A Literature review on an energy and exergy analysis of psychrometric processes

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***Abstract*— A Literature Survey on an energy and exergy analysis of psychrometric process is presented in this paper. The study focuses on finding energy and exergy efficiencies for basic psychometric processes, such as heating, heating with humidification, cooling with dehumidification, and adiabatic mixing. This psychrometric process will carry out on air conditioning experimental set up. The effects of atmosphere air temperature, relative humidity , mass flow rate of air and dead state properties on energy and exergy efficiency will be find out for further study . The range of parameters covered included atmosphere air temperature (T_0=10 - 44^{0}C) and relative humidity (RH0 = 50-85%), and mass flow rate of air (3.2 m/s). Two dead state conditions will select to further analyze their effects on the system. One dead state condition is 25^{0}c and 50% RH. And second dead state condition is atmosphere temperature of air during experiment analysis.**

Index Terms*—Energy, Exergy, Psychrometric process)*

I. INTRODUCTION

Study of psychrometric processes is very essential for a better design of heating ventilating air conditioning and refrigerating (HVAC&R) systems. One cannot design a HVAC&R system without having a thorough and true knowledge of psychometric processes. psychrometry is the science which investigates the properties of humid air. it deals with thermodynamic properties of moist air.

Air-conditioning processes are usually shown on a psychrometric chart, which was developed in the early 1900s by a German engineer named Richard Mollier. A psychrometric chart shows the properties of moist air in terms of dry-bulb temperature, wet-bulb temperature, relative humidity, humidity ratio and enthalpy.[1]

The first law of thermodynamics deals with the quantity of energy and asserts that energy cannot be created or destroyed. This law merely serves as a necessary tool for the bookkeeping of energy during a process and offers no challenges to the engineer. The second law, however, deals with the quality of energy. More specifically, it is concerned with the degradation of energy during a process, the entropy generation, and the lost opportunities to do work; and it offers plenty of room for improvement. The second law of thermodynamics has proved to be a very powerful tool in the optimization of complex thermodynamic systems.[2]

When we talk about exergy analysis of power plant lots of research was study about it but very few research was study about exergy analysis of psychrometric processes. exergy (also called availability), which is the maximum useful work that could be obtained from the system at a given state in a specified environment. Exergy analysis is give the reality of system performance and determines the true magnitudes of exergy destructions. Fig 1.show the triangle of exergy analysis of any system.

II. LITERATURE REVIEW

The energy needed to process and circulate air in buildings and to control the humidity and temperature has increased continuously during the last decades especially in developing countries. This energy demand was caused by the increase of thermal loads to fulfill occupant comfort demands, climate changes, and architectural trends. Energy and fuel cost savings and air conditioning system optimization are becoming more important in engineering design of psychrometric processes. In the case of an air conditioning system design, generally energy consumption can be minimized by analyzing losses in the system. One tool of analyzing losses is to analyze the exergy efficiency of a system. Exergy or availability of a system represents its maximum work potential at a given state. Therefore, exergy loss is a key factor to evaluate the thermodynamic performance of a system. By doing such an analysis, one can determine the parameters which have greater effect on the system and can be improved.

Kanoglu Mehmet, Ibrahim Dincer, Rosen, Marc A[3] carried out studied on Exergy Analysis of Psychrometric Processes for HVAC&R Applications. Mass, energy, entropy, and exergy balances and exergy efficiency relations are developed for common air-conditioning processes that include simple heating and cooling, heating with humidification, cooling with dehumidification, evaporative cooling, and adiabatic mixing of airstreams. An illustrative example of a heating process with humidification is considered and the effects of air temperature and relative humidity at the inlet and exit, the temperature of steam used for humidification, and the dead state properties of exergy efficiency and exergy destruction are investigated. The results indicate that processes with low exergy efficiency and high exergy destruction have significant potential for improving performance.

Bilal .A. Qureshi, Syed M. Zubair[4] carried out study on Application of exergy analysis to various psychrometric processes. The relation between work and changes in entropy generation arises from the simultaneous treatment of the first and second laws referred to as exergy (or available energy) analysis. In this paper, they discuss thermodynamic analysis of various psychrometric processes using the concept of exergy. A parametric study of each of the processes is carried out to determine the variation of second-law efficiency as a function of mass flow rate, relative humidity and temperature. Other trends such as variation of temperature with relative humidity are also shown where applicable. Irreversible losses are calculated by applying an exergy balance on each system. In this regard, an engineering equation solver (EES) programme is used, which is unique because it has built-in functions for most thermodynamic and transport properties; removing the need for approximate equations.

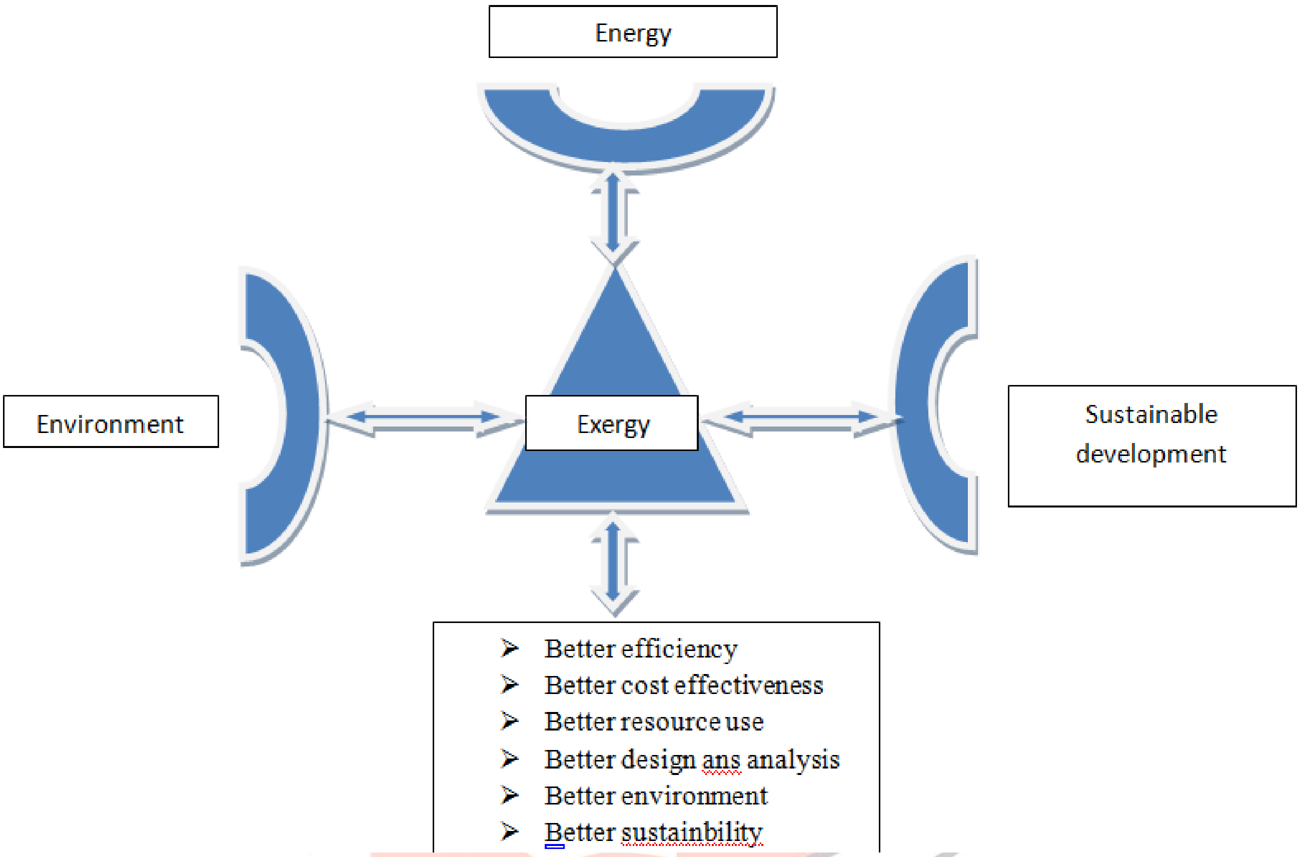

Fig.1:Triangle of exergy

T.A.H. Ratlamwala , I. Dincer[5] has worked on Efficiency assessment of key psychrometric processes. The study focuses on defining energy and exergy efficiencies based on three different types of approaches. For each of five key psychrometric processes, such as heating or cooling, heating with humidification, cooling with dehumidification, evaporative cooling, and adiabatic mixing, parametric studies are carried out. Two efficiencies are newly proposed here in this study, and the third efficiency is taken from the literature for comparison purposes. The results show that for heating process exergy efficiency varies from 0.012 to 0.48 with rise in ambient temperature. Increasing ambient temperature results in variation of exergy efficiency from 0.014 to 0.29 for heating with humidification process. For cooling with dehumidification process exergy efficiency varies from 0.002 to 0.73 with rise in ambient temperature. The exergetic efficiency of evaporative cooling process varies from 0.64 to 0.03 with an increase in ambient temperature. For adiabatic mixing process, exergy efficiency varies from 0.65 to 0.94 with rise in ambient temperature.

Abdullah Yildiz , Ali Gungor[6] carried out Energy and exergy analyses of space heating in buildings In the analysis, heating load is taken account but cooling load is neglected and the calculations presented here are done using steady state conditions. It is assumed that the office is heated by a liquid natural gas (LNG) fired conventional boiler, an LNG condensing boiler and an external air–air heat pump. With this study, energy and exergy flows are investigated. Energy and exergy losses in the whole system are quantified and illustrated. The highest efficiency values in terms of energy and exergy were found to be 80.9% for external air–air heat pump and 8.69% for LNG condensing boiler, respectively.

Ertac Hurdogana, Orhan Buyukalacaa, Arif Hepbaslib, Tuncay Yılmazc[7] perform Exergetic modeling and experimental performance assessment of a novel desiccant cooling system.One of the alternative systems that is brought to agenda is the desiccant cooling systems, which may provide important advantages in solving air conditioning problems. This study deals with the performance analysis and evaluation of a novel desiccant cooling system using exergy analysis method. The system was designed, constructed and tested in Cukurova University, Adana, Turkey and has been successfully operated since 2008. This system consists of a desiccant wheel, heat exchangers, fans, evaporative cooler, electric heater unit and refrigeration unit. The exergetic efficiency values for the whole system on the exergetic product/fuel basis are calculated to range from round 32% to 10% at the varying dead (reference) state temperatures of 0–30 ◦C.

Nomenclatures	
EX	exergy rate

EX_{dest}	exergy destruction rate
h	specific enthalpy
m	mass flow rate
p	Pressure
Q	heat transfer rate
RH	relative humidity
S	specific entropy
s_{gen}	entropy generation rate
T	Temperature
w	work rate
x	Quality
η_{en}	energy efficiency
η_{ex}	exergy efficiency
ψ	specific exergy of fluid stream,
ω	humidity ratio
ϕ	relative humidity
Subscripts	
0	ambient or reference condition
a	dry air
w	Water vapour
1, 2, and 3	state points

Mehmet Kanoglua, Ali Bolattu rkb, Necdet Altuntopc[8] had study Effect of ambient conditions on the first and second law performance of an open desiccant cooling process. An open desiccant cooling process is presented and applied to ventilation and recirculation modes of the system operation. The cooling system consists of a desiccant wheel, a rotary regenerator, two evaporative coolers, and a heating unit. Certain ideal operating characteristics based primarily on the first law of thermodynamics are assumed for each component As an additional study, a non-ideal system operation is considered and it is determined that both the COP and cooling load decrease with increasing ambient temperature and relative humidity, and they approach zero at high values of ambient temperature and humidity.

Mehmet Kanoglu , Melda Ozdinc ,Carpinlioglu, Murtaza Yildirim[9] carried out Energy and exergy analyses of an experimental open-cycle desiccant cooling system. A procedure is developed for the energy and exergy analyses of open-cycle desiccant cooling systems and it is applied to an experimental unit operating in ventilation mode with natural zeolite as the desiccant. Exergy destruction and exergy efficiency relations for the system and its components as well as the reversible COP of the system are derived. The energy and exergy formulations are applied to the experimental unit using the data collected during a typical operation of the unit Desiccant wheel has the greatest percentage of total exergy destruction with 33.8% followed by the heating system with 31.2%. Rotary regenerator and evaporative coolers account for the remaining exergy destructions.

A. Alahmer , M.A. Omar , A. Mayyas, Shan Dongri[10] has worked on Effect of relative humidity and temperature control on in-cabin thermal comfort state: Thermodynamic and psychrometric analyses. This manuscript discusses the effect of manipulating the Relative Humidity RH of in cabin environment on the thermal comfort and human occupants' thermal sensation. The study uses thermodynamic and psychrometric analyses, to incorporate the effect of changing RH along with the dry bulb temperature on human comfort. The results show that changing the RH along with dry bulb temperature inside vehicular cabins can improve the air conditioning efficiency by reducing the heat removed while improving the Human comfort sensations as measured by the Predicted Mean Value PMV and the Predicted Percentage Dissatisfied PPD indices.

Bilal A. Qureshi, Syed M. Zubair[11] Second-law-based performance evaluation of cooling towers and evaporative heat exchangers. A parametric study is carried out to determine the variation of second-law efficiency as well as exergy destruction as a function of various input parameters such as inlet wet bulb temperature. Irreversible losses are determined by applying an exergy balance on each of the systems investigated. In this regard, an engineering equation solver (EES) program, with built-in functions for most thermodynamic and transport properties, is used. We notice that an increase in the inlet wet bulb temperature invariably increases the second-law efficiency of all the heat exchangers. Also, it is shown that Bejan's definition of second-law efficiency is not limited in evaluating performance.

XIA Xiao-xia, WANG Zhi-qi, XU Shun-sheng[12] investigate study on Exergy Analysis of Energy Consumption for Primary Return Air Conditioning System. Combined with actual example the exergy loss of equipments and the exergy efficiency of system were calculated both in summer and in winter. The results show that the exergy efficiency is very low in two conditions. The exergy loss focuses on air-conditioned room. The exergy loss of reheater has obvious difference between summer and winner. Based on this, the improvement measure was proposed, which can provide guide for the energy conservation of equipments and system

Majed M. Alhazmy[13]carried out Analysis On The minimum work required for air conditioning process. The air conditioning process for hot and humid climates involves reducing air temperature and humidity. In the present analysis the inlet state is the state of the environment which has also been chosen as the dead state. The final state is the human thermal comfort fixed at 20 °C dry bulb temperature and 60% relative humidity. The general air conditioning process is represented by an equivalent path consisting of an isothermal dehumidification followed by a sensible cooling.

Zafer Utlu, Arif Hepbasli[14] study on the evaluation of energy utilization efficiency in the Turkish residential-commercial sector using energy and exergy analyses. This study evaluates the energy utilization efficiency of the Turkish residential-commercial sector (TRCS) in 2001 by using energy and exergy analyses. Total energy and exergy input are calculated to be 3194.90 and 3130.77 pJ in 2001. Annual fuel consumption in space heating, water heating and cooking activities as well as electrical energy uses by appliances are determined for 2001. The energy–efficiency values for the TRCS are found to be 55.75% while the exergy–efficiency values for that are obtained to be 8.98 in the same years.

III. EXPERIMENTAL SETUP

The schematic diagram of experimental set up of air conditioning system is shown in Fig 2. the air conditioning system that supply air to a specific temperature controlled room.

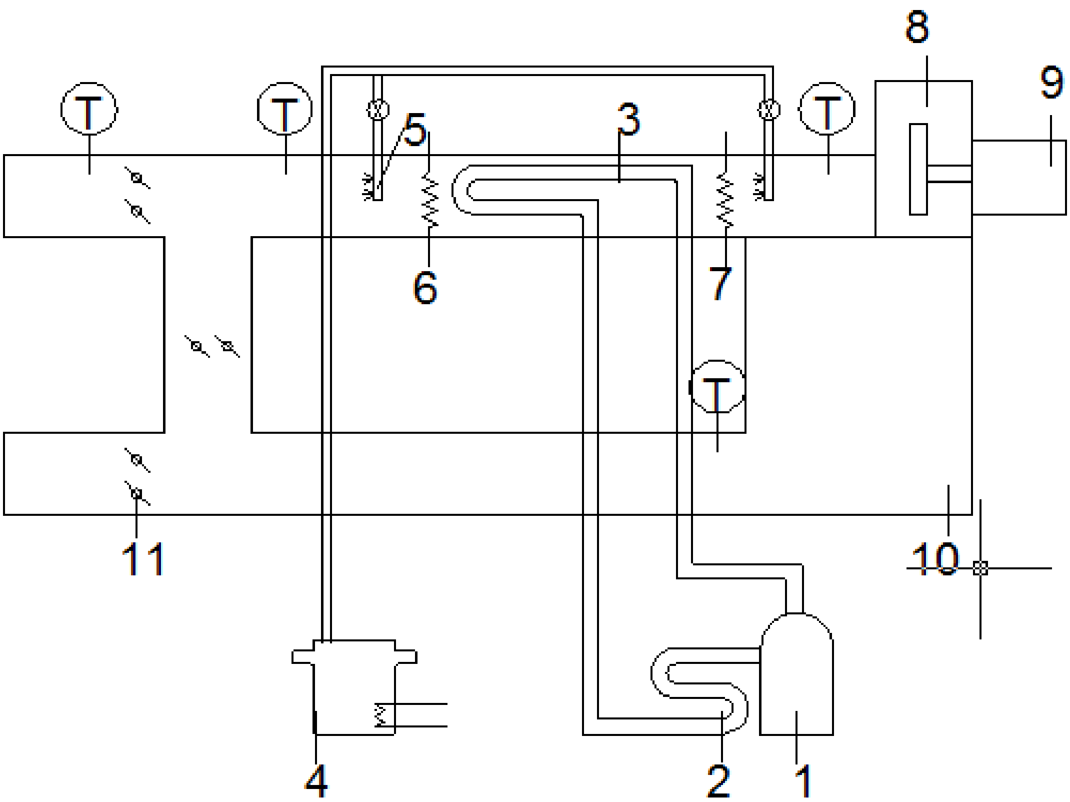

Fig.2.Experimental schematic diagram Set Up

1.Hermatic Shiled Compressor
2.Air Cooled Condenser
3.Evaporator
4.Steam Generator
5.Steam Injector
6.Preheater
7.Reheater
8.Blower
9.Blower Motor
10.Room
11.Air Flow Control Flappers

Fig.3 show the actual experiment set up of air conditioning system. By controlling one or more components of the system, following experiment can be performed.

- Cooling of fresh air with full exhaust.
- Heating of fresh air with full exhaust.
- Humidification of air with heating.

- Cooling or heating the air with partial recirculation.(calculation for mixing of two air streams having different characteristics.)

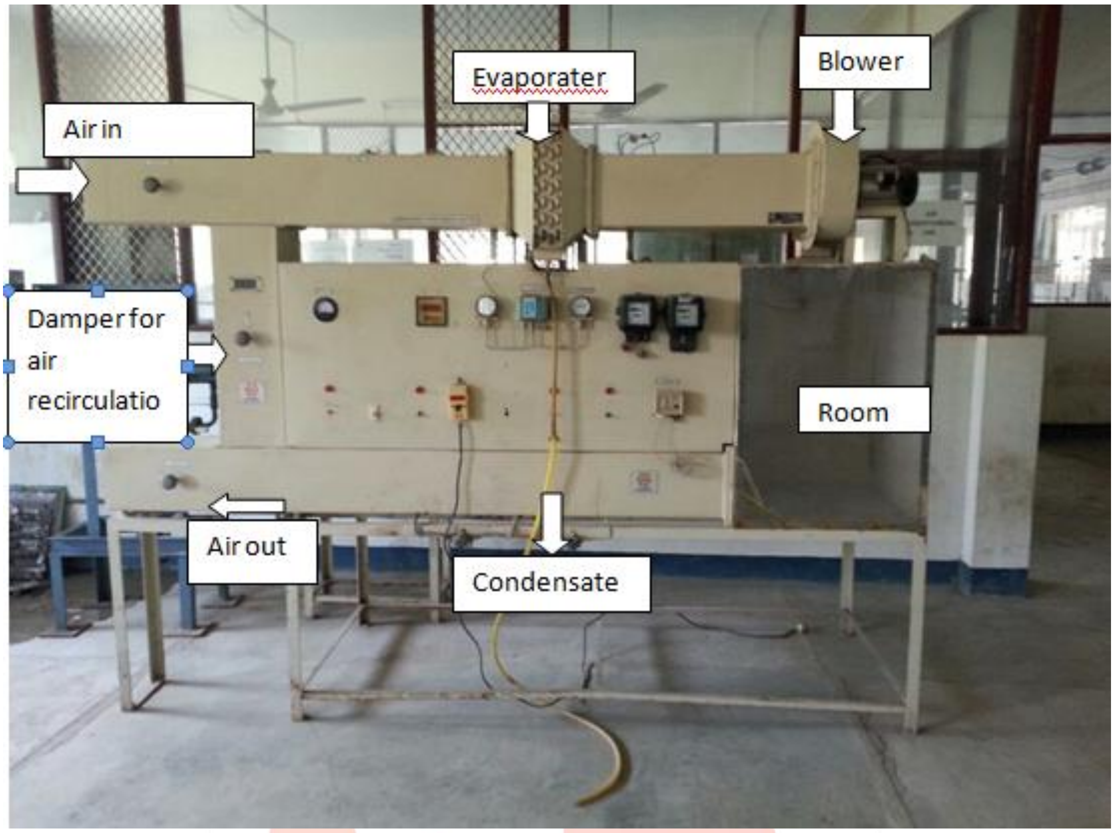

Fig.3.Actual Experiment Setup And Component(front view)

Specification of Experimental Set Up

1. For Cooling System:-

- Hermetic shielded compressor, kirloskar make having capacity of 0.6 tons of refrigeration using R 22 refrigerent.
- Finned tube air cooled condenser with fan.
- Thermostatic expansion valve.
- Finned tube type direct expansion cooling coil.
- Filter / drier and liquid indicator for refrigerator.

2. For Heating System:-

- 1000 W capacity preheater.
- 1000 W capacity reheater.

3. A steam generator with immersion heater and steam injection nozzles with control valve. It contain 2000W electric heater.

4. circulating system

IV. BASIC THERMODYNAMIC ANALYSIS PROCEDURE:

The mathematical formulation of an air conditioning system takes into account the mass balance of dry air and water, the energy balance by applying the first law of thermodynamics, and the entropy or exergy balance by using the second law of thermodynamics. The air and water properties were obtained from the ASHRAE Handbook of fundamentals.

The energy and exergy efficiency of four psychrometric processes are written based on the thermodynamic approach presented by Cengel and Boles. The principles of exergy analyses are obtained from Dincer and Rosen. The third definition of exergetic efficiency ($\eta_{ex,3}$) is defined on the basis of definition introduced by Kanoglu et al.[5]

The first exergy definition is by Cengel and Boles which states that exergy efficiency is a function of the useful work and the maximum possible (reversible) work. The second exergy definition is by Wepfer et al. and Dincer and Rosen , who define the exergy efficiency in terms of product and supply exergies. The third definition of exergetic efficiency (ηex,3) is defined on the basis of definition introduced by. [5]

Following are the equation for energy and exergy efficiency for various psychrometric process.

(1) For heating process:

	Energy efficiency	Exergy efficiency
By Cengel and Boles	$\frac{m_{a2}h_2 - m_{a1}h_1}{Q_{in}}$	$\frac{m_{a2}\psi_2 - m_{a1}\psi_1}{\left[1-\frac{T_0}{T}\right]Q_{in}}$
By Wepfer	$\frac{m_{a2}h_2}{Q_{in}}$	$\frac{m_{a2}\psi_2}{\left[1-\frac{T_0}{T}\right]Q_{in}}$
By Kanoglu	$\frac{m_{a2}h_2}{Q_{in} + m_{a1}h_1}$	$\frac{m_{a2}\psi_2}{\left[1-\frac{T_0}{T}\right]Q_{in} + m_{a1}\psi_1}$

(2) For Heating With Humidification process

	Energy efficiency	Exergy efficiency
By Cengel and Boles	$\frac{m_{a3}h_3 - m_{a1}h_1}{Q_{in} + m_w h_w}$	$\frac{m_{a3}\psi_3 - m_{a1}\psi_1}{\left[1-\frac{T_0}{T}\right]Q_{in} + m_w\psi_w}$
By Wepfer	$\frac{m_{a3}h_3}{Q_{in} + m_w h_w}$	$\frac{m_{a3}\psi_3}{\left[1-\frac{T_0}{T}\right]Q_{in} + m_w\psi_w}$
By Kanoglu	$\frac{m_{a3}h_3}{Q_{in} + m_{a1}h_1 + m_w h_w}$	$\frac{m_{a3}\psi_3}{\left[1-\frac{T_0}{T}\right]Q_{in} + m_{a1}\psi_1 + m_w\psi_w}$

(3) For cooling With dehumidification process.

	Energy efficiency	Exergy efficiency
By Cengel and Boles	$\frac{Q_{out} + m_{a2}h_2}{m_{a1}h_1}$	$\frac{\left[1-\frac{T_0}{T}\right]Q_{out} + m_{a2}\psi_2}{m_{a1}\psi_1}$
By Wepfer	$\frac{m_{a2}h_2}{Q_{out}}$	$\frac{m_{a2}\psi_2}{\left[1-\frac{T_0}{T}\right]Q_{out}}$
By Kanoglu	$\frac{Q_{out} + m_{a2}h_2 + m_w h_w}{m_{a1}h_1}$	$\frac{\left[1-\frac{T_0}{T}\right]Q_{out} + m_{a2}\psi_2 + m_w\psi_w}{m_{a1}\psi_1}$

(4) For adiabatic Mixing Process.

Energy efficiency	Exergy efficiency
$\frac{m_{a3}h_3}{m_{a1}h_1 + m_{a2}h_2}$	$\frac{m_{a3}\psi_3}{m_{a1}\psi_1 + m_{a2}\psi_2}$

V. CONCLUSIONS

In this paper, a literature review on an energy and exergy analysis of psychrometric process is presented. From literature survey, different findings are concluded. Basic thermodynamic analysis procedure is defined. Different parameters like temperatures, air velocity, air humidity & mass of the air streams entering during the different psychrometric process will be measured. From this data the effects of atmosphere air temperature, relative humidity, mass flow rate of air and dead state properties on energy and exergy efficiency will be find out for further study.

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