



ME – PhD Thesis Colloquium



Application of thermochemical energy storage system for heating in cold climates

Mr. Chate Akshay Bhimrao, PhD Student, Department of Mechanical Engineering, IISc Bengaluru

June 8th, 2026 at 11:00 AM

Venue: Conference Room, ME@IISc

ABSTRACT

The rising global demand for thermal energy and the intermittency of renewable sources such as solar thermal have intensified the need for effective thermal energy storage. A thermochemical energy storage system (TESS) offers higher storage density than sensible or latent heat systems and, by retaining stored energy in the form of chemical potential at ambient conditions, eliminates thermal losses during storage while enabling long-duration and portable storage. Among potential materials, potassium carbonate (K_2CO_3) salt hydrate is found to be suitable for low-to-medium temperature heating applications in cold climates because of its high energy density, suitable operating temperatures during charging (energy storage) and discharging (energy release), cyclic stability, low cost, and non-toxicity. However, studies addressing the design, analysis, and performance of practical-scale K_2CO_3 -based closed TESS remain limited. In particular, guidance on reactor design, system integration, and thermodynamic performance under realistic operating conditions is scarce. To address these research gaps, a three-stage approach is employed in the present work comprising of thermodynamic analysis, numerical reactor modelling, and experimental investigation of a laboratory-scale prototype of the TESS.

Thermodynamic analysis of a single-reactor TESS demonstrates the feasibility of upgrading ambient heat in the range of 5-15 °C to useful temperatures of 25-45 °C during discharging. The analysis is further extended to a novel coupled TESS configuration combining reactors with calcium oxide (CaO) and K_2CO_3 salt hydrate as storage materials. By using the second reactor for water vapour exchange, the coupled TESS eliminates the need for separate condenser and evaporator units while achieving higher cycle and exergy efficiencies than conventional CaO-based TESS.

A 2-D transient numerical model of the reactor i.e., energy storage bed (ESB), designed as a flat modular reactor, is developed to capture coupled heat transfer, mass transfer, and reaction kinetics. The model reveals non-uniform temperature and reaction distributions during charging and discharging. It is subsequently applied to a system-level study of battery preheating in electric vehicles, where multiple ESB modules are integrated into the battery thermal management system of an electric passenger car. The results show that the TESS can achieve heating rates comparable to conventional electrical heaters, demonstrating its potential for battery preheating without reliance on electrical energy in cold climates. Finally, a laboratory-scale prototype incorporating 4.5 kg of K_2CO_3 salt hydrate is developed, featuring a flat modular ESB enclosed within a transparent acrylic vacuum chamber and a novel combined evaporator-condenser vapour reservoir. Experimental results demonstrate rapid initial heating due to the high thermal energy release during discharging. With a heat source temperature of 110 °C and ambient temperature of 10 °C, TESS achieves a cycle efficiency of 30.8%, volumetric energy storage density of 79.6 kWh m⁻³ and discharging specific heating power of 9.3 W kg⁻¹. Across all three analyses, it is observed that the higher heat source temperature accelerates charging, while ambient temperature plays a dual role: lower values favour charging and higher values favour discharging.

ABOUT THE SPEAKER

Chate Akshay Bhimrao is a PhD student in the Department of Mechanical Engineering at the Indian Institute of Science (IISc), Bangalore, working under the supervision of Prof. Pradip Dutta. He completed his BTech in Mechanical Engineering from Visvesvaraya National Institute of Technology (VNIT), Nagpur, and his MTech in Mechanical Engineering, also from IISc. His research interests include thermodynamics and heat transfer, with a particular focus on thermal energy storage and battery thermal management.

