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Summary and Scope of the Future Work

9.1 Summary

The latent heat thermal energy storage system is one of the most important storage systems, where phase change materials are used as the thermal energy storage medium. The phase change materials are the most critical component of the latent heat thermal energy storage system (LHTESS), which is used as a medium to store and release heat. Therefore, detailed investigation of thermophysical properties of suitable phase change materials (PCMs) is very essential to design and develop an efficient thermal energy storage system.

The development of new eutectic PCMs is quite challenging and involves substantial experimental efforts using DSC and is a time consuming and expensive approach. Therefore, fatty acids (LA, MA and PA) and 1-dodecanole based new binary eutectic PCMs are designed computationally using simplified Schroeder-Van Laar approach, avoiding exhaustive experimentation. The enthalpy of fusion is computed by neglecting the specific heat of solid and liquid phases. Further, the computed results are experimentally validated using DSC measurements. The melting temperature and latent heat of fusion of these eutectic PCMs are 17-20 ºC, and ~175-190 kJ kg^{-1} respectively. These PCMs may be suitable for low temperature thermal energy storage applications such as building cooling and cool clothing applications.

Thermophysical properties of sodium acetate trihydrate (SAT) such as melting/solidification temperatures, degree of supercooling, heat retention/release time are tailored and optimized by varying ethylene glycol (EG) weight fraction in SAT-EG composite phase change materials for specific heat pack applications. The SAT with 3 wt% EG showed the optimal ~10% enhancement in heat retention time without affecting other thermophysical properties significantly. The thermal stability of metastable supercooled liquid SAT against spontaneous nucleation enhanced significantly for SAT-EG composite PCMs. In addition, the growth of large and lumped SAT crystallites is also restricted to the smaller crystallites after using EG. The SAT-EG composite PCMs with modified thermophysical properties may be more suitable for different possible applications such as therapeutic, body warming, building heating under adverse conditions and seasonal solar thermal energy storage. A low cost parabolic dish solar energy concentrator with 546.9 W heat duty and 49.2% overall thermal efficiency is designed and fabricated for charging of reusable PCM heat packs in extreme environmental conditions such as high altitude area. The dish concentrator is used to investigate charging of aqueous sodium acetate-EG PCM based heat packs and observed that 16 heat packs, containing 2.4 kg PCM material, are charged in ~35 minutes.

The conventional differential scanning calorimeter (DSC) does not provide reliable thermophysical properties of heterogeneous PCMs because of smaller sample size restrictions. T-history method is getting more attention due to its usefulness for large and voluminous sample measurements. However, T-history measuring instrument is not available commercially till now. Therefore, a T-history setup is designed and developed to measure thermophysical properties of the developed low temperature PCM using large samples in 0 - 100 ºC. The thermophysical properties of pure palmitic acid are measured using T-history measurements and results are validated using DSC and are in good agreement within ~ 05% variation. Thermophysical properties of aqueous SAT-EG composite PCMs nucleated at 60 ºC and 30 ºC are measured using T-history setup. The charging and discharging response of pristine myristic acid and myristic acid-exfoliated graphite are also measured using T-history setup.

The handling and homogeneous mixing of high temperature salts is very difficult to synthesize high temperature eutectic PCMs, especially at lower working temperatures. Therefore, a method is developed to synthesize high temperature eutectic PCM at room temperature by making aqueous solution, followed by evaporating the residual water. $NaNO_3$, KNO_3, $LiNO_3$ and NaCl based high temperature eutectics are synthesized at room temperature and their thermophysical properties are investigated using DSC. We observed that melting temperature and latent heat of fusion are comparable with literature values.

Thermal conductivity of developed organic eutectic PCM and high temperature inorganic eutectic PCMs are ~ 0.2 and 0.8 W m K^{-1}, respectively. These thermal conductivities are very low for thermal energy storage applications. Therefore, a process has been optimized for exfoliation of natural graphite flakes and preparation of PCM-ExG composites for improving thermal conductivity of PCM. PCM-ExG composites of organic (low temperature) and inorganic PCM (high temperature) PCMs are prepared by varying ExG wt% up to 20%. Thermal conductivity of organic and inorganic PCM enhanced significantly with ExG and that of $NaNO_3$-NaCl (88.8: 11.2 wt %) eutectic PCM enhanced from ~0.8 to ~13.8 W m^{-1} K^{-1} with 20 wt% ExG at 1400 kg m^{-3} density.

9.2 SCOPE of FUTURE WORK

The Temperature-history set is designed for low the temperature PCMs evaluation. The work can be further extended to design and development such measurement system for high temperature PCMs, which may lead to even commercialization of T-history system for thermal properties measurements of phase change materials for different applications.

The fatty acid/1-dodecanol eutectic PCMs work can be further extended in understanding their performance in the low temperature thermal energy storage applications such as building heating and cooling, PCM based cool clothings etc. Thermal properties of computed benzoic acid-acetamide and benzoic acid-phthalimide eutectic PCMs indicate that these eutectic PCMs may be suitable for solar water heating and solar cooling applications. Therefore, this work may be further extended to investigate the effect of these PCMs on efficiency enhancement of currently used solar water heating and cooking systems.

The aqueous sodium acetate trihydrate (SAT) – ethylene glycol (EG) composite PCMs can be used to develop heating devices for different applications such as therapeutic, infant baby mattresses for hypothermia treatment, blood sucking of infants etc. The work of parabolic dish solar energy concentrator can be further extended as experimental validation of thermal characteristic curve and charging of PCM heat packs in high altitude areas.

The exfoliated graphite work has huge potential in developing shape stabilized high thermal conductivity PCM composites for different solar thermal applications. The work can be extended to scale up the production of exfoliated graphite and development of different thermal conductivity low and high temperature phase change materials composites for possible applications. For example, these high thermal conductivity PCM systems can be integrated as the thermal energy management systems for lithium ion battery systems and electronic systems.