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Analysis of Humidified Air Circulation Over the Air Cooled Condenser of Vapour Compression Refrigeration System with Eco Friendly Refrigerants

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Abstract – *The performance behavior of vapour compression refrigeration system (VCRS) has been examined in two modes of operation namely atmospheric air circulation (AAC) and humidified air circulation (HAC) over the condensing coil at different loading conditions in the evaporator. This experimental work is carried out by using the refrigerant mixture of R290 and R600a which are eco friendly refrigerants as compared to conventional refrigerants like R12 and R134a. Humidifier unit is assembled with the existing VCRS and the mass flow rate of water supplied is maintained about 1.08 lit/sec. The various performance parameters like coefficient of performance (COP), refrigeration effect, heat rejection in the condenser and power input to the compressor are measured experimentally at different loads in the evaporator. The experimental results of the proposed investigation shows that 19.1% reduction in compressor power consumption and progressive increase in refrigeration effect & COP. COP of HAC mode is about 26.88% higher than AAC mode at 75% loading conditions.*

***Keywords**: Coefficient of Performance, Power Consumption, Heat Rejection, Humidifier*

Nomenclature

h	Enthalpy at states 1, 2, 3 and 4
T	Temperature at states 1, 2, 3 and 4
m_{ref}	Mass flow rate of refrigerant
Q_{air}	Heat gained by air
Cp_{air}	Specific heat of air
$T_{entry\ air}$	Temperature of entry air
$T_{exit\ air}$	Temperature of exit air
GWP	Global Warming Potential
ODP	Ozone Depletion Potential

I. Introduction

Implementation of energy efficient techniques in any thermal equipment will provide fruitful results in terms of higher efficiency, less power consumption, minimum wastage, etc. The requirement and the usage of refrigeration systems are escalating very rapidly in household and industrial sectors [1]-[24].

The performance of vapour compression refrigeration system is greatly depends up on two parameters namely refrigeration effect and power input given to the system. In order to maximum the performance of the refrigeration system either enhancement in refrigeration effect or power input to be decreased.

Normally air cooled condensers preferred due to their advantageous flexibility with the environment. Normally the effectiveness of air cooled condensers is influenced by the temperature of the environment.

During the hot climatic conditions, the condensation will not be a favorable one to maximize the phase change effect of refrigerant in the refrigeration systems. Evaporative cooling is used to enhance the heat transfer rate in the condenser [2] and also increase COP of the refrigeration system. Among the various techniques for enhance the performance of refrigeration system; humidified air circulation over the condenser is preferred instead of atmospheric air circulation.

Most of the refrigerators are charged with R134a as the refrigerant. R134a have higher GWP about 1300 and ODP about 20 [10]. With respect to the clean and green environmental standards, R134a could not be used for long term in the refrigerators. An alternative refrigerant is the only solution for this issue and these alternate refrigerants also should execute the requirements of the international protocols. Hydrocarbons having the similar thermodynamics characteristics and better heat transfer rate as compared to other refrigerants.

Their impact towards the environmental is also very low as comparing HFC and CFC due to very low GWP and zero ODP.

Due to this issue, the mixture of hydrocarbons (Propane and Iso butane) is selected as refrigerant with 50% mass fraction in each. Propane and Isobutane are having less impact on the environment in terms of GWP and ODP [10].

Mixture of R290 and R600a with each 50% mass fraction was used as a refrigerant instead of R134a in a domestic refrigerator of 440 liters capacity [12].

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Hajidavalloo et al. [2] carried out an experimental investigation on performance improvement of air conditioner with evaporative cooled air condenser and significant outcomes were obtained like 20% reduction in power consumption and 50% improvement in COP. Nasr et al. [3] studied that evaporative condenser could be used for residential refrigerators and found that heat rejection was 13 times more than the air cooled condenser.

Ebrahim Hajidavalloo [4] discussed the application and effect of evaporative cooling on the condenser of window air conditioner and reported that 16% reduction in power consumption and COP improved about 55%. Mathematical model of evaporative cooling for air conditioning system was analysised by Camargo et al. [5]. Maheshwari et al. [6] studied the possibility usage of indirect evaporative cooler and energy-saving potential in interior and coastal areas. Experimental studies on evaporative condenser compression refrigeration with R134a as refrigerant was performed by Mertin Ertunc et al. [7].

Based on these data, the models of evaporative condenser were developed by using artificial neural network and adaptive neuro-fuzzy inference system. Centrifugal humidification technique was used to cool the industrial sheds and the effect of mass flow rate water, disc speed, mass flow rate of rate were discussed by Senthilkumar et al. [8].

Krishan et al. [9] studied the effect of evaporative cooling in space conditioning for summers in Delhi. In this paper the effect of air-changes per hour and fresh-air bypass factor on the performance of the system was studied by simulation. 1.8 to 8.1% higher cooling capacity and enhancement in COP is obtained by evaporative condenser than the air cooled condenser using refrigerant R22 [13]. Experimental and analytical analysis on water mist cooled the chillers was carried out by Jia Yang et al. [17].

Boulet et al. [18] discussed the performance enhancement of tube and fin heat exchanger by flowing the air with water droplets. Exergy analysis of three stage auto refrigerating cascade system with zeotropic mixture of R1270/R170/R14 was examined by Sivakumar et al. [21]. The performance of auto refrigerating cascade system has been improved in terms of COP and exergic efficiency. Hydrocarbon mixture of propane, butane and isobutene was investigated by Hammad et al. [16] and proposed that the mixture can be used in domestic refrigerator to replace R12. Thangavel et al. [1] discussed that mixture of R290 and R600a with mass fraction of 50% each could be used in the refrigeration systems and 75% load in the evaporator is economical mode to operate the refrigerator. Thangavel et al. [20] discussed simulation analysis of VCRS with hydrocarbons as a refrigerant at different mass fractions.

From the above literature collection suggests that, HCM could be used as alternate refrigerants in VCRS.

As compared to R12 and R134a, the similar thermodynamic properties are obtained in the mixture of R290 and R600a with each 50% of mass fraction among the various mass fraction values of R290 and R600a. Even though the COP of HCM is less as compared to R134a, HCM provide more desirable uniqueness like zero ODP, lower GWP, lower pressure ratio, higher volumetric efficiency, lower discharge temperature and higher thermal conductivity with respect to condensing temperature. Among the various performance enhancement methods of refrigeration cycle, HAC over the condenser during the hot climatic conditions is preferred and effects of HAC are focused in this paper. In order to quantify the performance enhancement of refrigeration cycle, experimental investigation was performed on VCRS with HAC and compared with AAC over the condenser. The detailed performance enhancement study is and its momentous outcomes are discussed in the following titles.

II. Materials and Methods

II.1. Selection of Refrigerant

Normally the refrigerators are charged with R12 and R134a as refrigerants in refrigeration systems. Due higher range of GWP, these refrigerants should be eradicated from the practical applications like domestic refrigerators and industrial refrigeration systems.

In order to create clean and green environment, the selection of the refrigerant playing an important role and also fulfill the international standards. Hence an alternate refrigerant is solution for this issue and new refrigerants also should execute same kind of thermodynamic characteristics which are similar to conventional refrigerants. Hydrocarbon refrigerants are having similar characteristic feasibility to use an alternate refrigerant for R12 and R134a. The proposed refrigerant HCM leads to green environmental condition due to their environmental friendly properties.

The comparison of thermo physical properties of conventional refrigerants like R12, R134a with hydrocarbon refrigerants is shown in Table I. In order to get the similar thermodynamic characteristics of R12 and R134a, the mixture of R290 and R600a is suggested in VCRS [14], [15] and in this investigation, refrigeration system is charged with mixture of R290 and R600a with the mass fraction of 50% each [1], [12].

II.2. Experimental System with Instrumentation

Experimental refrigeration system is prearranged with VCRS and humidifier unit shown in Fig. 1. Experimental refrigeration system is incorporated with measuring system and data logging unit. Voltmeter (0-300)V and Ammeter (0-15)A are used to monitor the voltage and current flow into the system. Temperature measurements at various points were obtained by using RTD type thermocouples. The temperatures at compressor inlet & outlet, condenser inlet & outlet, evaporator inlet & outlet are measured by using thermocouples.

TABLE I
THERMO PHYSICAL PROPERTIES OF REFRIGERANTS

Refrigerant properties	Refrigerant and Chemical names				
	R12	R134a	R290	R600	R600a
	Dichloro Difluoro Methane	Tetra Fluro Ethane	Propane	Butane	Iso Butane
Formula	CCl_2F_2	CH_2FCF_3	C_3H_8	C_4H_{10}	C_4H_{10}
Natural	No	No	Yes	Yes	Yes
Boiling Point (°C)	-29.80	-26.10	-42.20	-2.00	-11.7
Flammability limit	Non Flammable	Non Flammable	2.1	1.5	1.7
Vapour density at 28°C	39.9	35.38	22.3	6.756	9.9
ODP	1	0	0	0	0
GWP	8500	1300	20	20	20

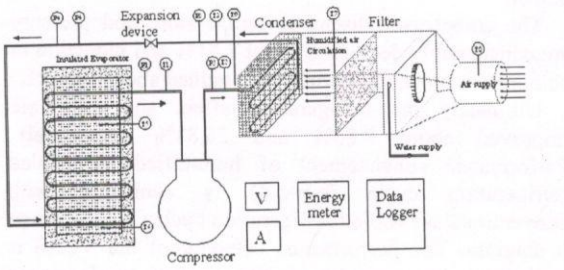

Fig. 1. VCRS coupled with humidifier unit

Pressure gauges are used to measure the pressure at low pressure side (evaporator outlet, compressor inlet) and high pressure side (compressor outlet, condenser inlet & outlet). Table II represents measured variables with its uncertainties.

TABLE II
MEASURED VARIABLES WITH ITS UNCERTAINTIES

Measuring instrument	Range	Accuracy
Temperature sensor	-50°C to 100°C	± 0.1°C
Pressure Gauge	0-300 psi	± 1 psi
Pressure Gauge	0-150 psi	± 1 psi
Anemometer	0.4-30 m/sec	± 2%

The evaporator is well insulated by insulating material (Glass wool) and arranged to operate at different loads.

In this investigation, 25%, 50%, 75% and 100% of loads are considered in the evaporator to identify the better performance of the refrigeration system. Water is used as a substance in the evaporator for experimental purpose and it is filled in the evaporator based on the load values. Cycling test (on/off) is performed for each load in the evaporator.

For each load, measurements like pressure & temperature at various points, energy meter reading are observed. An initial and final temperature of the water in the evaporator shows the refrigerated effect produced by the refrigeration system. The mass flow rate of refrigerant is considered as 1 kg/s for this analysis.

The temperature of the air stream entering and leaving from the humidifier unit is measured by thermocouples.

Anemometer is use to measure the velocity of air stream at the inlet and exit of the humidifier. The condenser of conventional VCRS is arranged to operate in both the mode of cooling like AAC and HAC.

II.3. Humidifier Unit

The main components of a centrifugal humidifier are rotating disc, stationary ring with strips, and air supply duct with filter.

Fig. 2(a) shows the arrangement of humidifier with the condenser unit of VCRS. Atmospheric air is supplied to flow over the rotating ring which consists of rectangular strips on its peripherals.

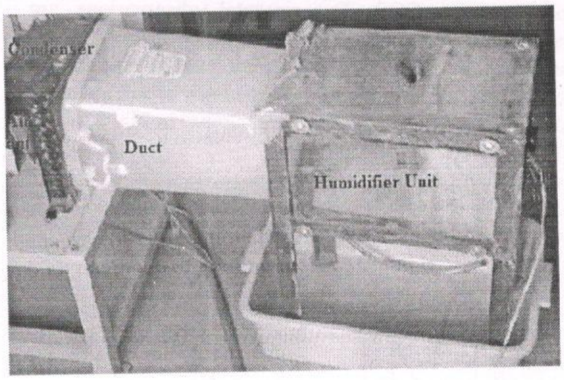

Fig. 2(a). Humidifier unit

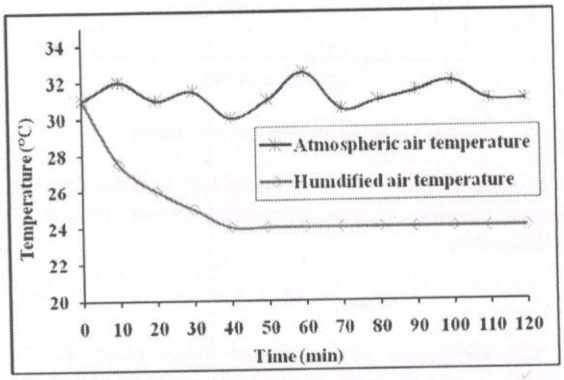

Fig. 2(b). Effect of humidification on air temperature with time

Due to centrifugal movement of the disc and the rectangular strips on the circumference of the disc, the impinged water will be atomized into very fine particles.

The atomization of water particles is controlled by the quantity of water sprayed, arrangement and shape of the strips, rotational speed of the disc and air velocity. In order to get better humidification of air, the quantity of water supplied in the sprayer is maintained about 1.08 lit/min and the velocity of circulated air before humidification is maintained about 4.5 m/s.

These atomized water particles are diffused into the atmospheric air and this humidified air is focused to flow over the condenser.

The temperature of the humidified air is achieved about 24°C after 30 minutes from the initiation of humidification process and the variation of humidified air temperature with atmospheric air temperature is shown in Fig. 2(b).

As compared to atmospheric air, 6°C reduction in dry bulb temperature and 80% of relative humidity are achieved through experimentally.

III. Computational Analysis

Refrigeration system performance is analysised based on the various performance measures like power consumption, refrigeration effect, heat rejection in the condenser and COP. Experimental observations are examined in two modes of operation namely AAC (Refrigeration cycle 1-2-3-4) and HAC(Refrigeration cycle a-b-c-d).Thermodynamic processes of refrigeration cycle is plotted in p-h diagram and shown in Fig. 3.

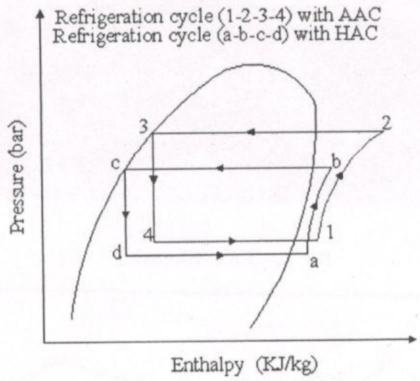

Fig. 3. Refrigeration cycle in p-h diagram

Isentropic compression (Process 1-2) is takes place in the compressor. Compressor input power (P_{comp}) is calculated by:

$$P_{comp}=m_r(h_2-h_1) \quad (1)$$

The refrigerant phase change takes place in the condenser and the heat rejected (Process 2-3) from the condenser (Q_{cond}) to the atmosphere is given by:

$$Q_{cond}=m_r(h_2-h_3) \quad (2)$$

The required refrigeration effect (RE) is obtained in the evaporator (Process 4-1) and is given by:

$$RE=m_r(h_1-h_4) \quad (3)$$

The performance of the refrigerator unit is expressed in terms of COP and is expressed:

$$(COP)_R=(RE/_{comp})=(h_1-h_4)/(h_2-h_1) \quad (4)$$

Heat gained by the circulated air over the condenser is calculated by:

$$Q_{air}=m_{air}\,Cp_{air}\,(T_{entry\ air}-T_{exit\ air}) \quad (5)$$

IV. Results and Discussion

Based on the experimental observations, condensation process greatly influences the performance of the refrigeration system.

For various loads in the evaporator, the performance measures are evaluated and compared with other loads in evaporator. The effect condensation in AAC and HAC are experimentally analysised and Table III shows the various performance measures acquired from the study in AAC & HAC modes at 75% of load in the evaporator. Condenser outlet temperature is dropped about 9°C and heat rejection from the condenser is also enhanced about 6.57%.

The compressor discharge temperature and pressure are considerably decreased about 7.81% and reduction in compressor power consumption is gained about 19.10%.

Ultimately the refrigeration effect and COP are improved about 9.85% and 26.88% respectively. Performance enhancement of humidified air cooled refrigeration cycle (a-b-c-d) is compared with conventional air cooled refrigeration cycle (1-2-3-4) in p-h diagram. The performance behavior of the VCRS is analysised by considering the various performance measures like power input to the compressor, condenser outlet temperature, heat rejection in the condenser, refrigeration effect and COP at different load conditions in the evaporator.

TABLE III
EXPERIMENTAL OBSERVATIONS OF REFRIGERATION SYSTEM

Observations	Unit	AAC mode	HAC mode	Percentage of improvement
Compressor inlet temperature (T_1)	°C	24	27	11.11
Compressor outlet temperature (T_2)	°C	64	59	7.81
Condenser outlet temperature (T_3)	°C	39	30	23.07
Evaporator inlet temperature (T_4)	°C	-3	-12	
Water temperature in evaporator (T_0)	°C	8	8	-
Atmospheric dry bulb temperature (T_a)	°C	31	31	-
Humidifier outlet temperature (T_b)	°C	-	24	-
Relative humidity	-	65%	80%	18.75
Compressor inlet pressure	bar	2.21	2.07	6.33
Compressor outlet pressure	bar	10.87	10.02	7.81
Power consumption in compressor	kJ/kg	44.5	36	19.10
Heat rejection in condenser	kJ/kg	345.5	369.8	6.57
Refrigeration effect	kJ/kg	300.9	333.8	9.85
COP	-	6.8	9.3	26.88

IV.1. *Effect of Compressor Power Consumption*

The effect of HAC over the condenser engenders the significant improvement in the performance of the VCRS as compared to AAC. Fig. 4 represents the variation of power consumption by the compressor at 25%, 50%, 75% and 100% loads in the evaporator unit at AAC and HAC modes. During AAC mode, highest and lowest power consumption by the compressor is captured at 25% and 75% loads respectively. The remaining loads are consuming moderately as compared to 25% and 75% loads respectively. Hence, 75% load in evaporator had consumed about 5.9%, 3.2% and 2.2% lower than 25%, 50% and 100% loads respectively. For each load of operation in the evaporator, the power consumption is significantly reduced in HAC as compared to AAC.

When the VCRS is in HAC mode, 75% load of operation having the lowest power consumption about 11.55%, 9.32% and 10.45% lower than 25%, 50% and 100% of loads respectively. Experimental results show that power requirement for the refrigeration system is decreased when the humidified air is used in condensation process instead of atmospheric air.

For achieving the minimum temperature in the evaporator, HAC consumed the power consumption about 19.10% lower than AAC.

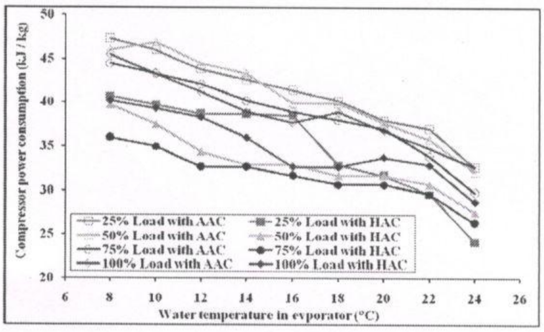

Fig. 4. Variation of compressor power consumption with water temperature in evaporator

IV.2. *Effect on Condenser Heat Rejection Rate*

Refrigerant cooling rate is very quick and heat rejection rate is enhanced in the condenser by HAC mode of operation as compared to AAC. The change in condenser discharge temperature is plotted in Fig. 5 and the drop in temperature is achieved about (7-15) °C with respect to water temperature in the evaporator.

During HAC over the condenser, the reduction in refrigerant temperature is achieved about 37.84%, 24.24%, 30.77% and 37.50% for 25%, 50%, 75% and 100% of loads respectively as compared to AAC.

Fig. 6 shows the variation in condenser heat rejection rate in AAC and HAC modes. Due to humidified air flow over the condenser, the heat rejection rate is improved and leads to increase the performance of refrigeration system. Better condensation rate is achieved in HAC mode. The improvement is about 8.9%, 4.56%, 18.63% and 9.76% higher than the AAC mode for 25%, 50%, 75% and 100% of loads respectively. Highest and lowest heat rejection rate is attained in 25% and 75% loads respectively during HAC mode.

IV.3. *Effect on Refrigeration Effect and COP*

Enhancement in refrigeration effect is obtained in HAC and variation in refrigeration effect is shown in Fig. 7.

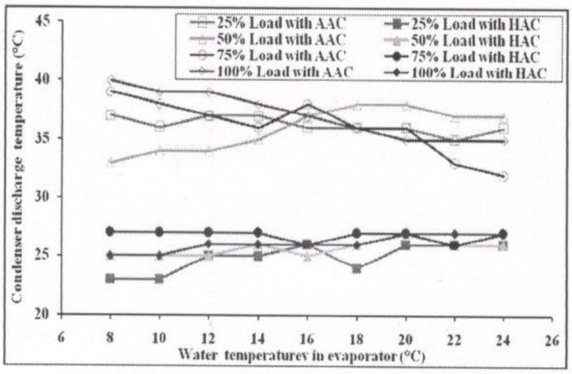

Fig. 5. Variation of condenser dischagre temeperature with water temperature in evaporator

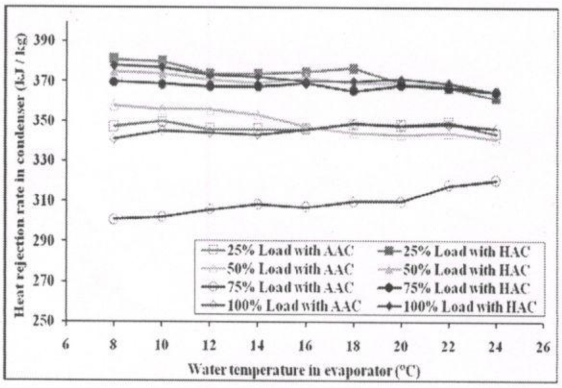

Fig. 6. Variation of heat rejection rate in condenser with water temperature in evaporator

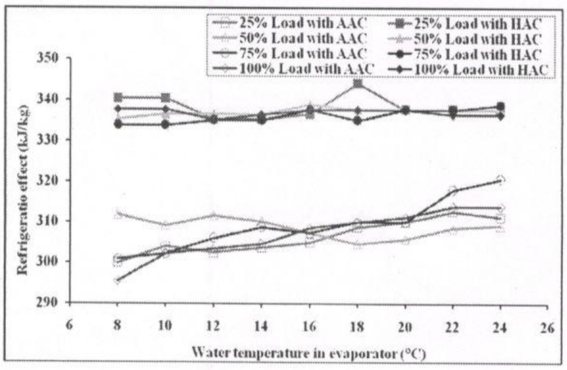

Fig. 7. Variation of Refrigeration effect with water temperature in evaporator

Highest and lowest refrigeration effect is produced in 50% and 100% loads respectively. Humidified air flow enhances the refrigeration effect and the range of improvement in refrigeration effect is reached about 6.98-12.50% for HAC mode.

In HAC mode, the highest refrigeration effect is attained in 100% of load in evaporator. Ultimately the enhancement in refrigeration effect and reduction in power consumption leads to increase in COP of the refrigeration system.

The COP variation is plotted in Fig. 8 and for 75% load of operation, COP is obtained about 9.6% higher than 25%, 50% and 75% loads respectively in HAC. In HAC mode, COP is augmented about 24.19%, 19.72%, 27.07% and 22.69% greater than AAC mode for 25%, 50%, 75% and 100% of loads respectively.

Experimental results show that better performance is accomplished at 75% of load of operation for AAC and HAC modes.

Comparing AAC and HAC, the percentage improvement in COP is represented in Fig. 9.

From the figure it is identified that COP is improved in HAC at 75% of load among various evaporator temperatures. Due to decrease in evaporator temperature, COP of the refrigeration system is also decreased and maximum of enhancement in COP is about 27.1% is achieved at 8°C of evaporator temperature.

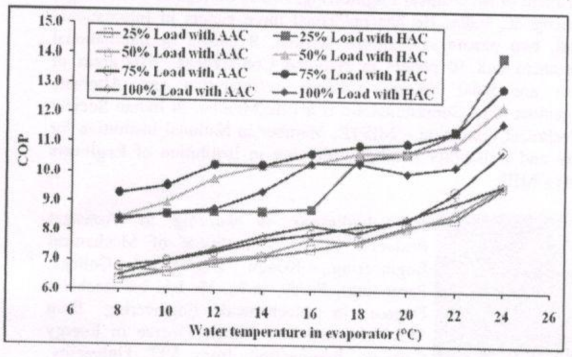

Fig. 8. Variations of COP with temperature in evaporator

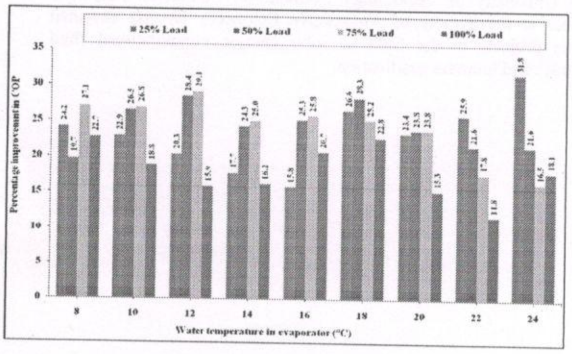

Fig. 9. Percentage improvement of COP

V. Conclusion

Experimental investigation was performed on VCRS with HCMs as refrigerant with and without centrifugal humidifier. The evaluated experimental results divulge the following productive outcomes during the HAC mode of operation in the refrigeration system:

- HCM of R290 and R600a may possibly used as an alternate refrigerant to R12 and R134a.
- Humidified air cooling is having better performance as compared to natural air cooling on the condenser in terms of low power consumption and higher COP.
- Among 25%, 50%, 75% and 100% loads in the evaporator, 75% load of operation having the lowest power consumption about 11.55%, 9.32% and 10.45% lower than 25%, 50% and 100% of loads respectively.
- In HAC, the power consumption by the compressor is dropped about 19.10% as compared to AAC mode.
- Heat rejection rate in the condenser and refrigeration effect are significantly enhanced about 6.57% and 9.85% respectively in HAC.
- Refrigeration cycle COP is improved about 26.88% in HAC as compared to AAC at 75% load in evaporator.
- Humidified air cooling refrigeration system is most suitable during hot climatic condition and lead to superior cooling performance & massive energy saving potentials.

The above results show that productive performance improvement is achieved in the refrigeration system in humidified air cooling over the condenser instead of atmospheric air cooling.

References

[1] Thangavel P, Somasundaram P. Part load performance of analysis of vapour compression refrigeration system with hydrocarbons refrigerants. *J Sci Ind Res 2013; 72: 454-60.*

[2] Hajidavalloo E, Eghtedari H. Performance improvement of air-cooled refrigeration system by using evaporatively cooled air condenser. *Int J Refrig 2010; 33:983-88.*

[3] Nasr MM, Salah Hassan M. Experimental and theoretical investigation of an innovative evaporative condenser for residential refrigerator. *Renewable Energy 2009; 34:2447–54.*

[4] Ebrahim Hajidavalloo. Application of evaporative cooling on the condenser of window-air-conditioner. *Appl Therm Eng 2007; 27:1937–43.*

[5] Camargo JR, Ebinuma CD. A mathematical model for direct evaporative cooling air conditioning system. *Engenharia Termica 2003; 4:30-34.*

[6] Maheshwari GP, Al-Ragom F, Suri RK. Energy-saving potential of an indirect evaporative cooler. *Appl Energy 2001; 69:69-76.*

[7] Mertin Ertunc H, Murat Hosoz. Comparative analysis of an evaporative condenser using artificial neural network and adaptive neuro-fuzzy inference system. *Int J Refrig 2008; 31:1426-36.*

[8] Senthilkumar K, Srinivasan PSS. Experimental study of centrifugal humidifier fitted in an industrial shed located in tropical climates. *J Therm Sci 2011; 15:467-75.*

[9] Krishan Kant, Ashvini Kumarl SC. Mullick. Space conditioning using evaporative cooling for summers in Delhi. *Build. Environ. 2001; 36:15-25.*

[10] Eric Granryd. Hydrocarbons as refrigerants – an overview. *Int J Refrig 2001; 24:15-24.*

[11] Mohanraj M, Jayaraj S, Muraleedharan C. Comparative assessment of environmental-friendly alternatives to R134a in domestic refrigerators. *Int J Energy Effic 2008;1: 189-98.*

[12] Ching-Song Jwo, Chen-Ching Tig, Wei-Ru Wang. Efficiency analysis of home refrigerators by replacing hydrocarbon refrigerants. *Int J Measurements 2009; 42:697–01.*

[13] Yunho Hwang. Reinhard Radermacher, William Kopko. An experimental evaluation of a residential-sized evaporatively

cooled condenser. *Int J Refrig 2001; 24:238-49.*

[14] Mohanraj M, Jayaraj S, Muraleedharan C, Chandrasekar P. Experimental investigation of R290/R600a mixture as an alternative to R134a in a domestic refrigerator. *Int J Therm Sci 2009; 48:1036–42.*

[15] Fatouh M, El Kafafy M. Experimental evaluation of a domestic refrigerator working with LPG. *Appl Therm Eng 2006; 26:1593–03.*

[16] Hammad MA, Alsaad MA. The use of hydrocarbon mixtures as refrigerants in domestic refrigerators. *Appl Thermal Eng 1999; 19:1181–89.*

[17] Jia Yang, Chan KT, Xiangsheng Wu, Xiaofeng Yang, Honagyu Zhang. Performance enhancement of air-cooled chillers with water mist: Experimental and analytical investigation. *Appl Thermal Eng 2012; 20:114–20.*

[18] Boulet P, Tissot T, Trinquet F, Fournaison. Enhancement of heat exchanges on a condenser using an air flow containing water droplets. *Appl Thermal Eng 2013; 50:1164–73.*

[19] Arrora C P, *Refrigeration and Air conditioning* (Tata McGrew-Hill Publishing Company Ltd.) 2004.

[20] Thangavel, P., Somasundaram, P., Navaneethakrishnan, P., Simulation analysis on thermo physical properties of hydrocarbon refrigerants in vapour compression refrigeration system, (2013) *International Review of Mechanical Engineering (IREME)*, 7 (4), pp. 646-651.

[21] Sivakumar, M., Somasundaram, P., Thangavel, P., Exergy and performance analysis of three stage auto Refrigerating Cascade (3 stage ARC) system using Zeotropic mixture of eco-friendly refrigerants, (2014) *International Review of Mechanical Engineering (IREME)*, 8 (1), pp. 124-134.

[22] Patil, S.S., Auti, A.B., Singh, T.P., CFD and experimental analysis of a condenser for domestic desalination system, *(2013) International Review of Mechanical Engineering (IREME)*, 7 (6), pp. 1159-1163.

[23] Chandraprabu, V., Sankaranarayanan, G., Iniyan, S., Suresh, S., Siva, V., Heat transfer enhancement performance of Al2O3/water nanofluid in condensing unit of air conditioner: Experimental study, *(2013) International Review of Mechanical Engineering (IREME)*, 7 (4), pp. 686-691.

[24] Senanayake, N.S., Efficiency improvement of domestic refrigerators by condenser modification, (2012) *International Review of Mechanical Engineering (IREME)*, 6 (6), pp. 1356-1360.

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