COMPARISON OF ACCURACY IN PINCH TECHNOLOGY METHOD

DASIMA BT NEN @ SHAHINAN

Universiti Malaysia Sarawak
2000

Borang Penyerahan Tesis
Universiti Malaysia Sarawak

R13a

BORANG PENYERAHAN TESIS

Judul COMPARISON OF ACCURACY IN PINCH TECHNOLOGY METHOD

SESI PENGAJIAN 1997/2000

Saya DASIMA BT NEN @ SHAHINAN

mengaku membenarkan tesis ini disimpan di Pusat Khidmat Maklumat, Universiti Malaysia Sarawak dengan syarat-syarat kegunaan seperti berikut:

1. Hakmilik kertas projek adalah di bawah nama penulis melainkan penulisan sebagai projek bersama dan di biayai oleh UNIMAS, hakmiliknya adalah kepunyaan UNIMAS
2. Naskah salinan di dalam bentuk kertas atau mikro hanya boleh dibuat dengan kebenaran bertulis daripada penulis
3. Pusat Khidmat Maklumat Akademik, UNIMAS dibenarkan membuat salinan untuk pengajian mereka.
4. Kertas projek hanya boleh diterbitkan dengan kebenaran penulis. Bayaran royalti adalah mengikut kadar yang dipersetujui kelak.
5. * Saya membenarkan/tidak membenarkan Perpustakaan membuat salinan kertas projek ini sebagai bahan pertukaran di antara institusi pengajian tinggi
6. ** Sila tandakan (✓)

[ ]	SULIT	(Mengandungi maklumat yang berdarjah keselamatan atau kepentingan Malaysia seperti yang termaktub di dalam AKTA RAHSIA RASMI 1972)
[ ]	TERHAD	(Mengandungi maklumat TERHAD yang telah ditentukan oleh organisasi/badan di mana penyelidikan dijalankan)
[✓]	TIDAK TERHAD	

Disahkan oleh

(TANDATANGAN PENULIS)

(TANDATANGAN PENYELIA)

Alamat Tetap: 2032, Jalan Tunku
Kampung Tunku,
93050 Petra Jaya,
Kuching, Sarawak

Nama Penyelia: Nazeri Abdul Rahman

Tarikh: 4 April 2000

Tarikh: 4 April 2000

CATATAN * Potong yang tidak berkenaan
** Jika Kertas Projek ini SULIT atau TERHAD, sila lampirkan surat daripada pihak berkuasa/organisasi berkenaan dengan menyertakan sekali tempoh kertas projek

Approval Sheet

This project report entitled "**COMPARISON OF ACCURACY IN PINCH TECHNOLOGY METHOD**" was prepared by **Dasima Bt Nen @ Shahinan** as a partial fulfillment of the requirement for the degree of Bachelor of Engineering with honours (Mechanical and Manufacturing System) is hereby read and approved by:

Nazeri B Abd Rahman
(Supervisor)

4 April 2000
Date

COMPARISON OF ACCURACY IN PINCH TECHNOLOGY METHOD

DASIMA BT NEN @ SHAHINAN

Tesis Dikemukakan Kepada
Fakulti Kejuruteraan, Universiti Malaysia Sarawak
Sebagai Memenuhi Sebahagian daripada Syarat
Penganugerahan Sarjana Muda Kejuruteraan
Dengan Kepujian (Kejuruteraan Mekanikal dan Sistem Pembuatan)
2000

CONTENTS

PENGHARGAAN		iv
ACKNOWLEDGEMENT		v
ABSTRAK		vi
ABSTRACT		vii
LIST OF TABLES		viii
LIST OF FIGURES		ix
NOMENCLATURE		xi
CHAPTER 1 – INTRODUCTION		**1**
1.1	Introduction to Heat Transfer	1
	1.1.1 Conduction	1
	1.1.2 Convection	2
	1.1.3 Radiation	3
1.2	Heat Exchanger	4
	1.2.1 Classification and Terminology of Heat Exchanger	6
1.3	History and Terminology of pinch Technology	9
1.4	Objectives of This Study	9
CHAPTER 2 - LITERATURE REVIEW		**11**
2.1	Study on Heat Transfer	11
2.2	Type of Heat Exchanger and Its Properties	12
2.3	Pinch Technology	16

CHAPTER 3 – METHODOLOGY 18

3.1 Graphical Method 18

3.2 Tabular Method 22

3.2.1 Interval Temperature 22

3.2.2 Temperature Interval Balance 23

3.2.3 Energy Targets 24

3.2.4 Pinch Determination 27

CHAPTER 4 - CASE STUDY QUESTION 29

4.1 The Stream Data 29

4.2 Graph Paper Method 30

4.2.1 Composite Stream Heat Flow Capacities 30

4.22 Constructing Curves 31

4.3 Graphical Method using Excel Program 32

4.3.1 Gathering The Stream Data 32

4.3.2 Constructing Composite Curves 34

4.4 Tabular Method 36

4.4.1 Stream Temperature Adjustment 36

4.4.2 Adjusted Temperature Intervals and Stream Data 36

4.4.3 External Heating and Cooling Determination 38

4.4.4 Pinch Determination 39

4.5 The Accuracy Determination 41

CHAPTER 5 - RESULT AND DISCUSSION 43

5.1 The Problem in Graphical Method (Manually) 43

5.1.1 Comparison Between Type of Graph Paper and Scale 44

5.2 The Error in Graphical Method Using Excel Program 45

5.3 Tabular Method 46

5.4 Different Result in Various Minimum Temperature Difference 47

CHAPTER 6 - CONCLUSION AND RECOMMENDATION 49

BIBLIOGRAPHY 51

APPENDIX 1 54

PENGHARGAAN

Setinggi-tinggi penghargaan ditujukan kepada En Nazeri Abdul Rahman di atas bimbingan dan tunjuk ajar beliau sepanjang tempoh penyediaan tesis ini. Pengarang juga ingin merakamkan ucapan terima kasih kepada rakan-rakan beliau yang telah membantu memberi idea dan tunjuk ajar terutama dalam penggunaan program Excel. Akhir sekali, pengarang ingin mengucapkan penghargaan yang tidak terkira kepada ibu beliau di atas doa, sokongan dan galakan beliau selama ini.

ACKNOWLEDGEMENTS

This acknowledgement is especially for Mr. Nazeri Abdul Rahman for his supervision and support during the preparation of this thesis. The author also would like to thank all of her friends who have gave the idea and taught her on Excel Programming. Finally, the author would like to thank her beloved mother for her prays, encouragement and support.

ABSTRAK

Teknologi 'Pinch' adalah satu penemuan yang baru yang di perkenalkan oleh Profesor Bodo Linnhof. Teknologi ini amat berguna di aplikasikan di dalam sistem penukaran tenaga haba. Teknologi ini digunakan untuk mengurangkan penggunaan tenaga di dalam sesuatu sistem. Apabila penggunaan tenaga dapat dikurangkan maka kos boleh dijimatkan. Terdapat dua kaedah yang penting dalam Teknologi 'Pinch' iaitu kaedah graf (Graphical Method) dan kaedah berjadual (Tabular Method). Tesis ini dibuat untuk melakukan analisa dan kajian tentang ketepatan setiap kaedah dalam menghasilkan sesuatu keputusan, dan membuat perbandingan di antara kaedah tersebut. Hasil kajian telah membuktikan bahawa kaedah bejadual (Tabular Method) telah menghasilkan japan dan keputusan yang tepat.

ABSTRACT

Pinch Technology is the new recovery which introduced by Professor Bodo Linnfot. This technology is useful in the application of heat exchanger system. The technology is to minimize the energy usage in the system. When the energy usage is reduced, thus the operating cost is also reduced. There are two important methods in Pinch Technology; Graphical Method and Tabular Method. This thesis will be carried out a research and analysis of the comparison of accuracy between both methods. The result of the study indicated that Tabular Method give the higher accuracy in producing result

LIST OF TABLES

Table 2.1:	Summary of Types of Heat Exchanger	15
Table 3.1:	Stream Data	18
Table 3.2:	Actual and Interval Temperatures	22
Table 4.1:	Stream Data	29

LIST OF FIGURES

Figure 1.1:	Shell and Tube Heat Exchanger	5
Figure 1.2:	Plate Heat Exchanger	5
Figure 1.3:	Parallel Flow Heat Exchanger	7
Figure1.4	Counter Flow Heat Exchanger	7
Figure 1.5:	Cross Flow Heat Exchanger	8
Figure 3.1:	Composite Stream Heat Flow Capacities	19
Figure 3.2:	Hot and Cold Composite Curves	20
Figure 3.3:	Composite Curves	21
Figure 3.4:	Stream Temperature Adjustment	23
Figure 3.5:	Adjusted Temperature Intervals and Stream Data	24
Figure 3.6:	Deficit and Surplus Heat Loads	26
Figure 3.7:	Table for Pinch Determination	28
Figure 4.1:	Hot Stream Composite	31
Figure 4.2:	Cold Composite stream	31
Figure 4.3:	Composite Streams from Excel	33
Figure 4.4:	Hot Composite Curve	34
Figure 4.5:	Cold composite Curve	35
Figure 4.6:	Composite Curves	35
Figure 4.7:	Stream Temperature Adjustment	37
Figure 4.8:	Adjusted Temperature Intervals	37
Figure 4.9:	Deficit and Surplus Heat Load Program	39
Figure 4.10:	Program for Pinch Determination	40
Figure 4.11:	The Accuracy of Method Program for 10 K and 20 K	42

Figure 5.1: The Accuracy for Different Pinch Technology Method 44

Figure 5.2: The Error in Excel Chart 46

Figure 5.3: The Accuracy for Different DT min 48

NOMENCLATURE

A	:	Area of the wall normal to heat flow [m^2]
C	:	Thermal capacity rate
DTmin	:	Minimum temperature difference
eb	:	Emissive power of blackbody [Energy per unit surface area and time]
h	:	Heat transfer coefficient [$W/m^2.K$]
L	:	The thickness of the wall [m]
Q	:	Heat flow rate [kW]
T	:	Temperature [°C]
T_{in}	:	Temperature inside the surface [°C]
T_{out}	:	Temperature outside the surface [°C]
T_s	:	Temperature of the Surface [°C]
T_∞	:	Temperature of the surrounding [°C]

Greek symbols

σ	:	Stefan-Boltzman constant [5.668×10^{-8} $W/m^2.K^4$]
∈	:	The emissity

Chapter 1
Introduction

Pinch Technology is the technology that relates with the system of heat exchanger. Thus, it is an advance study about heat transfer of stream flow in the heat exchanger.

1.1 Introduction to Heat Transfer

According to Bhalchandra and Robert [1989], heat is energy in transit due to a temperature difference. Heat transfer is the area of engineering that deals with the mechanisms responsible for transferring energy from one place to another when a temperature difference exists.

Transfer of heat between systems or phases occurs as a result of a difference in temperature. There are three different mechanisms in which the heat can be transferred; conduction, convection and radiation.

1.1.1 Conduction

Conduction occurs when the heat is transmitted from hot to cold region until the temperature is equalized. According to Fourier's Law of Heat Conduction:

$$Q = \frac{kA\,(T_{in} - T_{out})}{L} \qquad (1.1)$$

Where,

Q = Heat flow rate [W]

A = Area of the wall normal to heat flow [m^2]

L = The thickness of the wall [m]

T_{in} = Temperature inside the surface [°C]

T_{out} = Temperature outside the surface [°C]

For example, an oven is hot on the inside and cool on the outside. The rate of heat transferred, Q from the inside of the oven to the outside of the oven, is directly proportional to the surface area of the wall, A. The area is normal to the direction of heat flow, and inversely to the wall thickness, L, which is also depends on type of the material. [Bhalchandra et al, 1949]

1.1.2 Convection

Convection occurs whenever a surface is in contact with a fluid at a temperature that is different from its own. According to Bhalchandra and Robert [1989], when a hot vertical wall is heated by conduction, caused the fluid to become less dense. Due to the different in density, a buoyancy force is resulted and caused the lighter fluid to rise and replaced the cooler fluid. This process is being repeated continually. In practice, the following equation is used to determine convection heat transfers rates:

$$Q = hA\,(T_s - T_\infty) \qquad (1.2)$$

Where,

Q = Heat transferred from surface to the surrounding fluid [W]

A = Area of the surface [m^2]

T_s = Temperature of the surface [°C]

T_∞ = Temperature of the surrounding fluid [°C]

h = Heat transfer coefficient [W/ m^2K]

1.1.3 Radiation

This phenomenon is identical to the emission of light. It is a function of the absolute body temperature and nature of the emitting surface. According to John [1992], radiation is the transfer of heat from one body to another body not in contact with it by means of electromagnetic wave motion through space, even when a vacuum exists between them.

Liquid, solids and some gasses (especially water vapor and hydrocarbons) emit thermal radiation as a result of their high temperatures. An ideal emitter, called a blackbody, emits thermal radiation according to the Stefan-Boltzman equation [Bhalchandra et al, 1989]:

$$eb = \sigma T^4 \quad \text{------------------} \quad (1.3)$$

Where,

eb = Emissive power of the blackbody [Energy per unit surface area and time]

σ = Stefan-Boltzman constant [5.668×10^{-8} W/m^2.K^4]

T = Temperature in Kelvin

For non-black surface radiate according to the equation below:

$$e = \in e\,b \quad \text{------------------} \quad (1.4)$$

Where $\in$, the emissity, is a property of the surface and range from 0 for an ideal reflector to 1.0 for a blackbody.

1.2 Heat Exchanger

A heat exchanger is a device or equipment that can transfer thermal energy from a high temperature to a low temperature of moving fluid. Some examples of common heat exchangers are the baseboard heater, the automobile radiator and the domestic hot water heater.

Heat exchangers are widely used in chemical industries and power plant. Usually heat exchangers are specifically designed and fabricated for each service. There are two common types of heat exchangers; shell and tube exchanger as shown in **Figure1.1**, and plate heat exchanger as shown in **Figure 1.2**.

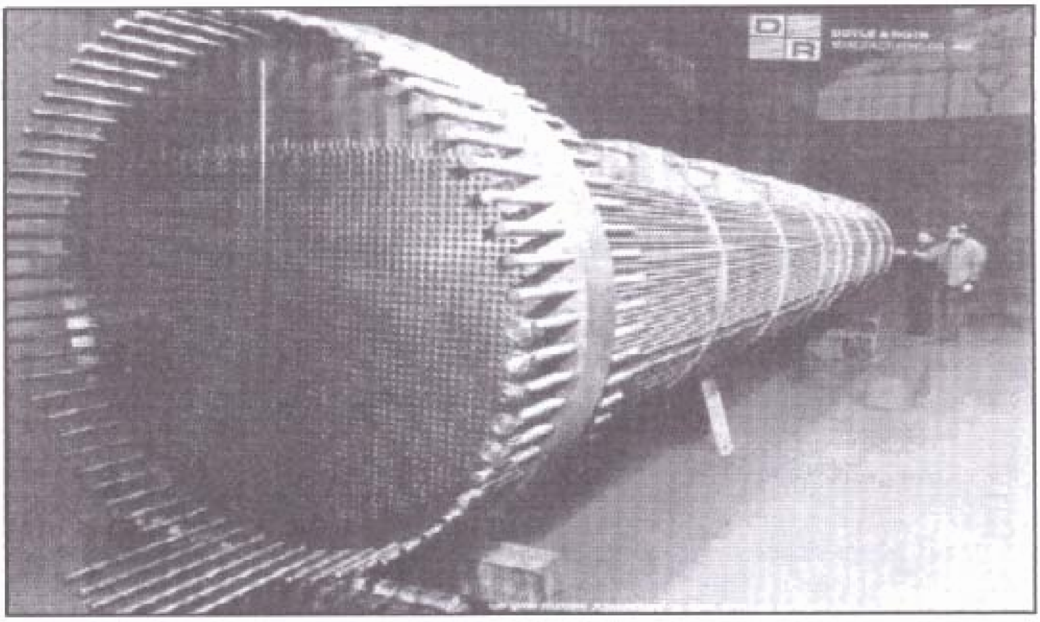

Figure 1.1: Shell and Tube Heat Exchanger [Nicholos et al, 1993]

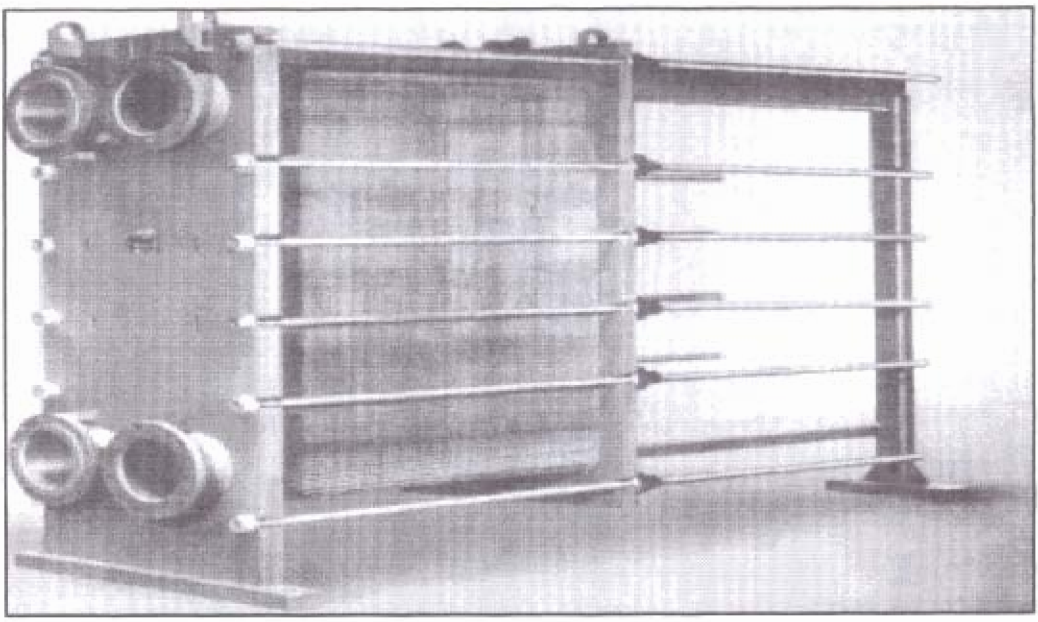

Figure 1.2: Plate Heat Exchanger [Nicholos et al, 1993]

1.2.1 Classification and Terminology of Heat Exchangers

Heat exchangers can be classified in many different ways. First is base on the relative directions of the flow of the hot and cold streams that are:

i) Parallel flow

The parallel flow occurs when both fluids move in the same direction. This arrangement is less efficient compare to counter and cross flow. For a given set of temperatures and heat transfer rate, this arrangement requires the largest heat transfer area. This arrangement is used when the heat exchanger performance is to be maintained constantly over a wide range of flow rates.

ii) Counter flow

Parallel flow occurs when the fluids move in parallel but in opposite direction. Thermodynamically, the counter flow arrangement is one of the most efficient arrangements. However, the problems associated with the headers for the two fluids can become rather complex, especially if the heat exchanger is to be physically compact.

iii) Cross flow

The cross flow arrangement occurs when the direction of flow is mutually perpendicular. The thermodynamic performance of a cross flow arrangement falls between parallel flow and counter flow. This arrangement can be very compact and it readily permits the use of extended surfaces. Consequently, in general, whenever one of the fluids is gas, the cross flow arrangement is used.

All these configuration are shown in **Figure 1.3** to **Figure 1.5**. According to the figures shown below, parallel flow and counter flow arrangement are applied in shell or tube heat exchanger, whereas cross flow arrangement is applied in plate heat exchanger.

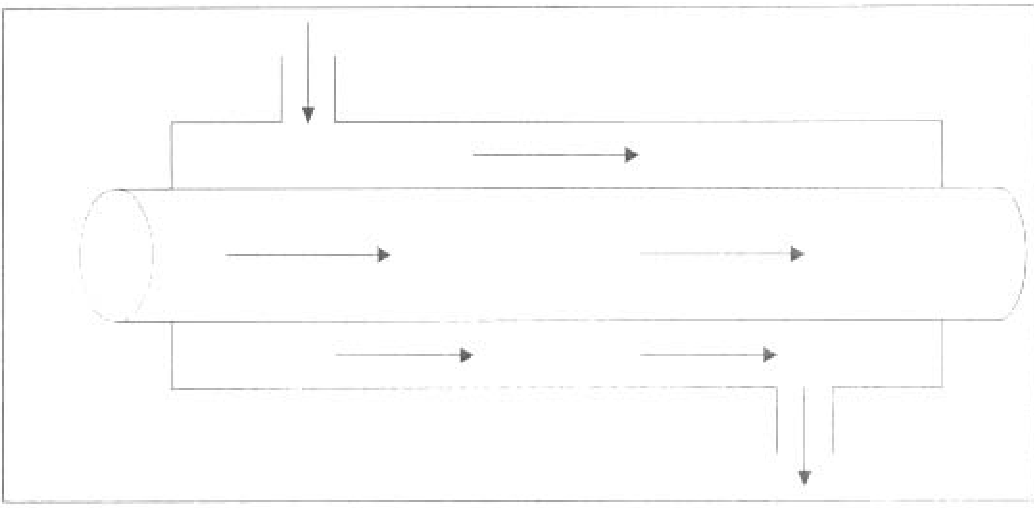

Figure 1.3: Parallel Flow Heat Exchanger [Bhalchandra et al, 1989]

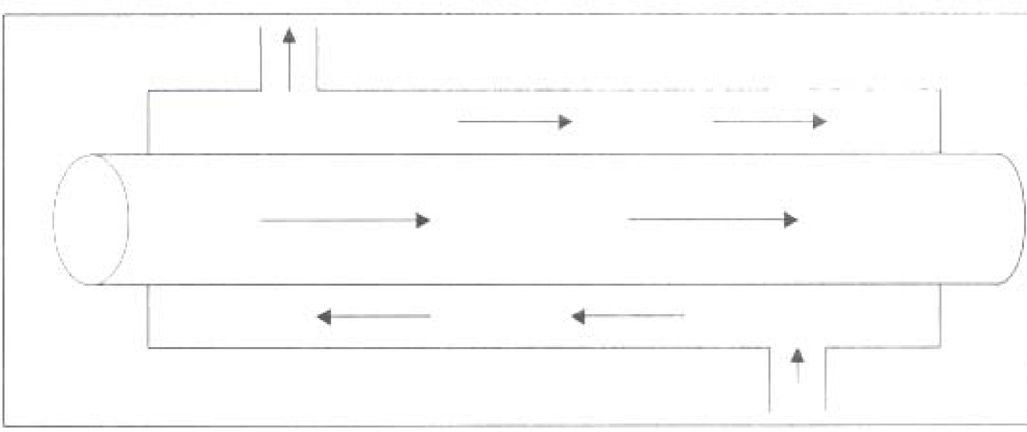

Figure1.4: Counter Flow Heat Exchanger [Bhalchandra et al, 1989]

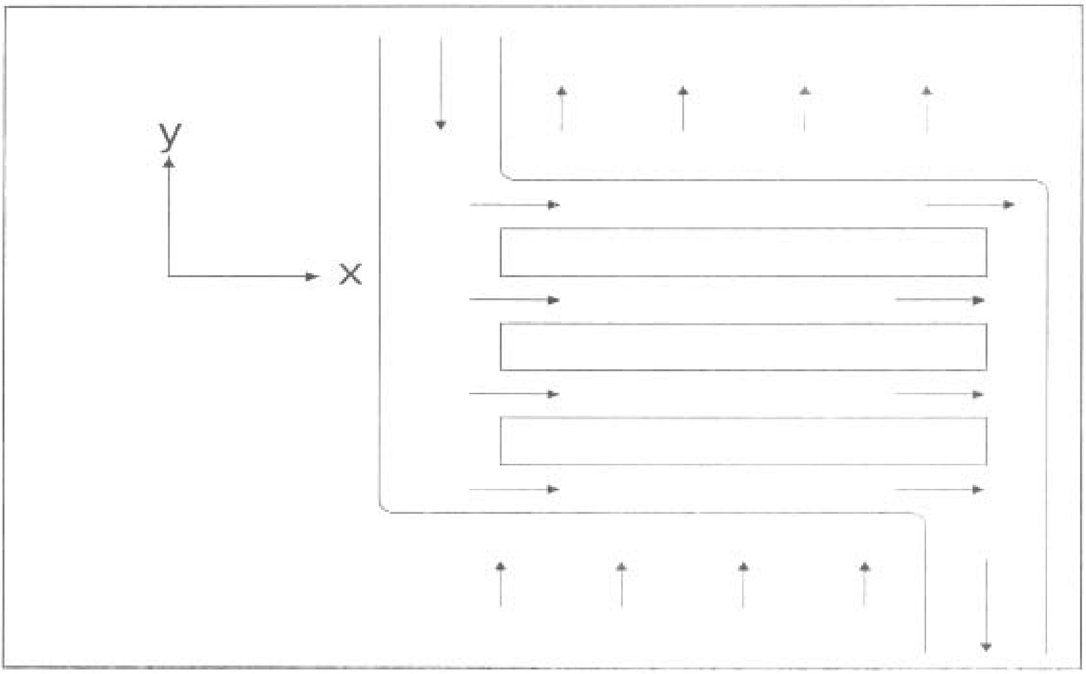

Figure 1.5: Cross Flow Heat Exchanger [Bhalchandra et al, 1989]

The parallel and the counter flow modes usually involve two concentric tubes with one fluid flowing in the central and the other flowing in the annulus. This configuration is shown in **Figure 1.3** and **Figure 1.4** and it is often called as double pipe heat exchanger since it involves two concentric pipes.

In **Figure 1.5**, there are a number of parallel paths for the fluid flowing in the x-direction (in the tubes), and each path is physically separated from its neighboring paths.

1.3 History and Terminology of Pinch Technology

Pinch Technology or Process Integration has been developed by Professor Bodo Linhoff and his co-workers of ETH Zurich, Leeds University, ICI and now University of Manchester Institute of Science and Technology (UMIST) in 1981 [Eastop, 1990]. The main purpose of designing this technology is to minimize the energy requirements for the heat exchanger of the process plants. Some of industries that are using process plant are oil refineries company, chemical, papers, food and drink manufacturing and many others.

Basically in the process plant require heating and cooling of the feed stock as the process occur.

The advantage of this advanced technology is, it's using the energy from a stream which requires cooling to heat another which requires heating. Therefore, the energy that has to be supplied from a high temperature source is reduced, and the energy that has to be rejected to a low temperature sink is also minimized. Both of these external transfers will also reduce the cost in running the plant.

Thus, Pinch Technology is an approach that provides a mechanism for automating the design process of heat exchangers and saving the energy for heat transfer with lower running cost.

1.4 Objectives of This Study

In Malaysia, the industrial area is still growing and many manufacturing companies have been developed by the government, private or even foreigners from other countries. According to Eastop [1990], many