, during this time all spheres are melted completely.

Data of the experimental material parameters are summarized in Table 1.

Table 1. Parameters of materials used in experiment [9, 10].

Sphere No.	Material	c_p solid phase, kJ/kg·K	c_p liquid phase, kJ/kg·K	Mass, kg	H_f, kJ/kg	T beginning, K	T melting, K	T max., K
n=1	Paraffin	2.48	2.76	0.0449	266	296	327	331
n=1	Graphite	0.71	-	0.0024	-	296	327	331
n=2	Paraffin	2.48	2.76	0.0429	266	296	327	331
n=2	Burned steel	0.6	-	0.0040	-	296	327	331
n=3	Paraffin	2.48	2.76	0.0395	266	296	327	331
n=3	Steel	0.6	-	0.0040	-	296	327	331
n=4	Paraffin	2.48	2.76	0.0498	266	296	327	331

Parameters for numerical calculations, such as specific heat capacity or heat of fusion are taken from scientific publications. Other parameters are measured by the authors. Each PCM sphere has its own number, where the sphere