ME- PhD Thesis Colloquium

EXPERIMENTAL INVESTIGATIONS ON NATURAL REFRIGERANT SYSTEMS AND ITS BLENDS FOR HEATING AND COOLING APPLICATIONS IN TROPICAL ENVIRONMENTS

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ABSTRACT

Growing demand for cooling and heating, driven by climate change, urbanization, industrialization, and rising living standards, necessitates the development of energy-efficient and environmentally sustainable thermal systems. Refrigeration and heat pump technologies are fundamental to applications such as food preservation, cold-chain logistics, healthcare, transportation, space conditioning, and industrial process heating. Environmental impact associated with conventional high-global-warming-potential (GWP) refrigerants is accelerating the transition toward sustainable alternatives. This research focuses on the development and experimental validation of next-generation refrigeration and heat pump systems employing natural refrigerants, low-GWP refrigerant blends.

The study combines thermodynamic modelling, energy and exergy analyses, numerical simulations, system optimization, and large-scale experimental investigations to assess the performance of Hydrocarbon (HC) and Hydrofluorocarbon (HFC) blends, including standalone CO_2-based systems. Advanced cycle configurations, including multi-evaporator ejector expansion systems, cascade refrigeration systems, and transcritical CO_2 cycles, are analysed to improve system efficiency and reduce environmental impact. The results demonstrate that system design and operating strategy are as critical as refrigerant selection in achieving enhanced thermodynamic performance. Ejector integration significantly reduces throttling losses and compressor power consumption, resulting in improved coefficient of performance (COP) and system efficiency. Parametric and optimization studies further establish the suitability of advanced CO_2 systems for operation under high ambient temperature conditions.

A major contribution of this work is the experimental validation of industrial-scale refrigeration and heat pump technologies. Environmentally friendly refrigerant blends comprising R290 and R134a are investigated as alternatives to the conventional refrigerant R404A. The blend demonstrates improved cooling rates, higher COP, lower energy consumption in bulk milk cooling applications. Furthermore, the research presents the development and testing of a 100 kW transcritical CO_2 refrigeration system for marine cooling, a 120 kW industrial process heat pump for a confectionary unit, a 20 kW cold-storage refrigeration system for a warehouse application, and a 140 kW heat pump for bulk cooking. Experimental results confirm reliable operation under tropical climatic conditions and highlight the potential of CO_2 technology for large-scale cooling and heating applications.

The outcomes of this research contribute to the advancement of low-carbon refrigeration and heat pump technologies and provide practical pathways for enhancing energy efficiency, reducing greenhouse gas emissions, and supporting the transition toward sustainable HVAC systems.

ABOUT THE SPEAKER

Vinod Laguri is a Ph.D. student in the Department of Mechanical Engineering at the Indian Institute of Science, Bangalore. He received his B.Tech. degree in Mechanical Engineering from Ranchi University, Ranchi in 2014 and his M. Tech. degree in Mechanical Engineering from Birla Institute of Technology, Mesra, Ranchi in 2016. His research includes the design, modelling, and experimental validation of refrigeration and heat pump system for HVAC and industrial applications.