

STUDY OF HEAT TRANSFER COEFFICIENT FOR MULTI-JET AIR IMPINGING
COOLING

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SUPERVISOR'S DECLARATION

I hereby declare that I have checked this project and in my opinion, this project is adequate in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering.

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I hereby declare that the work in this thesis is my own except for quotations and summaries which have been duly acknowledged. The thesis has not been accepted for any degree and is not concurrently submitted for award of other degree.

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**Dedicated to my beloved parents for their everlasting love, guidance and support
in the whole journey of my life**

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ABSTRACT

This thesis deals with a study of heat transfer coefficient for multi – jet air impinging cooling. Research and development for enhancement heat transfer using multi – jet air impinging cooling system shows variety possibilities. The required performance must be achieved in other to boost user satisfaction. The main objectives of this thesis are to study the effect of heat transfer coefficient by multi – jet impinging cooling system, and define the relationship between the heat transfer coefficient with the jet flow and the distance from exit nozzle to the heat source. The thesis described the methodology utilize and the result comparison among the jet used. Single, 4, and 9 jet nozzles with constant nozzle diameter, 4 *mm* were studied in this thesis with different jet flow and also various exit nozzle to heat source spacing. The heat source plate is constant at 100°C. Compressed Air as the coolant medium at room temperature with laminar flow at nozzle exit was studied along with 500, 950, 1960 and 2300 Reynolds numbers. From the results, it is observed that the experiment data using 9 jet array nozzle produced the highest Nusselt number in the range of 95 °C to 105 °C correspond to low temperature distribution due to many stagnation point formed. This shows the most efficient cooling system. The graph pattern shows the maximum and minimum point in view of the fact that there are many stagnation points. However, the single jet and 4 jet nozzle produced low Nusselt number. The Nusselt number graph trend is linearly decreased for single jet and linearly increased for 4 jet nozzle. The results concluded that the additional number of nozzle with higher Reynolds number and narrow spacing of exit nozzle to heat source plate being used, the more efficient performance produced. More stagnation point created during the impingement on the heat source will produced more effective cooling system. The experiment results are significant to improve the overheat component problem nowadays. The results can also significantly increase the performance of the needed component in order to improve product reliability and customer confidence.

ABSTRAK

Tesis ini membincangkan mengenai kajian berkaitan pekali pemindahan haba untuk penyejukan hentaman berbilang jet. Penyelidikan dan pembangunan untuk peningkatan pemindahan haba dengan menggunakan sistem hentaman jet dapat menunjukkan pelbagai kemungkinan. Prestasi yang diperlukan harus dicapai untuk meningkatkan kualiti produk dan kepuasan pengguna. Objektif utama tesis ini adalah untuk mengkaji kesan dari pekali pemindahan haba oleh sistem penyejukan hentaman jet berbilang, dan menentukan hubungan antara pekali perpindahan haba dengan aliran jet dan jarak daripada hujung nozel ke sumber haba. Tesis menerangkan metodologi dan keputusan perbandingan antara jet yang digunakan. Satu (1), empat (4), dan sembilan (9) jet nozel dengan diameter malar, 4 mm dikaji dalam tesis ini dengan jet yang berbeza aliran dan juga pelbagai jarak bagi hujung nozel hingga sumber haba. Sumber haba adalah tetap pada suhu 100 °C. Udara mampat dijadikan sebagai media penyejukan pada suhu bilik dengan aliran laminar pada hujung nozel dengan nombor Reynolds jet 500, 950, 1960 dan 2300. Daripada keputusan yang diperolehi, data menggunakan 9 jet nozel didapati menghasilkan bilangan nombor Nusselt tertinggi pada lingkungan 95 °C sehingga 105 °C. dan sesuai dengan taburan suhu rendah kerana banyak titik genangan terbentuk. Hal ini menunjukkan sistem penyejukan paling berkesan. Graf menunjukkan polar maksimum minimum berdasarkan fakta bahawa terdapat banyak titik genangan terbentuk pada 9 jet nozel. Namun, satu jet nozel dan 4 jet nozel menghasilkan nombor Nusselt yang rendah. Graf menunjukkan penurunan pada nombor Nusselt bagi satu jet manakala untuk 4 jet nozel pula menunjukkan peningkatan pada nombor Nusselt. Rumusan yang didapati adalah semakin bertambah jumlah tambahan nozel dengan peningkatan nombor Reynolds dan semakin kurang jarak hujung nozel ke sumber haba, maka semakin bertambah prestasi yang dihasilkan. Semakin bertambah titik genangan terhasil oleh hentaman jet, maka semakin bertambah berkesan sistem penyejukan tersebut. Keputusan ini dapat digunakan untuk memperbaiki masalah komponen yang terlalu panas pada ketika ini. Hasil ini juga dapat meningkatkan prestasi komponen yang diperlukan untuk menambah mutu produk dan kepercayaan pelanggan.

TABLE OF CONTENTS

	Page
SUPERVISOR’S DECLARATION	ii
STUDENT’S DECLARATION	iii
DEDICATION	iv
ACKNOWLEDGEMENTS	v
ABSTRACT	vi
ABSTRAK	vii
TABLE OF CONTENTS	viii
LIST OF TABLES	xi
LIST OF FIGURES	xiv
LIST OF SYMBOLS	xviii
LIST OF ABBREVIATIONS	xx
 CHAPTER 1 INTRODUCTION	
 1.1 Introduction	1
1.2 Problem Statement	2
1.3 Objectives	3
1.4 Scopes of Study	4
1.5 Process Flow Chart	4
 CHAPTER 2 LITERATURE REVIEW	
 2.1 Introduction	6
2.2 Jet Impingement Cooling	6
2.2.1 Jet Impingement Overview	6
2.2.2 Previous Research	10
2.3 Theory	16
2.3.1 Basic Concept in Heat Transfer	16
2.3.2 Laminar Boundary Layer	17
2.3.3 Nozzle Geometry	19
2.3.4 Reynolds Number	20
2.3.5 Entry Length in Laminar Flow	21

2.3.6	Heat Convection	22
2.3.7	Steady State	22
2.3.8	Heat Transfer Coefficient	23
2.3.9	Nusselt Number	24
2.3.10	Humidity	24

CHAPTER 3 METHODOLOGY

3.1	Project Process Flow	26
3.2	Experiment Apparatus	28
3.2.1	Portable Air Compressor	28
3.2.2	Heater (heat source)	28
3.2.3	Non – Contact Thermometer	29
3.2.4	Anemometer	29
3.2.4	Retort Stand	30
3.2.6	Pressure Control Valve	30
3.3	Overall Experiment Configuration	31
3.4	Plate Configuration	32
3.5	Velocity Calculation	32
3.5.1	For Reynolds Number, $Re = 500$	33
3.5.2	For Reynolds Number, $Re = 950$	33
3.5.3	For Reynolds Number, $Re = 1960$	33
3.5.4	For Reynolds Number, $Re = 2300$	33
3.6	Step by Step Procedure	34
3.7	Experiment Process Flow	35
3.8	Jet Impingement Cooling System Details	36
3.9	Experiment Data Distributions	37

CHAPTER 4 RESULTS AND DISCUSSION

4.1	Introduction	39
4.2	Results	39
4.2.1	For Reynolds Number, $Re = 500$; Height, $S = 0.8$ cm	43
4.2.2	For Reynolds Number, $Re = 500$; Height, $S = 1.6$ cm	44
4.2.3	For Reynolds Number, $Re = 500$; Height, $S = 2.4$ cm	45
4.2.4	For Reynolds Number, $Re = 500$; Height, $S = 3.2$ cm	46
4.2.5	For Reynolds Number, $Re = 950$; Height, $S = 0.8$ cm	47
4.2.6	For Reynolds Number, $Re = 950$; Height, $S = 1.6$ cm	48
4.2.7	For Reynolds Number, $Re = 950$; Height, $S = 2.4$ cm	49
4.2.8	For Reynolds Number, $Re = 950$; Height, $S = 3.2$ cm	50

4.2.9	For Reynolds Number, $Re = 1960$; Height, $S = 0.8$ cm	51
4.2.10	For Reynolds Number, $Re = 1960$; Height, $S = 1.6$ cm	52
4.2.11	For Reynolds Number, $Re = 1960$; Height, $S = 2.4$ cm	53
4.2.12	For Reynolds Number, $Re = 1960$; Height, $S = 3.2$ cm	54
4.2.13	For Reynolds Number, $Re = 2300$; Height, $S = 0.8$ cm	55
4.2.14	For Reynolds Number, $Re = 2300$; Height, $S = 1.6$ cm	56
4.2.15	For Reynolds Number, $Re = 2300$; Height, $S = 2.4$ cm	57
4.2.16	For Reynolds Number, $Re = 2300$; Height, $S = 3.2$ cm	58
4.3	Discussion	59
4.3.1	9 – Jet Nozzle with Various Reynolds Number, Re and Constant Height to Nozzle Diameter Ratio, $S/d = 2$	60
4.3.2	9 – Jet Nozzle with Reynolds Number, $Re = 2300$ and Various Height to Nozzle Diameter Ratio, S/d	61
4.3.3	The Predicaments	62

CHAPTER 5 CONCLUSION AND RECOMMENDATIONS

5.1	Conclusions	63
5.2	Recommendations	64

REFERENCES	65
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APPENDICES	66
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A	Table A-15	66
B1-B8	Data From Experiment	67
C	Sample Calculation	75
D1-D4	Graph of Plate Temperature After Impingement Versus Impingement Radius to Nozzle Diameter Ratio	76
E1-E4	Graph of Heat Transfer Coefficient Versus Impingement Radius to Nozzle Diameter Ratio	80
F1-F2	Gantt Chart	84
G	Experiment Setup	86
H	Experiment Progress	87

LIST OF TABLES

Table No.	Title	Page
3.1	Important parameter investigations	36
3.2	Experiment data distributions	37
4.1	Plate temperature, heat transfer coefficient, and Nusselt number distributions for Reynolds number, $R \epsilon = 500$ and height to nozzle ratio, $S/d = 2$	43
4.2	Plate temperature, heat transfer coefficient, and Nusselt number distributions for Reynolds number, $R \epsilon = 500$ and height to nozzle ratio, $S/d = 4$	44
4.3	Plate temperature, heat transfer coefficient, and Nusselt number distributions for Reynolds number, $R \epsilon = 500$ and height to nozzle ratio, $S/d = 6$	45
4.4	Plate temperature, heat transfer coefficient, and Nusselt number distributions for Reynolds number, $R \epsilon = 500$ and height to nozzle ratio, $S/d = 8$	46
4.5	Plate temperature, heat transfer coefficient, and Nusselt number distributions for Reynolds number, $R \epsilon = 950$ and height to nozzle ratio, $S/d = 2$	47
4.6	Plate temperature, heat transfer coefficient, and Nusselt number distributions for Reynolds number, $R \epsilon = 950$ and height to nozzle ratio, $S/d = 4$	48
4.7	Plate temperature, heat transfer coefficient, and Nusselt number distributions for Reynolds number, $R \epsilon = 950$ and height to nozzle ratio, $S/d = 6$	49
4.8	Plate temperature, heat transfer coefficient, and Nusselt number distributions for Reynolds number, $R \epsilon = 950$ and height to nozzle ratio, $S/d = 8$	50
4.9	Plate temperature, heat transfer coefficient, and Nusselt number distributions for Reynolds number, $R \epsilon = 1960$ and height to nozzle ratio, $S/d = 2$	51
4.10	Plate temperature, heat transfer coefficient, and Nusselt number distributions for Reynolds number, $R \epsilon = 1960$ and height to nozzle ratio, $S/d = 4$	52

4.11	Plate temperature, heat transfer coefficient, and Nusselt number distributions for Reynolds number, $Re = 1960$ and height to nozzle ratio, $S/d = 6$	53
4.12	: Plate temperature, heat transfer coefficient, and Nusselt number distributions for Reynolds number, $Re = 1960$ and height to nozzle ratio, $S/d = 8$	54
4.13	Plate temperature, heat transfer coefficient, and Nusselt number distributions for Reynolds number, $Re = 2300$ and height to nozzle ratio, $S/d = 2$	55
4.14	Plate temperature, heat transfer coefficient, and Nusselt number distributions for Reynolds number, $Re = 2300$ and height to nozzle ratio, $S/d = 4$	56
4.15	Plate temperature, heat transfer coefficient, and Nusselt number distributions for Reynolds number, $Re = 2300$ and height to nozzle ratio, $S/d = 6$	57
4.16	Plate temperature, heat transfer coefficient, and Nusselt number distributions for Reynolds number, $Re = 2300$ and height to nozzle ratio, $S/d = 8$	58
4.17	9 – jet nozzle with various Reynolds number, Re and constant height to nozzle diameter ratio, $S/d = 2$	60
4.18	9 – jet nozzle with Reynolds number, $Re = 2300$ and various height to nozzle diameter ratio, S/d	61
6.1	Table A – 15	66
6.2	Temperature distributions for Reynolds number, $Re = 500$ and height to nozzle ratio, $S/d = 2$	67
6.3	Temperature distributions for Reynolds number, $Re = 500$ and height to nozzle ratio, $S/d = 4$	67
6.4	Temperature distributions for Reynolds number, $Re = 500$ and height to nozzle ratio, $S/d = 6$	68
6.5	Temperature distributions for Reynolds number, $Re = 500$ and height to nozzle ratio, $S/d = 8$	68
6.6	Temperature distributions for Reynolds number, $Re = 950$ and height to nozzle ratio, $S/d = 2$	69
6.7	Temperature distributions for Reynolds number, $Re = 950$ and height to nozzle ratio, $S/d = 4$	69

6.8	Temperature distributions for Reynolds number, $Re = 950$ and height to nozzle ratio, $S/d = 6$	70
6.9	Temperature distributions for Reynolds number, $Re = 950$ and height to nozzle ratio, $S/d = 8$	70
6.10	Temperature distributions for Reynolds number, $Re = 1960$ and height to nozzle ratio, $S/d = 2$	71
6.11	Temperature distributions for Reynolds number, $Re = 1960$ and height to nozzle ratio, $S/d = 4$	71
6.12	Temperature distributions for Reynolds number, $Re = 1960$ and height to nozzle ratio, $S/d = 6$	72
6.13	Temperature distributions for Reynolds number, $Re = 1960$ and height to nozzle ratio, $S/d = 8$	72
6.14	Temperature distributions for Reynolds number, $Re = 2300$ and height to nozzle ratio, $S/d = 2$	73
6.15	Temperature distributions for Reynolds number, $Re = 2300$ and height to nozzle ratio, $S/d = 4$	73
6.16	Temperature distributions for Reynolds number, $Re = 2300$ and height to nozzle ratio, $S/d = 6$	74
6.17	Temperature distributions for Reynolds number, $Re = 2300$ and height to nozzle ratio, $S/d = 8$	74
6.18	Experiment setup	86
6.19	Experiment progress	87

LIST OF FIGURES

Figure No.	Title	Page
1.1	Process flow chart	5
2.1	Surface impingement of a single round or slot gas jet	7
2.2	The flow field characteristics of three turbulent slot jets	9
2.3	Full field heat transfer coefficient distribution; $d = 0.5 \text{ mm}$, $Re = 5000$; $H/d = 1$ (Air Jet)	11
2.4	Local Heat Transfer Coefficient; $d = 0.5 \text{ mm}$; $H/d = 2, 4$; $Re = 1000, 5000$; (Air Jet)	12
2.5	Local heat transfer coefficient distribution; $d = 0.5 \text{ mm}, 1 \text{ mm}, 1.5 \text{ mm}$; $H/d = 2$; $Re = 5000$; (Air Jet)	13
2.6	Local heat transfer distribution; $d = 1.5 \text{ mm}$, $H/d = 1, 2, 4$; $Re = 20000$; (Air Jet)	14
2.7	Local heat transfer coefficient distribution; $d = 1 \text{ mm}$; (Water Jet)	15
2.8	Local heat transfer distribution; $d = 1 \text{ mm}$, Air Jet (left), Water Jet (right)	16
2.9	A boundary layer of thickness, δ	17
2.10	Boundary layer on a long, flat surface with a sharp leading edge	18
2.11	Laminar – turbulent flow transition experiment	18
2.12	Humidity or Psychrometric chart based on normal temperature at sea level in SI metric units at barometric pressure 101.325 kPa	25
3.1	Project process flow chart	27
3.2	Portable air compressor	28
3.3	Flat plate heater (heat source)	28
3.4	Non – contact thermometer	29
3.5	Anemometer	29
3.6	Retort stand	30

3.7	Pressure control valve	30
3.8	Overall experiment configuration	31
3.9	Heat source plate configuration	32
3.10	Experiment process flow chart	35
4.1	Graphs of Nusselt number, Nu versus impinge radius to nozzle diameter ratio, r/d for Reynolds number, $Re = 500$ and height to nozzle ratio, $S/d = 2$	43
4.2	Graphs of Nusselt number, Nu versus impinge radius to nozzle diameter ratio, r/d for Reynolds number, $Re = 500$ and height to nozzle ratio, $S/d = 4$	44
4.3	Graphs of Nusselt number, Nu versus impinge radius to nozzle diameter ratio, r/d for Reynolds number, $Re = 500$ and height to nozzle ratio, $S/d = 6$	45
4.4	Graphs of Nusselt number, Nu versus impinge radius to nozzle diameter ratio, r/d for Reynolds number, $Re = 500$ and height to nozzle ratio, $S/d = 8$	46
4.5	Graphs of Nusselt number, Nu versus impinge radius to nozzle diameter ratio, r/d for Reynolds number, $Re = 950$ and height to nozzle ratio, $S/d = 2$	47
4.6	Graphs of Nusselt number, Nu versus impinge radius to nozzle diameter ratio, r/d for Reynolds number, $Re = 950$ and height to nozzle ratio, $S/d = 4$	48
4.7	Graphs of Nusselt number, Nu versus impinge radius to nozzle diameter ratio, r/d for Reynolds number, $Re = 950$ and height to nozzle ratio, $S/d = 6$	49
4.8	Graphs of Nusselt number, Nu versus impinge radius to nozzle diameter ratio, r/d for Reynolds number, $Re = 950$ and height to nozzle ratio, $S/d = 8$	50
4.9	Graphs of Nusselt number, Nu versus impinge radius to nozzle diameter ratio, r/d for Reynolds number, $Re = 1960$ and height to nozzle ratio, $S/d = 2$	51
4.10	Graphs of Nusselt number, Nu versus impinge radius to nozzle diameter ratio, r/d for Reynolds number, $Re = 1960$ and height to nozzle ratio, $S/d = 4$	52

4.11	Graphs of Nusselt number, Nu versus impinge radius to nozzle diameter ratio, r/d for Reynolds number, $Re = 1960$ and height to nozzle ratio, $S/d = 6$	53
4.12	Graphs of Nusselt number, Nu versus impinge radius to nozzle diameter ratio, r/d for Reynolds number, $Re = 1960$ and height to nozzle ratio, $S/d = 8$	54
4.13	Graphs of Nusselt number, Nu versus impinge radius to nozzle diameter ratio, r/d for Reynolds number, $Re = 2300$ and height to nozzle ratio, $S/d = 2$	55
4.14	Graphs of Nusselt number, Nu versus impinge radius to nozzle diameter ratio, r/d for Reynolds number, $Re = 2300$ and height to nozzle ratio, $S/d = 4$	56
4.15	Graphs of Nusselt number, Nu versus impinge radius to nozzle diameter ratio, r/d for Reynolds number, $Re = 2300$ and height to nozzle ratio, $S/d = 6$	57
4.16	Graphs of Nusselt number, Nu versus impinge radius to nozzle diameter ratio, r/d for Reynolds number, $Re = 2300$ and height to nozzle ratio, $S/d = 8$	58
4.17	Graph of 9 – jet nozzle with various Reynolds number, Re and constant height to nozzle diameter ratio, $S/d = 2$	60
4.18	Graph of 9 – jet nozzle with Reynolds number, $Re = 2300$ and various height to nozzle diameter ratio, S/d	61
6.1	Plate temperature versus r/d for Reynolds number, $Re = 500$, and S/d (a) 2, (b) 4, (c) 6, (d) 8	76
6.2	Plate temperature versus r/d for Reynolds number, $Re = 950$, and S/d (a) 2, (b) 4, (c) 6, (d) 8	77
6.3	Plate temperature versus r/d for Reynolds number, $Re = 1960$, and S/d (a) 2, (b) 4, (c) 6, (d) 8	78
6.4	Plate temperature versus r/d for Reynolds number, $Re = 2300$, and S/d (a) 2, (b) 4, (c) 6, (d) 8	79
6.5	Heat transfer coefficient versus r/d for Reynolds number, $Re = 500$, and S/d (a) 2, (b) 4, (c) 6, (d) 8	80
6.6	Heat transfer coefficient versus r/d for Reynolds number, $Re = 950$, and S/d (a) 2, (b) 4, (c) 6, (d) 8	81

6.7	Heat transfer coefficient versus r/d for Reynolds number, $Re = 1960$, and S/d (a) 2, (b) 4, (c) 6, (d) 8	82
6.8	Heat transfer coefficient versus r/d for Reynolds number, $Re = 2300$, and S/d (a) 2, (b) 4, (c) 6, (d) 8	83
6.9	Gantt chart for FYP 1	84
6.10	Gantt chart for FYP 2	85

LIST OF SYMBOLS

δ or t	Thickness, (m)
μ	Dynamic viscosity of the fluid, ($Pa \cdot s$ or $N \cdot s/m^2$)
\dot{m}	Mass flow rate, (kg/s)
\dot{Q}_{con}	Heat convection rate, ($Watt$)
$\dot{Q}_{stea-s ta}$	Rate of net heat transfer, (kJ/s)
ρ	Density of the fluid, (kg/m^3)
ν	Kinematic viscosity, ($\nu = \mu / \rho$), (m^2/s)
d	Inner diameter, (m)
h	Convection heat transfer coefficient, ($W/m^2 \cdot ^\circ C$)
k	Thermal conductivity, ($W/m \cdot K$)
A	Pipe cross-sectional area, (m^2)
A_c	Plate cross-section area, (m^2)
A_s	Heat transfer surface area, (m^2)
C_p	Constant pressure specific heat, ($kJ/kg \cdot K$)
L or r	Radius of the impingement region, (m)
L_h	Hydrodynamic entry length, (m)
N	Number of jet
Nu	Nusselt number
Q	Volumetric flow rate, (m^3/s)
Re	Reynolds number
S	Exit nozzle to heat source plate distance, (m)
ΔT	Temperature different, (K)
T_∞	Temperature of the fluid, ($^\circ C$)

T_s	Surface temperature, ($^{\circ}\text{C}$)
V	Mean fluid velocity, (m/s)

LIST OF ABBREVIATIONS

FKKASA	Fakulti Kejuruteraan Kimia dan Sumber Asli
FKM	Fakulti Kejuruteraan Mekanikal
FYP	Final year project
STD	Standard deviation

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

The demand for high performance electronic has increased from time to time. There is a competing race among electronic manufacturers to produce new high performance electronic products to satisfy users. Nowadays, more and more customers require electronic components to be faster, smaller, and able to handle a higher amount of power and be more reliable than ever before. In such electronic components, there will be problems arising due to smaller size and higher power which lead to high heat fluxes that need to be removed to avoid failure. The surface temperature of the devices or components must be decreased to a lower temperature to improve speed and reliability.

So the demand for effective cooling systems has made the industry to adapt several techniques. For example, traditional cooling systems are used with an air flow produced from an electric fan. But this method does not fulfill high performance requirements nowadays. It does not efficiently cool the electronic device so that the performance can be increased. Therefore as a promising technique, industrial engineering is paying attention on a cooling system which is known as ‘‘Spray Cooling Technique’’. This technique can be implemented by means of liquid jets or air jet impingement cooling system.

According to many researchers which work on jet impingement cooling systems, jet impingement provides a higher cooling performance compared to a duct flow type convective cooling systems. This is attributed to a thin boundary layer formed on a

heated surface by a jet impingement, which results in a higher convective heat transfer coefficient. Due to that reason, many researchers have performed lots of studies on the jet impingement heat transfer on smooth targets. Recently, several works on single jet impingement heat transfer from extended surfaces such as pin fin, pyramid fin, mesh fin and aluminum foam fin have been published and have reported more enhanced heat transfer. Among the various types of jet impinging schemes, it has been reported that the multi-jet impingement has a characteristic of multiple stagnation zones, thereby increasing the overall heat transfer coefficient from a heated surface. Whereas, the single jet impingement system provides gradually decreasing local heat transfer coefficients in downstream regions of the single stagnation zone.

1.2 PROBLEM STATEMENT

Nowadays, technology has under gone many changes due to IT. So as well as the engineering sector too. Many equipments or appliances need to have high heat transfer performance to guarantee the quality and also to increase the capability. For example in super computers, old cooling systems cannot be used anymore as it does not cool sufficiently. This problem can cause damage to the super computer processor. This makes it necessary to develop new techniques to meet the demand. So, researchers are moving toward the technology of jet impingement cooling systems. This technique becomes more interesting using multi-jet impingement cooling systems. Lots of researches have to be done in this field to make sure all capabilities required will be achieved.

Another limitation caused by excess heat generation is that it directly limits the performance potential of the component. A good example of this effect is in the case of computer processors. As the speed of the processor is increased, the amount of heat the device generates increases proportionally. Since this heat is typically dissipated by some external cooling system, the performance of the processor is directly linked to how well this system operates, so if it has limitations, those limitations will be reflected back onto the performance of the processor. An example of this comes from recent history; In the middle of 2005, Apple Computer Inc. announced that they would stop using IBM's PowerPC processor in their computers and switch to Intel's Core Duo line of

processors. (William Chow, 2006) The main motivation behind this switch was the fact that IBM's processor ran at very high temperatures when compared to Intel's chip. Since most modern personal computers are still air-cooled using fans and heat sinks, the IBM processor ultimately reached its limit; it could no longer increase its performance without exceeding the heat flux capacity of its air-cooling system.

Looking generally at the realm of consumer electronics, allowing a device to exceed its ideal operating temperature possesses even more consequences. Not only should the temperature be within the correct operating range for both performance and reliability, this ideal temperature should be low enough for safe handling by the consumer. For example, a common complaint about portable computers is that they tend to dissipate heat poorly, causing the heat from its internal components to radiate through the outer casing, making the surfaces hot to touch. This is an obvious deterrent, for if the temperature were to reach an unsafe level, the risk of injury would increase. Furthermore, the increasing demand for portability in modern electronics only further emphasizes the need for more effective methods of high-heat dissipation.

With this inspiration, there is an idea to study on how single jet and multi jet impingement cooling systems are working, and what will be the effect on the cooling system. There must be a comparison among these methods.

1.3 OBJECTIVES

The main objectives of this study are:

- i. To study the effect of heat transfer coefficient by multi – jet impinging cooling system,
- ii. And define the relationship between the heat transfer coefficient with the jet flow and distance, S (the distance from exit nozzle to the heat source).

1.4 SCOPES OF STUDY

This study was carried out using air as the coolant medium that impinge with laminar flow region from the nozzles to the heat source which has Reynolds number in the range of 500 – 2300 (500, 950, 1960, 2300). This study started with single nozzle impingement and continues with 4 and 9 jet array nozzle impingement. The heat source is constant temperature at 100 °C which used steel as the material with the dimensions (12.0 x 12.0 x 0.8) *cm* with 6.5 *cm* diameter impingement region. The impingement region is specialist with 2.5 *cm* height wall. The nozzle diameter and length is also constant with 0.4 *cm* inner diameter and 5 *cm* long respectively. The nozzle material is made from brass. This study have diameter ratio, 16 impingement diameter on the heat source to the nozzle diameter, D/d . Then, the temperature effect is measured on the heat source plate using laser thermocouple by pointing on the heat source plate point prepared. This study also consists of designing and fabricating the nozzle together with the impingement cooling system.

1.5 PROCESS FLOW CHART

Figure 1.1 shows the separation of information or processes in a step-by-step flow and easy to understand diagrams showing how steps in a process fit together. This makes useful tools for communicating how processes work and for clearly due time limitation on how a particular job is done in FYP 1 and FYP 2.

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