

Article

Experimental Thermodynamic Investigation on the Refrigerant Charge in a Transcritical CO₂ Electric Bus Air Conditioning System

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Abstract: Due to its considerable impact on climate, bus air conditioning systems are being pushed to take a new and sustainable path. Electric buses relying on transcritical CO₂ air conditioning units are perceived to be eco-friendly and future-proof solutions to achieving such a target. However, in order to have highly efficient air conditioning systems, the CO₂ charge needs to be optimized. In this paper the energy and energy-based analyses were performed to investigate the effect of normalized refrigerant charge on the system performance by using a test rig of a transcritical CO₂ air conditioning unit for an 8 m electric bus. Results showed that the normalized refrigerant charge range of 0.248–0.306 was recommended in order to ensure the maximum coefficient of performance (COP). In addition, in sufficient charge conditions, the optimal COP, cooling capacity and energy efficiency were 1.716, 18.97 kW and 29.79%, respectively, under the standard refrigeration condition of 35 °C/27 °C. As the ambient temperature rose from 35 °C to 40 °C, the COP, cooling capacity and energy efficiency decreased by 16.03%, 10.90% and 12.22%, respectively. Furthermore, the energy efficiency was found not to be sensitive to slightly insufficient charge, whereas overcharge was observed to be even beneficial to energy efficiency under the condition of ensuring the maximum COP. In addition, insufficient refrigerant charging seriously affected the irreversible losses in the indoor and outdoor heat exchangers, whereas slight overcharge had little effect on the component energy efficiency. Finally, the need to improve the CO₂ compressor efficiency to enhance the system performance was revealed.

Keywords: transcritical CO₂ system; electric bus; refrigerant charge; energy; experimental investigation; R744

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1. Introduction

Electricity as an energy vector for vehicle propulsion promotes the use of renewable and carbon-free energy sources in addition to favoring energy supply security as well as lowering air pollution. Therefore, the uptake of electric vehicles [1], including buses [2], is increasing considerably worldwide. On the one hand, at present, hydrofluorocarbons (HFCs) are the most widely used refrigerants for bus air conditioning systems, especially R407C and R410A [3], which have a high value of global warming potential (GWP). On the other hand, the wide adoption of the Kigali Amendment will result in HFC cut by around 85% before 2050 on a global basis, leading low-to-zero GWP refrigerants to take center stage in transport sector. CO₂ is a widely used natural working fluid (R744) with negligible GWP, zero ozone depletion potential (ODP), low cost and excellent thermo-

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