

“EXERGY ANALYSIS OF AIR CONDITIONING TUTOR”

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ABSTRACT

Exergy of a system is maximum useful work possible during that brings the system into equilibrium with heat reservoir energy accounts for the irreversibility due to increase in entropy. Effective energy utilization and its management for the minimizing irreversibility has made human to look for efficient energy consumption and conservation. Exergy analysis is a method that uses the conservation of the mass and conservation of energy principle together with the second law of thermodynamics for the analysis, design and improvement of the energy system and also to measure the system performance. Following system are taken as case study for carrying out exergy analysis as Air conditioning tutor.

Performance of some key observation has made and each presented in this project. Exergy could be use as the measure of the systems sustainability level, it shows quality of heat transfer process and energy is more complex measure for assessment cases than energy. The aim of this project is to analyze the exergy of some thermal system so that any process in the system which handle that having the largest exergy destruction can be identify that help thermal engineer to improve the performance of the components present in that system.

Keywords: Energy, exergy, second law of thermodynamics, exergy analysis, energy destruction

INTRODUCTION

Exergy is generally not conserved as energy but destroyed in the system. It is an extensive property of the system and depends on both the state of the system and on the properties of the environment. The state of the environment is referred to as the dead state, defined by the environmental temperature, pressure and composition.[5]

The first law of thermodynamics deals with the amounts of energy of various forms transferred between the system and its surrounding and with the changes in the energy stored in the system. It treats work and heat interaction as equivalent forms of energy in transient and offers no indication about possibility of spontaneous process proceeding in a certain direction. The first law places no restriction on the direction of process, but satisfying the first law does not ensure that the process can actually occur. This inadequacy of the first law to identify whether a process can take place is remedied by introducing another general principle of second law of thermodynamics.

The method of exergy analysis is based on second law of thermodynamic and the concept of irreversible production of entropy. The fundamentals of the exergy method were laid down by Carnot in 1824 and Clausius in 1865. The energy related engineering systems are designed and their performance is evaluated primarily by using the energy balance deduced from the first law of thermodynamics. Engineers and scientist have been traditionally applying the first law of thermodynamics to calculate the enthalpy balances for more than a century to quantify the loss of efficiency in a process due to the loss of energy. The exergy has gained

considerable interest in the thermodynamics analysis of thermal process and plant system, since it has been seen that, first law analysis has been insufficient from an energy performance stand point.

1.1 Exergy

“The maximum useful work that can be obtained from system at a given state in a given environment. In other words, the most work you can get out of a system.” In the last decades, exergy analysis has begun to be used for system optimization.[4]

1.2 Exergy Analysis

Exergy analysis involves the application of exergy concepts, balances, and efficiencies to evaluate and improve energy and exergy of other systems. Many engineers and scientist suggested that devices are best evaluated and improved using exergy analysis in addition to or in place of energy analysis.

1.3 Characteristics of Exergy

Some important characteristics of exergy are described and illustrated as follows:

- 1) A system in complete equilibrium with its surrounding does not have any exergy. No difference appears in temperature, pressure.
- 2) The exergy of a system increases the more it deviates from the environment. A block of ice carries a little exergy in winter while it can have significant exergy in summer.
- 3) Exergy is the part of the energy that is useful.
- 4) Exergy by definition depends not just on the state of a system, but also of the environment.

1.4 Exergy Efficiency

Exergy efficiency (Ψ) is defined as the ratio of the exergy output and exergy input of the system. Exergy efficiency is an efficiency based on the second law of thermodynamics. [4]

Exergy in = exergy output in product + exergy emitted with waste+ exergy destruction.

$$\Psi = \frac{\text{Exergy output in product}}{\text{Exergy input}} = \frac{e_{out}}{e_{in}} = \frac{e_{out}}{e_{out} + \sum \Delta e} = \frac{e_{in} - \sum \Delta e}{e_{in}}$$

$$= 1 - \frac{\text{Exergy losses}}{\text{Exergy input}} = 1 - \frac{\sum \nabla e}{e_{in}} = 1 - \sum \epsilon = \Delta e + \sum \epsilon = 1$$

Where ϵ = relative energy loss in the component.

$$\epsilon = \frac{\nabla e}{e_{in}}$$

Percentage loss in component can be expressed as:

$$\% \text{ loss} = \frac{\nabla e}{e_{in}} \times 100$$

LITERATURE SURVEY

This chapter includes brief information about research papers referred during exergy analysis of the systems mention below. A lot of work is done in past and still going on Exergy analysis of thermal systems particularly on Air conditioning system. Useful information and formulae required to carry out analysis is taken from research papers and thus, these research papers stands as a backbone to carry out analysis.

“Jing-Nang Lee¹, Chien-Chih Chen², and Chen-Ching Ting³”, [1] The article presents numerical analysis of exergy for air-conditioning influenced by ambient temperature. The model of numerical simulation uses

exergy concepts, formulations, applications of exergy based system. Moreover, example of exergy concepts are illustrated with simple concepts. It includes exergy analysis of vapor compression refrigeration system.

“Prateek D. Malwe, Bajirao S. Gawali et. Al” [3] Energy consists of two parts, one is available energy and other is unavailable energy. The available energy is useful part of energy from which maximum useful work is obtained which is known as an integrated air conditioning system exposed in varied ambient temperature to observe change of the four main devices, the compressor, the condenser, the capillary, and the evaporator in correspondence to ambient temperature. The analysis devices of the four device’s exergy influenced by the varied ambient temperature and found that the capillary has unusual increasing exergy loss vs. increasing ambient temperature in comparison to the other devices.

“Yunus A. Cengel, Michael A. Boles” [2] This book gives introduction about exergy, definition of second law of efficiency, Exergy. Unavailable energy accounts for the losses and irreversibility’s occurring in the system. Exergy analysis is an assessment technique for systems and processes that is based on the second law of thermodynamics. It has been increasingly applied over the last several decades largely because of its advantages over energy analysis.

“Guiyin Fang, Lin Xing, Fan Yang and Hui Li” [4] This paper introduces the dual-mode refrigeration system for ice storage air conditioning. A case study is presented to demonstrate the applicability of the model developed. Exergy analysis results of the refrigeration system in ice storage operating mode are compared with that of the refrigeration system in air conditioning operating mode. The results show that the exergy efficiency of the refrigeration system in ice storage operating mode is 17.63% lower than that of the refrigeration system in air conditioning operating mode. The energy saving and Exergy loss reduction possibilities are also analyzed and discussed.

“Ibrahim Dincer and Marc A. Rosen” [5] This book is a research oriented textbook and therefore includes practical features in a usable format. Theory and analysis are emphasized through in this book, reflecting new technique used in regards of Exergy analysis, models and applications, together with complementary materials and recants information. It includes basic information like concepts in thermodynamics, entropy generation, Exergy analysis of various practical case studies.

EXERGY ANALYSIS METHODOLOGY

Procedure for Exergy Analysis

- 1) Subdivide the process under consideration.
- 2) Perform conventional mass and energy balances.
- 3) Select a reference – environment model.

- 4) Calculate energy and exergy values at each point of system components.
- 5) Evaluate energy and exergy efficiency.
- 6) Interpret the results and draw appropriate conclusions, suggesting theoretical remedies.

General Assumptions

- 1) Kinetic exergy, potential exergy and chemical exergy were neglected.
- 2) Specific assumptions were made in the analysis of each subsystem.
- 3) Ambient conditions: $P_0=1$ bar , $T_0=300$ K.

1.5 Case Study : Air Conditioning Tutor

Air conditioning is defined as the simultaneous control of temperature humidity, air purity and air motion. An air conditioning tutor is always a confined place.

In this case study, experimental readings are taken on an air conditioning tutor using R12 as refrigerant. It consist of hermetically sealed reciprocating compressor, fin and tube type air cooled condenser, a finned coil type evaporator and expansion device valve which operate separately in their respective cycles. A constant loading in evaporator is done with the help of a heater provided inside of evaporator is done with thermostatic expansion valve as expansion device is done and result are shown in tabular form. Highest exergy efficiency is found for condenser.



Fig 1.5.1: Air conditioning tutor

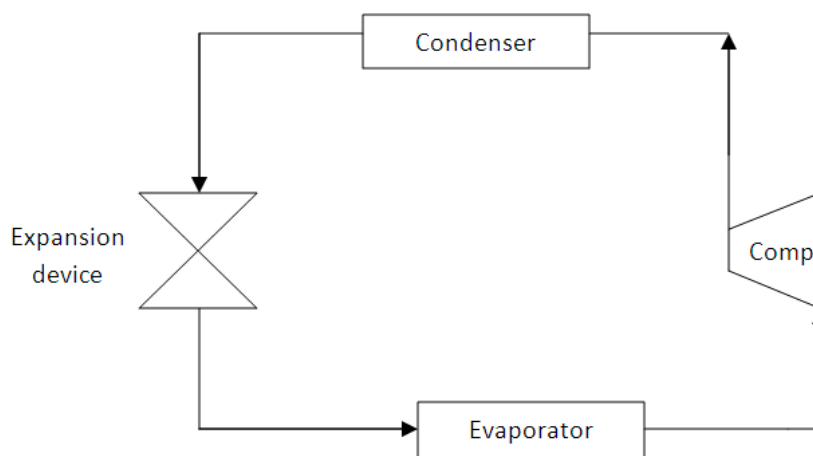


Fig 1.5.2: schematic representation of air conditioning tutor

Table 1.5.1: Specifications of air conditioning tutor

Sr. no.	Types	Air conditioning tutor
1	Capacity	1 TR
2	Refrigerant	R12
3	Compressor	Hermetically sealed, reciprocating
4	Condenser	Finned coils, Air cooled
5	Expansion device	Thermostatic expansion valve
6	Evaporator	Finned coil type

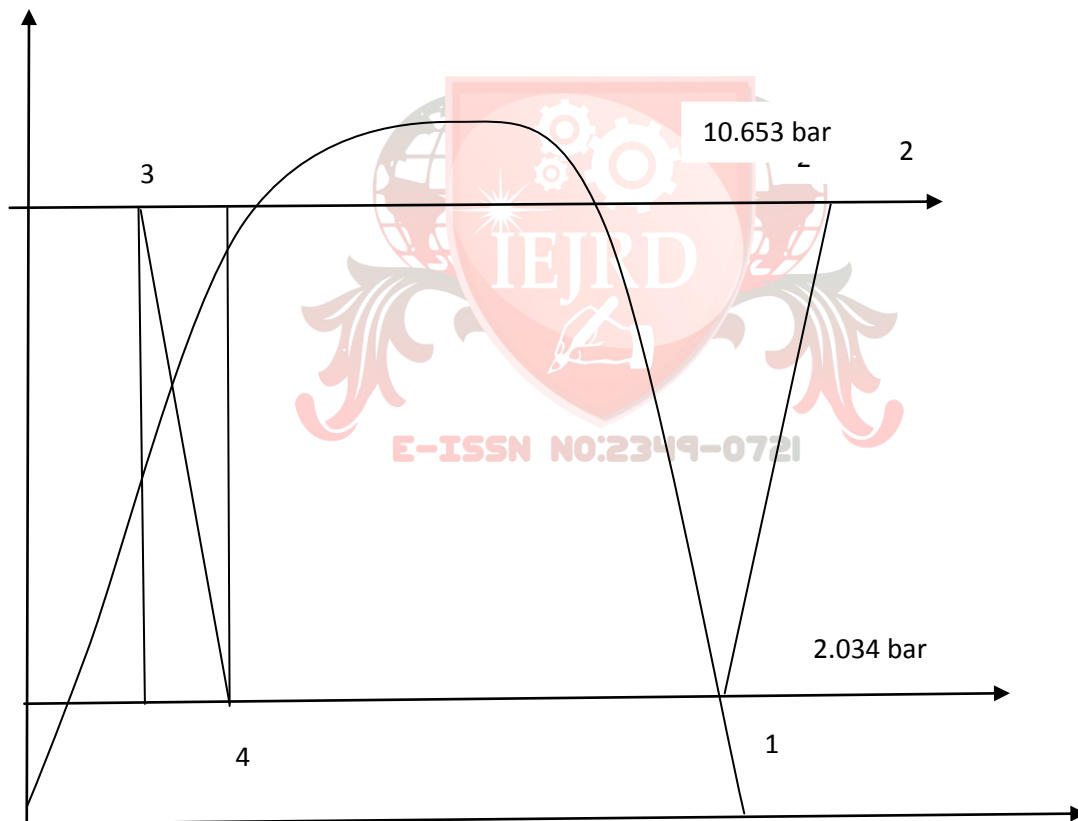


Fig 1.5.3: p-h chart of air conditioning tutor

1.5.1 Formulae Used

$$Q_e = V \times I$$

$$m'_r = \frac{Q_e}{h_1 - h_4}$$

$$Q_{\text{cond}} = m'_r \times (h_2 - h_3)$$

$$W_{\text{comp}} = m'_r \times (h_2 - h_1)$$

$$W_{\text{comp,ip}} = \frac{N_c \times 3600}{t_c \times 1200}$$

$$W_{\text{heater,ip}} = \frac{N_h \times 3600}{t_h \times 1200}$$

1. Compressor

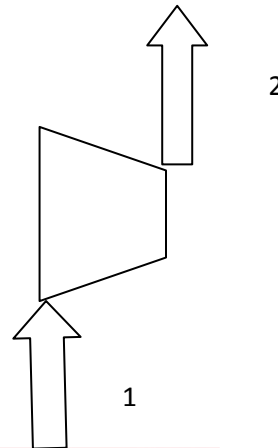


Fig. 1.5.4: Compressor

$$E_{x,\text{dest}2-3} = E_{x,\text{in}} - E_{x,\text{out}} = (E_{x,2} - E_{x,3}) - E_{x,\text{QH}}$$

$$= [m'_r (h_2 - h_3) - T_0 (S_2 - S_3)] - Q_H \left(1 - \frac{T_0}{T_H}\right)$$

$$E_{x,\text{dest}2-3} = T_0 \times S_{\text{gen},2-3} = m'_r \times T_0 \left[(S_2 - S_3) + \frac{Q_H}{T_H} \right]$$

$$(\eta_{\text{ex}})_{\text{cond}} = \frac{E_{x,\text{qh}}}{E_{x,2} - E_{x,3}} = \frac{Q_H \left(1 - \frac{T_0}{T_H}\right)}{[m'_r (h_2 - h_3) - T_0 (S_2 - S_3)]} = 1 - \frac{E_{x,\text{dest},2-3}}{E_{x,2} - E_{x,3}}$$

2. Condenser

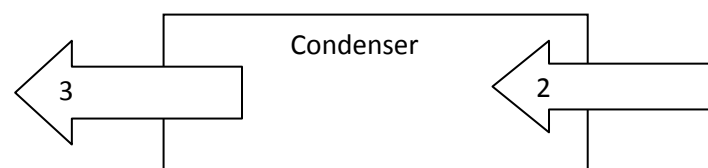


Fig 1.5.5 Condenser

$$E_{x,\text{dest}2-3} = E_{x,\text{in}} - E_{x,\text{out}} = (E_{x,2} - E_{x,3}) - E_{x,\text{QH}}$$

$$= [m'_r (h_2 - h_3) - T_0 (S_2 - S_3)] - Q_H \left(1 - \frac{T_0}{T_H}\right)$$

$$E_{x,dest2-3} = T_0 \times S_{gen,2-3} = m'_r \times T_0 \left[(S_2 - S_3) + \frac{Q_H}{T_H} \right]$$

$$(\eta_{ex})_{cond} = \frac{E_{x,qh}}{E_{x,2} - E_{x,3}} = \frac{Q_H \left(1 - \frac{T_0}{T_H} \right)}{[m'_r (h_2 - h_3) - T_0 (S_2 - S_3)]} = 1 - \frac{E_{x,dest,2-3}}{E_{x,2} - E_{x,3}}$$

3. Expansion Valve

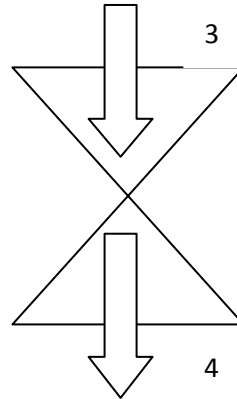


Fig. 1.5.6: Expansion valve

$$E_{x,dest3-4} = E_{x,in} - E_{x,out} = (E_{x,3} - E_{x,4})$$

$$= m'_r [(h_4 - h_3) - T_0 (s_4 - s_3)]$$

$$E_{x,dest3-4} = T_0 \times [(S_{gen,3-4})] = m'_r \times T_0 (s_4 - s_3)$$

$$(\eta_{ex})_{Exp\ valve} = 1 - \frac{E_{x,dest3-4}}{E_{x,3} - E_{x,4}}$$

4. Evaporator

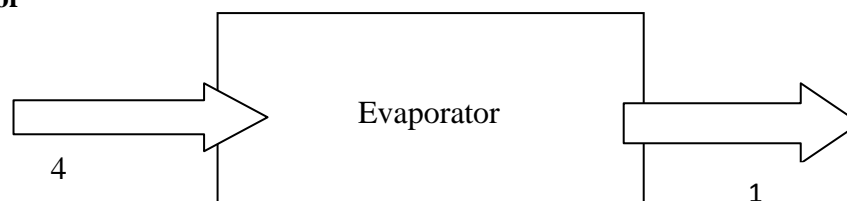


Fig.1.5.7: Evaporator

$$E_{x,dest4-1} = E_{x,in} - E_{x,out} = (E_{x,1} - E_{x,4}) - E_{x,QL}$$

$$= m'_r [(h_1 - h_4) - T_0 (s_1 - s_4)] - [Q_L \left(1 - \frac{T_0}{T_L} \right)]$$

$$E_{x,dest4-1} = T_0 \times S_{gen,4-1} = m'_r \times T_0 [(s_1 - s_4) - \frac{T_0}{T_L}]$$

$$(\eta_{ex,Evap}) = 1 - \frac{E_{x,dest,4-1}}{E_{x,1} - E_{x,4}} = \frac{-Q_L \left(1 - \frac{T_0}{T_L}\right)}{[m'_r (h_1 - h_4) - T_0 (s_1 - s_4)]}$$

$$(COP)_{carnot} = \frac{T_L}{T_H - T_L}$$

$$(COP)_{theo} = \frac{RE}{W_C}$$

$$(COP)_{actual} = \frac{w_{heater,ip}}{w_{comp,ip}} = \frac{t_c}{t_h}$$

$$(\eta_{ex})_{II} = \frac{COP_{act}}{COP_{carnot}}$$

Table 1.5.2. Air Conditioning Tutor Operating Parameters

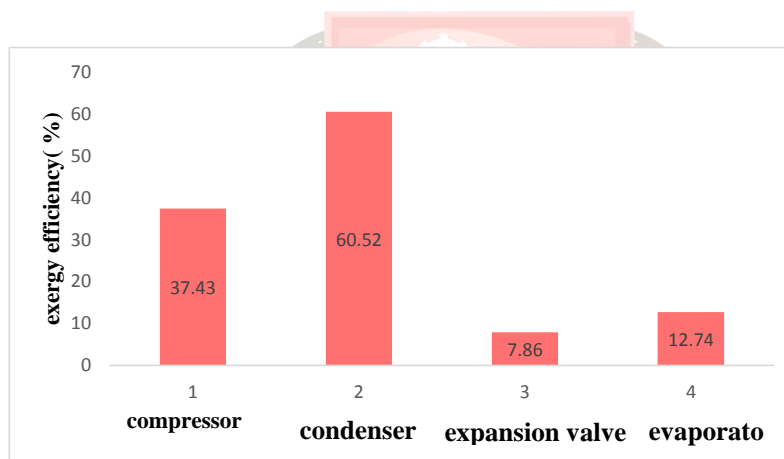
Sr. no.	Parameters	Symbol	Unit
1	Voltage	V	V
2	Current	I	A
3	Condenser pressure	P_c	bar
4	Evaporator pressure in	$P_{e,in}$	bar
5	Condenser inlet temperature	$T_{c,in}$	$^{\circ}C$
6	Condenser outlet temperature	$T_{c,out}$	$^{\circ}C$
7	Evaporator inlet temperature	$T_{e,in}$	$^{\circ}C$
8	Evaporator outlet temperature	$T_{e,out}$	$^{\circ}C$
9	Time for 10 rev of compressor meter	t_c	sec

1.5.2 Experimental Results:

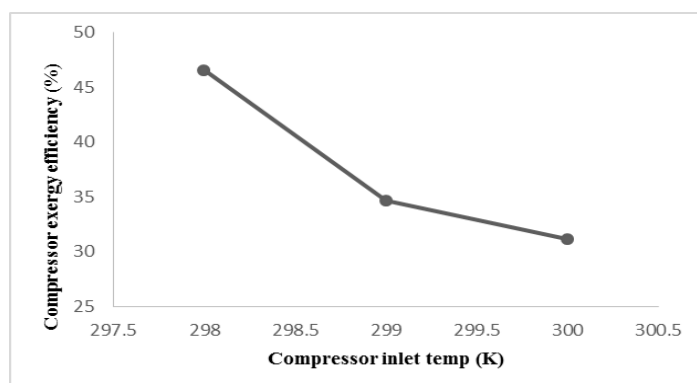
Table 1.5.3: Air Conditioning Tutor Results

Sr. no.	Exergy efficiency of Compressor (%)	Exergy efficiency of Condenser (%)	Exergy efficiency of Expansion valve (%)	Exergy efficiency of Evaporator (%)	Exergy efficiency of Second law (%)
1	31.13	77.00	7.8	12.66	49.52
2	34.64	44.00	7.8	12.55	55.00
3	46.53	60.56	8	13.02	54.31

1.5.3 Graphical Representations:

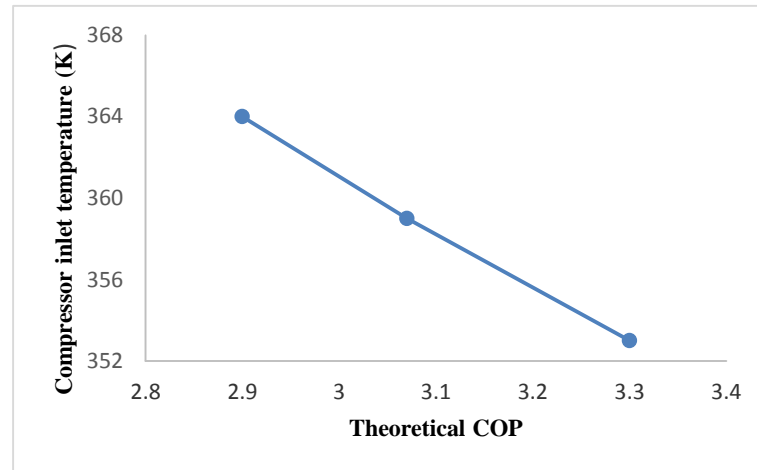


Graph 1.5.1: Component wise exergy efficiency for air conditioning tutor



Graph 1.5.2: Variation of compressor exergy efficiency versus compressor inlet temperature

Graph 1.5.2 shows that compressor exergy efficiency decreases with increase in compressor inlet temperature it means that compressor work more effectively at lower compressor inlet temperature because at higher temperature it has to deal with highly superheated refrigerant which needs more volume to be handled and correspondingly to do more work. [4, 5]



Graph 1.5.3: Variation of inlet compressor temperature with theoretical coefficient of performance

Graph 1.5.3 shows that inlet compressor temperature decreases with increase in its theoretical coefficient of performance (COP) due to increase in refrigerating effect. [4,5]

CONCLUSION

One of the key stones for obtaining sustainable development is the use of exergy analysis. Energy can never be lost as stated in the first law of thermodynamics. Exergy can be lost and this loss, called irreversibility, created during the use of non-renewable has to be minimized.

It has been observed that exergy efficiency is always lower than energy efficiency. It is due to irreversibility's and various losses associated with the system.

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