INVESTIGATION OF CIRCULAR BASED MICROPUMP DIFFUSER

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Report submitted in partial fulfillment of the requirements
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FACULTY OF MECHANICAL ENGINEERING

I certify that the project entitled "*Investigation of Circular Based Micropump Diffuser*" is written by *Johari Bin Bar Azwar*. I have examined the final copy of this project and in our opinion; it is fully adequate in terms of scope and quality for the award of the degree of Bachelor of Engineering. I herewith recommend that it be accepted in partial fulfillment of the requirements for the degree of Bachelor of Mechanical Engineering with Manufacturing.

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Examiner Signature

SUPERVISOR’S DECLARATION

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

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Date	: 6 DECEMBER 2010

STUDENT'S DECLARATION

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

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ABSTRACT

This thesis deal with the investigation of circular based piezoelectric micropump diffuser, fabrication and testing of the liquid flow rate that flow in the micropump. It is made emphasize on the development of piezoelectric micropump. Its layout is very different from other conventional micropump that has only three main parts. The prototype is modeled using SOLIDWORK and flow analysis of the model was using COSMOS and Fluent. The quantitative analysis done have determined the effect of differential diffuser angle to the outlet flow rate of water. For the fabrication purpose are to determined real flow rate to the outlet that has been compared with Fluent analysis flow rate. The objective of material selection was to reduce fabrication cost without reducing the micropump functional performance and efficiency. The type of piezoelectric circuit was the simplest design that required. Simple circuits were chosen as it easier to troubleshoot and provide more reliability in executing motion compared to complex coding. From COSMOS simulation, the micropump flow motions of liquid are smooth and functional. From Fluent simulation, the result comparable as calculated by the theory. Guide by preliminary result, a handmade fabrication is carried out to create a prototype to show how this innovative circular based micropump produce flow liquid from inlet to outlet diffuser, the other facting factor that can control the flow rate, the pulse in functioned and the flow motions are performed. The real testing is carried out resulted were tabulated. The experimental results are compared with the simulated results and the resulted are acceptable.

ABSTRAK

Tesis adalah berkaitan dengan penyelidikan micropump diffuser melingkar berasaskan fabrikasi piezoelektrik, dan ujian laju aliran cecair yang mengalir di micropump tersebut. Hal ini dilakukan menekankan pada pembangunan micropump piezoelektrik. Binaannya adalah sangat berbeza dari micropump konvensional yang lain yang hanya mempunyai tiga bahagian utama. Prototaip dimodelkan menggunakan analisis SOLIDWORK dan aliran model menggunakan COSMOS dan Fluent. Analisis kuantitatif dilakukan telah menentukan pengaruh sudut muncung pembezaan dengan tingkat laju aliran air. Untuk tujuan fabrikasi adalah untuk ditentukan laju alir cecair ke mucung keluar yang telah dibandingkan dengan laju alir analisis Fluent. Tujuan dari pemilihan bahan adalah untuk mengurangkan kos fabrikasi tanpa mengurangkan prestasi dan kecekapan mikropam. Jenis litar piezoelektrik adalah rekaan paling sederhana yang diperlukan. Litar yang paling ringkas dipilih sebagai lebih mudah untuk menyelesaikan masalah dan memberikan kecekapan yang lebih dalam melaksanakan fungsinya dibandingkan dengan aturcara perisian yang kompleks. Dari analisis COSMOS, gerakan aliran mikropam cair yang halus dan lancar. Dari analisis Fluent, hasil setanding yang dikira oleh teori. Panduan oleh hasil awal, fabrikasi buatan tangan dilakukan untuk membuat prototaip untuk menunjukkan bagaimana micropump berdasarkan inovatif melingkar menghasilkan aliran cecair dari mucung masuk ke mucung keluar, faktor lain yang dapat mengawal laju aliran, denyutan nadi berfungsi dan gerakan aliran yang terhasil. Ujian yang sebenar dihasilkan, dilaksanakan dan direkodkan keputusannya. Keputusan eksperimen berbanding dengan hasil simulasi dan yang dihasilkan boleh diterima.

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LIST OF SYMBOLS

□	Dynamic viscosity
ρ	Fluid density
g	Gravitational force
h	Height
n	Number of propeller rotation per second
υ	Speed of object relative to fluid
A	Surface area
C_d	Drag coefficient
D	Height of diameter of the bodies, propeller diameter
P	Pressure
Re	Reynolds number
T	Thrust
V	Volume
$\sum$	Total
f	Frequency
π	Pi
ω	Omega
V_{avg}	Average Velocity
h_L	Head Lost

LIST OF ABBREVIATIONS

3D	Third Dimensional
DIY	Do It Yourself
DPDT	Double Pole Double Throw
FYP	Final Year Project
PVC	Polyvinyl Chloride
RF	Radio Frequency
PZT	Piezoelectric
H2O	Pure Water
LCD	Liquid Cristal Display
LED	Light Emitting Diode
ADC	Analog Digital Converter
TDC	Top Dead Center
BDC	Bottom Dead Center
CTRL	Control
GND	Ground
OUT	Output
DIS	Discharge
CFD	Computational Fluid Dynamic
DC	Direct Current

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

This chapter presents the study purpose, current issues, problem statement of the study, and limitation of the study.

1.2 PROJECT BACKGROUND

While miniaturization is revolutionizing the world of sensors and various mechanical systems, Micro fluidic is currently one of the major areas of application of miniature devices. While many mechanical systems are now feasible on a micro scale, devices like micro pumps, miniature mixers, flow sensors, etc. are already commercially available and widely used. These micro pumps find their greatest application in chemical and biomedical also in electronic applications requiring the transport of small, accurately measured liquid quantities. When utilized in chemical applications, micro pumps are often a component of a lab-on-a-chip device. Such devices are envisioned as providing for reasonably inexpensive, possibly even disposable, means to conduct laboratory experiments.

Micro pumps can be classified into two groups: mechanical pumps with moving parts and non-mechanical pumps without moving parts. Two movement mechanisms have been employed in mechanical micro pumps: reciprocating and peristaltic movements. The actuators play very important roles in achieving the maximum flow rate and the output pressure of the pump. The maximum output pressure of a micro pump depends directly on the available force an actuator can deliver.

1.3 PROBLEM STATEMENT

There are many types of micro pump had been created with many types of function. Most of these micro pumps have complex structures and high power consumption. On the contrary, PZT actuation has advantages due to its relatively simple structure and lower power consumption.

One of the types of micro system is using circular piezoelectric micro pump. This study helps to improve the performance of the circular piezoelectric micro pump to choose the best size and also functional to be applied in the industry. This project also can help increase the accuracy fluid flow rate depend on its used.

1.4 PROJECT OBJECTIVE

To determine the performance PZT of micropump and diffuser angle through experiment and simulation analysis.

1.5 PROJECT SCOPE

i. Initial study for micro pump application.
ii. CAD modeling of micro pump.
iii. CFD analysis for diffuser angle.
iv. Experiment setup of micro pump and circuit.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter contains general information on PZT micropump. The developed PZT micropump consists of mechanical part and electronics. Thus the related review have resulted focus on the behavior of PZT actuator, classification of micropump, the quantitative theories and the mechanical and electrical component of the micropump. The relevance of the literature review to the project resulted be included in this chapter as well. The facts and information were collected from reliable source and elaborated based on understanding of the review. The quoted phrases only attached within text as a factual detail whilst others elaborated from the source.

2.2 HISTORY OF MICROPUMP

Micropumps are the essential components in the digital data storage (DDS). Since one of the early piezoelectric micropumps for insulin delivery was fabricated in 1978, various mechanical micropumps with different actuating principle have been developed , such as thermopneumatic , electrostatic, shape memory alloy (SMA) , electromagnetic as well as piezoelectric. The piezoelectric actuation presents its advantages of moderately pressure and displacement at simultaneously low power consumption, good reliability and energy efficiency . These features are preferred for medical application. Microsystems have the advantages of small volume, cheap cost, high precision and fast reaction time. Micro pumps are essential devices in the micro fluidic systems, which provide momentum to cause fluid flow.

2.3 TYPE OF PIEZOELECTRIC (PZT) MICROPUMP

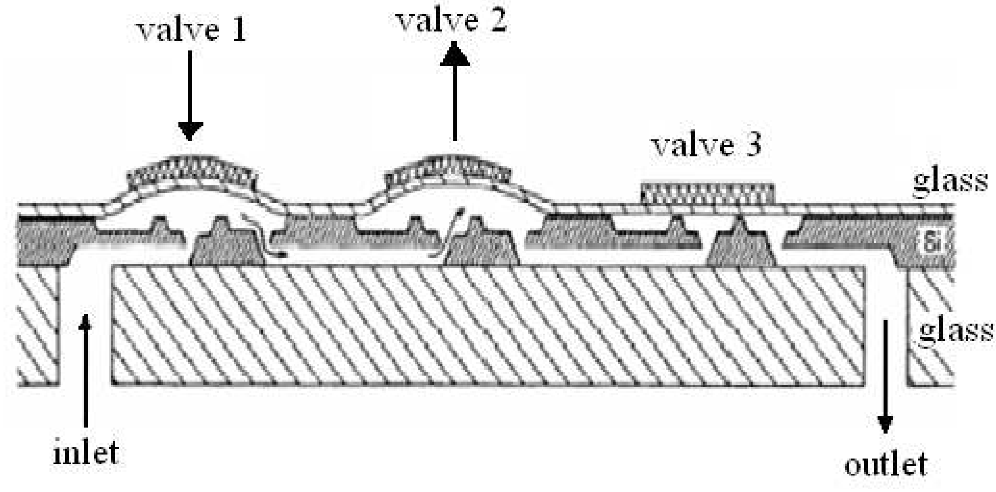

Figure 2.1: The first micropump used piezoelectric actuated and includes three valves working peristaltically.

Source: Smits, J.G.,1990.

Each valve consists of a chamber with inlet and outlet each covered by a flexible membrane. By deflecting the membrane, which was made of two piezoelectric discs, an under pressure was generated. The pump was able to pump 100 ml/min without pressure difference between inlet and outlet and was able to reach a maximum pump pressure of 60 cm H2O.

The flow directing elements and the actuator play important roles in the flow rate and the maximum pressure. Many types of actuators like piezoelectric, pneumatic, electrostatic and thermopneumatic have been used as based of micropump new design and concept. Also now the modern design of micropump are using electric motor actuated that can give highest flow rate and velocity for the liquid transfer using micropump and increased the efficiency.(Smits, J.G.,1990)

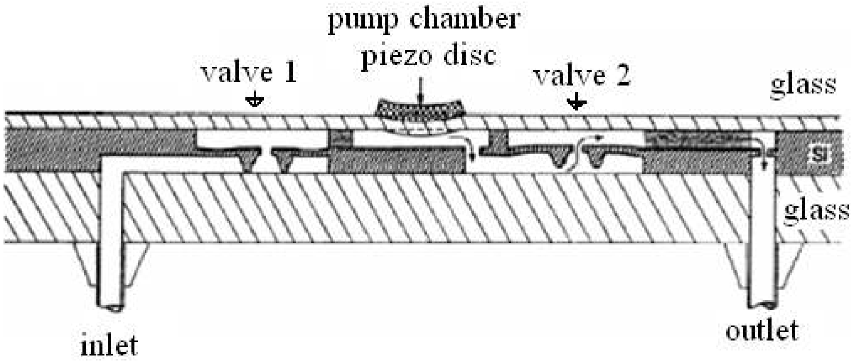

Figure 2.2 : Piezoelectric two-valve pump

Source : Van Lintel, H. T. G., et al,1988

These pumps had one or two pump chambers and a thin glass pump membrane actuated by a PZT disc. They used passive silicon check valves to direct the flow, see Figure 2.1. Based on the same principle another pump was developed which used electro-thermopneumatic actuation instead of piezoelectric actuation, see Figure 2.2.

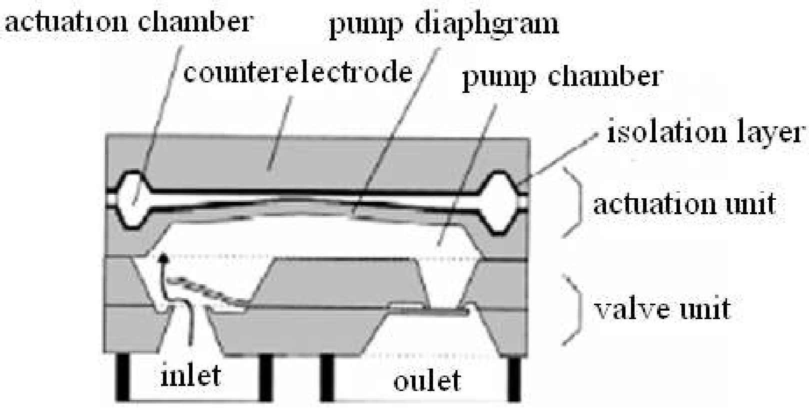

Figure 2.3 : Bi-directional silicon micropump with passive check valves.

Source : Zengerle, R., et al,1995.

Several different diaphragm pumps with different actuation principles have been developed. One of the most interesting used electrostatic actuation and was further developed into a bi-directional pump , illustrated in Figure 2.3. This pump works in the forward direction for low frequencies (0.1-800 Hz) and in the reverse direction for higher frequencies (2-6 kHz).

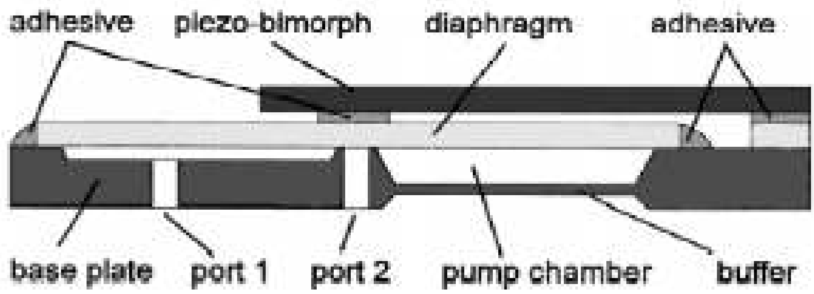

Figure 2.4 : Bi-directional micropump with selfblocking effect.

Source : Stehr,M., et al,1996.

The pump diaphragm acts as an active valve and two new pump mechanisms called "the Elastic Buffer mechanism" and "the Variable Gap mechanism" are used. The direction of the fluid transport can be switched by varying the driving frequency. The pump was shown to work for both liquid and gas and is the first liquid self priming micropump

In valve-less reciprocating pumps the flow channels at the inlet and the outlet are designed to give different flow resistance in the forward and the reverse directions. This eliminates wear and fatigue in the check-valves and also reduces the risk of valve clogging.

2.4 OSCILLOSCOPE

Oscilloscope is a type of electronic test instrument that allows signal voltages to be viewed, usually as a two-dimensional graph of one or more electrical potential differences (vertical axis) plotted as a function of time or of some other voltage (horizontal axis). Although an oscilloscope displays voltage on its vertical axis, any other quantity that can be converted to a voltage can be displayed as well. In most instances, oscilloscopes show events that repeat with either no change or change slowly.

Oscilloscopes are used when it is desired to observe the exact wave shape of an electrical signal. In addition to the amplitude of the signal, an oscilloscope can show distortion and measure frequency, time between two events (such as pulse width or pulse rise time), and relative timing of two related signals. Oscilloscopes are used in the sciences, medicine, engineering, telecommunications, and industry. General-purpose instruments are used for maintenance of electronic equipment and laboratory work. Special-purpose oscilloscopes may be used for such purposes as analyzing an automotive ignition system, or to display the waveform of the heartbeat as an electrocardiogram.

Originally all oscilloscopes used cathode ray tubes as their display element and linear amplifiers for signal processing, but modern oscilloscopes can have LCD or LED screens, fast analog-to-digital converters and digital signal processors and some oscilloscopes used storage CRTs to display single events for a limited time.

Oscilloscopes generally have a checklist. The basic measure of virtue is the bandwidth of its vertical amplifiers. Typical scopes for general purpose use should have a bandwidth of at least 100 MHz, although much lower bandwidths are acceptable for audio-frequency applications.

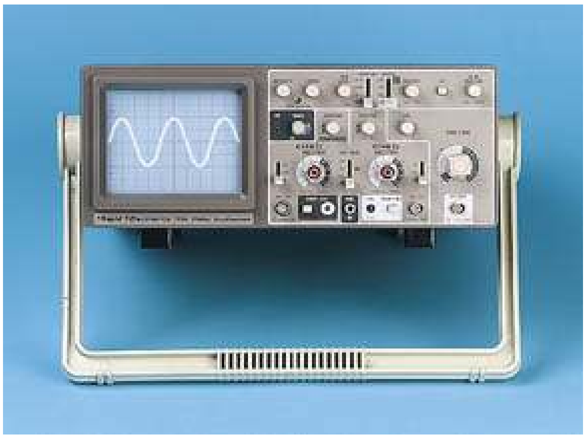

Figure 2.5 : Digital Oscilloscope

Source : Tektronix Catalogue., 1971

2.4.1 Oscilloscope Basic Functional

Like a television screen, the screen of an oscilloscope consists of a **cathode ray tube**. Although the size and shape are different, the operating principle is the same. Inside the tube is a vacuum. The electron beam emitted by the heated cathode at the rear end of the tube is accelerated and focused by one or more anodes, and strikes the front of the tube, producing a bright spot on the phosphorescent screen.

The electron beam is bent, or deflected, by voltages applied to two sets of plates fixed in the tube. The horizontal deflection plates or **X-plates** produce side to side movement. During the rising phase of the saw tooth, the spot is driven at a uniform rate from left to right across the front of the screen. During the falling phase, the electron beam returns rapidly from right or left, but the spot is 'blanked out' so that nothing appears on the screen. In this way, the time base generates the X-axis of the *V*/*t* graph.

The slope of the rising phase varies with the frequency of the saw tooth and can be adjusted, using the TIME/DIV control, to change the scale of the X-axis. Dividing the oscilloscope screen into squares allows the horizontal scale to be expressed in seconds, milliseconds or microseconds per division (s/DIV, ms/DIV, and µs/DIV). Alternatively, if the squares are 1 cm apart, the scale may be given as s/cm, ms/cm or µs/cm.

The signal to be displayed is connected to the **input**. The AC/DC switch is usually kept in the DC position (switch closed) so that there is a direct connection to the **Y-amplifier**. In the AC position (switch open) a capacitor is placed in the signal path. As will be explained in Chapter 5, the capacitor blocks DC signals but allows AC signals to pass.The Y-amplifier is linked in turn to a pair of **Y-plates** so that it provides the Y-axis of the *V*/*t* graph.

This is possible using the X-POS and **Y-POS** controls. For example, with no signal applied, the normal trace is a straight line across the centre of the screen. Adjusting Y-POS allows the zero level on the Y-axis to be changed, moving the whole trace up or down on the screen to give an effective display of signals like pulse waveforms which do not alternate between positive and negative values.(Tektronix Catalogue., 1971)