# Abstract

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*Analysis and Design Optimization of Latent Heat Thermal Energy Storage System based on Phase Change Material Climate Modules*

Buildings worldwide (both residential and industrial) consume more than 40% of total world energy consumption and they are responsible for approximately one-third of global $CO_2$ emissions. Free cooling of buildings using Phase Change Materials (PCMs) based Thermal Energy Storage (TES) systems is one the most investigated techniques to improve the energy efficiency of buildings. In this technique, a dedicated mass of the PCM is employed in buildings either in stand-alone form or integrated with Heating, Ventilation and Air Conditioning (HVAC) systems to improve the energy efficiency of the HVAC systems for space cooling and heating applications.

The main aim of this PhD research work is to investigate the development and performance of a PCM based thermal energy storage system for its possible integration with a commercially available decentral ventilation system VEX308. The work is divided into experimental investigations and simulation work. In the start of the experimental work, performance analysis of two thermal energy storage design configurations of a research platform consisting of PCM storage plates has been done. The parameters investigated are air flow distribution in the system and thermal performance of the PCM storage. The design with smaller gap size between the PCM plates (1.5mm gap) provided faster melting and solidification rates of the PCM and provided approximately 8.7% more energy storage potential. Based on the results of research platform, a dual stack PCM based thermal energy storage prototype (with two design configurations) has been developed and tested for its possible integration with VEX308. Air flow distribution in two PCM stacks and thermal performance of the PCM storage has been investigated. The flow distribution during the charging and discharging cycles of the PCM for design 1 has been found to be skewed towards first stack of PCM with a flow distribution of approximately 55%. While for design 2, stack 1 receives approximately 65% of the total air flow. The energy storage rates for discharging and charging cycles are much larger at the beginning of the experiments and decrease over time for both the designs. It takes around 3.4 hours to completely melt/discharge and 3.1 hours to completely charge/solidify the energy storage for the case of design 1. For design 2, it takes around 3.2 hours for completely melt and approximately 3.0 hours to completely solidify the PCM. Both designs show almost same average effectiveness values of 0.89. PCM phase segregation phenomenon was noticed and investigated experimentally. The results showed that the segregated layers of the PCM have almost same density, thermal conductivity and almost same phase change temperatures.

In simulations work, a 3D model 3-plate model of the PCM energy storage has been developed and simulated to investigate pressure loss through the narrow gaps between the PCM plates. The results of the simulations are validated with the experimental results. The results show that there is a fair agreement between the simulation results and experimental results at low and medium flow rates with relative deviation values less than 5%. In order to reduce the computational cost, a 3D sliced model from full 3-plate model and a 2D simplified flow model have been developed. The reduced 2D model employs a through-thickness resistance term in the Navier-Stokes equation which captures the behaviour of fluid flow between parallel plates to producing same or nearly the same results as the 3D model. A comparison of the results showed that the reduced 2D model works fine for low velocities and larger channel heights with a relative deviation around 12%.