STUDY OF SOLIDIFICATION CHARACTERISTICS IN A METALLIC SPHERICAL CAPSULE USING EXTENDED SURFACES

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ABSTRACT

This article reports the results of an experimental study on the freezing characteristics of PCM contained in a stainless steel spherical capsule with two and four fins of fin material of Stainless Steel with a fill volume of 90%. A suitable Phase Change Material, distilled water is used for efficient functioning of the Latent Heat Energy Storage Systems (LHTES). The effect of fins on the the solidification time has been studied at different HTF temperatures -6º C, -9º C and -12º C. The effect of subcooling is also studied with the usage of two or four fins in the stainless steel capsule. The experimental results indicated that there was a considerable reduction in the solidification time ranging from 3% to 33.3% with the help of two extended surfaces at different HTF temperatures -6º C, -9º C and -12º C. But with the four fins in the metallic capsule, the solidification time increased at various HTF temperatures. In case of four SS fins spherical encapsulation the solidification time increased in the range from 8% to 14.5%.

Keywords: Solidification time, Fins, Phase change material


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1. INTRODUCTION:
HVAC in buildings consumes a large part of energy which in turn increases the depletion of fossil fuels and in turn increases the pollution in the environment. Thermal energy storage is an widely accepted concept where energy is stored during off peak load hours and utilised in peak hours. Latent heat energy storage is an attractive energy storage technique where the PCM stores the energy during charging and releases the energy during discharging. Latent heat energy storage system is widely due to its high energy storage and isothermal behaviour during charging and discharging. Literature studies showed that a major of work has been carried out in heat transfer enhancement technique using fins, metal matrix, nano particle immersion in base fluid, metal fibres etc. M. Cheralathan et al [1] investigated the unsteady behaviour of a phase change material based cool thermal energy storage (CTES) system consisting of a cylindrical storage tank filled with encapsulated phase change materials (PCMs) in spherical container integrated with ethylene glycol chiller plant. The model is suitable method to determine the heat transfer characteristics of CTES system. Kalaiselvam Siva et al [2] in their article, investigated the phase change characteristics of finned encapsulations in HVAC systems for buildings. The effect of various fin configurations on moving interface position and complete solidification time was investigated for spherical and cylindrical geometries. The proposed predictions are very helpful in developing improved latent heat thermal energy storage used in buildings with large storage capacities. Aneesh V. et al [3] in their review on Heat transfer enhancement during solidification of PCM reviewed the work carried out by different researchers in the heat transfer enhancement techniques in thermal energy storage system and solidification of PCM. P.Chandrasekaran et al [4] investigated the freezing characteristics of water based copper oxide Nano fluid PCM in a spherical capsule and reported that sub cooling is reduced with the addition of surfactant. Ismail et al [5] in their experimental study investigated the solidification of PCM in spherical geometry capsules and reported that increasing the diameter of the spherical capsule leads to increase in time for complete solidification. P. Chandrasekaran et al [7] investigated the solidification characteristics of water as PCM under different fill volumes of PCM in a spherical capsule. They reported that increase in fill volume had a considerable reduction in sub cooling & eliminated completely at 95% fill volume. Very less work has been reported in spherical capsule using extended surfaces. Thus in this article the solidification characteristics has been studied in a metallic spherical capsule using extended surfaces.

2. EXPERIMENTAL SET- UP:
The schematic of the experimental apparatus is shown in Figure.1 which consists of a refrigerator unit, thermally insulated constant temperature bath, spherical capsule made of stainless steel, PDTC, data acquisition system (34972A) with necessary temperature sensors for the measurement. The bath is made of stainless steel and insulated with PUF which consists of 70% water and 30% ethylene glycol as heat transfer fluid. A refrigeration unit with a capacity of 3 kW were used to maintain the bath temperature by using PDTC (proportionate differential temperature controller). A mechanical stirrer is used to maintain a constant temperature in the bath. Spherical capsule of size 75 mm OD and 74 mm ID is taken for the study. Four RTD (Pt-100) thermocouples are placed at a radial locations of 29 mm (T1), 23 mm (T2), 17 mm (T3) and one at the centre of the capsule (T4) with distilled water as PCM of fill volume of 90% as shown in figure.3. Four fins of size 3 mm diameter and 30 mm long each is taken for the study. Two and four fins are brazed to the capsule diagonally as shown in the figure.2.
3. RESULTS & DISCUSSION:

Without fins:

**Figure 4** Temperature vs Time history without fins
From the above figure, it is observed that the complete solidification of PCM takes place at time duration of 58.5 minutes at the centre. Sub-cooling exist in all points.

**Figure 5** Temperature vs Time history without fins

From the above figure, it is observed that the complete solidification of PCM takes place at time duration of 83 minutes at the centre. Sub-cooling exist in all points.

**Figure 6** Temperature vs Time history without fins

From the above figure, it is observed that the complete solidification of PCM takes place at time duration of 129 minutes at the centre. Sub-cooling exist in all points.
With two Fins:

**Figure 7** Temperature vs Time history with two fins

From the above figure, it is observed that the complete solidification of PCM takes place at time duration of 39 minutes at the centre. No Sub-cooling exists.

**Figure 8** Temperature vs Time history with two fins

From the above figure, it is observed that the complete solidification of PCM takes place at time duration of 76.5 minutes at the centre. No Sub-cooling exists.
Figure 9 Temperature vs Time history with two fins

From the above figure, it is observed that the complete solidification of PCM takes place at time duration of 125 minutes at the centre. No Sub-cooling exists.

With 4 Fins:

Figure 10 Temperature vs Time history with four fins

From the above graph, it is observed that the complete solidification of PCM takes place at time duration of 67 minutes at the centre. No Sub-cooling exists.
From the above figure, it is observed that the complete solidification of PCM takes place at time duration of 86 minutes at the centre. Sub-cooling is observed near the wall of the capsule.

From the above graph, it is observed that the complete solidification of PCM takes place at time duration of 139.5 minutes at the centre. Sub-cooling is observed evidently at all points of thermocouple locations.

4. CONCLUSION:
The results of the experiment on the freezing characteristics of PCM contained in a stainless steel spherical capsule with two and four stainless steel fins with a fill volume of 90% at various HTF temperatures of -6°C, -9°C and -12°C are discussed below.
Study of Solidification Characteristics in a Metallic Spherical Capsule Using Extended Surfaces

1. The solidification time for the PCM (distilled water) in stainless steel spherical encapsulation without fin at three HTF temperature of -6°C, -9°C and -12°C are, 129, 83 and 58.5 minutes respectively.

2. The solidification time for the PCM (distilled water) in stainless steel spherical encapsulation with two SS fins at three HTF temperature are 125, 76.5 and 39 minutes.

3. The solidification time for the PCM (distilled water) in stainless steel spherical encapsulation with four SS fins at three HTF temperature are 139.5, 86 and 67 minutes.

4. When comparing solidification time for spherical encapsulation with two SS fin with solidification time for spherical encapsulation without fin, there is decrease in solidification time by 3%, 7.8% and 33.3% at HTF temperature of -6°C, -9°C and -12°C.

5. When comparing solidification time for spherical encapsulation with four SS fin with solidification time for spherical encapsulation without fin, there is increase in solidification time by 8%, 3.6% and 14.53% at HTF temperature of -6°C, -9°C and -12°C respectively.

REFERENCES:


