Studies on Energy Storage Capacity of a Spherical Encapsulated PCM Using Eutectic Salt as Phase Change Material


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SUMMARY

The need for higher productivity to match the growing competition has forced employers to look for better Indoor Work Environments. Since most of the buildings are being air conditioned, the Heating Ventilating and Air Conditioning (HVAC) systems account for nearly 40% of total building energy consumption. To reduce this energy consumption, Thermal energy storage systems (TES) were developed. The Latent heat thermal energy storage (LHTES) systems using water/ice are commonly used for peak shifts in electrical demand. To maintain a temperature below 0°C, the water/ice storage system is not suitable, but for a HVAC application the chiller requires a temperature below 0°C. In TES systems, phase change materials (PCMs) have attracted a great interest as thermal storage materials because the thermal energy is stored in them with high density and it is also possible to maintain below 0°C. This research uses Sodium nitrate along with nucleating agent (borax), freeze point depressant (ethylene glycol) and thickening agent (propylene) as a eutectic mixture in PCM. The percentage of composition of these selected phase change materials are Sodium nitrate 33%, ethylene glycol 27%, borax 22% and propylene 18 %. The numerical studies are conducted to determine the maximum storage capacity of the eutectic mixture and also the influence of the nodule size on TES.

INTRODUCTION

Thermal energy storage systems are used during periods of low cooling demand. To store the cooling energy, the chill storage media such as water, ice, or a phase change material are used. Thermal storage systems using latent heat of phase change material has the advantages of high storage density and heat retrieval at constant temperature during phase change. The storage application involves a 24-hour or alternatively, weekly or seasonal storage cycle depending on the system design requirements. It is proved that the cool storage technology is an effective means of shifting peak electrical loads as part of the strategy for energy management in buildings [1]. It is also considered as a useful tool to reduce the size of refrigeration machinery and air conditioning by means of spreading the daytime load over a 24-hour period. PCMs are used for various heat storage applications since 1800s, but they are recently used as cool storage media. Most of the PCMs for cool storage are inorganic salt hydrates and mixtures of salt hydrates. They are employed due to their high latent heats of transition, high densities and low cost. The experimental results using stearic acid as phase change material showed that the melting stability of PCM is better in the radial direction than in the axial direction. [2]. Ze-shao et al [3] introduced a new style cool storage scheme with high temperature water for air-conditioning. The capital cost of the cool storage system with paraffin waxes as phase change material indicates that the cool storage system not only saves energy and other operating costs but also saves a significant fraction of the initial capital costs.
[4]. The manganese (II) nitrate hexahydrate, with melting point from 15°C to 25°C is used as a new PCM for the TES cooling system [5]. It was also found that the modulation of melting point and reduction of super cooling can be made by dissolving small amounts of salts in the material.

METHODOLOGY

To determine the maximum storage capacity of the eutectic mixture, this research uses sodium nitrate along with additives as suitable PCM, because of their desirable properties such as lesser degree of super cooling, high density, large heat of fusion and stability for repetition of melting and solidification. Additives such as nucleating agents, freeze point depressants and thickening agents are added along with sodium nitrate to attain the required temperature. Nucleating agent, borax is used to stabilize the refreeze temperature. The freeze point depressant, ethylene glycol is used to provide greater cooling capacity and the thickening agent, propylene is used to overcome separation and degrading problems. The eutectic mixture is considered in nodular form for this analysis and the heat storage capacities of PCM nodules of different size are compared.

SYSTEM DESCRIPTION

An air-conditioning system is simulated with a chiller of capacity 1.7 kW and heater of 1.8 kW, connected to the storage system of height 0.52m, diameter 0.484m, and volume 0.0956 m³ is shown in figure 1. The cold fluid (ethylene glycol) and hot fluid (hot water) are circulated to transfer stored thermal energy in the system. The coriolis flow meter and RTDs are to monitor the mass flow rate and temperature of cold and hot fluids respectively. To pump the cold and hot fluids into the storage tank, 1.5 kW capacity pumps are connected across the chiller and heater units. Cold fluid of -6°C from the chiller enters into the storage tank and absorb heat from the hot fluid and leaves at -3°C. Hot fluid at 15°C from heater rejects heat to the cold fluid and leaves at 11°C. In the storage tank 60% of volume is filled with spherical nodules, where the PCMs are packed and remaining 40 % is filled with a heat transfer fluid (ethylene glycol).

NUMERICAL ANALYSIS

The simulation is fast becoming a substitute to real time experimentation trends where the stakes involved are too high to implement. For this model the type of analysis is thermal transient non-linear. The material properties such as conductivity, density and enthalpy are specified for the PCM, ethylene glycol, and water. Figure 2 shows the volume of the tank considered for analysis. In the storage tank, 60 % of the volume is filled with spherical nodules and remaining 40 % is filled with heat transfer fluid. The fluid acts as medium to accommodate the expansion and compression of phase change material during heat transfer. The modelled storage tank is symmetrical about x-y plane; hence the heat transfer characteristics are similar in the plane. To reduce the complexity, a portion of the storage tank is considered for analysis.
RESULTS AND DISCUSSION

The characteristics of thermal energy storage system like heat transfer capacity of the nodules in the storage tank and the time required to attain steady state phase change temperatures are examined to predict the influence of nodule size. The various nodules considered are of diameters 77mm, 88mm, and 98 mm. Figure 3 shows the temperature profile of the storage tank with nodules of size 77mm. It shows that the temperature of the nodule of diameter 77mm and the heat transfer fluids are of uniform temperature of -3.8°C. To attain a required steady state temperature, the system requires duration of 3100 seconds, which is less than the available commercial eutectic salts.

The time required to obtain a steady temperature is shown in figure 4. It shows for the first 3100s the temperature of the PCM is gradually reduced and attains a steady state temperature. Further increase in cooling does not have any effect in PCM; hence it attains a complete phase change, i.e. it solidifies completely. Figure 5 shows the breaking point where the complete phase change occurs for the particular mixture of PCM. It shows that the temperature drops continuously until a complete phase change occurs.

Similarly the analysis is performed for the other two nodules of diameters 88 mm, 98 mm. The temperature contour plots for the nodule diameters 88 mm, 99mm are shown in figure 6 and figure 9 respectively. The time taken to attain complete phase change in nodule of size 88 mm is 12000 seconds as shown in figure 7 and figure 8. In the case of nodule of size 98 mm the time taken to solidify completely is 23000 seconds as shown figure 10 and figure 11.
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Figure 3. Temperature profile for the nodule of size 77mm.

Figure 4. Steady temperature for the nodule of size 77mm.

Figure 5. Phase change breaking point for the nodule of size 77mm.

Figure 6. Temperature profile for the nodule of size 88mm.

Figure 7. Steady temperature for the nodule of size 88mm

Figure 8. Phase change breaking point for the nodule of size 88mm
CONCLUSIONS

The study on thermal energy systems depicts that to obtain a steady state temperature of -3.8°C, this eutectic mixture requires continuous cooling for 3100 seconds, 12000 seconds, and 23000 seconds for nodules of diameter 77 mm, 88 mm, and 98 mm respectively. The heat transfer capacity of nodules of diameter 77 mm, 88 mm and 98 mm are 47.66 kWh, 45.369 kWh and 45.01 kWh respectively. Hence the results indicate that the reduction in nodule diameter leads to lesser time for attaining a steady state. It also indicates that heat transfer decreases with increasing nodule diameter.
REFERENCES