Scientific Journal Impact Factor (SJIF) : 1.711
International Journal of Modern Trends in Engineering and Research
ISSN (ONLINE) : 2349 - 9745
ISSN (PRINT) : 2393 - 8161

Exergy Analysis of Window Air Conditioning (VCR) System with Refrigerant R22 and R407C

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Abstract—The real useful energy loss can't be justified the first law of thermodynamics, because it does not differentiate between the quality and quantity of energy. Energy analysis presents only quantitative results while exergy analysis presents qualitative results about actual energy consumption. The exergy of a system is the maximum useful work possible during a process that brings the system into equilibrium with a heat reservoir. Exergy analysis is performed in the field of industrial ecology to use energy more efficiently. In the said experiment a detailed analysis of VARS (vapour compression refrigeration system) is done. Exergy analysis of window air conditioner using different refrigerant such as R22, R407C is calculated. Exergy analysis is carry out using 85% mechanical, electrical and compressor efficiency. Using this experimental set up it would be able to evaluate on different operating condition. The coefficient of performance, exergy destruction and exergentic efficiency for variable refrigerant will be calculated. Refpor will be used to calculate the properties of refrigerant at each state which will enable to find different parameters and understand the performance of window air conditioner

Keywords— Energy, Exergy, Exergy Analysis, vapour compression system, window air conditioning system.

I. INTRODUCTION

Refrigeration plays a very important role in industrial, domestic and commercial sectors for cooling, heating and food preserving applications. There are innumerable applications of such systems and they are the major consumer of electricity around the world. Energy consumption is directly proportional to the economic development of any nation, however this area is in great interest now because of increase in the cost of conventional fuels and environmental concerns globally. The scientists are looking for new and renewable sources of energy so as to minimize the costs. Due to the increasing energy demand, degradation of environment, global warming and depletion of ozone layer etc. There is urgent need of efficient energy utilization and waste heat recovery for useful applications. The researchers are concentrating on the alternate and environment friendly refrigerants, especially after the Kyoto and the Montreal protocols. However, in a quest to find out alternate and environment friendly refrigerants, the energy efficiency of the equipment having conventional refrigerants is also very important in the present age of competitive business community. The aim of the scientific community all over the world is to switch to new and renewable energy sources besides, efficient utilization of all conventional sources. In this study, the main objective is to investigate the performance of a simple VCR system based on exergy analysis. The experimental analysis has been done on a 1.866TR window air conditioning system using R22 and R407C as refrigerant. With the objective to find out the losses at different operating conditions for vapour compression cycle, exergy analysis has been done by several of refrigerant charge. The system has been modified for experimental study to find the possible design conditions with the minimum exergy destruction. In the present study, the effects of temperature changes in the condenser and evaporator on the plant's irreversibility rate was determined. The analysis is performed by doing energy and exergy balances for the system. The properties of refrigerant at each state point are calculated using Refrop software and Excel sheet the results are discussed.

II. ANALYSIS OF GOVERNING EQUATION OF WIDOW AIR CONDITIONING SYSTEM

Mass flow rate (m_r): Mass flow rate may be calculated from reading as shown in below.

Mass flow rate (m_r) = $\frac{refrigrtation\ capacity}{refrigeration\ ffect} = \frac{Total\ cooling\ load}{h_1 - h_4}$ kg/s

Refrigeration effect: It is the amount of heat absorbed by the refrigeration in its travel through the evaporator. This effect is represented by the expression

Refrigeration effect $Q_e = m_r(h_1 - h_4)$ kW

Actual coefficient of performance (COP): It is defined as the ratio of heat absorbed by the refrigerator while passing through the evaporator to the work input required
Compressing the refrigerant in the compressor; in short it is the ratio between heats
Extracted & work of compressor.

Actual coefficient of performance = $\frac{refrigrtation\ effect}{compressor\ work}$

COP= $\frac{q_e}{w_c}$

Compressor Power Consumption (W):

W=$m_r(h_2 - h_1)$ kW

Heat Rejected through Condenser (Q_c): Heat removed through condenser includes all heat removed through the condenser, either as latent heat, heat of superheat, or heat of liquid.

Heat rejected by condenser Q_c = $m_r(h_2 - h_3)$ kW

Energy Analysis

The energy analysis based on first law of thermodynamic, the performance of vapour
Compression refrigeration system can be predicted in terms of coefficient of performance (COP), which is defined as the ratio of net refrigerating effect produced by the refrigerator to the work done by the compressor. It is expressed as

COP= $\frac{q_e}{w}$

COP= $\frac{h_1 - h_4}{h_2 - h_1}$

Exergy Analysis

The modern approach based on second law of thermodynamic i.e. exergy analysis can be used to measures the performance of the vapour compression refrigeration system. This analysis derives the concept of exergy, which is always decreasing due to thermodynamic irreversibilities. Exergy is the maximum useful work that could be obtained from the system at a given state in a specified environment. Exergy balance for a control volume undergoing steady state process is expressed as

$$Ed_i = \Sum(me_x)_{in} - \Sum(me_x)_{out} + \left[\Sum(Q(1-\frac{T_0}{T})_{in}\right] - \left[\Sum(Q(1-\frac{T_0}{T})_{out}\right] \pm \Sum W$$

- Exergy Destruction in the system components

1) Exergy Destruction in evaporator

$$E_{de} = E_{X4} + Q_e\left(1-\frac{T_0}{T_r}\right) - E_{X1}$$

$$= m_r(h_4 - T_0S_4) + Q_e\left(1-\frac{T_0}{T_r}\right) - m_r(h_1 - T_0S_1)$$

2) Exergy Destruction in Compressor

$$E_{decomp} = E_{X1} + W - E_{X2}$$

$$= m_r(h_1 - T_0S_1) + \frac{w}{\eta_m \eta_{el}\, \eta_{ex}} - m_r(h_2 - T_0S_2)$$

3) Exergy Destruction in Condenser

$$E_{dc} = E_{X2} - E_{X3}$$

$$= m_r(h_2 - T_0S_2) - m_r(h_3 - T_0S_3)$$

4) Exergy Destruction in Throttle valve

$$E_{dc} = E_{X3} - E_{X4}$$

$$= m_r(h_3 - T_0S_3) - m_r(h_4 - T_0S_4)$$

- Total Exergy Destruction

Total exergy destruction in the system is the sum of the exergy destruction in different components of the system and is given by

- $\sum Ed_i = E_{de} + E_{dcomp} + E_{dc} + E_{dt}$
- EP = $Q_e\left(1 - \frac{T_0}{T_r}\right)$
- EF=EP+$\sum Ed_i$
- Exergetic Efficiency

$$\eta_{ex} = 1 - \frac{\sum Ed_i + \sum EL_i}{EF}$$

- Exergy Destruction Ratio (EDR)

Exergy destruction ratio is the ratio of the total exergy destruction in the system to the Exergy in the product and it is given by

Also, in terms of second law efficiency

$$EDR = \frac{1}{\eta_{ex}} - 1$$

Observation Data for 1.866 TR window air conditioner with R22

Sr No	Time (min)	P Suc kPa	P disc kPa	Temperature (°C)					
				$(Cond)_{In}$	$(Cond)_{out}$	$(Evap)_{in}$	$(Evap)_{out}$	T_0	T_r
1	10	396	1896	76.5	39.5	17.6	12.3	25	12.3
2	20	396	1896	76.6	40.	17.7	12.2	25	11
3	30	396	1896	76.6	40.4	17.6	12.2	25	10.3
4	40	396	1896	76.7	40.4	17.7	12.1	25	10.0
5	50	396	1896	76.7	40.6	17.7	12.1	25	10.0

Sr No	Time (min)	P Suc kPa	P disc kPa	Temperature (°C)					
				$(Cond)_{In}$	$(Cond)_{out}$	$(Evap)_{in}$	$(Evap)_{out}$	T_0	T_r
1	10	551	2189	68	28.5	17.6	10.5	25	10.0
2	20	551	2189	67.9	28.4	14.8	10.4	25	6.0
3	30	551	2189	67.8	28.3	14.1	10.4	25	5.5
4	40	551	2189	67.7	28.2	14.0	10.4	25	5.5
5	50	551	2189	67.7	28.3	14.1	10.3	25	5.5

III. Discussion and Comparison result of R407C and R22

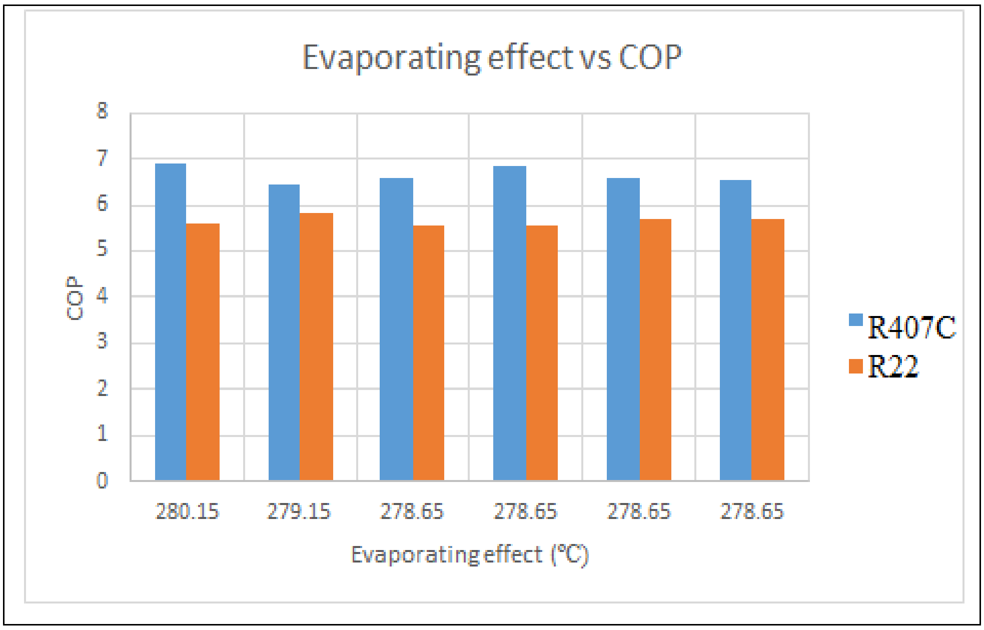

Fig 1 evaporating effect vs COP

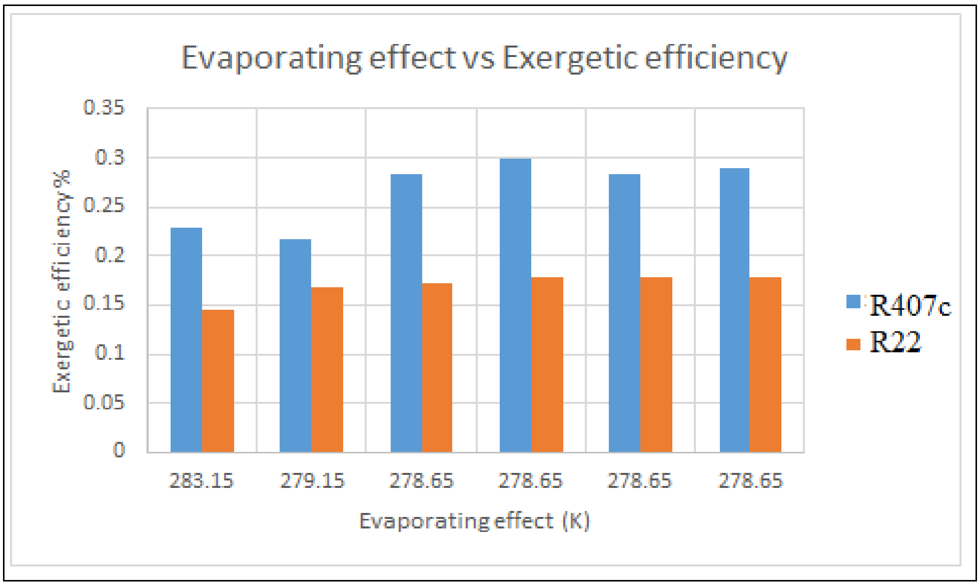

Fig 2 evaporating effect vs exergetic efficiency

Fig 1 shows the variation of evaporating effect with COP for window air conditioning with R22 and R407C. With increase evaporating effect COP is also increasing for both refrigerant. For R22 and R407C.becasuse they required lower work done at lower temperature. Thus the with increasing COP increasing evaporating effectFor R407C maximum value is 6.8732 and 5.8069 for R22 thus for this window air conditioning most use full for R407C increasing evaporating effect.

Fig 2 shows the variation of evaporating temperature with total exergy destruction for window air conditioning with R22 and R407C. With increase evaporating effect total exergy Destruction rate is also decrees for both refrigerant. For R22 and R407C. The value of exergetic efficiency R407C 29.87 % and R22 are 17.84 % thus for this system refrigerant R407C are most usefully.

IV. CONCLUSION

Second law or exergy analysis has been performed in this thesis is able to understand the performance of window air conditioning system and justify possible efficiency improvements. It gives logical solution for improving the system performance in window air conditioning system from the exergy analysis of window air conditioning system following conclusion can be given

Using R407 C different values obtained are as follow total exergy destruction are 1.51kW, exergy destruction of compressor is 0.3719 kW , exergy destruction of condenser is 0.3339 kW exergy destruction of expansion valve is 0.2127 kW, exergy destruction of evaporator is 0.2340 kW, when the maximum exergetic efficiency is reached. Exergetic fuel supplied 1.16 kW, compressor work 1.16 kW. COP (coefficient of performance) 6.87, exergy destruction ratio (EDR) is 2.51, exergetic efficiency 29.87 %, evaporating effect 5 to 9 ºC

Using R22 different values obtained are as follow total exergy destruction are 1.5980 kW, exergy destruction of compressor is 0.2138 kW , exergy destruction of condenser is 0.6659 kW, exergy destruction of expansion valve is 0.2359 kW, exergy destruction of evaporator is 0.4829 kW, when the maximum exergetic efficiency is reached, Exergetic fuel supplied 1.91 kW, compressor work 1.915 kW. COP (coefficient of performance) 5.88, exergy destruction ratio (EDR) is 5.60, exergetic efficiency 17.84 %, evaporating effect 10 to 12.3 ºC.

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