NUMERICAL SIMULATION ON MICRO CHANNEL HEAT EXCHANGER

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I / We* admit that had read this dissertation and in my / our* opinion this dissertation is satisfactory in the aspect of scope and quality for the bestowal of Bachelor of Mechanical Engineering (Thermal and Fluid)

Signature :…………………

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Date :…………………

"I declare that this report is done by my own exclude the citation with the mentioned references for each."

Signature: …………………….

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Date: 13th May 2008………….

ABSTRACT

Recently, advanced in the technologies have made possible the use of microchannel heat exchanger in wide industry application. There are numbers of experiments and numerical simulations carried out by previous researcher in order to investigate the performance of the microchannel. In order to see and understand the optimal performance of microchannel heat exchanger, heat transfer and pressure drop behaviour and characteristics was analyzed through the numerical simulation. The incompressible laminar Navier Stokes will be employed as the governing conservation equation. A three dimensional model was developed to simulate the heat transfer performance of microchannel heat exchanger. CFD software was used in this study. With the appropriate meshing size, the model was tested on the grid independence test. The three dimensional model will be use and validated with the numerical code technique. The results then will be analysis for further studies.

ABSTRAK

Sejak kebelakangan ini, dengan teknologi yang semakin berkembang membolehkan penggunaan penukaran haba dalam saiz yang kecil iaitu penukar haba *microchannel* dapat meluaskn penggunaannya terutama di dalam bidang perindustrian. Eksperimen-eksperimen dan simulasi kaedah berangka telah dilaksanakan oleh penyelidik-penyelidik terdahulu untuk menyiasat prestasi penukar haba yang bersaiz mikro ini. Antara parameter-parameter yang penting untuk dianalisis adalah seperti pemindahan haba dan jisim serta penurunan tekanan. Jenis aliran bendalir yang tidak boleh mampat akan mengunakan persamaan dari *Navier Stokes*. Model tiga dimensi akan digunakan untuk proses simulasi ini dan perisian CFD akan digunakan untuk menentukan keputusan. Teknik simulasi yang akan digunakan. Setelah keputusan didapati, nilai ini akan di analisis untuk penggunaan pembelajaran dimasa akan dating. Hasil dari keputusan serta perbincangan akan direkodkan.

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LIST OF SYMBOL

AR	=	Aspect ratio
CFD	=	Computational Fluids Dynamic
Dh	=	Hydraulic diameter
f	=	Other forces such as gravity or centrifugal, N
H	=	Height of Channel, m
k	=	Thermal conductivity, W/mK
L	=	Length of the channel, m
Pr	=	Prandlt number
Δp	=	pressure loss, Pa
wc	=	Width of Channel, m
V	=	Velocity vector
Re	=	Reynolds number
t	=	Time, s
Tin	=	Temperature inlet, K
C_p	=	Pressure coeeficient
	=	Mass flow rate
q_w	=	heat flux, W/m^2
u,v,w	=	Velocity components in x, y and z direction. m/s
x,y,z	=	Cartesian coordinates
ρ	=	Density, m/kg
μ	=	Dynamic Viscosity
τ	=	Wall shear stress
ε	=	Heat transfer efficiency, l

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.0 Introduction to Microchannel Heat Exchanger

The development of heat exchangers become more advanced and with the technology improved, the size of conventional macro-scale heat exchangers turn to micro-scale heat exchangers. Microchannel heat exchanger applications have been used in various industries despite the trend towards miniaturization and the advances in micro fabrication. Some of the industries have been use micro fabrication applications in their works. The industries are such as automotive, electronic, robotics and commercial telecommunications.

Microchannels heat exchanger transfer heat through multiple flat fluid filled tubes containing small channels while air travels perpendicular to the flow. The widths of the channel range from 10 to 1000 μm (Qu and Issam, 2002). By constraining the flow to such narrow channels, thermal diffusion lengths are short, and the characteristic heat transfer coefficients are very high. Since the thermal performance is so strong, short flow passages are required, and with many flow passages in parallel in a small device, the pressure drop can be small as well. These are important factors in the design of heat exchangers.

The study Hwang *et* al. (2004) present the approach for determining simulation flow in microchannel heat sink using an analytical method of calculating the geometric parameters involves the usage of Computational Fluid Dynamic (CFD) simulation where it develop the CFD code. In the mainstream of the numerical approaches, a very simple 2-dimensional heat transfer model was used to determine the optimal value or in some cases, a very coarse mesh was adopted to use in the numerical approach. Numerical approach is the study of algorithms for the problems of continuous mathematics (as distinguished from discrete mathematics). The interpolation algorithms were used as part of the software for solving differential equations. In recent times, 3-dimensional semi-normalized numerical method were proposed by Li and Peterson, (2007) to explore the optimal geometry of the parallel microchannel heat sinks and demonstrated that on a silicon wafer with a typical thickness of 450 μm, the configurations first used by Tuckerman and Pease (1981) were quite close to the optimized values predicted by their numerical model.

In this study, important consideration such as the parameters and related boundary conditions were used to analyze the heat transfer in microchannel. A numerical model of three dimensional with fully developed flow is presented and is based upon simplified approach using CFX software. The measurements and predictions are very important for development of micro-channel, in order to be more efficient and more reliable system. It is also to understand the behaviors of microchannel under different thermal loads. The thermal loads parameter from the basic research mainly focuses on pressure drop, temperature distributions and heat fluxes distributions.

1.1 Microchannel Structure

Microstructure heat exchangers are working according to the same principles as conventional heat exchangers. Micro scale devices are available as commercial-off-the-shelf components from a number of vendors, in a variety of basic designs (cross flow, counter flow and concurrent flow), and suited to mass flows ranging from some milligrams per hour to several tons per hour, dependent on the sizes of the device as a whole and on the size of the integrated microstructures (Brandner, J.J *et* al. 2006). The manufacturing of microstructure heat exchangers is made by mechanical micromachining of stainless steel foils, their subsequent stacking, diffusion bonding, and packaging. Figure 1.1 shows cross flow microstructure made of stainless steel.

Figure 1.1 Cross flow microstructure heat exchanger made of stainless steel
(Source: Brandner *et* al. 2006)

Microchannel heat exchangers are design with planar arrays of micro channel such as thin foils and by subsequently assemble stacks of foils. Microchannel implies that all characteristic dimensions of the channels, for width and depth and wall thicknesses are in the sub-millimeter range of size. Figure 1.2 shows an example of microchannel heat exchanger of the silicon layer.

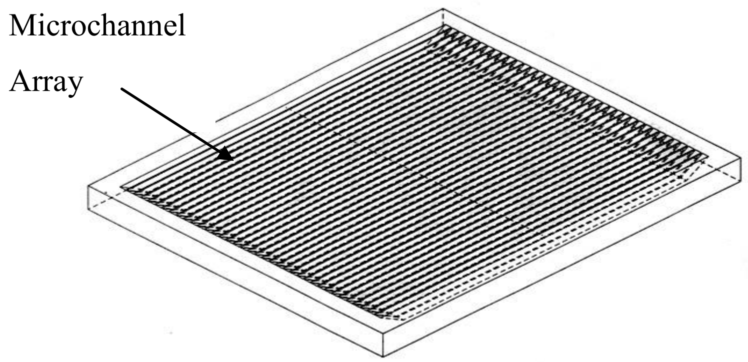

Figure 1.2 Schematic of the silicon layer of the micro-channel heat exchanger.
(Source: www.engineering.ucsb.edu)

1.2 Advantages of Microchannel Heat Exchanger

Current heat exchangers use a conventional fin-tube design, which results in a big volume and low efficiency of thermal management systems. For the same thermal duty and pressure drops of conventional heat exchangers, microchannel is typically about one-fifth the size and highly compact. The innovative technology of microchannel enables compact micro channel heat exchangers with enhanced heat transfer area to be fabricated from any material (including metals, ceramics inter metallic and composites). The thermal efficiency of the microchannel heat exchangers, which combine the advantages of micro channel and foam structures in one device, will be significantly higher than that of traditional ones.

1.3 Industrial applicability

Commercial applications and other benefits for microchannel is lightweight, environmental restoration, global climate control, and industrial chemical processing. Other applications of microchannel heat exchangers are include man-portable heating and cooling systems, distributed space conditioning of buildings and water heating.

For industrial production applications only a very limited number of involving microstructure heat exchangers has been realized to date. Application development tests are mainly being run on the laboratory and prototype scale, like the DEMIS® project for the heterogeneously catalyzed epoxidation of propane in the chemical industry. Many of the projects being conducted today specifically focus on fuel cell technology and the required peripherals. Fouling inside the microstructures from macro scale connection tubing to micro structured parts of the flow path is expected to limit the usefulness of microstructure devices in a production environment. Another factor affecting industry's willingness to consider the use of microstructure devices is the perceived low throughput of these devices. Early demonstrators and prototypes of microstructure devices were only suitable for small throughputs, there are today devices available designed for mass flows of several tons per hour and used in commercial production in the chemical industry. One example for the industrial use of microstructure heat exchangers is electrically powered device used in the production of bio-diesel were shown in Figure 1.3.

By expanding the range of materials used to fabricate such as polymers and ceramic, may further enhance the performance on microchannel heat exchanger in industrial applications. Figure 1.4 shows sinusoidally shaped microchannels in two halves (facing each other) of a polymer device made by microstereolithography.

Figure 1.3 Electrically powered microstructure heat exchanger used in the production of bio-diesel
(Source: Brandner, J. J. *et.* al. 2006)

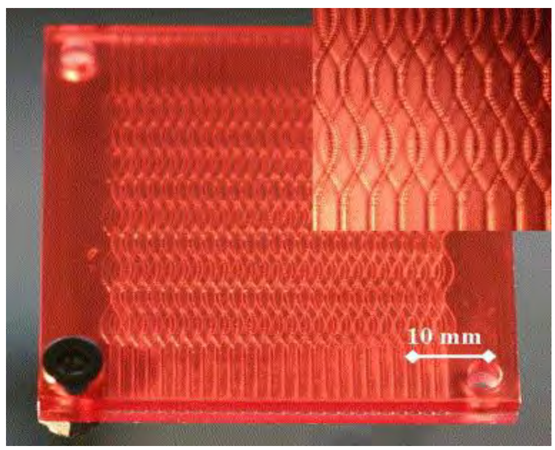

Figure 1.4 Sinusoidally shaped microchannels in two halves (facing each other) of a polymer device made by microstereolithography
(Source: Brandner, J. J. *et.* al. 2006)

1.4 Objective

The main objectives of this research are as below:-

a) To simulate flow in microchannel heat sink using CFX software
b) To study the behaviors under different thermal loads parameter. The parameters include in this study are pressure drop, heat flux and temperature distributions.

1.5 Problem Statement

a) To evaluate the pressure loss phenomenon and heat transfer efficiency of micro channel heat exchanger, due to the constraint where heat exchanger is extremely small and difficult to be measured.

b) Previous published journal of micro channel provided some guidance and information about the behavior of the fluid flow field and heat transfer, but some important absolute values were not presented example the total pressure drop along the flow. The neglecting of pressure drop may influence the results of simulation

Related to the problem statement, this study is intended to determine the desirable value of pressure drop. In order to interpret data accurately, the value of pressure drop will be define by the Nusselt number (Nusselt number is a dimensionless number that measures the enhancement of heat transfer from a surface that occurs in a real situation, compared to the heat transferred if just conduction occurred) distributions and heat flux distributions. It is essential to develop the temperature measurement method to measure temperature distribution so thermal stress may be predict and evaluation of pressure drop can be done.

CHAPTER 2

LITERATURE REVIEW

2.0 Analysis of Microchannel for Intergrated Cooling

The technologies in microfabrication allow microchannel heat exchanger where consisting of multiple flow conduits to be manufactured. The microchannel were being characterized by extremely high surface area per unit volume of working fluid, low thermal resistance, low mass, low volume and low inventory of working fluid. Weisberg *et* al. (1991) analyze the microchannel heat exchanger by solving numerically a conjugate heat transfer problem consisting of the simultaneous determination of the temperature fields in both the solid substrate and the fluid.

Typically, the flow channels are fabricated from thin sheets of silicon, metal or other suitable materials. The individual thin sheets can be either used separately to form flat plate heat exchangers or they can be stacked and bonded to form a parallel, counter, or cross flow heat exchangers (Weisberg *et* al. 1991). The illustrations of flat plate are shown in Figure 2.1 and Figure 2.2.