AIN SHAMS UNIVERSITY

FACULTY OF ENGINEERING

Mechanical Power Engineering

Studying the Characteristics of Heat Pipe Heat Exchangers in Air Conditioning Systems

A Thesis submitted in partial fulfillment of the requirements of the degree of

Master of Science in Mechanical Engineering

(Mechanical Power Engineering)

Submitted by

Ahmed Mohamed Farouk Ahmed Hamed Mousa

Bachelor of Science in Mechanical Engineering

(Mechatronics Engineering)

Ain Shams University, 2007

Supervised By

Prof. Mahmoud Mohamed Abo El-Nasr

Prof. Mahmoud Mohamed Kamal

Dr. Hany El-Sayed Abd El-Haleim

Cairo - (2017)

AIN SHAMS UNIVERSITY

FACULTY OF ENGINEERING

Mechanical Power Engineering

Studying the Characteristics of Heat Pipe Heat Exchangers in Air Conditioning Systems

By

Ahmed Mohamed Farouk Ahmed Hamed Mousa

Bachelor of Science in Mechanical Engineering

(Mechatronics Engineering)

Faculty of Engineering, Ain Shams University, 2007

Examiners' Committee

Name and Affiliation	**Signature**
Prof. Ramadan Mohamed Abd El Aziz Amer Mechanical Power, Benha University	…….
Prof. Raouf Naseef Abd El Maseeh Mechanical Power, Ain Shams University	…….
Prof. Mahmoud Mohamed Abo El-Nasr Mechanical Power, Ain Shams University	…….
Prof. Mahmoud Mohamed Kamal Abd El Aziz Mechanical Power, Ain Shams University	…….

Date: 27 February 2017

Statement

This thesis is submitted as a partial fulfillment of Master of Science in Mechanical Engineering Engineering, Faculty of Engineering, Ain shams University.

The author carried out the work included in this thesis, and no part of it has been submitted for a degree or a qualification at any other scientific entity.

Student name

Ahmed Mohamed Farouk Ahmed Hamed Mousa

Signature

Date:

27 February 2017

Researcher Data

Name	: Ahmed Mohamed Farouk Ahmed
Date of birth	: 09/August/1985
Place of birth	: Jeddah, Saudi Arabia
Last academic degree	: Bachelor of Science
Field of specialization	: Mechanical Engineering
University issued the degree	: Ain Shams University
Date of issued degree	: June, 2007
Current job	: Design Engineer at SHAKER Consultancy Group

Thesis Summary

Thesis subject: studying the characteristics of heat pipe heat exchangers in air conditioning systems

In this thesis a study has been made on a heat pipe heat exchanger used in heat recovery. The test rig has been built to simulate the same conditions of the heat recovery systems in air conditioning applications. In these systems, the heat pipe-heat exchanger is considered one of the best solutions especially in hospitals and laboratories in which zero cross contamination is required.

The measured data acquired from the test rig were analyzed to evaluate the thermal behavior and effectiveness of the heat exchanger.

Cold and hot air ducts have been connected to a heat pipe heat exchanger. The first two experiments have been carried out by changing the hot air inlet temperature from 32 ~ 55 °C.

The inlet cold air temperatures has been maintained constant at 26 °C in one experiment and 28 °C in the other one.

Another three experiments have been carried out, by changing the ratio of the air mass flow rates between the cold and the hot air from 1 to almost 2, whilst the temperature of the cold air remained constant at 26 °C. Also the hot air temperature is maintained constant at either 35 °C, 40 °C and 45 °C. Hence for each experiment the thermal performance and effectiveness of the heat recovery system were investigated.

The results indicate that when the hot (fresh) air temperature increases, the temperature difference of the hot and cold air streams increase.
The effectiveness of the evaporator was increased up to almost 39 % due to increasing the hot air temperature to 55 °C.

The effectiveness of the heat pipe evaporator section was subjected to a positive effect with changing the mass flow ratios. It is also found that the fresh (hot) air temperature has a great effect on enhancing the heat transfer performance of evaporator part of heat pipes heat exchanger.

Key words:

Heat pipe, Heat exchanger, Heat recovery, Air conditioning

Acknowledgment

In appreciation and gratitude

To:

My supervision team

Prof. Mahmoud Mohamed Abo El-Nasr

Prof. Mahmoud Mohamed Kamal

Dr. Hany El-Sayed Abd El-Haleim,

The wonderful and helpful staff of Ain Shams University, teaching assistants and lab technicians,

SHAKER CONSULTANCY GROUP,

and all my family

For their continuous support and gracious consideration

All of them had made a difference in my life, and pushed me forward, thank you all

February 2017

Table of Contents

List of Figures

List of Tables

Nomenclature

C : heat capacity rate, (W/K)

c_p : Specific heat at constant pressure, ($kJ/kg°C$)

$\dot{m}$: Air mass flow rate, ($kg\ s^{-1}$)

q: Heat transfer rate, (W)

T: Temperature, ($°C$)

ΔT*:* Temperature change of air stream, (°C)

Dimensionless Numbers

Nu : Nusselt number, UD/K

Pr: Prandtl number, μCp/K

Re: Reynolds number, ρvD/μ

Greek Symbols

ε*:* Heat pipe heat exchanger effectiveness

μ*:* Dynamic viscosity Ns/m^2

ρ*:* Density kg/m^3

Subscript

C : Cold air

Cn : Condenser

E : Evaporator

H : Hot air

i : air inlet

o : air outlet

1. CHAPTER 1: INTRODUCTION

The environmental aspect now is one of the most important aspects that humanity shall give a special priority in its way to progress and prosperity. During the last decade; humanity was facing many problems, namely; limited reserves of fossil fuels, great increasing emissions of carbon dioxide, global warming and ozone depletion...etc. Those were the main environmental challenges for human beings.

Waste energy recovering techniques are considered one of the major tools that engineers use to reduce the harsh impact of civilization on the environment and also to reduce the cost of applying modern engineering solutions.

As a general definition, energy recovery system, is a technique used to reduce the energy consumed by a certain process through exchanging energies between sub systems of the overall system. Energy recovery systems have a wide range of application and methodologies, but in this thesis we will focus on the recovery systems used in air conditioning systems and specially those systems which exchange energy through heat pipe heat exchangers.

Many buildings owners and designers now are adopting the air to air energy recovery in air conditioning systems, due to the large energy consumption of the air conditioning system in buildings compared to

the other systems, which is about 32% of the total energy consumed by building.

This economic point of view will lead also at the end for better environmental effect through reducing quantities of coal operated power stations, reducing NOx, CO2 and airborne particles, to enhance the air quality and contribute in slowing the climate change. Generally, adopting an energy recovery process is important to maintain an acceptable degree of the (IAQ) while conserving energy and reducing overall energy consumption.

There are wide diversity of system techniques developed for energy recovery in air conditioning systems in buildings [1], depending on certain factors like available space, type of energy recovered (latent or sensible), pressure drop, temperature range, cross contamination of air, cost (capital, pumping power and maintenance) and total effectiveness.

The right technique can be properly determined. Plate heat exchangers, rotary wheels, heat pipes heat exchangers, runaround loops, thermosiphons and twin tower enthalpy recovery loops are all techniques used in the air conditioning energy recovery.

1.1 Techniques for heat recovery inside building

In references [1] and [2], the design consideration of various energy recovery systems has been illustrated as follows: