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EXERGY ANALYSIS OF VAPOUR COMPRESSION REFRIGERATION CYCLE- A REVIEW

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ABSTRACT

In our daily life refrigeration has very important role mainly in industrial, domestic and commercial sector. This paper deals with study of vapour compression cycle based on exergy analysis so we know that, the amount of irreversibility in each component of vapour compression cycle and we also know the location where we get the maximum irreversibility in the vapour compression cycle. The primary objective is to study the various component separately and for this study we use the second law approach because the analysis based on first law of thermodynamics is very common and it deals with conservation of energy hence it not tells, where in the system irreversibility occur. For our study purpose we use the different refrigerant and we can also compare the different refrigerant so we know that, which refrigerant will perform better on the basis of exergy analysis.

Key Words: ***Exergy, Exergy efficiency, Exergy destruction, EES (Engineering Equation Solver).***

Nomenclature

h – Specific enthalpy (KJ/kg)
s – Specific entropy (KJ/kg k)
m – Mass flow rate (kg/s)
T_0 – dead state temperature (K)
Qe – heat addition in evaporator
Te – Evaporator temperature

I. INTRODUCTION

Refrigeration bears an enormous value due to thermal comfort which is very essential in residential area as well as in industrial sector. This system requires energy for its functioning and our challenge is to use this system with less energy requirement. The information will be required to know where the more energy is lost or to know where more irreversibility is occurring. For this a thermodynamic analysis is required.

The analysis based on second law is better way as it deals with evaluation of irreversibility in various thermodynamic process. It evaluates the magnitude of irreversibility associated in process qualitatively and point out the direction where we have to focus more in order to improve the performance of thermodynamic system.

Thermodynamic process which should be occur in vapour compression cycle, releases an enormous amount of heat to the environment and also the heat transfer which is going to be in the cycle, means in between the evaporator and refrigerated space and also in between the condenser and the surrounding will take place through a finite temperature difference and it should be a major cause which should be a responsible for irreversibility in the cycle (1).

Modern approach which is going to use for the study of vapour compression cycle is on the basis of exergy analysis, as it give information in a better way so we get better understanding of what should be occur in the process. The exergy analysis is a modern method uses the thermodynamic approach and comes as a useful and advance tool engineering process evaluation (2).

The conventional energy analysis which should be use various sector will not provide about the amount and the location where the energy is wasted in the cycle as it deals only with conservation of energy. On the other hand exergy calculation exergy calculation and exergy balance will provide better insight of the process and also we get the idea about the component in which the improvement should be required in the system(3) .Dincer (4) will provide the relationship in between the energy, exergy, environment and also about the energy making policy.

Schematic diagram of vapour compression cycle is shown below

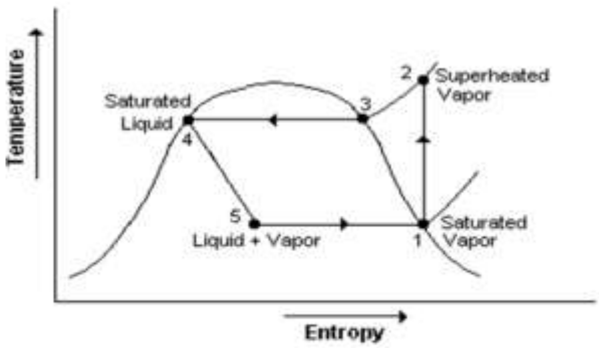

Fig 1 T-S Plot of Vapour compression cycle

The following T-S plot consists of four process:

•**Isentropic compression process**: The refrigerated vapour which is at low pressure is isentropically compressed to high pressure so the saturated refrigerant will convert into superheated vapour.

•**Constant pressure heat rejection process**: The superheated vapour enters the condenser so the high temperature refrigerant will reject the heat to the surrounding or the coolant in the condenser.

•**Isenthalpic expansion process**: The high temperature high pressure refrigerant vapour enters the expansion valve where the refrigerant will losses the pressure and convert into two phase mixture.

•**Constant pressure heat addition process:** Here the low pressure low temperature refrigerant will absorb the heat from refrigerated space so the two phase mixture will convert into saturated vapour.

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Schematic diagram of various component of vapour compression refrigeration system

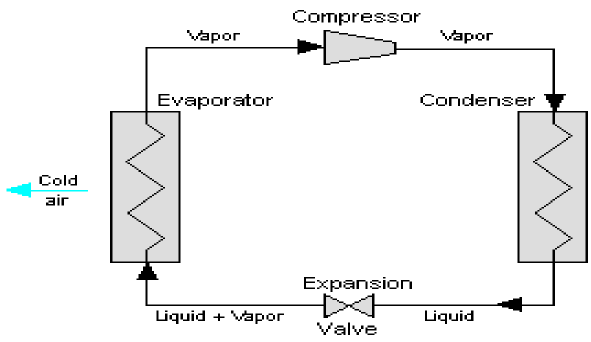

Fig 2 Component of vapour compression refrigeration system

The above figure has following main component:
ø**Compressor:** The power to run the compressor is provided from the outside source and the refrigerant vapour which enters in the compressor is at low pressure and low temperature, so that after isentropic compression process it will convert into high pressure and high temperature refrigerant.
ø**Condenser:** The superheated refrigerant enters at high temperature and it will rejects heat to the surrounding or to the coolant.
ø**Expansion valve**: The high temperature saturated liquid will enter the expansion valve and will goes under isenthalpic process and convert into two phase mixture.
ø**Evaporator**: The low pressure low temperature refrigerant will enters the evaporator and extracts the heat from refrigerated space so the two phase mixture will convert into the saturated vapour.
The main objective of this study is to judge the parameter related to exergy so we know in more detail about the location of irreversibility in various component by reviewing the various studies conducted on vapour compression cycle by various researchers.
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II. LITERATURE REVIEW

Recep Yumrutas et.al. (5) Works in the study of vapour compression refrigeration system by using a computational model and perform study on the basis of exergy analysis. From this paper we get the information that due to only phase change in evaporator and due to less temperature difference, exergy loss will be minimum and the most of the loss occur in the compressor.

J U Ahamed et.al. (1) Study in the field of exergy analysis and uses the refrigerant refrigerant R407a, R600a, R410a, and R134a and he also concluded that the major part of exergy loss would occur in compressor and also give the information that R600a, R410a will give better performance as compare to other refrigerant.

Gaurav et.al. works on the performance analysis of domestic refrigerator and uses the software EES (Engineering Equation Solver) to compare the different refrigerant and in his study he focus on the refrigerant R290,R600, R600a, R152a, and R134a and concluded that R152a have better exergy efficiency and most of the exergy loss occur in compressor.

Aprea et.al.(6) use the refrigerant R22 and R407 and on his study he get the result the maximum irreversibility is occur in compressor part and R407 would not be a proper substitute of R22 on the basis of exergy efficiency.

Ozgur et.al.(7) perform a theoretical study by using the refrigerant R290, R600, R600a, R1270, R22 and R134a and also use software EES (Engineering Equation Solver) for analysis and concluded that the R1270 will give better performance on the basis of exergy loss and exergy efficiency.

III. THEORETICAL FORMULATION

For analyzing the vapour compression system on the basis of exergy analysis we need some mathematical relation. Through mathematical relation we find out the exergy loss in various component and also compare the different refrigerant on the basis of different exergy parameter. For theoretical formulation we need some assumptions which are as follow:

1. Steady state condition
2. Neglect the exergy associate with the heat transfer in the condenser
3. Neglect the kinetic energy losses
4. Neglect the potential energy losses
5. Pressure losses in condenser and evaporator is neglected
6. Isentropic efficiency will be 100%.

Mathematical equation for different component of vapour compression refrigeration system on the basis of exergy analysis (30)

Specific exergy for any particular state is given as

= (h-ho) – To*(s-so)

Evaporator:

Heat addition = Qe = m*(h1 – h5)

Exergy destruction,

I_1 = m*((h5 – h1) – To*(s5 – s1)) + Qe*(1 - To/Te)

Compressor:

Electrical Power,

Wel = (Compressor Power)/ (mechanical efficiency)

Compressor power = m*(h2 – h1)

Exergy destruction,

I_2 = m*((h1 – h2) – To*(s1 – s2)) + Wel

Condenser:

Exergy destruction,

I_3 = m*((h2 – h4) – To*(s2 – s4))

Expansion valve:

Exergy destruction,

I_4 = m*(s5 – s4)

As h5 = h4

Total Exergy destruction = Sum of exergy destruction of all components

I $_{total}$, It = $I_1 + I_2 + I_3 + I_4$

Coefficient of performance = (Heat addition in evaporator)/ (Electrical work)

Exergy efficiency = (Qe*(1 - To/Te))/Wel

In this system the value of coefficient of performance, exergy efficiency, exergy destruction value will decreases as we change the refrigerant or by changing the parameter like evaporating temperature, condensing temperature etc. From this analysis we find out the location where more irreversibility occur so we work on that area to improve the performance of the system by reducing the losses.

Many of the researchers have done a lot of study in the field of vapour compression cycle on the basis of exergy analysis by the use of different refrigerant and almost all have concluded the, among various component of vapour compression refrigeration cycle, compressor have higher amount of irreversibility as compare to other component of the cycle.

IV. SUMMARY

Most of the researcher have done a lot of study on vapour compression cycle on the basis of exergy analysis but many research is still needed for more improvement in the system. Following points are to be noticed in various research paper:

- Most of the researcher noticed that the compressor have maximum amount of irreversibility
- Choosing the higher evaporator pressure will reduce the temperature difference between two pressure limit so system will perform in a better way
- Subcooling and superheating will reduce the losses in the system
- R1270, R600a and R32 will show better performance
- By changing the evaporator temperature, exergy loss will be varied.
- On increasing the evaporator pressure exergy loss will be decreases.

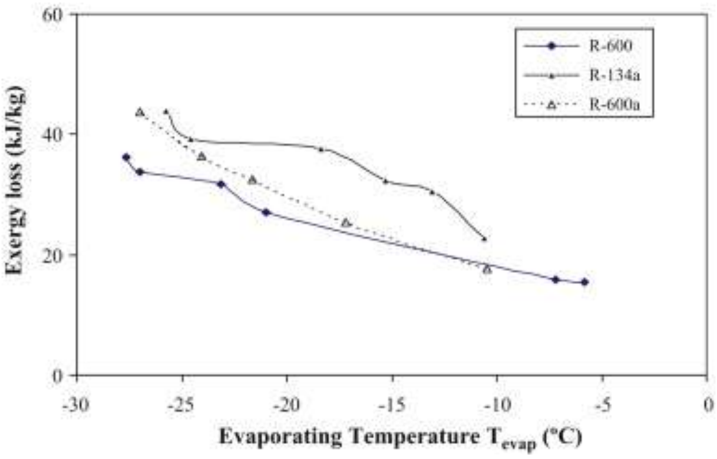

Fig 3 variation of exergy loss of different refrigerant at different evaporating temperature (1)

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