Comparison of the experimental performance of an automotive heat pump system using HFO1234yf and HFC134a

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Abstract—In order to provide thermal comfort inside passenger compartments of vehicles in winter season, a heating system using engine coolant as a heat source is commonly utilised. However, it is reported that modern diesel engines cannot supply sufficient amount of waste heat in a reasonable period of time after starting up the engine due to their high efficiency caused by the advances in the development of injection engines and turbocharger use. Moreover, because electric vehicles do not employ internal combustion engines, they do not have any waste heat for comfort heating of the passenger compartment. Therefore, the aforementioned vehicles may utilise another heat source to fulfil the thermal comfort demand in cold climate conditions. One of the alternative systems for comfort heating is to reverse the operation of the automotive air conditioning (AAC) system, thus operating it as a heat pump. Such a heat pump system may provide supplementary comfort heating in a vehicle with diesel engine, or it may provide all heating load in an electric vehicle. On the other hand, European Union's f-gas regulation bans the use of HFCs with a Global Warming Potential (GWP) above 150 in the AAC systems of all new vehicles placed in the EU market after January 1st, 2017. Therefore, HFC134a, the refrigerant presently used in AAC systems, will be fully replaced soon. Because CO_2 requires extremely high system pressures and has relatively low performance, HFO1234yf has been regarded as the best potential alternative to HFC134a in AAC systems. This new refrigerant has an Ozone Depleting Potential of zero and a GWP-per-100-year of 4. In this study, performance characteristics of an experimental automotive heat pump (AHP) system charged with HFO1234yf and HFC134a have been evaluated and compared with each other. The bench-top experimental AHP system was made up from original components of the air conditioning system of a compact car added with some extra equipment to operate the system in reverse direction as an air-source heat pump. The AHP system was equipped with instruments for temperature, pressure, compressor speed and refrigerant mass flow rate measurements as well as data acquisition system. The system were tested at five different compressor speeds, namely 1000, 1500, 2000, 2500 and 3000 rpm, and for each compressor speed, the temperatures of the air streams at the inlets of the evaporator and condenser were maintained at four different sets, namely $T_{evap,ai}$=0°C – $T_{cond,ai}$=0°C, $T_{evap,ai}$=5°C – $T_{cond,ai}$=5°C, $T_{evap,ai}$=10°C – $T_{cond,ai}$=10°C and $T_{evap,ai}$=15°C – $T_{cond,ai}$=15°C. It was determined that the AHP system for both refrigerant cases provided enough heating capacity and conditioned air temperatures, and these two performance parameters increased with rising compressor speed. Furthermore, although HFO1234yf provided slightly lower heating capacity and lower coefficient of performance, it yielded comparable performance with HFC134a in heat pump operations. As a result, this study shows that HFO1234yf is a sound alternative to HFC134a for not only summer air conditioning but also winter heating by using it in a heat pump.