APPROVAL

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

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Date	: 18 MEI 2009

STUDY ON THE LAMINAR PULSED FLOW IN MICROCHANNEL

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MEI 2009

DECLARATION

"I verify that this report is my own work except for the citation and quotation that the source has been clarify for each one of them"

Signature :………………………..

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Date : 18 MEI 2009

DEDICATION

To my beloved family for their encouragement and support especially, and for their understanding in the way I am.

ACKNOWLEDGEMENT

In this great opportunity, I would like to thank Allah for providing me strengths to finish up this project and finally it was completed. Here, I would like to acknowledge with appreciation to all those people who helped me numerously during finish up my project for this year.

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ABSTRACT

The present work aims to model fully developed laminar flow, particularly pulsed flow, of Newtonian fluids in rectangular channels and to analyze the application of pulsed flow to microfluidic devices. For this purpose simulation using GAMBIT version 2.2 and FLUENT version 6.2 are extended. The meshes generated had been tested for grid independency and the result numerically iterated by FLUENT have to validate from published paper. Simulation solutions for these flow properties under any pressure gradient are obtained and simplified for periodic pressure gradients. The pulsating flow amplitude was 50% of the mean pressure and the flow regime is laminar. Pulsation tested with frequency by 5 kHz and the result of simulation had been analyzed and compared to various published data. The validation was unsuccessful due to difficulty to get a complete data from published analytical paper and too many assumptions had to be made, resulting to unsuccessful validation. Although, the validation of the model was unsuccessful, this study has somehow show a possibility of simulating oscillating flow using Computational Fluid Dynamic software (CFD).

ABSTRAK

Dalam kajian-kajian terkini yang telah dilakukan untuk mencapai sepenuhnya aliran lamina, terutama bila terdapat aliran yang berdenyut, terhadap cecair-cecair Newton dalam saluran segiempat tepat dan mengkaji denyutan aliran untuk bendalir yang kecil. Perisiaan GAMBIT versi 2.2.10 dan FLUENT versi 6.2 telah dilakukan adalah digunakan untuk tujuan simulasi. Kekisi yang dihasilkan telah diuji dengan jaringan bebas dan hasil dari segi pengiraan yang diulangi oleh FLUENT tidak berjaya. Jaringan itu menghasilkan telah diuji untuk kekisi kemerdekaan dan hasil dari segi bilangan mengulangi oleh FLUENT diperlukan untuk pengesahan terhadap kertas bercetak. Simulasi penyelesaian di bawah aliran kecerunan tekanan di perolehi dan dipermudahkan untuk cerun tekanan berkala. Amplitud untuk denyutan aliran adalah 50% purata tekanan dan keadaan aliran itu merupakan aliran lamina. Frekuensi denyutan diuji dengan 5 kHz dan hasil simulasi telah dianalisa dan dibandingkan dengan kertas bercetak. Pengesah hádala gagal akibat daripada kesukaran mendapat satu data yang lengkap daripada yertas bercetak analisa dan terlalu banyak tanggapan perlu dibuat mengakibatkan pengesahan tidak berjaya. Walaubagaimanapun, kajian ini menunjukkan satu kemungkinan aliran berayun boleh dikaji mengunakan perisian *Computacional Fluid Dynamic* (CFD).

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LIST OF SYMBOLS

VLSIC	=	Very Large Scale Integrated Circuit
ULSIC	=	Ultra Large Scale Circuit
Re_LRe,R, Re_D, Re_R	=	Reynold Number in varius of length
IC engine	=	Ignition Combustion engine
ρ	=	Density, kg/m^3
V	=	average fluid velocity
V	=	mean fluid velocity, m/s
υ	=	kinematic viscosity, m^2/s
L	=	characteristic length, m
Dx,	=	Length for x-axis
Dy	=	Length for y-axis
Dz	=	Length for y-axis
mf	=	Mass flux
u	=	Velocity in x direction, m/s
DA	=	Surface Area, m^2
SF_x	=	Sum Of The External Forces
F_H,F_x,F_y,F_z	=	Force, N or kg m/ s^2
g_x	=	Gravity, m/ s^2
Q	=	Flow rate
A	=	Cross section Area

APPENDIX

CHAPTER I

INTRODUCTION

Chapter I are focusing on the project background, project objectives, and problem statements, scope of work and flow of the project.

1.1 Project Background

Another class of flow channels that have received some attention in literature are those with hydraulic diameters below 600 µm. These channels are referred to as microchannels. There are very few quantitative studies available for the microchannel geometry under laminar pulsed flow. Further efforts are needed in this area to generate high-quality data in microchannels under in laminar pulsed flow.

Laminar flow through rectangular ducts is important in various fields such as microfluidic devices, and many papers have been devoted to solutions for steady and unsteady flows in rectangular channels under different pressure gradients. For steady state fully developed laminar flow of a viscous incompressible fluid, the theoretical solutions for the velocity profile are well recognized, see e.g. Fan and Chao (1965), Round and Garg (1986) and Spiga and Morini (1994). For fully developed oscillatory flow under purely time–harmonic pressure gradients only, Drake (1965) obtained analytical solutions for the velocity for the cases of small and large values of frequency. Yakhot et al. (1999) also considered oscillatory flow under sinusoidal pressure gradients, and numerically analyzed velocity distribution and wall shear stress. Both of the above studies restricted their analysis to harmonic flows only and did not consider transient responses to imposed pressure gradients, which we believe was first reported by Fan and Chao (1965). They obtained an exact analytical solution for the velocity of transient flow under an impulse pressure gradient, i.e., the Green function for the velocity. They applied it to obtain solutions for the velocity under any pressure gradient by convolution and analyzed the velocity distribution under a purely harmonic pressure gradient. Flow through arbitrary-shaped ducts including rectangular channels under any pressure gradient has also been considered by Ray and Durst (2004), who presented semianalytical solutions.

This brief discussion of the literature shows that velocity distributions have been widely investigated and the solutions can be used to study various flow effects in rectangular channels. For example, flow reversal under a purely harmonic pressure gradient was discussed by Fan and Chao (1965) and Yakhot et al. (1999), and phase shifts of velocity and wall shear stress with frequency approaching infinity or zero were predicted using asymptotic solutions (Yakhot et al., 1999). Local wall shear stress is an important factor in the formation, mitigation and removal (cleaning) of fouling layers on the surface of process equipment and particularly heat exchangers. Fouling is a common and major problem for many processes including microfluidic devices such as microheat exchangers. Rectangular microchannels produced by mechanical cutting or etching techniques are widely used in microfluidic heat exchangers.

Rectangular microchannels produced by mechanical cutting or etching techniques are widely used in microfluidic heat exchangers (Brandner et al., 2007). The channels are prone to fouling due to their small characteristic dimensions, resulting in laminar flow with low velocity and low local wall shear stress. Fouling often increases thermal resistance and pressure drop, leading to decreased rates of heat transfer and increased pumping energy demand.

Pulsed flow, where pulsations are imposed on a steady flow, presents a possible mitigation method and its efficacy as a cleaning method has been demonstrated experimentally (Augustin and Bohnet, 1999; Gillham et al., 2000; Bode et al., 2007). The shear stress imposed by the fluid on the surface plays an important role in both formation and removal of fouling deposits: flow pulsation represents a method for enhancing this property without using higher flow rates continuously. Celnik et al. (2006) recently employed the Green function method to obtain solutions for laminar pulsed flow in circular and annular ducts and quantitatively discussed the wall shear stress enhancement. However, little theoretical work on local wall shear stress and its enhancement in rectangular channels by pulsed flow has been reported.

1.2 Project Objectives

This part will discuss deeply about the project objectives. This project is developing with the following objectives:

(a) To computationally simulate laminar flow in rectangular microchannel by using Computational Fluid Dynamics (CFD) software. There are many types of CFD software, but for this project GAMBIT version 2.2 and FLUENT version 6.2 are used.

(b) To study and understand on how to create and meshing geometry in GAMBIT and selecting the right solver to compute in FLUENT and know how to use both software effectively.

(c) To study on microchannel characteristic and the application in this new microfluid era technologies.

(d) To study the pulsed flow and pressure drop in single phase rectangular microchannel.

1.3 Problem Statements

This work has been carried out to do research work on fouling mitigation and cleaning enhancement in process equipment, which is a major problem in several industry sectors. For example, dairy heat exchangers often have to be cleaned daily and downtime can be in excess of 40% of available process time (Gillham et al., 2000). Many units subject to fouling, particularly in the food sector, employ cleaning-in-place systems where a cleaning fluid is circulated through the system: the cleaning agent converts the surface fouling layer to a form which is more readily removed by hydraulic or diffusive processes. In many dairy applications, aqueous solutions of sodium hydroxide are employed as these cause proteinaceous deposits to swell and weaken. In the interests of hygiene and to avoid contamination of the product such cleaning agents must be purged from the system before the system can be reused. It is therefore pertinent to optimize the cleaning cycles to give both environmental and economic improvement.

Past studies have used a variety of techniques to improve the cleaning of whey-protein and dairy systems. Gillham (1997) studied the effect on cleaning of imposing flow pulses on a steady laminar flow through cylindrical pipes. Pulsing has the effect of raising the maximum shear stress at the pipe wall, thus increasing the cleaning rate (Gillham et al., 2000). High values of wall shear stress can also be achieved using larger flow velocities and are used in some commercial cleaning-in-place systems to reduce cleaning time. Gillham et al. (2000) showed that the same effect may be achieved at lower velocities by using pulsation, which may be advantageous in systems where the inventory of cleaning agent is to be minimized, the liquid is very viscous, or velocity related effects such as erosion need to be avoided. Thus, a study of these effects in laminar flow is of interest. In Malaysia, the application usage of minichannel and microchannel still not wide. Many of cooling component still used channel (3mm and above) as a transportation of fluid. For example, many of server room using air-conditioning to cooled the temperature of the room so that it will cool the computer server unit.

1.4 Scope of Study

This project will concentrate on simulating laminar flow in rectangular microchannel. This concept and the correct calculation must be known to get the correct value for each parameter that has been studied. The detailed scope for this project is:

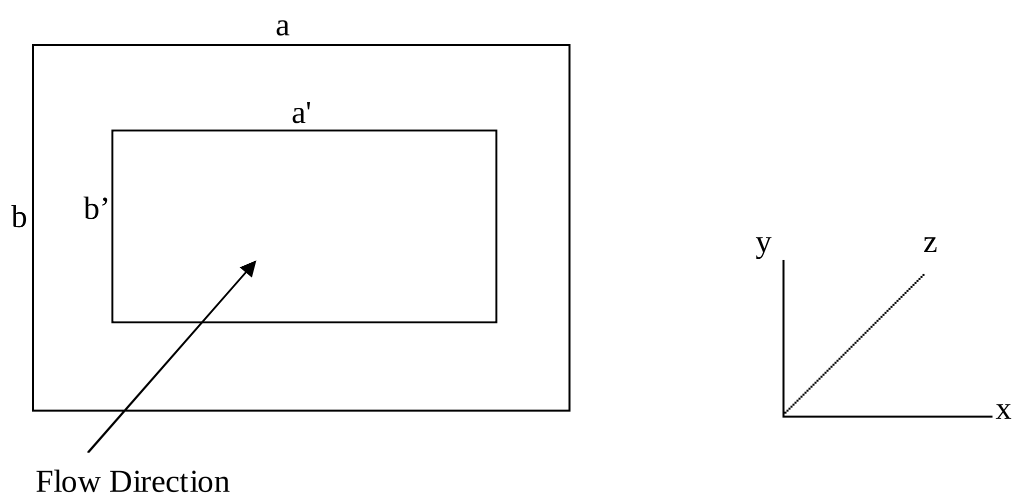

Figure 1.1 Schematic of flow through a rectangular duck and the coordinates system.

(a) We consider fully developed laminar flow in a duct of rectangular cross-section of width a = 0.8 milimeter and height b = 0.8 milimeter respectively. The length c = 5 milimeter for fluid region, and for the solid region, the cros-section of width a’ = 0.4 milimeter, height b’ = 0.4 milimeter respectively and the length is c’ = 5 milimeter.

(b) The fluid is incompressible and Newtonian with constant physical properties; natural convection and gravity are negligible and the pressure gradient is non-zero in the z-direction only; changes to the pressure gradient are effectively instantaneous throughout the system; velocities in the x and y directions are zero.

(c) Three Dimension rectangular duct geometry (3-D) is simulated Fluent 6.2 software using three dimension double precision (3DDP).

(d) This study only considers a single phase flow condition. The application of single-phase heat transfer enhancement in conventional sized passages has been widely accepted and developed area of research.

1.5 Project Flow Chart

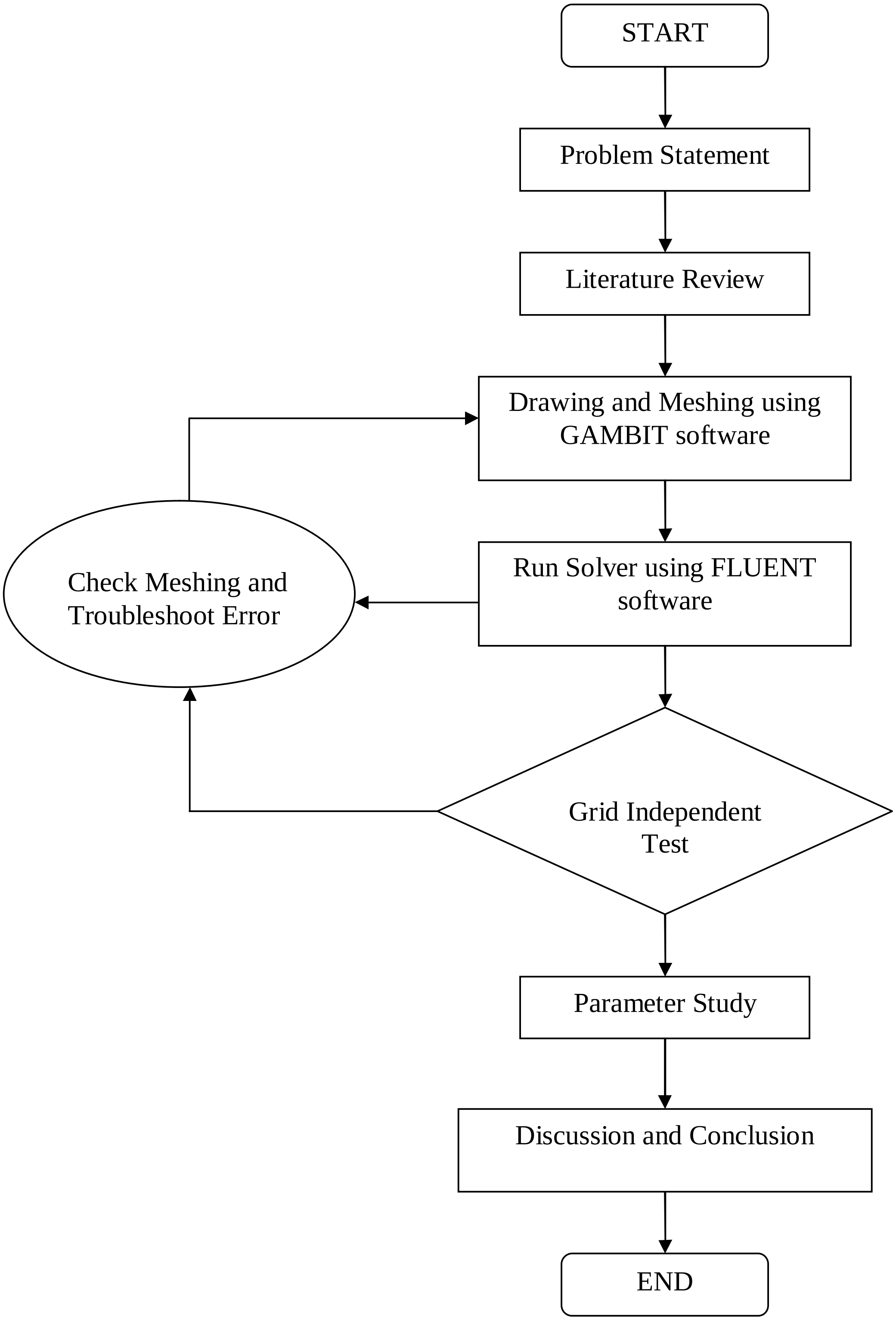

Figure 1.2: Flowchart for the whole project

CHAPTER II

LITERATURE REVIEW

Chapter II is about the literature review that regarding to the project. It contains methods to do research, theory used to solve problems in this project and so on.

2.1 Microchannel

Over the past 10 years, micromachining technology has been used to develop a number of microfluidic systems in silicon, glass, quartz, or plastics. Microchannels and chambers are the essential part of any such system. In addition to connecting different devices, microchannels are also used for reactant delivery, as biochemical reaction chambers, in physical particle separation, in inkjet print heads, or as heat exchangers for cooling computer chips. Currently, fluid flows in microchannels and microma-chined fluid systems like pumps and valves are analyzed using the Navier–Stokes equations. However number of publication indicated that flows on the microscale are different from that on the macroscale and that the Navier–Stokes equations are incapable of explaining the occurring phenomena. Thus, in order to design and fabricate such micro devices effectively, the fluid flow on the microscale must be understood. The first studies of fluid flow on the micro scale were performed by Wu and Little (1983 and 1984). They conducted experiments measuring Darcy friction factors for both laminar and turbulent gas flow in microchannels to evaluate the performance of Joule Thompson cryogenic devices. The microchannels were etched in silicon or glass, with hydraulic diameters ranging from 50 to 80 mm. The observed Darcy friction factors were larger than predicted by classical macroscale theory (Ian Papautsky et al. 1998).

Addition, microfluidic system in miniaturized devices have found application in many areas such as chemical processes, propulsion and power generation, cooling of electronic devices, aerospace industry, inkjet printers, and biomedical industry. In case of microdevices, the continuum approach can still be applied for modeling fluid flow, especially if the fluid is liquid. However, there are many situations where fluid flow behavior in microdevices can considerably deviate from those in macroscopic devices. The characteristic dimension of a microchannel within a microfluidic system is in the range of 1–1000 lm. The Reynolds numbers encountered in microfluidic systems are quite small (often on the order of 1.0 or smaller). Surface forces, which originate due to intermolecular forces, could be important in microchannel flows. These forces are generally ignored at macroscale. Surface effects also alter the value of viscosity. It is found that the apparent viscosity is lower in the narrower channel, which is contrary to the expected trend. Another important effect is air-dampening, which could directly influence quality factor of the devices. The strong air dampening is due to the dramatic increase in the surface- to-volume ratio. Due to large surface-to-volume ratios in microdevices, both convective and radiative heat transfer rates are enhanced considerably. Despite deviation of flow behavior at the microlevel, one should carefully analyze to see if the continuum approach is valid in a given microfluidic device (Tuba Bayraktar, Srikanth B. Pidugu, 2006).

2.1.1 Type Flow In Microchannel

Fluid is transported in several ways in the microchannels used in microfluidic devices. Two important methods of transport are flows driven by pressure differential and electro-osmotic flows. In the former case, flow is transported by means of applied pressure differences. In the latter case, flow transport is initiated by application of a high electric field. This type of flow is broadly classified as electrokinetic's flow. Capillary driving forces owing to surface tension, ''wetting'' of surfaces by the fluid, can also lead to pressure gradients in liquids. This pressure gradient causes flow transport, so it is similar in many ways to pressure driven flows. However, the shape of the interface is an important factor in this type of flow. Free surface flows are caused by gradients in interfacial tension (Marangoni flows). These can be manipulated using the dependence of surface tension on temperature or chemical concentration (Tuba Bayraktar, Srikanth B. Pidugu, 2006).

2.2 The Important and Application of Microchannel

Microstructure technology has practical applications in many fields, including bioengineering and biotechnology, aerospace, mini-heaters and mini-heat exchangers, materials processing and manufacturing. For example, microchannels and mini-heat exchangers with flow channels having dimensions ranging from several hundred microns to 0.1/μm have found application in bioreactors for the modification and separation of biological ceils and selective membranes. In addition, microstructure technology may provide new tools for examining more closely physical phenomena and may result in the development of a method or methods by which thermal phenomena, often considered very difficult or impossible to investigate due to the small length scale, can now be studied. These suggest the types of creative and innovative applications that may result from a better understanding of flow characteristics and heat transfer