Abstract

Carbon dioxide (CO_2), is a promising natural refrigerant due to its excellent thermophysical properties and material compatibility. However, due to its low critical temperature ($\approx 31^oC$), when it is used in a vapour cycle, the system has to be operated in transcritical mode when the heat sink temperature is high. In this mode the heat rejection is supercritical, while the heat extraction is subcritical. Unlike subcritical cycles, transcritical cycles need a control strategy to optimise the high-side pressure for maximum COP. In addition, for good performance, it is essential to maintain required superheat at evaporator exit. Some studies show that both these objectives can be met simultaneously if two electronic expansion valves are used in series instead of a single valve. In addition, proper sizing of the components and charging with an optimum amount of refrigerant are also important. However, detailed studies which consider all these aspects are scarce, especially for operation in tropical countries. These observations form the basis for the present thesis.

The primary objective of the present work is to analyse the performance of a transcritical CO_2 based summer air-conditioning unit. Two configurations: one with single-stage expansion (SSE) and the other with two-stage expansion (TSE) have been considered. A fully instrumented CO_2 based air-conditioning test-rig is developed with indigenously made fin-and-tube gas cooler and evaporator and a detailed system simulation model is developed. Results show that for SSE, variation in COP is marginal for a charge variation of ±18% from the optimum value. For TSE, maximum COP is maintained over a larger range of refrigerant charge. For same performance, compared to SSE, the required charge is around 15% less for TSE. For both configurations, a) each 10K increase in the ambient temperature, the system COP decreases by about 24%, and b) COP drops gradually for up to 60% reduction in gas cooler face velocity and the drop is very sharp after this. A good agreement is found between the theoretical system simulation model and experimental results under all conditions.

Keywords: *transcritical cycle, CO_2, gas cooler pressure, refrigerant charge, two-stage expansion, receiver*