Transient Analysis of an Air-conditioning System for Electric Vehicles Using Carbon Dioxide

高, 在德

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氏　　名　: Jaedeok Ko
Name

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論 文 内 容 の 要 旨

Thesis Summary

This work addresses a transient analysis of an air-conditioning system (AC) for electric vehicles. The entire AC model consisting of a vapor compression system, an air handling unit, and a cabin was established using commercial software which offers acausal, equation-based, and object-oriented modeling approaches. R-744, one of the environmental-friendly refrigerants, was selected for the working medium. The model was validated by the in-house experimental data set and three different research articles. Validation results showed that the model predicts an actual system operation and performance adequately and demonstrates reliability. Transient characteristics and performance of an AC for electric vehicles were investigated using the model in various operating conditions. The results provide dynamic behavior of the AC according to operating parameters and performance comprehensively.

In this investigation, it is observed that the AC consumes tremendous energy during the start-up and cabin pull-down operation to achieve a target cabin temperature, and the coefficient of performance (COP) degrades during that period. The outdoor and indoor thermal conditions influence the energy consumption and pull-down time in the order of initial cabin temperature, cabin target temperature, number of occupants, initial cabin relative humidity, and solar irradiance. Concerning ventilation operation, intake of relatively high-temperature and high-humidity outdoor air results in a cooling load increase; thus, the compressor consumes more energy. Also, an increase in air temperature supplying to the cabin increases the cooling load on AC, under the same cabin set temperature.

The effect of system operating parameters on the COP was also investigated. The results showed that heat rejection pressure and refrigerant temperature at the main gas cooler’s outlet affect the COP markedly.

The optimum heat rejection pressure ensuring the maximum COP was clearly observed, and the results are well-matched with the model in the literature. The optimum heat rejection pressure highly depends on the refrigerant temperature at the outdoor heat exchanger (OHX) outlet while the evaporator operating condition has a relatively tiny effect on the optimum heat rejection pressure. The COP of the AC controlled for optimal heat removal pressure was compared to the COP of the AC otherwise. The comparison results showed that the COP operating under control is superior to that without control.

Considering that the average duration of a single driving for business and personal is about 30 minutes, the average operation time of the automobile AC is less than 30 minutes; meanwhile, it is known that electric vehicles suffer energy shortage, so have relatively shorter mileage than conventional vehicles. Given those, therefore, the amount of energy consumption in the start-up and pull-down period is worth considering in the preliminary designing phase for an electric vehicle AC. Also, a proper control strategy to the heat rejection pressure can improve the COP of an R-744 AC, significantly. It is expected that an electric vehicle can achieve additional energy-saving potential with real-time control on heat rejection pressure, thereby it can secure further mileage.