ABSTRACT

The thesis makes contributions in two distinct domains of an Automotive Air Conditioning System (AACS). First, an in-depth study is done to predict the behavior of the system for both steady state and dynamic conditions. Second, the performance of the AACS is investigated for two injected faults–namely, airflow maldistribution across the condenser surface and drop in the speed of fans due to battery malfunction.

For this, an off-board test bench of the AACS has been developed which replicates the hardware arrangement of the actual automobile as far as practicable along with a number of additional sensors and a stand-alone control system which follows the protocol of an automobile.

The steady state performance of the system has been investigated for three major independent variables relevant for automobiles in running conditions, namely the amount of refrigerant charge, the compressor speed and the speed of the evaporator blower. Considering the complexity of the system, an Artificial Neural Network (ANN) optimized for 3-10-3 configuration with Lavenberge-Marquardt algorithm is used to predict the system performances like cooling capacity, compression work, and COP.

In parallel, a transient model of the system has been developed using the moving boundary representation for phase change heat exchangers. The model utilizes the system mean void fraction instead of a fixed void fraction. Further, an Extended Kalman Filter (EKF) based state estimator is used to tune the model based on limited experimental results.

Airflow maldistribution across the microchannel condenser of the AACS causes substantial deterioration of the system performance. To study this, experiments are planned to create air maldistribution by placing screens simulating face blockages of different types and magnitudes at the upstream of the condenser surface. The condenser is also modeled for identical conditions using a software package 'CoilDesigner'. Variation of overall heat transfer, heat load and refrigerant temperature distribution in each tube of the louvered fin condenser due to airflow maldistribution are investigated.

In an automobile, conventionally, a 12 volt lead-acid storage battery is used to empower the evaporator blower and the condenser fan. If there is any malfunction of battery or its charging system, the prime movers will not run at the design speed. This not only deteriorates the performance of the condenser and the evaporator, but also affects the performance of the entire system. With a consideration of these facts, the present investigation attempts a simulation of the charging and discharging processes of the battery with experimental validation. The performance of the AACS during discharge is also assessed through a simulated experimentation.

Keywords: Automotive air conditioning; Artificial neural network; Void fraction; Moving boundary model; Extended Kalman filter; Maldistribution of air; CoilDesigner; Battery discharge; State-of-Charge.