SUPERVISOR DECLARATION

" I hereby declare that I read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering (Plant & Maintenance)"

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CONTROL DESIGN OF AN ADAPTIVE PROSTHETIC LEG FOR AMPUTEES USING MAGNETO-RHEOLOGICAL DAMPER

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DECLARATION

" I hereby declare that the work in this thesis is my own except for summaries and quotation which have been duly acknowledged "

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Date : ....

Praise to Allah the Almighty and to my beloved Father and Mother,

And to my beloved siblings and friends

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ABSTRACT

This project is a about the development and designing control artificial limbs passive to semi active for those who are physically handicapped. Installation of this artificial leg will connect the top of the knee. The amputation can occur in various factors which include the effects of an accident or illness that involve imperfect circulation such as diabetes. The proposed design of prosthetic limbs with a design that has a magneto-rheological (MR) damper where this damper will replace the missing leg muscle that functioned from the knee to the ankle . Before the damper is applied, all damper properties should be identified in advance. Bouc - Wen model is the best model for the description of the hysteresis nature of MR damper. Control strategy used for this process is the development of prosthetic limbs using proportional, integral and derivatives (PID) controller. Generally, the system response in entirely unstable in open-loop form. The criteria to get the stability of the system are (i) settling time, T_s for θ of less than 5 seconds and (ii) pendulum angle θ never more than 0.05 radians from the verticals. From the results, it shows that PID controller can stabilize the nonlinearity function. While PID controller can be attributed partly to their good performance in a wide range of operating conditions and partly to their functional simplicity that make it simple, straightforward manner in operation. This result indicates that the model can be effectively used for control algorithms development and system evaluation.

ABSTRAK

Projek ini merupakan satu pembangunan dan mereka bentuk kawalan kaki palsu yang pasif kepada semi aktif kepada golongan cacat fizikal. Pemasangan kaki palsu ini akan disambungkan bahagian atas lutut. Kecacatan fizikal boleh terjadi dalam beberapa faktor antaranya ialah kesan akibat kemalangan atau penyakit yang melibat kitaran darah yang tidak sempurna seperti kencing manis. Rekaan kaki palsu ini dicadangkan dengan reka bentuk yang mempunyai peredam MR „*magnetorheologikal*" di mana peredam ini akan menggantikan fungsi otot kaki yang hilang dari atas lutut hingga ke pergelangan kaki. Sebelum peredam tersebut diaplikasikan, semua sifat peredam hendaklah dikenalpasti terlebih dahulu. Model Bouc-Wen merupakan model terbaik untuk memberi gambaran sifat yang histeresis yang dimiliki oleh peredam MR. Kami juga memodelkan kaki manusia menggunakan sistem bandul terbalik. Strategi kawalan yang digunakan untuk proses pembangunan kaki palsu ini adalah menggunakan kaedah kawalan perkadaran, kamiran dan terbitan (PID) dan bandul terbalik. Secara umumnya, tindak balas sistem pada keseluruhannya tidak stabil dalam bentuk gelung buka. Kriteria untuk mendapatkan kestabilan sistem ialah (i) masa pengenapan, untuk kurang daripada 5 saat dan (ii) sudut pendulum tidak lebih daripada 0.05 radian dari sudut menegak. Berdasarkan hasil keputusan, ini menunjukkan bahawa pengawal PID boleh menstabilkan fungsi ketaklelurusan. Walaupun pengawal PID boleh dikaitkan sebahagiannya untuk prestasi yang baik dalam pelbagai keadaan operasi dan sebahagian lagi untuk meringkaskan kerja supaya mudah beroperasi. Keputusan ini menunjukkan bahawa model yang boleh digunakan secara berkesan untuk pembangunan algoritma kawalan dan penilaian sistem

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LIST OF ABBREVIATION/SYMBOL

a	=	Bouc-Wen model parameter related to the MR material yield stress
k_0	=	Spring stiffness
c_0	=	Dashpot damping coefficient respectively
z	=	Hysteretic deformation of the model
A	=	Bouc-Wen model parameter
β	=	Bouc-Wen model parameter
γ	=	Bouc-Wen model parameter
c_{0a}	=	Damping coefficient a at 0
c_{0b}	=	Damping coefficient b at 0
c_{1a}	=	Damping coefficient a at 1
c_{1b}	=	Damping coefficient b at 1
k_1	=	Spring stiffness 1
x_0	=	Displacement
a_a	=	Third-order polynomial a
a_b	=	Third-order polynomial b

LIST OF ABBREVIATION/SYMBOL

n	=	Parameter for power
η	=	Viscosity of fluid
M_c	=	Mass of the cart
m_p	=	Mass of the pendulum
b	=	Friction of the cart
I	=	Inertia of the pendulum
l	=	Length to the pendulum‟s center of mass
F	=	Impulse force applied to cart
P	=	Reaction force on the pivot from vertical direction
N	=	Reaction force on the pivot from horizontal direction

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CHAPTER 1

INTRODUCTION

1.1 PROJECT BACKGROUND

Every part of our body plays an important role in implementing the daily activities such as walking, running and etc. But not everyone in this world are so lucky because of some unwanted situation or disease. There are number of reasons that cause them to need an amputation. The common ones include the circulation problem from atherosclerosis or also known as diabetes. The traumatic injuries also the common cause including from traffic accidents and military combat. While for cancer is the least causes among others.

According to Amputations by Cause Limb Loss in the United States, there are approximately 1.7 million people living with limb loss. Most commonly, limb amputation resulting from the causes stated involved the lower limb, above-knee and below-knee amputations. From the data statistical, it shows that the need for prosthetic leg is quite high in order to continue or survive their daily activities like normal people. Prosthetic leg is not bionic, it have to combine their energy and willpower into learning how to use it. Therefore, the comfortable is the important key in order to produce a prosthetic leg.

The proposed design of prosthetic leg featuring magneto-rheological (MR) damper in which the damper is able to replace the missing leg muscles from knee to ankle. Magneto-rheological (MR) damper have a component of MR fluid, a pair of wires, housing, a piston, a magnetic coil and an accumulator. MR fluid have been discovered by Jacob Robinow in the 1940s, of which yield stress and viscosity varies in the presence of magnetic field, various applications using MR fluid have been developed such s shock absorbers, clutches, engine mounts, haptic devices and structure dampers, etc (Kim et al., 2002).

Magneto-rheological fluid is called a smart material because of its properties can be controlled by applying a magnetic field whose consistency can be rapidly switched to any intermediate state between liquid and solid. The MR fluid consists of suspension of fine magnetically polarisable particles in a carrier medium such as mineral oil and silicone oil. When a magnetic field is applied to the MR fluids, it will align themselves in chains along the field lines. The value of fluid viscosity will affect the damping characteristics of the damper system. Due to the road or track irregularities, MR fluid is used to control the damping characteristics of the damper according to the force acting on it. This property can be used to control the stiffness and viscous damping. Therefore, the prosthetic leg for amputees featuring magneto-rheological damper will offer effective performance over a variety of amplitude and frequency range.

1.2 PROBLEM STATEMENT

Current existing prosthetic legs are primarily cosmetic with very little functionality except for minimal gripping capabilities using the passive-adjustment armatures. In other words, the prosthetic leg is lack of comfort and control. Based on the survey and summary that written jointly by the O&P EDGE and the Amputee Coalition stated that they " found it easier to perform daily task without it " due to they do not like the way the prosthetic devices look and cited lack of comfort. In term of complain, some of the amputees reported that wearing a prosthesis increases joint and muscle pain caused by irregular surface. When they do some extreme activities such as going up and down slopes, it will affect their movement. According to Professor Michael Goldfarb, it was tough to make the prosthetic leg light and quite enough. In addition, the biggest technical challenge, however, was to develop the control system. Furthermore, one of the members from the faculty has designed and introduced a MR damper based prosthetic leg in order too make the user fell comfortable. The proposed control method for the prosthetic leg is using Proportional Integral Derivative (PID) controller. This prosthetic leg featuring magneto-rheological (MR) damper is classified as semi-active devices. Semi-active devices are characterized by their ability to dynamically vary their properties with a minimal amount of power (Housner et al., 1997; Spencer and Sain, 1997). The controller has to perform individual operation reliability, but also it has to perform several operations at the same time and not to get confused. Therefore, the most consideration to be taken is the development of mathematical modeling and control system for magneto-rheological (MR) damper.

1.3 OBJECTIVE

The objective for this project as shown as below :

i) To design a controller for an adaptive prosthetic leg with magneto-rheological (MR) damper.

1.4 SCOPE

i) Study the control strategies for prosthetic leg featuring magneto-rheological (MR) damper.

ii) Propose the suitable mathematical modeling and controller for magneto-rheological (MR) damper.

iii) Analyse and simulate the performance of the control system.

CHAPTER 2

LITERATURE REVIEW

2.1 MAGNETO-RHEOLOGICAL (MR) FLUIDS

Magneto-rheological (MR) fluids is called smart material that contain dispersed micro-sized magnetically particles, some kind of controllable carrier fluids. These particles are polarized and arranged in a pattern of magnetic line when exposed to magnetic field, resulting in behaviour of the fluid is changed from being linear viscous to a semi-solid in milliseconds and reversibly. First development of MR fluids is in the late 1940"s by Jacob Rabinow at the US National Bureau of standard. Furthermore, the changes of the fluid particles restrict the movement of the MR dampers by adjusting the current within allowable range and will increase the fluid viscosity. The characteristics of damping for the damper system is dependent upon the value of fluid viscosity. There are some interesting features in MR fluid which are inexpensiveness cost, small power requirement, reliability, stability, and continuously changes its state. When activated, MR devices capable of much higher yield strength. The use of MR fluids to MR damper can be considered as semi-active control devices due to producing of controllable damping forces.

2.2 MAGNETO-RHEOLOGICAL (MR) DAMPER

A schematic diagram of a typical MR damper is illustrated in Figure 2.1. There are three main types of MR damper which are mono-tube, twin-tube and double-ended tube. In this research, the mono-tube damper is set as the fundamental concept of MR damper design. A MR damper commonly consists of a mono-tube house, wire with magnetic coil, floating, piston, piston rod, valve, oil seals, upper cover, lower cover, mounting bracket, pressurized gas inside the accumulator and magneto-rheological fluid. The force desired by the system to be controlled will determine the size of the MR damper.

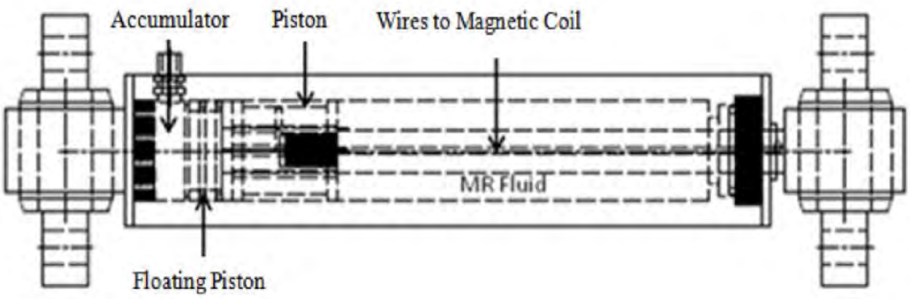

Figure 2.1 :Schematic diagram of lateral MR damper design

Upper cover functions as to seal the top of MR damper to prevent the flow out of MR fluid from the cylinder. The mounting bracket is designed and fabricated on the upper cover. During compression and extension as the movement of piston, there are two oil seals working to prevent the MR fluid flow out of the cylinder at the upper cover. The oil seals also serve to keep out dust from entering the cylinder.

Piston rod is one component that acts to transfer forces from the mounting bracket to the piston to perform the reaction force. The movement of piston during compression and extension is in linear motion.

The design of floating piston is to separate the two different medium between MR fluids and pressurized air. As mention before, the installation of two oil seals on the floating piston to prevent the mixing of MR fluid and pressurized air. In order to initiate pressurized air into the cylinder then valve is used. The accumulator was applied about four bar of pressurized air into the MR fluid damper. The leaking of pressurized air from the cylinder can be prevented by the design of lower cover. The installation of MR damper on the test rig can be facilitate easily by mounting bracket. All the function of each MR damper components are summarized in the Table 1 below :

Table 2.1:Component of MR damper and its function

Component	Function
Cover of upper	i) To close the top of MR damper ii) To prevent the MR fluid flow out of the cylinder
Cover of lower	i) To prevent pressurised air leaks from the cylinder
Oil seal	i) To prevent flow out of MR fluid ii) To keep out dust from entering the cylinder
Piston rod	i) To transfer forces from the mounting bracket to the piston to perform the reaction forces
Floating piston	i) To separate two different medium between MR fluid and pressurised air
Valve	i) To initiate pressurised air into the cylinder
Accumulator	i) To apply air pressure to the MR fluid damper
Mounting bracket	i) To facilitate the MR damper easily installed on the test rig
Wire on the coil	i) To generate maximum current and resistance according to the number of turns of wire on the coil.