UNIVERSITI TEKNIKAL MALAYSIA MELAKA

STUDY A PNEUMATIC MUSCLE ACTUATOR AND SIMULATION FOR INSECT WALKING ROBOT

This report submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor Degree of Manufacturing Engineering (Robotic & Automation) with Honours.

by

MOHAMMAD FAHMI BIN DAUD

B050710229

FACULTY OF MANUFACTURING ENGINEERING

2011

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

BORANG PENGESAHAN STATUS LAPORAN PROJEK SARJANA MUDA

TAJUK: **STUDY A PNEUMATIC MUSCLE ACTUATOR AND SIMULATION FOR INSECT WALKING ROBOT**

SESI PENGAJIAN: 2010/11 Semester 2

Saya **MOHAMMAD FAHMI BIN DAUD**

mengaku membenarkan Laporan PSM ini disimpan di Perpustakaan Universiti Teknikal Malaysia Melaka (UTeM) dengan syarat-syarat kegunaan seperti berikut:

1. Laporan PSM adalah hak milik Universiti Teknikal Malaysia Melaka dan penulis.
2. Perpustakaan Universiti Teknikal Malaysia Melaka dibenarkan membuat salinan untuk tujuan pengajian sahaja dengan izin penulis.
3. Perpustakaan dibenarkan membuat salinan laporan PSM ini sebagai bahan pertukaran antara institusi pengajian tinggi.
4. **Sila tandakan (√)

☐ SULIT (Mengandungi maklumat yang berdarjah keselamatan atau kepentingan Malaysia 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:

____

Alamat Tetap:
Lot 172 Taman Sri Rantau,
17200 Rantau panjang,
Kelantan.

____
PENYELIA PSM

Tarikh: _______________________   Tarikh: _______________________

** Jika Laporan PSM ini SULIT atau TERHAD, sila lampirkan surat daripada pihak berkuasa/organisasi berkenaan dengan menyatakan sekali sebab dan tempoh laporan PSM ini perlu dikelaskan sebagai SULIT atau TERHAD.

DECLARATION

I hereby, declared this report entitled "Study a Pneumatic Muscle Actuator for Insect Walking Robot" is the results of my own research except as cited in references.

Signature :

Name of Author : MOHAMMAD FAHMI BIN DAUD

Date :

APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of UTeM as a partial fulfillment of the requirement for the degree of Bachelor of Manufacturing Engineering (Robotic and Automation) with honours. The member of the supervisory committee is as follow:

……………………………………………….

Supervisor

ABSTRAK

Projek pengerak berotot penumatik merangkumi aktiviti merekabentuk kaki robot serangga berserta pengerak berotot penumatik. Tujuan kajian ini dilakukan adalah untuk menyelidik dan menganalisa pengerak berotot untuk memilih rekabentuk yang terbaik. Selepas proses ini, pengerak berotot 'pleated' telah dipilih untuk digunakan dalam projek ini dan proses merekabentuk untuk mengantikan produk sedia ada dengan pengerak berotot penumatik ini. Seterusnya, dari pemilihan pengerak berotot ini, kerja-kerja pengumpulan maklumat mengenai komponen ini mula dilakukan untuk mencapai objektif penyelidikan ini. Setelah beberapa proses pencarian maklumat dibuat, didapati bahawa pemilihan ciri-ciri pengerak berotot adalah salah satu perkara yang penting untuk proses rekabentuk untuk robot. Berikutnya, setelah program simulasi dijalankan mengunakan perisian 'Solid Work' dan sistem kawalan menggunakan 'Automation Studio', analisis mengenai projek ini dilakukan untuk mendapatkan maklumat mengenai kestabilan dan mekanisma.

ABSTRACT

The project pneumatic muscle actuator at insect walking robot covers the activities to design the legged section of the robot with pneumatic muscle actuator. This study is to investigate and analyze muscle actuator to choose the best design. After this process, the pleated muscle actuator is being selected and designed to replace existing products with muscle actuator legs. Lasted from the selection of this muscle actuator, work collecting data on these components become done. This work is done in order to achieve the objectives of this research and subsequent proof that the selected items in the case study. It appears that the selection of the characteristics of muscle actuator is one important matter to be considered in the process of searching the maximum and most appropriate to design the robot. After the simulation using solid work and control system by using Automation studio is done, the analysis has been carried out to obtain information about the walking stability and the mechanism of the robot.

ACKNOWLEDGEMENT

I would like to dedicate my appreciation to my lecturer, En. Khairol Anuar bin Rakiman for serving as my supervisor and for providing guidance while conducting the research and the writing of this Projek Sarjana Muda (PSM). Also as my academic advisor for advices and guidance since the first day I step in UTeM.

Thank you also goes to my entire lecturers. Furthermore, I would like to offer thanks and deepest gratitude from the bottom of my heart for all the support, encouragement and inspirations I obtained through the duration of this project.

Last but not least, I thank everyone who involved directly and indirectly in this project. The sacrifice and commitment given towards me earning my bachelor's degree are indescribable and without them, this PSM thesis would have been impossible.

DEDICATION

Specially dedicated to my beloved mother BIDAH BINTI IBRAHIM and my lovely wife who had been so consistently and patiently supporting me in this research. Besides that, I also dedicated all of this to all of my lecturers and colleagues who interested in this research.

TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

CAD	Computer Aided Design
DOF	Degree Of Freedom
FMA	Flexible Micro Actuator
FPA	Flexible Pneumatic Actuator
PAM	Pneumatic Artificial Muscles
PLC	Programmable Logic Controller
PMA	Pneumatic Muscle Actuator
UTeM	Universiti Teknikal Malaysia Melaka

LIST OF SYMBOLS

SYMBOLS	SUBJECTS
x	Displacement of Load mass [m]
x	Velocity of Load mass *[mls]*
tt/J	Air Mass flow rate [kg/s]
*F*m	Muscle force [N]
Fa	Contractile element [N]
Bm	Damping element [N·s/m]
Km	Spring element [N/m]
u	Input control voltage [V]
M	Load mass [kg]
p	Absolute Muscle Pressure
Pa	Atmosphere pressure = 1.01325 x 105
Ps	Supply pressure = *3xl05+Pa*
Per	Critical pressure [-]
R	Gas constant = 286.85 [N·m/kg·K]
A	Muscle Cross-sectional area [m^2]
Ae	Effective area of Proportional valve [m^2]
V	Muscle volume [m^3]
T	Air temperature [K]

CHAPTER 1

INTRODUCTION

Pneumatic muscle actuator is a contractile or extensional devices operated by pressurized air filling a pneumatic bladder. In a vague approximation of human muscles, pneumatic artificial muscle (PAM) are usually grouped in pairs: one agonist and one antagonist.

Pneumatic actuators, usually cylinders, are widely used in factory floor automation. Lately, robotics as well is starting to use pneumatics as a main motion power source. One of the major attractions about pneumatics is the low weight and the inherent compliant behavior of its actuators. Compliance is due to the compressibility of air and, as such, can be influenced by controlling the operating pressure. This is an important feature whenever there is an interaction between man and machine or when delicate operations have to be carried out (e.g. handling of fragile objects). Thanks to compliance a soft touch and safe interaction can be easily guaranteed. Hydraulic and electric drives, in contrast, have a very rigid behavior and can only be made to act in a compliant manner through the use of relatively complex feedback control strategies.

Several types of pneumatic actuators—e.g. cylinders, bellows, pneumatic engines and even pneumatic stepper motors—are commonly used to date. A less well-known type is that of the so-called Pneumatic Artificial Muscles (PAMs). These are in fact inverse bellows, i.e. they contract on inflation. Their force is not only dependent on pressure but also on their state of inflation, which makes for a second source of spring-like behavior. They are extremely lightweight because their core element is but a membrane, and yet, they can transfer the same amount of energy as cylinders do, since they operate at the same pressure ranges and volumes. For these reasons they carry a great potential to be used to power mobile robots, where they have additional advantages, such as direct connection, easy replacement and safe operation.

Although PAMs have been around for quite some time now, these actuators have not been widely used to date, which is not easily explained for. Possible reasons the authors see are the lack of large-scale need for this specific type of actuator and resulting from this a lack of technological effort to improve the existing designs. The most commonly used design to date, the McKibben Muscle, has some important drawbacks, mainly with regard to its control, as was mentioned before, but also with regard to service life: the flexible membrane is connected to rigid end fittings which introduces stress concentrations and there from possible membrane ruptures. Cylinders, being entirely composed of rigid materials, do not suffer from this problem.

In view of the problems robotics has in finding suitable actuators, the need for the strong and lightweight PAMs could very well mount in the near future, using PAMs the structure of a robot arm can be made a lot lighter and consequently its payload to weight ratio a lot higher compared to electric drives, PAM operation characteristics make it inherently apt and easy to use for delicate handling operations or to power an adjustable firmness gripper. Especially for mobile robots—demanding lightweight actuators, able to generate high torques at low and moderate speeds, able to be connected to the structure without gearing, having a natural compliance and shock resistance and a possible autonomous operation—Pneumatic Artificial Muscles seem a better choice than present day electric or other drives. (D.Frank, L.Dirk, 2002).

1.1 Problem Statement

Flexible pneumatic actuator is one of the important branches in the research on robot actuator and end manipulator. It was first proposed in the 1950s, but did not catch the attention and interests of researchers until recent years. In 1990s, researches on flexible pneumatic actuators were carried out in colleges in America, Japan, Germany and corporations such as Toshiba, Bridgestone, Festo, Imagesco, WestGroup and etc. Some products of flexible pneumatic actuator are commercially available. Unlike the traditional hydraulic and power driving system, they feature excellent flexibility, high power/weight ratio, small volume and nonpollution.

Pneumatic artificial muscle actuator can be applied in bionic mechanical arm, medical treatment and prosthetic device, service robot etc. In 1950s, Joseph L.McKibben, an atomic physicist of America, developed the first pneumatic artificial muscle actuator, which is called McKibben PMA (Pneumatic Muscle Actuator). The main component of McKibben PMA is a rubber bladder, which is wrapped by fibre braiding and sealed by metal hoops at each end. When pressurized with compressed air inside, the rubber bladder will expand in radial direction. Then the force in radial direction will change to the contraction force because of fibre braiding.

This mode of motion is quite similar to that of bio-muscle. Ching-Ping Chou and Blake Hannaford from Washington University profoundly studied the static model of PMA. They deduced the static model of McKibben PMA based on the law of energy conservation. Nonlinearity and hysteresis of PMA were observed and a simplified static model was given. Ching-Ping Chou and Blake Hannaford compared the McKibben PMA with bio-muscle and reached the conclusion that they are similar in force-length property but different in force-velocity property. Tsagarakis and Caldwell from Salford University in England, Robb.W from America also did some work on the modeling of McKibben PMA. They gave mathematic models of PMA through different approaches.

Rubbertuator of Bridgestone corporation, Fluidic Muscle of Festo corporation and Air Muscle of British Shadow corporation are similar to McKibben PMA in structure and fundamental characteristics. In 1980s, Toshiba Corporation developed a 3-DOF (degree of freedom) Flexible Microactuator, FMA for short. It is a tube made of silicon rubber, which has three symmetrically distributed chambers inside. The nylon fibre in the wall of silicon rubber tube can enforce the FMA. Each end is sealed by a cap and the chambers are interconnected with outside through air tubes. Suzumori et al analyzed the static and dynamic properties of FMA based on infinitesimal elastic deformation theory. Gofuku and Tanaka from Okayama University developed a type of grasping finger, which is similar to the Toshiba 3- DOF FMA. It is also composed of rubber tube and fibre braiding, but has only one chamber and a constraining fibre embedded into the wall of the tube.

Toshiro NORITSUGU from Okayama University developed a type of pneumatic rotary soft actuator. It comprises two side plates and a sector circular arc. The sector circular arc is fibre-reinforced along the radial direction and an air pipe is installed on the side plate. The side plate is restrained from deforming by its own thickness and the radial displacement of the sector circular arc is constrained by the fibre reinforcement. When the actuator is inflated with compressed air, it expands only in the circumferential direction. Then the actuator rotates from original state to inflated state.(Yang et al, 2006)

Thshiro NORITSUGU investigated the properties of pneumatic rotary soft actuator, such as the relation between air pressure inside and output torque, static and dynamic model. Because of the initial sag of the fibre embedded in the silicone rubber, there is a dead zone under about 5 kPa. And because of the visolasticity of actuator, the response of a step signal can be modeled by a first order lag system. In recent years, a lot of research on flexible pneumatic actuator has been done in Zhejiang University of Technology, China, and a new type of actuator, called FPA (Flexible Pneumatic Actuator), is proposed. The structure of FPA is shown in Fig.1.1.

Figure 1.1: Flexible pneumatic actuator (Yang et al, 2006)

It consists of an elastic rubber tube, two covers and an air connector. Embedded in the wall of rubber tube is a spring, which can not only restrain the tube's deformation in radial direction, but also enforce the stiffness of FPA. Each end of rubber tube is sealed by a cover. An air connector, through which the actuator can be inflated, is fixed in one of the covers. Under the high pressure of compressed air inside FPA, the rubber tube will expand. Because the spring restrains its deformation in radial direction, FPA will stretch in axial direction.

When the FPA is deflated, it will return to its original state, due to the elastoplasticity of rubber tube and the rebounding elasticity of spring. Compared with the widely focused and researched McKibben artificial muscle actuator, FPA uses spring as the constraint instead of fibre, which enhances the stiffness of it. The enforcing spring is embedded in the shell of rubber tube, which produces no friction. McKibben muscle actuator produces force by shrinking, while FPA produces force by stretching. The deforming scope of FPA is smaller than that of McKibben muscle actuator. Hence, FPA occupies less space in applications. (Yang et al, 2007)

1.2 Objective

The objective of the project is:

(a) Study of pneumatic muscle actuator aspect that focuses on insect walking robot

(b) Analyze the pneumatic muscle actuator characteristic aspect for insect walking robot

(c) To carry out simulation on pneumatic muscle actuator at insect walking robot using solid work software

1.3 Scope of Project

The scope of study of the pneumatic muscle actuator at insect walking robot is:

(a) Identify the suitable gait design of the insect robot.

(b) Develop the interactive insect walking robot simulation using Solid Work.

(c) Design the pneumatic control circuit system for the insect walking robot.

(d) Analyze the pneumatic such as the force, air consumption and the energy.

(e) Analyze using Solid Work design.