Applied Mechanics and Materials
ISSN: 1662-7482, Vol. 388, pp 111-115
doi:10.4028/www.scientific.net/AMM.388.111
© 2013 Trans Tech Publications, Switzerland
Online: 2013-08-30

Experimental Study on the Replacement of HFC-R134a by Hydrocarbons in Automotive Air Conditioning System

Mohd Rozi Mohd Perang[1,a], Henry Nasution[1,2,3,b], Zulkarnain Abdul Latiff[1,2,c], Azhar Abdul Aziz[1,2,d], Afiq Aiman Dahlan[2]

[1]Automotive Development Centre, Universiti Teknologi Malaysia
81310 Skudai, Johor, Malaysia

[2]Faculty of Mechanical Engineering, Universiti Teknologi Malaysia
81310 Skudai, Johor, Malaysia

[3] Department of Mechanical Engineering, Bung Hatta University
25134 Padang, Sumatera Barat, Indonesia

[a]rozi@mail.fkm.utm.my, [b]henry@fkm.utm.my, [c]zkarnain@fkm.utm.my, [d]azhar@fkm.utm.my

Keywords: Hydrocarbon refrigerant, automotive air conditioning system, alternative refrigerant, energy saving.

Abstract. The HFC-R134a and hydrocarbon refrigerant (HCR) will be evaluated on the automotive air conditioning (AAC) experimental test rig which completed with the AAC system including the blower, evaporator, condenser, radiator, electric motor, compressor, alternator and equipped with the simulation room acting (equipped with internal heat load) as the passenger compartment. The electric motor operated as a car's engine and will drive the compressor simultaneously to the alternator to recharge the battery. The tests have been performed by varying the motor speed; 1000, 2000 and 3000 rpm, temperature set-point; 21 and 23^{0}C, and internal heat loads; 0, 500, 700 and 1000 W. The results of the performance characteristics of the HCR indicate the encouraging enhancement of the AAC system compared to hydrofluorocarbon refrigerant (HFC-R134a).

Introduction

The automotive air conditioning (AAC) system is designed to provide the human thermal comfort level of the driver and passengers defined by the American Society of Heating, Refrigeration and Air Conditioning Engineers (ASHRAE) as the state of mind that expresses satisfaction with the surrounding environment (ASHRAE Standard 55) [1].

Currently, the AAC system is used HFC-R134a as the working fluid which is one of the gases can contribute to the greenhouse effect. Several research have been done pertaining the used of HCR in AAC system would improve the performance of the system [2, 3]. Hydrocarbon (HC) is the new formulation of the refrigerant used to substitute the current HFC-R134a as the refrigerant for AAC system. At an early stage, the HCR was used as the refrigerant which was accepted before the emergence of CFCs (chlorofluorocarbons) and HCFCs (hydrochlorofluorocarbons). After a long period, HCR is no longer in use because of the flammability characteristic, not practical and harmful to a user [4]. Thus, CFCs and HCFCs are being used instead of using HCR.

The research work will be executed the results of the experimental studies on HCR as an alternative refrigerant to the AAC system in Malaysia. The formulation of HCR used for this evaluation contains butane (R600), propane (R290) and isobutane (R600a). The mixture is known as HCR of the AAC system and Wongwises et al. [5, 6], Ghodbane [7] and Tashtoush et al. [8] are one of the researchers that involved in HCR research.

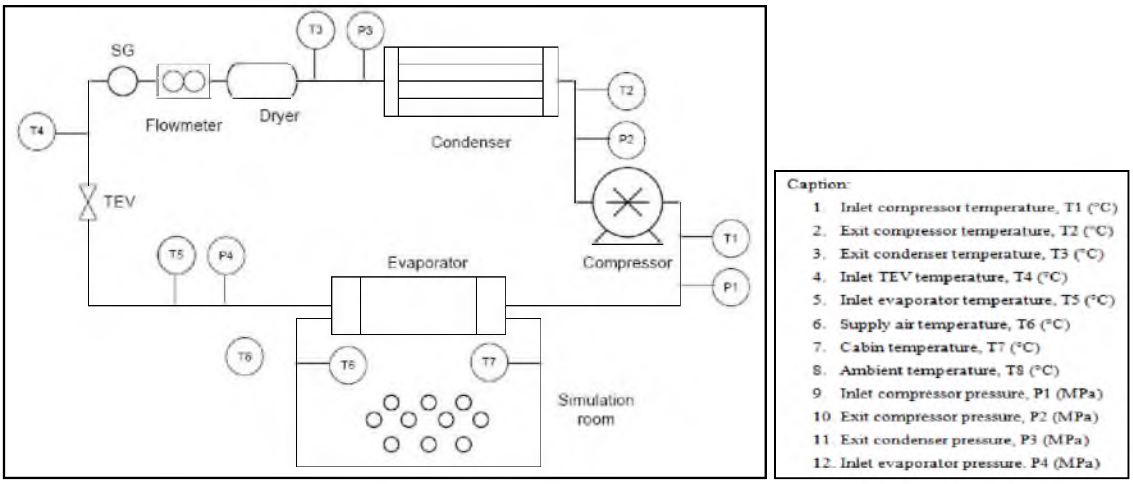
Table 1 shows the properties of the refrigerant used in this experimental work, especially for HCR formulation and HFC-R134a [5, 9]. HCR can be considered as environmental friendly refrigerant as well as has been used again regarding to the noticeable value of the Global Warming Potential (GWP) and zero Ozone Depletion Potential (ODP).

Table 1: Properties of refrigerant

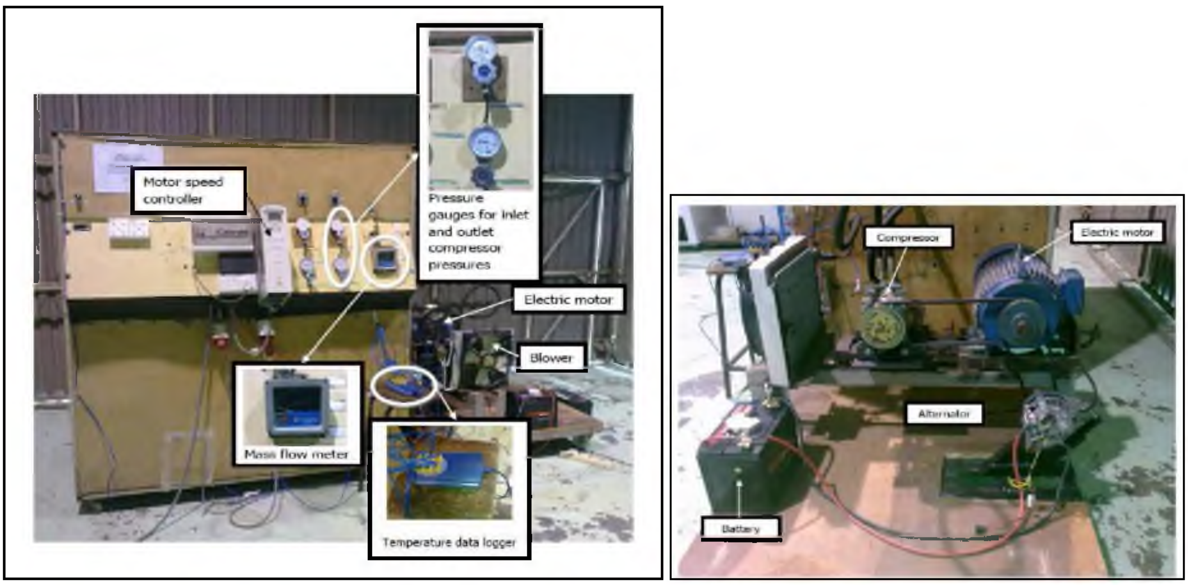
Code	Chemical formula	Boiling point at 101.325 kPa (°C)	Latent heat (kJ/kg)	ODP	GWP
12	CCl_2F_2	-29.8	165.24	0.82	8100
134a	CH_2FCF_3	-26.1	216.87	0	1300
50	CH_4/Methane	-161.5	510.54	0	20
170	C_2H_6/Ethane	-88.8	487.03	0	20
290	C_3H_3/Propane	-42.07	423.33	0	20
600	C_4H_{10}/Butane	-0.5	385.77	0	20
600a	C_4H_{10}/Isobutane	-11.73	364.25	0	20

Experimental Apparatus and Procedure

Fig. 1 (a) illustrates the schematic diagram of the system that has been used in this work.



(a) System diagram



(b) Experimental test rig

Fig. 1: Automotive air conditioning (AAC) system

Fig. 1 (b) shows on the experimental rig completed with AAC system components of the actual car including the blower, evaporator, condenser, radiator, compressor, electric motor, alternator and simulation room (equipped with internal heat load) in order to evaluate the coefficient of performance (COP) and power consumption. The refrigerants used for the compressor's working fluid are HFC-R134a and HCR. The experiments have been done in this work by varied the motor speed, internal heat load and cabin temperature using HFC-R134a and HCR (refer to Table 2). The thermostat was set to the maximum cool position.

Table 2: Range of variation parameters

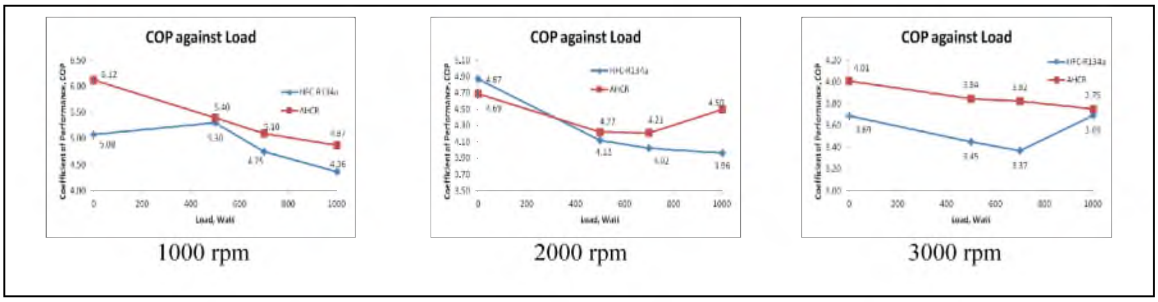
Parameter	Range of variation
Cabin temperature (°C)	21 and 23
Motor speed, N (rpm)	1000, 2000 and 3000
Internal heat load (W)	0, 500, 700 and 1000
Type of refrigerants	HFC-R134a and HCR

Thermodynamic properties of the HFC-R134a and HCR used were taken from the REFPROP database [9] and thermodynamic properties (given by the company) respectively.

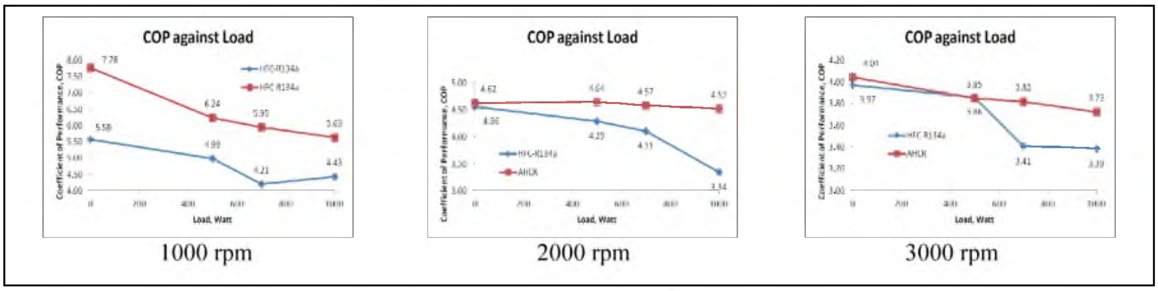
Results and Discussions

The measured parameters have been analyzed in order to obtain the performance of the AAC system, which are the COP and power consumption consumed by the compressor. COP of the system is a relationship between the energy released from the evaporator (refrigerating effect (Q_e)) and the energy required by the compressor (W_c) [10]. In order to get the enthalpy value through REFPROP software, refrigeration cycle needs to be illustrated on the P-h (pressure vs. enthalpy) diagram. FigFig. 2(a) and 2(b) show the graph of COP versus load at compressor speed of 1000, 2000 and 3000 rpm with HFC-R134 and HCR refrigerants. The result shows that the COP of HCR used is higher than HFC-R134a in which is up to 33%. This is a positive enhancement because high COP will indicate the better performance of the AAC system. When the compressor speed increases simultaneously with the increment of internal heat load and compressor speed, the COP will decrease.

The compressor work will affect the COP value at constant condition of the evaporator heat absorption. Therefore, COP will be increased when the compressor work is in steady-state condition and the evaporator heat absorption is decreased.



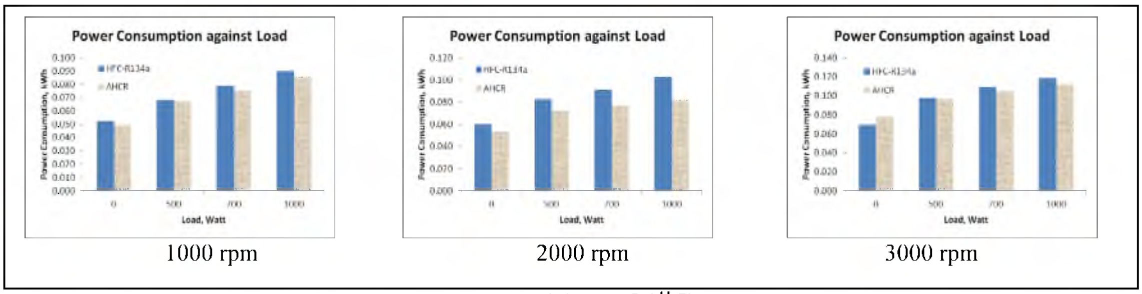
(a) At 21^0C



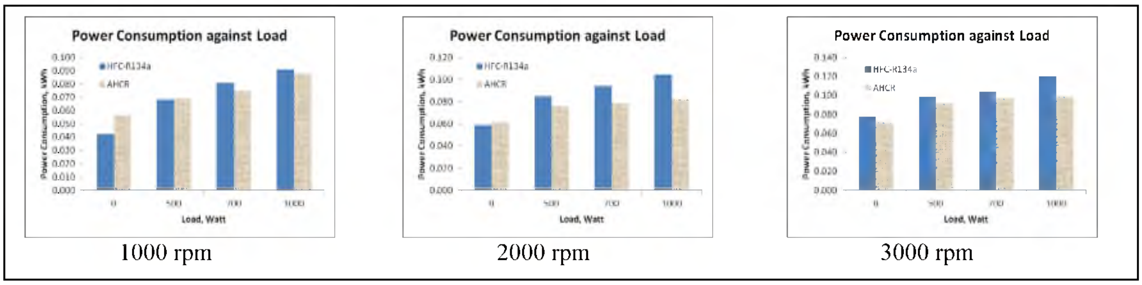
(b) At 23^0C

Fig. 2: Graph of COP against load (at compressor speed of 1000 – 3000 rpm).

Fig.3(a) and 3(b) exhibit the relationship between power consumption and heat load at compressor speed 1000, 2000, 3000 rpm. The compressor power consumption is increased proportionally with the increasing of heat load. At the both temperatures set-point, the graphs show the same trend of rising. At every temperature set-point temperature and with the increasing of heat load, the compressor desires to work more and then more power will be consumed. The results show that the compressor is using more power to compress the refrigerant to achieve higher pressure condition in order to maintain the temperature in the cabin. This can be concluded that the compressor power consumption of HCR is lower than HFC-R134a which indicates a positive improvement up to 15% (an average decreased is 10.3 %).



(a) At 21^0C



(b) At 23^0C

Fig. 3: Graph of power consumption against load (at compressor speed of 1000 – 3000 rpm).

Conclusions

From the HCR research that has been performed on the AAC system, the HCR shows an encouraging enhancement of performance characteristics compared to HFC-R134a in term of COP and power consumption. As a result, the HCR type is recommended to be the alternative refrigerant used for replacement of current HFC-R134a used in the automotive industry.

References

[1] ANSI/ASHRAE Standard 55, *Thermal environmental conditions for human occupancy*. American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., 2008.

[2] Tom Birch, "*Automotive Heating and Air Conditioning 2nd Edition*", Prentice Hall, 2000.

[4] Granryd, E., *Hydrocarbons as refrigerants – an overview*. International Journal Refrigeration, 24:15-24, 2001.

[2] D. Jung and C.B. Kim., *Testing of propane/isobutene mixture in domestic refrigerator*. International Journal Refrigeration, 2000.

[3] K. Mani and V. Selladurai, *Experimental Analysis of a new refrigerant mixtures as drop-in replacement for CFC12 and HFC134a*. International Journal of Thermal Sciences, 2008.

[5] Wongwises, S., Kamboon, A., and Orochon, B., *Experimental investigation of hydrocarbon mixtures to replace HFC-134a in an automotive air conditioning system*, Energy Conversion & Management; 47:1644-1659, 2006.

[6] Wongwises, S. and Chimres, N., *Experimental study of hydrocarbon mixtures to replace HFC-134a in a domestic refrigerator*, Energy Conversion & Management; 46:85-100, 2005.

[7] Ghodbane. M., *An Investigation of R152a and Hydrocarbon Refrigerants in Mobile Air Conditioning*, SAE Paper 1999-01-0874, 1999.

[8] Tashtoush, B., Tahat, M., Shudeifat, M.A., *Experimental study of new refrigerant mixtures to replace R12 in domestic refrigerators*. Application Thermal Engineering; 22:495-506, 2002.

[9] REFPROP, *Thermodynamic properties of refrigerants and refrigerant mixtures*, Version 6.1, Gaittherbeurg, MD, National Institute of Standards and Technology, 1998.

[10] Y.A. Cengel and M.A. Boles., *Thermodynamics: An engineering Approach (6 ed.)*. McGraw-Hill, 2007.