ME – PhD Thesis Defense

Analysis of CO_2 and CO_2 + Propane Mixtures for Tropical Cooling Applications

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Meeting link: Click here to join the meeting **(Microsoft Teams)**

ABSTRACT

The increasing global average ambient temperatures coupled with stringent environmental regulations has turned the focus on natural working fluids such as Carbon dioxide (CO_2), and hydrocarbons for use in the refrigeration industry. CO_2 being a natural, non-flammable and non-toxic fluid with a triple point temperature of -56.6 °C at pressure of 5.2 bar makes it a good choice for wide range of refrigeration applications including deep freezing. The use of CO_2 for refrigeration applications is not new, it was perhaps the only refrigerant in the early 20th century for deep freezing applications. However, the advent of efficient synthetic refrigerants with lower operating pressures led to a gradual decline of use of CO_2 for refrigeration applications. CO_2 has a low critical temperature of 31.1°C at pressure of 73.8 bar, making it unsuitable for operating in the transcritical mode for cooling at high ambient conditions. Therefore, CO_2 refrigeration systems work in transcritical mode for ambient conditions greater than 30 °C. Consequently, the standstill pressures of transcritical CO_2 (T-CO_2) systems are not only higher, but also require substantial energy for compressing CO_2 to higher pressures. Compressing CO_2 to high pressures results in high gas cooler temperatures with significant amount of heat rejection. As a result, T-CO_2 systems suffer from lower COP's compared to conventional subcritical refrigeration systems.

There has been considerable work reported in the literature for improving the COP of T-CO_2 systems. Among the many methods that have been proposed, meaningful utilization of gas cooler heat seems to be the most preferred choice. The thesis proposes a host of novel concepts like cascaded gas cooler heat driven vapor ejector refrigeration systems (VERS) to CO_2 propane mixtures for reducing the work of compression. The first part of the thesis presents a comprehensive analysis of variable geometry ejector systems for reducing the compressor work in standard T-CO_2 systems. The developed ejector model is verified by experimental measurements obtained from IIT-Madras T-CO_2 refrigeration test system. Subsequently, comprehensive analysis of a novel T-CO_2-VERS hybrid system is presented which is entirely driven by the heat rejected in the gas cooler. The hybrid system shows an improvement of 10% -50% in cooling capacity over the baseline T-CO_2 system for the range of evaporator temperatures investigated. The system provides highest COP at an evaporating temperature of 12.5°C, which it is ideal for chilled water-based data center cooling or centralized air conditioning applications. Finally, a zeotropic mixture of CO_2 + Propane (C_3H_8) is proposed for reducing the operating pressure of a standard T-CO_2 system. The presence of CO_2 in the mixture suppresses the flammability of C_3H_8, while, the presence of C_3H_8 reduces the critical pressure of CO_2 + Propane mixture. In this case two models of the evaporator are proposed based on constant pressure and constant temperature operation, both of which utilize the temperature glide to provide cooling. The performance of the mixture is analyzed for the various mass compositions of CO_2 permissible within the flammability suppression envelope. The analysis shows that 15% CO_2 in the mixture is ideal for most refrigeration and air-conditioning applications.

ABOUT THE SPEAKER

Kundan Kumar is a PhD student enrolled in the Dept. of Mechanical Engineering, IISc Bangalore. He has a Bachelor's degree in Mechanical Engineering from RGPV Bhopal and a Master's Degree in Industrial Engineering and Management from NIT Trichy. His research interests include refrigeration and heat transfer with a focus on natural refrigerants and multi-ejector systems for T-CO2 applications.