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Performance evaluation of an integrated automotive air conditioning and heat pump system

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Abstract

This study deals with the performance characteristics of an R134a automotive air conditioning system capable of operating as an air-to-air heat pump using ambient air as a heat source. For this aim, an experimental analysis has been performed on a plant made up of original components from an automobile air conditioning system and some extra equipment employed to operate the system in the reverse direction. The system has been tested in the air conditioning and heat pump modes by varying the compressor speed and air temperatures at the inlets of the indoor and outdoor coils. Evaluation of the data gathered in steady state test runs has shown the effects of the operating conditions on the capacity, coefficient of performance, compressor discharge temperature and the rate of exergy destroyed by each component of the system for both operation modes. It has been observed that the heat pump operation provides adequate heating only in mild weather conditions, and the heating capacity drops sharply with decreasing outdoor temperature. However, compared with the air conditioning operation, the heat pump operation usually yields a higher coefficient of performance and a lower rate of exergy destruction per unit capacity. It is also possible to improve the heating mode performance of the system by redesigning the indoor coil, using another refrigerant with a higher heat rejection rate in the condenser and employing a better heat source such as the engine coolant or exhaust gases.

Keywords: Automotive air conditioning; Heat pump; R134a; COP; Exergy

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Nomenclature

COP	coefficient of performance
$\dot{E}_d$	rate of exergy destruction (W)
h	specific enthalpy (kJ kg^{-1})
$\dot{m}$	mass flow rate (g s^{-1})
n	compressor speed (rpm)
$\dot{Q}$	cooling or heating capacity (W)
s	specific entropy (kJ kg^{-1} K^{-1})
T	temperature (K)
T_0	environmental temperature (K)
$\dot{W}$	compressor power (W)

Subscripts

a	air
c	condenser
comp	compressor
e	evaporator
IC	indoor coil
IN	inlet
OC	outdoor coil
r	refrigerant
rv	reversing valve
t	total
v	expansion valve

1. Introduction

Automotive air conditioning (AC) systems usually employ a vapour compression refrigeration circuit, currently using R134a as the working fluid, to achieve summer thermal comfort in the passenger compartment. In winter, on the other hand, after an outdoor air stream has absorbed waste heat from the engine coolant, it is supplied to the passenger compartment to keep it comfortably warm. However, it is known that some modern high efficiency, direct injection Diesel engines cannot produce sufficient waste heat in this manner to achieve thermal comfort in an acceptable time-to-comfort period [1,2]. The vehicles with this type of engine currently employ electric, fuel burning or visco-heaters to supplement the main heating system. These devices, however, are usually inefficient, heavy, expensive and not environmentally friendly [3].

An attractive method of providing supplemental heat to the passenger compartment is to reverse the direction of the refrigerant flow in an automotive AC system, i.e. to operate it as a heat pump (HP). In this case, after an air stream has absorbed heat from the indoor coil serving as a condenser, it is blown into the passenger compartment to warm it. Besides assisting the main heating system of the vehicles with high efficiency internal combustion engines, particularly during the