ME – PhD Thesis Colloquium

Studies on Metal Hydride based Multifunctional Coupled Thermal Battery Systems

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ABSTRACT

Metal hydrides (MHs) have received significant attention for chemisorption-based heat storage applications. The decomposition of MH into metal/alloy and hydrogen gas is an endothermic reaction which can be used to store heat, whereas the formation of MH is an exothermic reaction that can be used to deliver the stored heat. Coupled MH based thermal energy storage systems (MH-TESS) with two distinct MHs, one for heat storage and the other for hydrogen storage, are of particular interest. In this context, the primary objective of this thesis is to investigate various aspects of coupled MH-TESS.

Selection of thermodynamically compatible pairs of hydrides being crucial for the cyclic operation of the system, the thesis initially focuses on this aspect. This is followed by an analysis of mass and heat transfer characteristics of coupled MH-TESS through simulation. MH-TESS can be operated in long-term and buffer modes depending on the requirement. In long-term mode, thermal energy is stored at ambient temperature for long durations and heat is delivered when needed. Whereas, in buffer mode, heat delivery process immediately succeeds the charging process for its subsequent application in thermal systems. The performance of a coupled MH-TESS in long-term and buffer modes is investigated using a pair of Mg_2Ni-$LaNi_5$ hydrides for high temperature applications. In addition to hydrogen storage and release, the low temperature MH can also simultaneously produce heating and cooling effects. This multifunctionality of a coupled MH-TESS is also investigated using a medium temperature MH ($LaNi_{4.25}Al_{0.75}$) coupled with a low temperature MH ($LaNi_5$) in this work.

Based on theoretical and computational studies, the design of MH devices, development of a hydrogen loop, and experimental investigations on individual and coupled reactors are carried out. The hydride bed forms the key component of the MH-TESS. A novel cartridge reactor is developed that offers a thin bed, large surface area and compactness in size. A test rig consisting of HTF loop, hydrogen gas loop and test section for mounting the cartridge reactors is fabricated. Parametric studies are performed on high temperature and low temperature alloys to study the sensitivity of the alloys to various operating conditions. A systematic procedure to arrive at the optimum initial equilibrium condition of coupled hydride beds is proposed. Experimental investigations on the coupled reactors reveal that the charging temperature and the surrounding temperature where the low temperature alloy is intended to operate, significantly affects the performance of the system. Also, the flow rate of HTF controls the heat delivery temperature. The coupled MH-TESS with $LaNi_{4.25}Al_{0.75}$-$La_{0.75}Ce_{0.25}Ni_5$ pair, delivered 227.7 kJ of heat at an average heat transfer rate of 130.7 W at the heat transfer fluid inlet temperature of 25 ℃ while also producing a cooling effect of 171.8 kJ with an average cooling rate of 103.5 W.

ABOUT THE SPEAKER

K Malleswararao is a Ph.D. student in the Department of Mechanical Engineering at IISc Bangalore. He is working with Professor Pradip Dutta and his research focuses on metal hydride based thermal energy storage systems. He completed his B.Tech. in Mechanical Engineering from RGUKT Nuzvid, AP in 2016. Following that, he completed his M.Tech in Fluids and Thermal Engineering in 2018 at Indian Institute of Technology, Guwahati (IITG).