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Experimental and numerical study on microchannel and round-tube condensers in a R410A residential air-conditioning system

Chang Yong Park, Pega Hrnjak[*,1]

Department of Mechanical and Industrial Engineering, University of Illinois at Urbana-Champaign, 1206 West Green Street, Urbana, IL 61801, USA

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ABSTRACT

The effect of different type of condensers on the performance of R410A residential air-conditioning systems was investigated in this study. Two R410A residential air-conditioning systems, one with a microchannel condenser and the other with a round-tube condenser, were examined experimentally, while the other components of the two systems were identical except the condensers. Two condensers had almost same package volumes. The two systems were operated in separate environmental chambers and their performance was measured in ARI A, B, and C conditions. Both the COP and cooling capacity of the system with the microchannel condenser were higher than those for the round-tube condenser in all test conditions. The refrigerant charge amount and the refrigerant pressure drop were measured; the results showed a reduction of charge and pressure drop in the microchannel condenser. A numerical model for the microchannel condenser was developed and its results were compared with the experiments. The model simulated the condenser with consideration given to the non-uniform air distribution at the face of the condenser and refrigerant distribution in the headers. The results showed that the effect of the air and refrigerant distribution was not a significant parameter in predicting the capacity of the microchannel condenser experimentally examined in this study. Temperature contours, generated from the measured air exit temperatures, showed the refrigerant distribution in the microchannel condenser indirectly. The temperature contours developed from the model results showed a relatively good agreement with the contours for measured air exit temperatures of the microchannel condenser.

Etude expérimentale et numérique sur les microcanaux et les condenseurs à tubes ronds dans un système de conditionnement d'air résidentiel au 410A

Mots clés : Système frigorifique ; Conditionnement d'air ; Condenseur ; Micro-canal ; Tube lisse ; Tube aileté ; Modélisation ; Simulation ; Comparaison ; Expérimentation

[*] *Corresponding author.* Tel.: +1 217 244 6377; fax: +1 217 333 1942.
E-mail address: pega@uiuc.edu (P. Hrnjak).
[1] Member of IIR Commission E2, United States.

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Nomenclature

d	difference between inlet and outlet
D	difference
OD	outside diameter (mm)
P	pressure (kPa)
Q	capacity (kW)
T	temperature (°C)
x	vapor quality
Subscript	
a	air side
c	condenser side
cp	compressor
e	evaporator side
g	glycol
i	inlet
n	nozzle
o	outlet
or	orifice
r	refrigerant side

1. Introduction

Heat exchangers with multi-ported microchannel tubes are already used in mobile air-conditioning systems due to their compactness and high performance. For better understanding of the physical phenomena in microchannel tubes, the characteristics of heat transfer, pressure drop, and flow patterns have been studied by many researchers as Kandlikar (2002) and Thome (2004) reviewed. Also, the performance of microchannel heat exchangers and their effect on CO_2 systems have been investigated by Pettersen et al. (1998), Richter et al. (2003), and Elbel and Hrnjak (2004). In these studies, the microchannel heat exchangers on the high pressure side were operated as gas coolers, not condensers, due to the transcritical operating condition.

Besides the application of microchannel heat exchangers as gas coolers in CO_2 systems and as condensers in mobile air-conditioning systems, there is a possibility that microchannel heat exchangers can be used as condensers in a residential air-conditioning system instead of the widely used condensers with round tubes. It is widely known that microchannel heat exchangers have an obvious advantage over RTPF (Round Tubes and Plate Fins) heat exchangers in compactness. Consequently, it is inferred that microchannel heat exchangers have a larger capacity than RTPF heat exchangers for an identical heat exchanger package volume. Even though apparently better heat transfer characteristics of microchannel heat exchangers exist, microchannel heat exchangers are not commonly used in residential air-conditioning systems because RTPF heat exchangers have a cost advantage, which is one of the most critical factors of commercial products. As a result, the experimental validation of the effect of a microchannel condenser on a residential air-conditioning system was difficult to find in the open literature.

In this study, two heat exchangers were used as condensers in the same R410A residential air-conditioning system, one with round tubes and the other with multi-ported microchannel tubes in a parallel-flow arrangement. The microchannel condenser was made to have nearly an identical face area, depth and fin density as the round-tube condenser which was the baseline. The size of the microchannel condenser might be unrealistic, because it is obvious that a microchannel condenser should provide higher capacity and system COP than a round-tube condenser for a nearly identical heat exchanger package volume. However, the purpose of this study is to experimentally estimate improved condenser and evaporator capacity and system COP by replacing a round-tube condenser with a microchannel condenser having almost identical frontal area and depth, without considering heat exchanger cost. The baseline (round tube) condenser along with all other elements of the system was part of a carefully sized air-conditioning system. The baseline system was examined in detail by Beaver et al. (1999). In this study, the system with the round-tube condenser was operated at several standard test conditions, and then the baseline condenser was replaced with the microchannel condenser without any change of other components in the system. In identical test conditions, the performance and capacities of the system with the microchannel condenser were measured and compared with those with the round-tube condenser. In addition, a model was developed for the microchannel condenser and it was validated by comparison with experimental results. With this model, the effect of non-uniform air velocity distribution at the face of the microchannel condenser and refrigerant distribution in headers on the condenser capacity was investigated.

2. Experimental facilities and test conditions

An air-conditioning system was installed in separate environmental chambers containing wind tunnels for simulating indoor and outdoor conditions according to ANSI/ASHRAE Standard (2005). Fig. 1 shows a layout of the system arrangement and test facilities. The system with a hermetic scroll compressor used an orifice tube as an expansion device. Air temperature was maintained within ±0.3 °C in both chambers and absolute humidity was controlled within ±2% in the indoor chamber. A variable-speed wind tunnel in each chamber simulated the operating conditions encountered in real application, and allowed an air flow rate measurement within ±1%. The refrigerant mass flow rate was measured by a mass flow meter with an accuracy of ±0.1% of the reading. The temperatures and pressures of R410A at the inlet and outlet of each component were measured by immersed thermocouples with an accuracy of ±0.1 °C and pressure transducers with an accuracy of ±3.4 kPa, respectively. For determining capacity of heat exchangers, were used for the evaporator and the condenser. The uncertainty calculation of the measured capacity was based on the guidelines presented by Taylor and Kuyatt (1994) and it was performed using EES (Klein, 2005). The maximum uncertainty of the capacity measurement was 1.6%. More information about the complete facility was presented by Beaver