Analysis of Energy Efficiency Ratio of Domestic Refrigerator By Using Alternate Refrigerant 'R134a'

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Abstract- *In our daily life refrigeration has very important role mainly in industrial, domestic and commercial sector. This work deals with study of vapour compression cycle based on energy 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 energy analysis.*

It has been ascertained that refrigerators are the devices that work virtually twelve months around the clock,therefore our scope of energy potency improvement initiates with the coining of latest term "energy analysis" of the refrigerator. The new term introduced for refrigerator can be alone supported the properties of refrigerants utilized in this paper.

This paper is planned with an effort to pick the proper refrigerant for domestic refrigerator with given refrigeration capacity to improve the performance of a domestic refrigerator. For this purpose energy analysis is finished with different refrigerants R12,R134a,R290,R600,R600a for computing COP,EDR ratio,energy efficiency and efficiency defect by EES (ENGINEERING EQUATION SOLVER).

Keywords- Energy, Energy efficiency, Energy destruction, EES (Engineering Equation Solver).

Nomenclature

T_o – Ambient temperature (K)
T_1 – Evaporator temperature(K)
T_2 – Compressor outlet temperature(K)
T_3 – Condenser temperature(K)
p_1 – Evaporator pressure(KPa)
p_2 – Condenser pressure(KPa)
h – Specific enthalpy (KJ/kg) s
– Specific entropy (KJ/kg k) m
– Mass flow rate (kg/s)
Q_e – Refrigeration capacity(KW)
W_c – Theoretical compressor work(KW) W_a – Actual compressor

Cop – Coefficient of performance
T_r – Refrigerated space temperature(K)
I_1 – Irreversibility in compressor(KW)
I_2 – Irreversibility in condenser(KW)
I_3 – Irreversibility in expansion valve(KW)
I_4 – Irreversibility in evaporator(KW)
I_t – Total Irreversibility in vapor compression refrigeration cycle(KW)
Eo – Product exergy rate(KW)
Ei – Fuel exergy rate(KW)
Eff – Exergy efficiency
EDR – Exergy destruction ratio
ED – Efficiency defect

I. INTRODUCTION

Refrigeration bears an enormous value due to cooling which is very essential in food preservation as well as in industrial sector. This system require energy for its functioning and our challenge is to use this system with less energy requirement so we reduce the power consumption. The quantitative information will be required to know where the more energy is lost or to know where is more irreversibility occur. For this a thermodynamic analysis is required.

The analysis based on first law of thermodynamics is very common but it deals with conservation of energy hence it not tells where in the system irreversibility occur.

The analysis based on second law is better way as it deal with evaluation of irreversibility in various thermodynamic process. It evaluate 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.

The energy analysis represents a good convenient standard to evaluate the maximum work obtainable from a given form of energy by bringing the system to the state of the surrounding environment and it plays a very important role in understanding the overall performance of whole system and its components [11]. This analysis also help in taking various decision regarding design parameter [12]. Many researcher have applied energy studies in various thermodynamic process so as to describe the energy analysis in simple and effective manner. Padilla et al [13] carried out the analysis and direct impact of replacement of R12 with zeotropic mixture R413A. By his analysis he concluded that the overall energy and energy performance of the system working with R413A is better than R12. Kumar et al [14] derive a method to deal with energy analysis of vapour compression refrigeration system working with R11 and R12 as refrigerants.

In this study the main objective is to identify the amount and location of irreversibility within the cycle by energy analysis by using different refrigerants.

Schematic diagram of vapour compression cycle is shown below

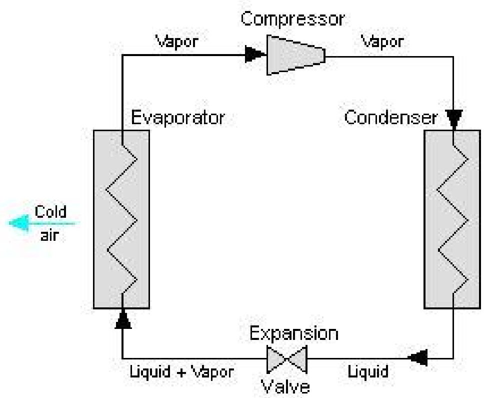

Fig 1 Component of vapour compression refrigeration system

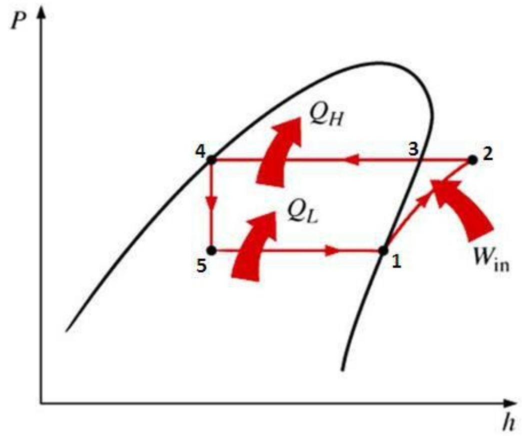

Fig 2 P-h Plot of Vapour compression cycle

The following p-h plot consist 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.

Schematic diagram of various component of vapour compression refrigeration system

The above figure has following main component:

- **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.

- **Condenser:** The superheated refrigerant enters at high temperature and it will rejects heat to the surrounding or to the coolant.

- **Expansion valve**: The high temperature saturated liquid will enter the expansion valve and will goes under isenthalpic process and convert into two phase mixture.

- **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 energy 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.

DOMESTIC REFRIGERATOR

A refrigerator is a famous household appliance that consists of a thermally insulated compartment and a heat pump which may be mechanical, electronic or chemical that transfers heat from the inside of the fridge to its external surrounding so that the inside space of the fridge can be cooled to a temperature below the ambient temperature of the room.Refrigeration is an essential food storage technology in developed countries. The lower temperature lowers the reproduction rate of bacteria, so that the refrigerator can reduce the rate of spoilage. A refrigerator maintains a temperature a few degrees above the freezing point of water. Promising temperature range for perishable food storage is 3 to 5 °C (37 to 41 °F).A similar device that can maintain a temperature below the freezing point of water is called a freezer. The refrigerator replaced the icebox, which had been a famous household appliance for almost a century and a half. For this reason, a refrigerator is usually referred to as an icebox in American usage.

Energy

It is the maximum work which is obtainable by bringing a system into equilibrium with environment. System which is in equilibrium with environment having zero energy because it has no ability to do work with respect to environment.

Energy analysis is a technique based on second law of thermodynamics. The fundamental of the energy technique are developed by carnot in 1824 and clausius in 1865. The energy technique has gained more importance in various thermal process and plant system because the first law analysis is not sufficient to find out the amount and location of losses in the system. In such circumstances the energy analysis is well suited to locate the system imperfection.

Why Energy Analysis

Conventional thermodynamics analysis is based primarily on first law of thermodynamics which state the principle of conservation of energy.

An energy analysis of an energy-conversion system is basically an accounting of the energies coming into it and exiting it. Efficiency are often evaluated as ratio of energy quantities, and are often used to assess and compare various system. For example Power Plant, thermal storage, heaters and refrigerators are often compared based on energy efficiency.

Energy analysis allows several of the shortcomings of energy analysis to be overcome. Energy method which is based on the second law of thermodynamics and is useful in identifying the cause, location and magnitude of process irreversibility. The energy related to an energy amount would be a quantitative assessment of its usefulness or quality. Energy analysis acknowledges that the, though energy cannot be created nor be destroyed, it is degraded in quality, eventually reaching a state during which it's in complete equilibrium with the environment and hence of no more use for performing tasks.

II. LITERATURE REVIEW

Miguel Padilla et.al. has performed the energy analysis of the impact of direct replacement R12 with the R143A on the performance of a domestic VCR system which was originally designed to work with R12. In a contorted condition at the condenser and evaporator.

Prateek D. Malwe et.al. works in the study of vapour compression system on the basis of energy analysis and concluded by his study that the major part of energy loss is coming from the irrerversibilites which is being generated in the system due to entropy generation and this has to be minimized in order to increase the performance of a particular system and also concluded that in among various component of vapour compression system, the compressor have lowest value of exergetic efficiency.

Min-Hsiung Yang et.al. works in the study of vapour compression refrigeration system by changing the evaporating and condensing temperature with superheating in evaporator to evaluate the performance of a system based on energy analysis using the refrigerant R22, R134a, R410a and

R417.They work on a numerical model to evaluate the performance enhancement and analyse the energy destruction and finally conclude that the optimal degree of sub-cooling will be necessary.

ReepYumrutas et.al . has developed computational model based on the energy analysis for the investigation of the effects of the evaporating temperature and condensing temperatures on the pressure losses, the energy losses, the exergetic efficiency. He has also calculated the cop of vcr cycle

Gaurav et.al. has performed a comparison of energy and energy analysis for R134a,R152a,R290,R600 and R600a in refrigerator by computing cop,edr,energy efficiency and efficiency defect.He found that the efficiency defect is maximum in condenser and lowest in evaporator.

Mahmood Mastani Joybari et.al. perform experiment on domestic refrigerator based on energy analysis and concluded that the compressor has higher energy destruction among the other components.

E. Bilgen et.al. has performed an energy analysis of heat pump-air conditioner system has been carried out by taking irreversibility due to heat transfer and friction. The coefficient of performance based on the first law of thermodynamics as a function of several parameters, their improved values, and the efficiency and coefficient of performance based on energy analysis have been calculated.Based on the energy analysis, a simulation program has been developed to simulate and evaluate experimental systems.

Md. Nawaz khan et.al. works in the study of vapour compression system based on energy and energy analysis by using refrigerant R12, R134a and R22. They mainly focus on changes which occurs on energy efficiency, cop, energy destruction ratio due to working of a particular system on various evaporative temperature and all the equation which should be required for evaluation are developed for each component of vapour compression system.

Neera Jain et.al. works in the study of vapour compression system and there is study is based on energy analysis so as to achieve better efficiency. They designed a model predictor controller so that through energy analysis they minimize the energy destruction and maximize the exergetic efficiency.

Hakan Caliskan et.al. deals with the two system which is able to be use for cooling purpose in building and mainly concentrate on dead state temperature so by varying the dead state temperature he compare the two system on basis of energy analysis.

Pooja Yadav et.al. perform the study of energy analysis of actual vapour compression refrigeration cycle using the refrigerant R134a and perform study on energy destruction which is unused work potential which occur during a process due to the irreversibilities occur during a process.

Mohan Chandrasekharan works in the study of vapour compression refrigeration system by using the method energy analysis and perform his analysis by using the refrigerant R12 and R134a. For obtaining the result he use the computational model so that he compare the two

Amir Fartaj et.al. uses the second law analysis approach so as to determine the irreversibility of individual component and its influence on the performance of CO2 refrigeration cycle and also to know the effectiveness of the various component of the system and the analysis reveals that the compressor will need more improvement so as to enhance the system performance.refrigerant based on energy analysis by evaluating the parameter like energy efficiency, coefficient of performance and study the effect which should be occur in this parameter by changing the operating condition like evaporating temperature and also by degree of sub-cooling.

Amir Fartaj et.al. uses the second law analysis approach so as to determine the irreversibility of individual component and its influence on the performance of CO2 refrigeration cycle and also to know the effectiveness of the various component of the system and the analysis reveals that the compressor will need more improvement so as to enhance the system performance.

III. METHODOLOGY

Energy analysis is a technique that is based on the second law of thermodynamics and it also uses the conservation of mass and energy principles for the analysis, design and improvement of the system. Many engineers and scientist advised that the thermodynamic performance of a system is best evaluated by doing an energy analysis additionally to or in situ of place of standard energy analysis because energy analysis appears to provide more insights and to be more useful in furthering efficiency improvements efforts than energy analysis.

3.1. Refrigerant used for analysis

The following refrigerants are used for energy analysis of domestic refrigerator.

REFRIGERANTS	CHEMICAL FORMULA	NORMAL BOILING POINT(oC)	CRITICAL TEMPERATURE (oC)	GWP (PER 100 YEAR)
R12	CCl2F2	-26.07	111.97	2400
R134a(HFC)	CF3CH2F	-26.07	101.06	1300
R290(HC)	C3H8	-42.1	96.8	20
R600	C4H10	-0.56	153	20
R600a	(CH3)3CH	-11.67	135	20

- Neglect the energy associate with the heat transfer in the condenser
- Neglect the kinetic energy losses
- Neglect the potential energy losses
- Pressure losses in condenser and evaporator is neglected
- Isentropic efficiency will be 100%

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.

IV. CONCLUSION

The following conclusion can be drawn from analysis

- R134 shows highest value of coefficient of performance among R12,R600a,R290,R600a,R600.After R600,R12 shows good result with respect to coefficient of performance.After R12,R600a with a slight advantage over R134a show satisfactory cop value.Also COP value is increasing as the evaporator temperature is increasing.
- As the evaporator temperature increases, the energy destruction ratio increase which is not good for a refrigeration system, so the refrigerant should have less value of energy destruction ratio, so as per this criteria the refrigerant R134 shows better result and after that R12 is showing better performance followed by R600a,,R290.
- As evaporator temperature increases the energy efficiency decreases because the product energy rate decreases as the evaporator temperature increases. So as per energy efficiency criteria refrigerant R134a
- shows best result among R12,,R290,R600a,R600 and it gives high value of energy efficiency at low value of evaporator temperature. After R600, R12,R600a,R134a show good result as per energy efficiency followed by R290 at last.
- As the evaporator temperature increases, the value of total irreversibility decreases and the refrigerant R290 shows the highest value of total irreversibility among R12,R134a,R290,R600a,R600.
- Among all refrigerants R12,R134a,R290,R600a,R600,Irreversibility is highest in compressor.
- As the evaporator temperature increases the irreversibility in compressor decreases and as per this criteria the refrigerant R12 shows best result among R12,R600a,R290,R600a,R600 and R134a shows a highest value of irreversibility in compressor.
- As the evaporator temperature increases the irreversibility in condenser decreases and as per this criteria the refrigerant R12 shows best result followed by R134a,R600a,R290,R600.
- As the evaporator temperature increases the irreversibility in expansion valve decreases and as per this criteria the refrigerant R12 shows best result followed by R134a,R600,R600a,R290.
- As the evaporator temperature increases the irreversibility in evaporator decreases

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