

Project Summary

Particle Image Velocimetry Measurements and CFD-Based Predictions of Air Distribution at Evaporator Inlet

The air distribution at the evaporator inlet strongly affects the performance of air-to-refrigerant heat exchangers. It has been shown that the air flow distribution in residential applications is far from uniform, and as much as 30% capacity reduction has been observed in some extreme cases due to this air-side non-uniformity. The majority of this capacity degradation can be eliminated by properly designing the refrigerant circuitry for the actual air flow distribution. Unfortunately, the air-side velocity distribution is not well understood, and studied. The current state-of-the-art approach is to use hot wire anemometers to measure the air-side velocity distribution, which is a time-consuming task with low accuracy. The current computational fluid dynamics (CFD) models provide the predictions with low confidence level due to the lack of the supportive information from the experimental measurements. Hence, the objectives of this research are to make high-accuracy measurements of the inlet air distribution, and to provide validated CFD-based models with high-accuracy predictions of the air velocity profiles.

To measure the air flow distribution accurately, Particle Image Velocimetry (PIV) technique is applied in this research. PIV is an optically based measurement technique which uses a high-speed and high-resolution camera to track the motion of laser-illuminated dust particles in a flow field. The proposed test setup is illustrated in Figure 1. The test section is set up in an environment chamber which can condition the inlet air to specific test conditions. A fin-tube heat exchanger with A-shape configuration is placed in an air duct. Chilled water is circulated through the heat exchanger to simulate the refrigerant flow. Air passes through the heat exchanger upwards. Lasers are positioned carefully to illuminate the heat exchanger surface. A high speed camera is used to capture the images of illuminated particles. Commercially available CFD software is used to perform all the simulation tasks. The experimental results are used to provide necessary information to formulate the CFD models, and to validate the simulation results.

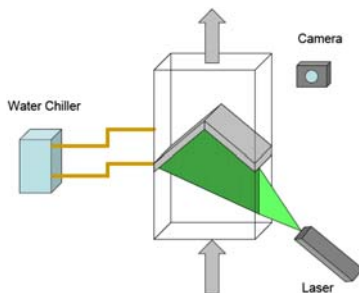


Figure 1: Schematic of Test Apparatus

The expected outcome of this research is to reduce system energy usage by well understanding the inlet air distribution and providing optimum design of the refrigerant circuitry in heat exchangers. Preliminary results have shown a 5% improvement in capacity and 2% reduction in power consumption. The knowledge gained and the computation methods developed in this study are applicable to general air-to-refrigerant heat exchangers. It can contribute to meet ARTI Research Roadmap goals for residential, commercial and refrigeration applications.