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An Investigation on the Performance Characteristics of Environment-Friendly Refrigerant Mixtures in a Window Air Conditioner

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Abstract: This paper deals with the simulation studies that have been carried out in an air conditioning system working with R22/R407C and R290 refrigerant mixture. The properties of the individual refrigerants and refrigerant mixtures were obtained from REFPROP 7.0 (NIST) for the given operating conditions. The software named as Simulink has been used for calculating and predicting the performance of the selected ternary refrigerant mixtures like HCFC, HFC and HC blends with various mass percentages. In the studies carried out the mixed refrigerants (M1 – M6) have shown better results as far as various performance characteristics are concerned and they are also benign to the environment.

Key words: Window Air conditioner · Simulation · Simulink · Refrigerant · Environment · Zero ODP

INTRODUCTION

In the global scenario of pollution problem, refrigerant play a major role in contributing for the depletion of ozone layer along with all other sources of global warming. Despite the fact that the conventional refrigerants have excellent thermodynamic properties like flammability, stability, higher energy efficiency and non-toxic characteristics, they have harmful effect on the stratospheric region which raises serious issue of global warming. Due to these reasons, conventional refrigerants like CFCs (chlorofluorocarbons) have been prohibited by the Montreal Protocol. In another ten years, Hydrochloroflourocarbons will also be phased out due to their ODPs. GWPs are relatively placed at higher levels but less than that of the chlorofluorocarbons. Half way compounds, such as R22 which are harmless to the environment and ozone layer are to be used until the year 2030. After that period, in order to obtain good performance and to protect the earth surface, all nations are expected to proceed with eco-friendly refrigerant mixtures for refrigeration, Air-conditioning and heat pumping applications.

D.B. Jabaraj *et al*. [1] stated that the performance of R407C/HC290/HC600a refrigerant mixtures which were experimentally investigated in window air conditioner as a result of indicated 11.91- 13.24% efficiency higher than that of HCFC22. The overall performance has proved that R407C/HC refrigerant blends could be environment friendly refrigerants. Ki-Jung Park *et al*. [2] suggested that two HCs and seven mixed refrigerants containing propane, propylene HFC 152a and DME as the suitable alternative to R22 used in residential air conditioners and heat pumps. These working fluids possess Zero Ozone Depleting Potential (ZODP) and relatively Low Global Warming Potential (LGWP) and thus can be used as a long term candidate. In the past years, performance of various blends, eco-friendly refrigerant mixtures were comprehensively studied by many researchers; S.G.Kim *et al*. [3] A.S. Dalkilic *et al*. [4], Ki-Jung Park *et al*. [2], M.Fatouh *et al*. [5]. Hang Tao QIAO *et al*. [6] have generated mathematical models for compressor, orifice and heat exchanger and analyzed with the help of governing equations in both refrigerant side, finned wall and air side.

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Jianyong chen *et al*. [7] investigated the performance of a new refrigerant mixture R32/R134a for residential air conditioner as a replacement of R22 experimentally. Bin Li *et al*. [8] discussed the building of dynamic modeling method in performance prediction for prospective product designs and control accomplishment for system performance enhancement. B.G. Lee [9] *et al*. have dealt with the study of various alternative refrigerant mixtures and its performance for HCFC22 using the thermodynamic calorimeter and they have been compared with that of HCFC22, R407C and R410A. The results showed that refrigeration capacity of every mixture was 1.64-23.17% larger than that of R22.

Jiangtao Wu *et al*. [10] have reviewed various studies on the performance of refrigerant blends R152a/R32 with different mass ratio 48/18/34 as a suitable alternative to R22.REFPROP7.0 has been used for predicting the thermo physical properties. The new blends of refrigerants have shown better performance than R410A and R407C in terms of Co-efficient of Performance, volumetric cooling capacity, condensing and evaporating pressure.

In broad spectrum, all the papers described above, for the majority, immersed on the studying of the alternative refrigerant properties and performance characteristics by experimentation, mathematical and simulation methods, though many new designs may sustain the use of appropriate alternative working fluids and uphold the cycle performance. In this work, Simulation studies carried out on the performance of ternary mixtures of HCFC, HFC and HC with various compositions (by weight) have shown to reduce ozone depletion, global warming which are benign to environmental aspects. Ternary refrigerant mixtures like R22/R290 and R32/R125/R134a were found to provide better energy efficiency without causing any environmental hazard and thus can be used as an alternative working fluid for residential air conditioning applications instead of individual refrigerants.

Simulation Work: Simulation work has been carried out by MATLAB Simulink tool which is software that allows the users to calculate the results of thermodynamic performance of Vapor compression refrigeration system. It uses mathematical modeling of states in HFC mixtures and appropriate equation of states for other mixtures according to composition.

M1 - R22-40%/R290-30%/R407C-30%
M2 - R22-30%/R290-40%/R407C-30%
M3 - R22-30%/R290-30%/R407C-40%
M4 - R22-40%/R290-20%/R407C-40%
M5 - R22-40%/R290-40%/R407C-20%
M6 - R22-20%/R290-40%/R407C-40%.

RESULTS AND DISCUSSION

The results reveal that each blend used in the study has certain favorable aspect considering a particular parameter. Two mixtures (M3, M5) have given better results considering overall performance.

The results were also compared with unmixed refrigerants like R22, R290 and R407C apart from the six mixtures. It is clear that R290 is the best performing refrigerant among the unmixed refrigerants. But R290 is highly flammable. Hence to take advantage of its favorable property,40% of R290 is taken to produce the optimum mixture M5.

Table 1: Performance Parameters of selected refrigerant and its mixture at various operating conditions.

Refrigerant	Input Values				Output values								
& Mixtures	T_e°C	T_{SH}°C	T_{Sub}°C	T_c°C	COP	η_{vol}(%)	(kg/sec)	W_{isen} (kJ/kg)	CR (kW)	CP (kW)	T_{cd}°C	PR	OPI kJ.°C/m³
R22					3.487	94.78	0.0159	50.89	2.823	0.8094	91.32	2.252	65810
R290					4.234	94.61	0.00762	75.58	2.433	0.5745	68.3	2.151	59500
R407C					3.364	93.61	0.01496	52.66	2.65	0.7878	80.3	2.39	58960
M1					3.292	94.37	0.01649	59.42	3.227	0.9801	76.4	2.161	78750
M2	10	20	8	40	3.368	94.4	0.01507	61.78	3.136	0.9311	74.6	2.152	76820
M3					3.216	94.27	0.01697	60.04	3.277	1.019	75.8	2.165	79900
M4					3.164	94.17	0.01739	58.77	3.201	1.012	78.9	2.21	76540
M5					3.44	94.49	0.01405	61.34	3.091	0.8984	75.2	2.149	75760
M6					3.295	94.31	0.01552	62.24	3.183	0.9662	74.1	2.155	77940
R22					2.961	93.43	0.01568	57.76	2.681	0.9056	99.56	2.539	65620
R290					3.671	93.24	0.007492	83.34	2.292	0.6243	73.7	2.409	59240
R407C					2.854	91.88	0.0468	59.35	2.487	0.1713	87.1	2.719	57790
M1					2.778	92.84	0.01623	67.05	3.022	1.083	82.6	2.424	77980
M2	10	20	8	45	2.851	92.89	0.01483	69.41	2.935	1.029	86.7	2.413	76010
M3					2.712	92.69	0.01669	67.69	3.063	1.129	81.9	2.429	78970
M4					2.667	92.57	0.0171	65.73	2.998	1.124	85.3	2.486	75630
M5					2.917	93.61	0.01442	68.92	2.899	0.9936	81.3	2.409	75120
M6					2.78	92.75	0.01527	70.02	2.973	1.07	80.1	2.418	76970

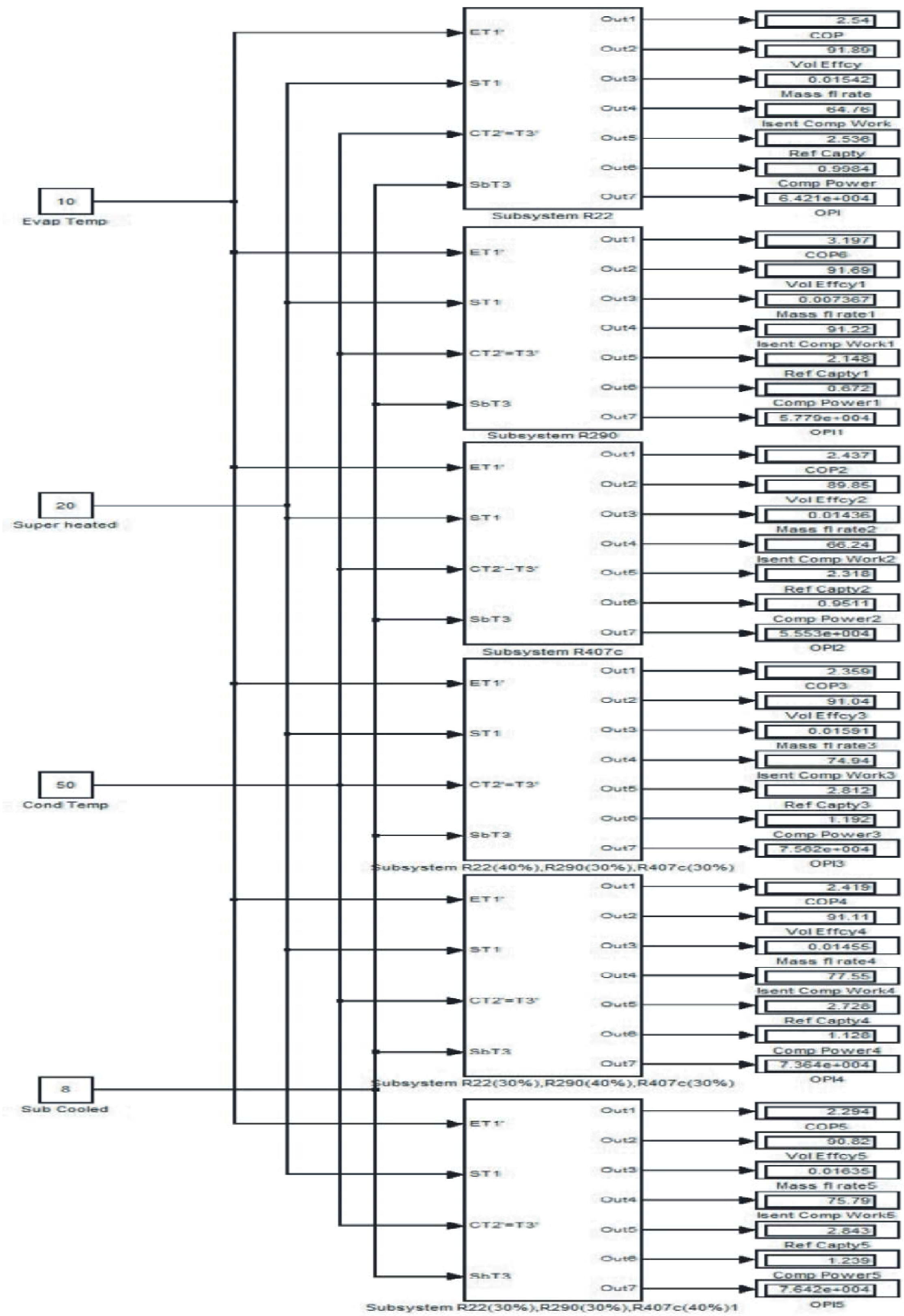
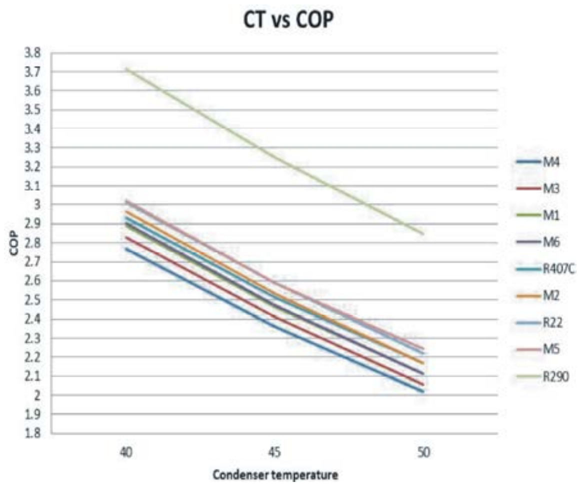
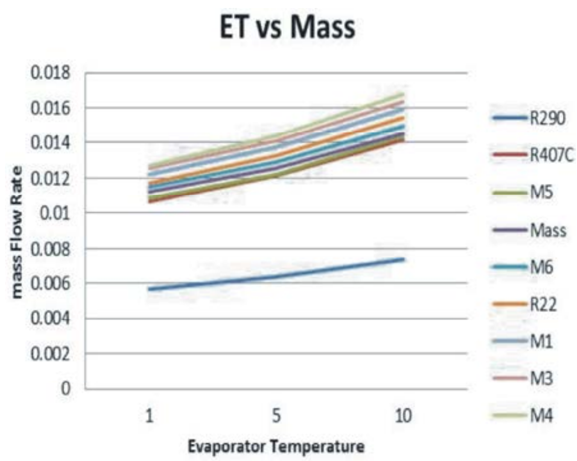


Fig. 1: Simulation model



ET=5°C SHT=15°C SUBT=8°C CT=40,45, 50°C

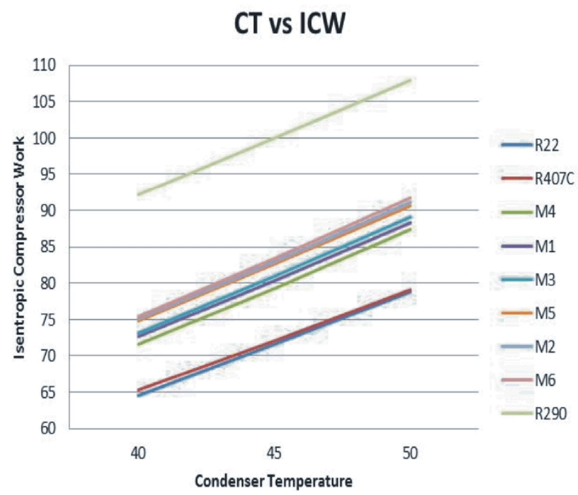
Fig. 2: Effect of Condenser Temperature with COP



ET=1,5, 10°C SHT=11,15,20°C SUBT=8°C CT=40,45, 50°C

Fig. 3: Effect of Evaporator Temperature with mass flow rate

Co-efficient of Performance: The effect of COP for refrigerant mixtures R22, R290 and R407 with six different mixtures are shown in Fig 2. The experiments were carried out by varying either condenser temperature or evaporator temperature one at a time, keeping the other constant. When the condenser temperature is 40°C and the evaporator temperature is varied from 1°C to 10°C, the COP showed a increasing trend for all the mixtures. On the other way, when the evaporator temperature was kept constant at 1°C and condenser temperature was varied in the region of 40°C to 50°C, the COP decreased. The investigation revealed that the COP increases with increasing evaporator temperature, but decreases for rise in condenser temperature [11-18].



ET=1°C SHT=11°C SUBT=8°C CT=40,45, 50°C

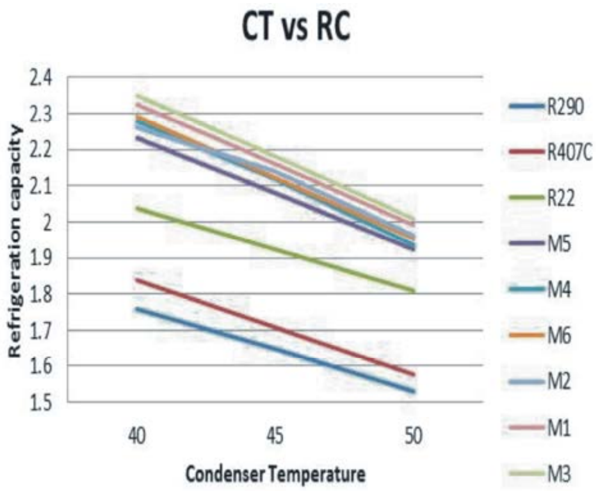
Fig. 4: Effect of Condenser temperature with Isentropic compressor work

An increase of COP by 4.12% was observed for M5 under above operating conditions.

Refrigerant Mass Flow Rate: The effect of evaporator temperature with mass flow rate is shown in Fig. 3 for refrigerants R22, R290 and R407C along with six different mixtures. When the evaporator temperature is maintained constant at 1°C and condenser temperature is varied from 40°C to 50°C the mass flow rate decreases. For M5,a decrease of 8.6% was observed due to the influence of R290 which is inflammable and has less mass flow rate. In case of M4 an increase of 7% in mass flow rate was observed as R22,R407C provide considerable disparity in mass flow rate.

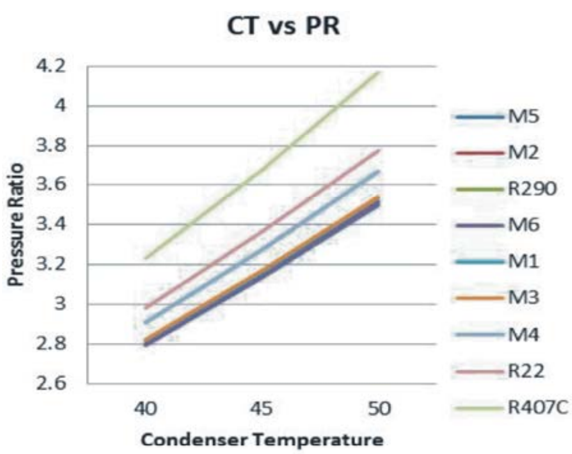
Isentropic Compressor Work: The effect of condenser temperature with isentropic compressor work is shown in Figure. 4. As the condenser temperature is maintained at 40°C and evaporator temperature varied from 1°C to 10°C the refrigerant mixtures show decreased isentropic compressor work. When the evaporator temperature (T_e) is maintained constant at 1°C and condenser temperature (T_c) varied from 40°C to 50°C isentropic compressor work increases. The isentropic compression work was found to be decreased for M5 by 7% and increased by 4.7% for M3 which is due to increase in the percentage of composition of 407C by weight in the mixture.

Refrigeration Capacity: The effect of Refrigeration Capacity (CR) on condenser temperature is also shown in Fig. 5 in which variation for R22, R290 and other mixtures



ET=1°C SHT=11°C SUBT=8°C CT=40,45, 50°C

Fig. 5: Effect of Condenser temperature with refrigeration capacity



ET=1°C SHT=11°C SUBT=8°C CT=40,45, 50°C

Fig. 6: Effect of Condenser Temperature with Pressure ratio

for the same inputs are investigated. When the condenser temperature (T_c) is maintained at 40°C and evaporator temperature (T_e) is varied from 1°C to 10°C the refrigerant mixture shows increased Refrigeration Capacity. When the evaporator temperature (T_e) is maintained constant at 1°C and condenser temperature varied from 40°C to 50°C refrigeration capacity is decreased in individual components. On comparison to R22 and R407C, the refrigeration capacity (RC) of R290 is considerably less.M5 shows 2.5% decrease, M3 shows 2.7% an increase in view of the fact that there is significant variation in the mixing ratio of R407C and R22.

Compressor Power: Compressor Power has also been obtained for refrigerants R22, R290 and R407C along with six different mixtures. As the condenser temperature is maintained at 40°C and evaporator temperature is varied from 1°C to 10°C the refrigerant mixture shows increased Compressor power. The compressor power found to be increased by 4.2% for M3 and decreased by 7% for M5 which is due to the influence of R407C.

Pressure Ratio: The effect of Pressure Ratio (PR) has also been observed for refrigerant mixtures R22, R290 and R407C along with six different mixtures (M1 – M6). The condenser temperature (T_c) is kept at 40°C and evaporator temperature (T_e) is varied from 1°C to 10°C, the pressure ratio of the refrigerant decreases. When the evaporator temperature is maintained constant at 1°C and condenser temperature is varied significantly from 40°C to 50°C, M5 shows 1% decrease in pressure ratio and M4 shows 3% increment due to addition of 40% of R407C in the mixture.

CONCLUSION

With aid of Simulink software, the investigations have been carried out to study the individual refrigerants R22, R407C, R290 besides the mixtures M1 to M6. The inferences have been given below.

- When the mixed refrigerant is used, co-efficient of performance and mass flow rate are improved and power consumed by compressor is also reduced.
- The results noticeably point out that the use of hydrocarbon refrigerant (R290) improves the performance of small capacity (1TR) window air conditioner.
- The mixed refrigerants hold comparatively good environment friendly characteristics and can be utilized for household and industrial applications.

REFERENCES

1. Jebaraj, D.B., P. Avinash and D. Mohanlal, 2006. Experimental investigation of HFC407/ HC290 /HC600a mixture in a window Air Conditioner-Energy Conversion management, 47: 2578-2590.
2. Ki-JunkPark and Dongsooung, 2007. Thermodynamic Performance of HCFC22 alternative refrigerants for residential air conditioning applications, Energy and Buildings, 39: 675-680.

3. Kim, S.G. and M.S. Kim, 2002. Experiment and simulation on the performance of an auto cascade refrigeration system using carbon dioxide as a refrigerant, International Journal of Refrigeration, 25: 1093-1101.
4. Dalkilic, A.S. and S. Wongwises, 2000. A performance comparison of vapour compression refrigeration system using various alternative refrigerants, International Communication in Heat and MassTransfer, 37: 1340-1349.
5. Fatouh, M., Talaat Ibrahim and A. Mustafa, 2010. Performance assessment of a direct expansion air conditioner working with R407C as an R22 alternative, Applied Thermal Engineering, 30: 127-133.
6. Hangtao, Q.I.A.O., Vikranth AUTE and Reinhard Radermacher, 2012. Comparison of Equation-based Non-equation-based approaches for transient modeling of a vapour compression cycle, International refrigeration and air conditioning conference at Purdue, 2190.
7. Chen Jianyong and Jianlin Yu, 2008. Performance of a new refrigeration cycle using refrigerant mixture R32/R134a for residential air conditioner applications, Energy and Buildings, 40: 2022-2027.
8. Bin Li and Steffen Peuker, 2011. Refrigerant mass migration modeling and simulation for air conditioning system, Applied Thermal Engineering, 31: 1770-1779.
9. Lee, B.G., J.Y. Park and J.D. Kim, XXXX. A study on the performance of alternative refrigerant mixtures for HCFC22 KIST, P.OBox 131, Cheongryang, Seoul 130-650, South Korea.
10. Wu Jiangtao, Yingjie chu, Jing Hu and Zhingang Liu, 2009. Performance of mixture refrigerant R152a/R125/R32 in domestic air conditioner, International Journal of Refrigeration, 32: 1049-1057.
11. Park Ki-Junk, Dongsoo Jung and Yun –Bo shim, 2009. A ‘drop-in’ refrigerant R431A for replacing HCFC22 in residential air conditioners and Heat pumps, Energy conversion and Management, 50: 1671-1675.
12. Kim, S.G., M.S. Kim and S.T. Ro, 2002. Experimental Investigation of the performance of R22, R407C and R410A in several capillary tubes for air conditioners, International Journal of Refrigeration, 25: 521-531.
13. Wu, J.H. and L.D. Yang, 2012. Experimental performance study of a small wall room air conditioner retrofitted with R290 and R1270. International Journal of Refrigeration, 35: 1860-1868.
14. Jadhav, S.S. and K.V. Mali Evaluation of a Refrigerant R410A as Substitute for R22 in Window Air-conditioner. IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE) ISSN (e): 2278- 1684, ISSN (p): 2320–334X, 23-32.
15. Park, C.Y. and P. Hrnjak, 2008. Experimental and numerical study on micro channel and round-tube condensers in a R410A residential air-conditioning system, International Journal of Refrigeration, 31(5): 822-831.
16. SozenAdnan and Erolcaklioglu, 2009. Determination of the thermodynamic properties of an alternative refrigerant (R407C) using Artificial Neural Network, Expert systems with Applications, 36: 4346-43456.
17. Propainop, R. and K.O. Suen, 2012. Simulation of potential refrigerants for retrofit replacement, ARPN Journal of Engineering and Applied Sciences, 7(9).
18. UNEP, 2000. The Montreal Protocol on substances that deplete the ozone layer. United Nation Environment Programme, Nairobi, Kenya; ozone secretariat.