ME – PhD Thesis Colloquium

On the development of sensible heat storage for concentrated solar power applications: Thermo-fluid management and materials

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ABSTRACT

Sensible heat storages have extensive use in thermal energy deployment, including concentrated solar power (CSP) applications. Usually, CSP pants demand various techno-economic features in sensible heat storage, such as low-cost, high-capacity, efficiency, and ease of operation. These requirements demand investigations to assess and develop novel strategies to improve the efficacy of sensible heat thermal energy storage (TES) technology. Accordingly, the present study focuses on thermo-fluid management and material characterization for stratified TES.

The first section discusses the computational fluid dynamics simulations employed to analyze the effects of an inlet inertial jet on the thermal blending of hot and cold heat transfer fluid (HTF) (molten salt) for a single-tank sensible heat TES system. The simulations show the evolution of the initial stratified layer (thermocline) for a temperature difference of 300 K and an Atwood number (A_t) of 0.066. Accordingly, a hemispherical diffuser is developed. In addition, a mathematical index is proposed to quantify the degree of thermal stratification, which can be equally applicable to charging, discharging, and storage processes. In the second section, this study focuses on thermosyphon-charging and storing for a single-medium stratified TES. The experiments were conducted on a 370 liters cylindrical storage (aspect ratio 4:1) with a heat-pipe system (3-liter volume) acting as a collector. Dowtherm-A oil was used as the HTF, and the thermal expansion of HTF was accommodated in an expansion tank via two different designs (top and bottom connections from storage tank to expansion tank). Moreover, continuous and pulsatile charging are investigated for low (150 °C) and high (250 and 300 °C) temperatures.

From a materials viewpoint, high specific heat capacity (C_P) is essential for sensible heat TES, which can be improved by adding nanoparticles to molten salt. However, the causality between system parameters introduced in nanofluid preparation and C_P enhancement is not clearly understood. Since difficulties are associated with identifying the explicit relations due to complex molecular interactions between molten-salt and nanoparticles, we inquired whether there are common patterns/clusters in the nanofluid samples reported in earlier studies. So in the third section, the data-driven correlations among samples are explored by employing unsupervised machine learning methods: Hierarchical cluster analysis (HCA) and Principal component analysis (PCA). Additionally, previous literature report inconsistency in C_P enhancement for molten salt nanofluids. Since random sampling was not ensured, the average C_P obtained from these results may not represent for the bulk-C_P of the nanofluids. Therefore, the final section presents a comparative analysis of HITEC salt nanofluids using alumina and silica nanoparticles. To capture the measurement variability, the DSC test is employed on small-sized batches (< 10 mg) and the T-history method on large-sized batches (~20g). Further, the C_P values of both tests are compared using a nonparametric statistical test, Mann-Whitney U Test.

ABOUT THE SPEAKER

Dipti Ranjan Parida is a PhD student in the Department of Mechanical Engineering, IISc, Bangalore. He completed his MTech from the Indian Institute of Technology, Bhubaneswar, in 2017. Subsequently, he joined IISc as a PhD student in August 2017. His research interests include multi-physics modeling of thermofluidic systems, data-driven analysis, and material characterization. His dissertation focuses on sensible heat thermal energy storage systems for high-temperature concentrated solar power plant applications.