**ABSTRACT**

In the recent past, growing dependency on fossil fuels and the fast depletion of natural resources are the key concerns of sustainable development. The effective utilization of solar energy is the potential solutions to control the misuse of natural resources. However, thermal energy needs to be stored to fill the gap between energy supply and demand caused due to intermittent nature of solar. Thermal energy may be accumulated as thermochemical energy, sensible or latent heat. Among these, storage of heat through latent mode is possibly the most effective heat storage method because of the high energy density it contains during phase change. However, materials can have latent heat in various phase combinations such as solid–liquid, solid–solid, or vapor-liquid phase change. Out of these, solid–liquid phase change is considered more efficient because liquid–vapor transition undergoes a high-volume difference while the solid–solid transition has a low latent heat of phase transformation. Hence, latent heat storage through PCMs in solid–liquid phase is a useful option to accumulate a large amount of heat at a smaller volume of material. However, most of the PCMs have low thermal conductivity and poor rates of thermal diffusivity. The thermal performance of a PCM can be upgraded by several thermal performance improvement methods such as the adding of nanoparticles having high thermal conductivity, addition of metallic foams, insertion of expanded graphite, and encapsulation of PCMs.

This thesis focuses on the study of the charging phenomenon of the PCM-based LHTES system having an operating temperature of up to 200 °C. The credibility of any PCM must be meticulously examined prior to its use as an efficient energy storage medium for any practical application. In this regard, detailed thermal characterization of the selected PCM (D-mannitol) is attempted. The outcomes of characterization reveal that the melting enthalpy of D-mannitol reduces by 8.6 % during the 100$^{th}$ cycle compared to the 11$^{th}$ cycle. However, no significant mass reduction is

experienced while heating the D-mannitol at a temperature of 100 °C higher than that of its melting point. It shows the thermal stability of D-mannitol and its suitability as an efficient energy storage material. Moreover, infrared thermography and digital imageries complemented each other to understand the thermal response behaviour of the sample. Among various alternatives explored to study the thermal performance of the LHTES systems, numerical and experimental approaches are popular among researchers. Limited studies are attempted for LHTES systems using an analytical approach. In this thesis, the transient melting behavior of PCM using an analytical approach is presented. A mathematical model is developed to investigate the performance of S&T type LHTES systems using one and two-dimensional approaches. PCM melts 49% faster when entry temperature of HTO rises from 185 °C to 200 °C. The time-based variation of the melt front and the effect of HTO tube temperature is further studied using the analytical solution. It is detected that the melt front propagates axially upward while melting of the PCM. The analytical solution formulated in the thesis shall be helpful in investigating the thermal behavior of LHTES system.

Finally, an experimental setup of the LHTES system is developed to enhance the thermal response of D-mannitol employing active heat enhancement using a stirrer. The PCM melting and solidification fronts move radially inward during the experiment. However, the axial movement of PCM is upward and downward in the melting and solidification processes, respectively. Further, the design calculations of stirrer reveal that the height of the stirrer blade must be 15 % of the tank height while the stirrer diameter must be 80 % to 90 % of the storage tank diameter. Further, a decrease in the overall melting time by 1200 s and a decrease in the net input energy by 52 kJ was observed by employing the stirrer rotating at a constant speed of 200 RPM. Consequently, the charging efficiency of the LHTES system improved by 3.4 %. Therefore, it is concluded that the active stirring method is influential in improving the thermal performance of an LHTES system.