Influence of wall material on solidification characteristic of water based encapsulated PCM capsule

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Abstract. The experimental study is performed to investigate the solidification behaviour of water-based PCM in different capsule materials filled with 90% of its volume. The experiments are conducted with two stainless steel material and high-density polyethylene (HDPE) spherical capsules are maintained at different surrounding temperatures of -9°C and -12°C filled with 90% of PCM in its total fill volume. From the experimental results observed that the capsule material gives considerable effect on subcooling at lower temperature driving potential. Considering the experimental study which is concluded that solidification process time of encapsulated PCM of stainless steel material requires less time comparing to HDPE material.

1. Introduction

In building and industrial sector spaces use of air conditioning technique to maintain the indoor comfort temperatures. This has led to an increase in energy consumptions as mechanical, thermal and electrical energy usage of HVAC systems that can efficiently control the temperature in large spaces through centralised air conditioning. There is a number of ways to reduce the power consumption of HVAC systems and to enhance its mean efficiency. The cold thermal energy storage system (CTES) is one of the best methodology to accumulate the thermal energy and to use in peak time in energy demand.

The various heat transfer improvement methods are designed with an encapsulated PCM in a variable geometry. It has resulted that the increase in thermal conductivity depends on the diameter ratio of the PCM container [1-2]. An experimental work was presented for solidification inside a sphere in which the solidification takes place in front concentrically inwards from the outside surface of the sphere. [2]. The CTES with the PCMs is gives more effective usage during off-peak time as they have more storage density in an isothermal manner for a given temperature potential. Due to higher thermal conductivity ratio between solid to liquid as water used widely as PCM in the CTES applications. In the CTES system, the subcooling is the major problem that demands lower evaporator temperature in the refrigeration cycle [3]. The experiment is carried out with different PCMs with nano composites resulted that the NFPCM were increase the thermal conductivity due to the modified heat transfer rate, so the NFPCM increase the thermal conductivity compare than the other PCMs [4].
Solidification behavior examined with H$_2$O based nanofluid PCMs with a nucleating agent for CTES system. It is resulted that the NFPCM is eliminates the sub-cooling and also accelerate the charging for more efficient CTES system [5].

In the area of CTES has been done various studies, but limited work is done for solidification behaviour on encapsulated PCM with different wall material. The aim of present work is to investigate solidification behaviour and also compare with two different wall materials of encapsulated spherical capsules are stainless steel and polyethylene. The current work has decided to use of encapsulated spherical capsule with different material, in which determine more effective in thermal storage.

2. Methods and Methodology

2.1 Fabrication of experimental setup

The CTES consists of refrigeration circuit in which evaporator tank is modified to test the encapsulated spherical capsule. An evaporated tank is well insulted with a polyurethane material stainless steel tank of 32-liter volume capacity. The surroundings fluid of capsule is a mixture of 35% ethylene glycol with 65% distilled water to its volume. The evaporator fluid is not solidified at lower temperature because low freezing temperature of ethylene glycol. The thermo control heater and stirrer is attached in the evaporator tank which is used to maintain constant temperature in the chiller unit. So, the evaporator as a chiller unit is more efficient to test the encapsulated spherical capsule at lower temperature. Figure.1 The schematic diagram of the experimental setup that shows a design of an evaporator unit of stirrer, heater, PDTC controller, condenser, compressor and expansion valve of the refrigeration circuit. A computerized data logger is used to store the temperature variation inside the capsule by using PT-100 thermo couples at different locations.
An experiment is carried out by using water-based PCMs filled in spherical capsule made up HDPE material and stainless-steel material. The diameter of the capsule is 70 mm for both the material which is used better comparison the solidification behavior as its same 90% fill volume. The capsule surroundings temperature as bath fluid is maintained constant temperature at -9°C and -12°C. The DI (deionized water) water is used as a PCM in the capsules. A PT-100 type thermocouple is used to measure the temperature variation inside the capsule during solidification. The radial locations of temperature measurement in the capsule is shown in figure 2. All the RTDs are communicated to data logger with good accuracy to store the continuous data generated during the experimental trials. The experiments were performed at the surrounding bath temperature of -9°C and -12°C.

Figure 1. Schematic layout of an experimental setup
3. Results and Discussion

The experimental trails are carried out by the above-mentioned procedure and the observation results are presented in this chapter. The temperature history of PCM inside the spherical capsule at the various radial locations.

![Figure 2. Thermocouple location in the capsule.](image)

![Figure 3. Temperature history of the PCM at various radial locations (T_{surround}=-12°C).](image)

The temperature with time history of PCM at various points of the spherical capsule is shown in Figure. 3 when the surrounding bath temperature is maintained at -12°C. Rather than a linear increase in charging time in all the RTD kept at different radial point, there was a non-linear increase not only because of the high driving potential but also because of high heat trans rate towards the outer most layer of spherical capsule which gradually varied as it reached the center of the capsule.
The uniform rate of charging was achieved during the first 25% of the freezing time during which 50% of the mass was frozen. It is observed that the size of the capsule had the considerable influence on sub cooling at lower temperature and it is totally eliminated at higher temperature potential. Thus with different driving potential faster solidification is obtained in the capsule.

Figure 4. Different wall material temperature history at the center of the capsule

The capsule with steel wall has reduced the time taken to charge the latent heat of the PCM compared to polyethylene ball. From fig.4, we can also conclude that higher driving potential has made the PCM reach its freezing point comparatively faster and after 100% solidification of PCM, the steel capsule reaches the low temperature at a comparatively shorter duration when compared to polyethylene capsule, due to its increased heat transfer rate.

4. Conclusion

The experimental trail is carried out to analysis the dynamics of solidification bahaviour of water as PCM filled in the capsule of various material at various surrounding temperatures. As per experimental observations the following conclusions are made to understand the more efficient CTES system. During this study, it is concluded that the solidification process time of encapsulated PCM of steel material requires less time comparing to polyethylene material.

- The steel wall has comparatively reduced the time taken to charge the latent heat
• The size of the capsule had the considerable influence on sub cooling at lower temperature driving potential and was totally eliminated at higher temperature potential.
• Higher driving potential has made the PCM reach its freezing point comparatively faster.
• The TES has very big potential and it is still development to reduce the cost, increase the compactness of the systems, increase the energy density of the materials and systems, and increase the thermal conductivity of the materials and to develop new materials, fluids that act as heat transfer fluids and storage material.

5. References

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