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Thermodynamic Performance Analysis of Eco friendly Refrigerant Mixtures to Replace R22 Used in Air conditioning Applications

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Abstract

In the present study theoretical thermodynamic performance of a 0.8 TR window air conditioner with ten binary refrigerant mixtures consists of propylene (R1270) and propane (R290) was investigated based on actual vapour compression refrigeration cycle. All the investigated refrigerant mixtures consist of zero ozone depletion potential. Global warming potential of R22 is 1760 whereas GWP of all the studied refrigerant mixtures were below three and also these mixtures are closer to azeotropic containing the temperature glide below 0.4ºC. Thermodynamic performance of all the refrigerant mixtures are computed at the evaporating and condensing temperatures of 7.2ºC and 54.4ºC (ARI conditions) respectively. The results revealed that the coefficient of performance for the mixture R1270/R290 (75/25 by mass %) was closer to R22. The percentage variation in cop for the mixture R1270/R290 (75/25 by mass %) was least by 0.97% among the ten investigated refrigerant mixtures when compared to R22. Refrigeration capacity of all the considered refrigerant mixtures was similar to that of capacity of refrigerant R22. The compressor discharge temperature for all the studied refrigerants were reduced in the range of 5.6-8.4ºC when compared to the reference refrigerant R22. The power required per ton of refrigeration for the refrigerant mixture R1270/R290 (75/25 by mass %) was least among the ten investigated refrigerant mixtures. Since refrigerant mixtures consist of hydrocarbons, therefore they had better miscibility with the mineral lubricant oil. Overall the thermodynamic performance of a refrigerant mixture R1270/R290 (75/25 by mass %) was nearest to R22 and hence it is a suitable environmentally alternative refrigerant to substitute R22 used in residential air conditioning applications.

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Keywords: Alternative refrigerants; Compressor discharge temperature; COP; ODP; GWP; Refrigeration capacity

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1. Introduction

A hydrochlorofluorocarbon refrigerant R22 is the most commonly used in heat pump, air conditioning and refrigeration applications because of its outstanding thermodynamic Properties. But R22 has unfavourable ecological effects like ozone depleting potential and high global warming potential. Therefore Montreal Protocol 1987, have been decided to phase out HCFCs in the developed countries by 2030 and for developing countries by 2040 [1, 2]. Therefore it is essential to develop the alternative refrigerants which are eco-friendly in nature in order to meet the requirements of Montreal and Kyoto protocols. In this context hydrocarbon refrigerants were eco-friendly in nature except its flammability. Therefore much attention was required for the hydrocarbons towards safety of the leakage from the system. Earlier various alternative refrigerants was proposed and tested to replace R22. An experimental investigation was carried out with R290 as an alternative to replace R22 used in window air conditioner. Results revealed that the performance of R290 was better when compared to R22 [3]. Experimental studies were conducted in a window air conditioner when it is retrofitted with mixture of R407C, propane (R290) and isobutane (R600a) without changing mineral lubricant oil. From this study it was observed that a blend of R407C/R290/R600a would be an appropriate alternative refrigerant to R22 [4]. Experimental tests were done with hydrocarbons and different blends consist of R1270, R290, R152a and RE170 as a substitute fluids to R22 used in both heat pump and air conditioning devices. Test results revealed that the performance of all the fluids was similar to R22 or superior to that of R22 [5]. Theoretical thermodynamic performance studies were carried out with various refrigerants like R290, R1270, R600a, R600, R32, R134a, R152a and their mixtures as a substitute fluids to R12, R22 and R134a. It was reported that the refrigerant mixture R290/R1270 (20/80 by wt. %) is an alternative to R22 among the other refrigerant mixtures investigated in the study [6]. Performance testing of R433A was conducted in heat pump test equipment under both heat pump and air conditioning working conditions. R433A is a binary mixture consists of 30% R1270 and 70% R290 on mass basis. Test results revealed that performance of R433A was better when compared to R22. Therefore R433A was a suitable alternative refrigerant to R22 [7]. Experimental testing of R432A was carried out as a substitute to R22 used in both heat pump and air conditioning devices. R432A is a binary blend consists of 80% R1270 and 20% RE170 on mass basis. Experimental results revealed that performance of R432A was higher than R22. Therefore R432A was an appropriate eco-friendly refrigerant to replace R22 used in both air conditioning and heat pump applications [8]. The present work focuses on performance investigation of ten binary refrigerant mixtures composed of propylene and propane as alternatives to replace R22. All the considered refrigerant mixtures are having zero ozone depletion potential and very small global warming potential less than three. In this study thermodynamic performance investigation of considered refrigerant mixtures is carried out based on actual vapour compression refrigeration cycle. In this work, effect of thermodynamic performance parameters like COP, compressor discharge temperature, refrigeration effect, refrigeration capacity, degree of subcooling, degree of superheating, type of refrigerant and power consumption per ton of refrigeration are considered for the performance investigation of selected refrigerants. In this study pressure drop at high pressure side of the system is taken as 0.4 bar whereas at low pressure side of the system is 0.2 bar.

Nomenclature

ARI	Air conditioning and refrigeration institute	ODP	Ozone depletion potential
COP	Coefficient of performance	P	Pressure (MPa)
GWP	Global warming potential	Q_c	Refrigeration capacity (W)
h	Enthalpy (kJ/kg)	RE	Refrigeration effect (kJ/kg)
h_1	Enthalpy at inlet of the compressor (kJ/kg)	t_c	Condensing temperature (°C)
h_{1l}	Enthalpy at outlet of the evaporator (kJ/kg)	t_e	Evaporating temperature (°C)
h_2	Enthalpy at outlet of the compressor (kJ/kg)	T_d	Compressor discharge temperature (°C)
h_4	Enthalpy at inlet of the evaporator (kJ/kg)	$\dot{W}$	Power per ton of refrigeration (kW/TR)
HCFCs	Hydrochlorofluorocarbons	W_c	Compressor work (kJ/kg)
$\dot{m}$	Mass flow rate of the refrigerant (kg/s)		