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MOTION STUDY OF BIONIC LEG USING

HYDRAULIC MOTOR

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MOTION STUDY OF BIONIC LEG USING HYDRAULIC MOTOR

QUAK ZHI YUAN

A report submitted in partial fulfilment of the requirements for the degree of Bachelor of Mechatronic Engineering

Faculty of Electrical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2014

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I declare that this report entitle “Motion study of bionic leg using hydraulic motor” is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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ABSTRACT

Nowadays, several sicknesses such as stroke, injury on the lower limb and elder people cannot walk in a proper way due to joints' injury. These sicknesses may cause lots of inconvenient in their daily life especially when their lower limb cannot move well in a proper motion. From the research of journal, lots of designs regarding exoskeleton leg (bionic leg) were done to assist the human in term of gait. Different types of method proposed according to the research such as gravity balancing orthosis (GBO), MATLAB software as controller, sliding mode controller (SMC) and humanoid robot biped with heterogeneous legs (BRHL) and etc. Some methods relate to the hydraulic motion study and some relate to the motion of exoskeleton legs. Derivation of mathematical modelling on bionic leg in term of kinematic analysis is the first objective. Another objective of this project is to design the motion of bionic leg using hydraulic actuator for stand and sit position. Besides, analysis on the design of motion study of hydraulic actuator in overall performance to give accuracy and reliability for rehabilitation application was done. There are three phases to be undergone according to the objectives. The derivation of mathematical modelling on bionic leg in term of kinematic analysis was done for the phase 1.The design of motion of bionic leg using hydraulic actuator with stand and sit position was done in phase 2 whereas analysis of the overall performance is done for the phase 3 for bionic leg. FluidSIM used as simulation to test the forces relative to the time taken for the hydraulic actuator. The result to be expected achieve is that able to control the hydraulic actuator for stand and sit position and analysis on overall performance such as accuracy needed so that it suitable used for rehabilitation purpose.

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ABSTRAK

Pada zaman ini, pelbagai penyakit seperti strok, kecederaan pada anggota badan yang lebih rendah dan orang tua yang tidak mampu berjalan dalam perjalanan yang betul atas sebab kecederaan pada sendi lutut. Semua penyakit ini akan memberi kesan dan menyusahkan aktiviti harian terutamanya sendi lutut yang tidak mampu bergerak dalam posisiyang betul. Dalam kajian jurnal, pelbagai reka bentuk mengenai exoskeleton kaki (kaki bionik) telah dikaji untuk membantu manusia dari segi gaya pengerakan. Terdapat pelbagai jenis kaedah yang dicadangkan menurut kajian jurnal seperti ‘ gravity balancing orthosis(GBO), ‘MATLAB software’ sebagai pengawal, ‘ sliding mode controller(SMC)’ dan ‘ humanoid robot biped with heterogeneous legs(BRHL)’, serta yang lain. Terdapat sebahagian kaedah yang mengenai dengan kajian pengerakan hidraulik da nada yang berkaitan dengan pengerakan kaki exoskeleton. Objektif utama ialah perolehan pemodelan matematik di kaki bionic dari segi analisis kinematik. Objektif kedua dengan projek ini adalah untuk reka bentuk kajian usul kaki bionik dengan menggunakan penggerak hidraulik pada gerakan yang digunakan bagi posisi berdiri dan duduk. Selain itu, analisis mengenai reka bentuk kajian gerakan penggerak hidraulik dalam prestasi keseluruhan untuk memberikan ketepatan dan kebolehpercayaan bagi pemulihan telah dikaji. Terdapat tiga tahap untuk dikaji berdasarkan objektif. Asal pemodelan matematik pada kaki bionik dari segi analisis kinematik telah dilaksanakan bagi fasa 1. Reka bentuk gerakan kaki bionik dengan menggunakan penggerak hidraulik bagi posisi berdiri dan duduk telah dilaksanakan dalam fasa 2 manakala analisis prestasi keseluruhan dilakukan bagi fasa 3 untuk kaki bionik. FluidSIM digunakan untuk menguji kuasa relatif kepada masa yang diperlukan untuk penggerak hidraulik daya .Hasil kajian yang dijangka mencapai ialah mampu mengawal penggerakan hidraulik untuk berdiri dan duduk serta analisis mengenai prestasi keseluruhannya seperti ketepatan yang diperlukan supaya ia boleh digunakan sesuai untuk tujuan pemulihan.

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LIST OF ABBREVIATIONS

Abbreviation	Description
VDHM	Variable displacement hydraulic motor
PID	Proportional, Integration, Derivative
SISO	Single Input Single Output
MIMO	Multiple Input Multiple Output
BRHL	Humanoid robot biped with heterogeneous legs
FCV	Flow Control Valve
PRR	Prismatic-revolute-revolute
GBO	Gravity balancing orthosis
COG	Centre of gravity
GA	Genetic Algorithm
HSS	Hydraulic servo system
VDHM	Variable (different) displacement hydraulic motor
DH	Denavit Hartenberg
LQR	Linear Quadratic Regulator
IEC	International Electrotechnical Commission

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CHAPTER 1

INTRODUCTION

1.1 Project Background

Bionic legs had been developed few years recently. They are widely used for people whom had injury on their lower limb or loss of legs due to some accidents or sickness. This may cause inconvenient for them to walk in normal pattern and cause a lot of difficulty in their daily lifestyle. There are lots kind of application on the bionic leg either using pneumatic actuator or hydraulic actuator. Lots of studies had been done to improvise the development on bionic legs. The design on bionic leg itself are complex and require lots of engineering knowledge to enable the succeed in the project. In order to aid the elder people with difficulty to walk due to several illnesses or injury, the studies of bionic leg was introduced to aid them. Other than aid the patients, the previous research on the exoskeleton suit to let the soldier to carry heavy load for the running and climbing which include the armor or weapon. This may reduce the injuries on the lower limb and ease the soldier in term of their movement. The motion study of bionic leg using hydraulic motor was proposed to overcome and improve the situation for the real life application. This will improve their lifestyle and provide a comfortable condition for the elders whom faced difficulty on walking. This bionic leg which is used in rehabilitation should not be heavy weight and the material used for the design should be reliable so that it is not too heavy which may cause burden to them.

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1.2 Motivation

Bionic which is also known as the bionical creativity engineering which is the method used to study and design of the engineering systems and modern. This bionic leg can be used in lots of field such as medical field which help patient in term of their walking gait during their physiotherapy. Patients are able to walk in a proper way with the aid of bionic legs using hydraulic actuator.

For instances, patient that had stroke may have difficulty to walk and statistic shown that there are nearly 1 in 6 people may have stroke in their lifetime. About 50, 000 Australians suffered these strokes and there are nearly 1000 strokes every week. For the global, there are over 420, 000 people living with stroke and this value may be predicted to be continue increase. This shown that the bionic leg is useful in medical field to aid these stroke patients and improve their daily lifestyle. [1]

For the injuries of sport, there are lot of sports activities can be categorized for different type of injuries. Sport such as football, soccer, basketball and baseball may have their own risk and injuries on different part of body. Statistics showed that sports such as basketball, football and soccer had the high risk of injuries on ankle and knee. Thus, this project of the bionic leg using hydraulic actuator able to aid these patients too. Figure 1.1 shows the bar chart of type of injury for different sports among age 25 to 40 years.[2]

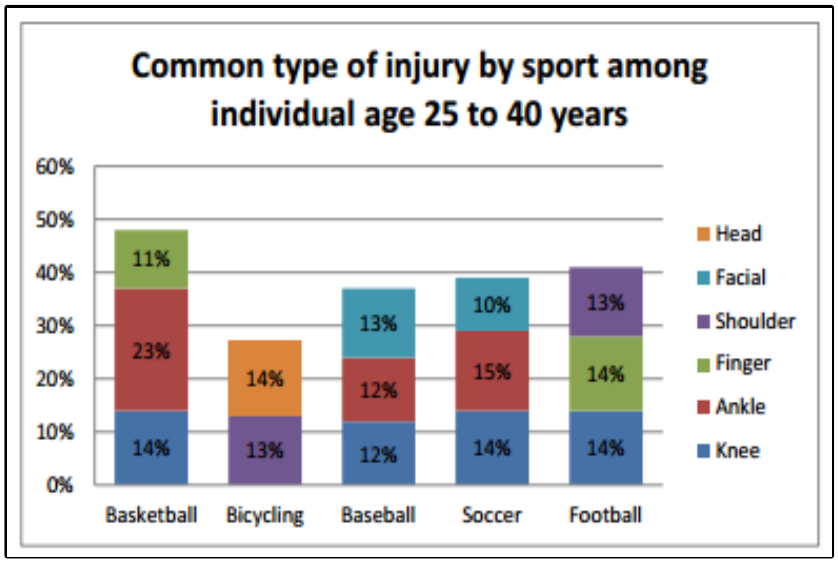

Figure 1.1 Type of injury by sport among age 25 to 40 years [2]

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Figure 1.2 shows the number of injuries at the age of 25 to 40 years and by gender. We noticed that about nearly 80, 000 injured for the basketball sports and 93% of injuries were among men. For the soccer players, there were around 30,000 people injured and 83% of injuries are men whereas for the football, about 38,000 people injured and 88% were men. This statistic shows that how important on this research to aid those injuries especially on the lower limb and hydraulic actuator is used because hydraulic actuator able to withstand high load and accurate in position. [2]

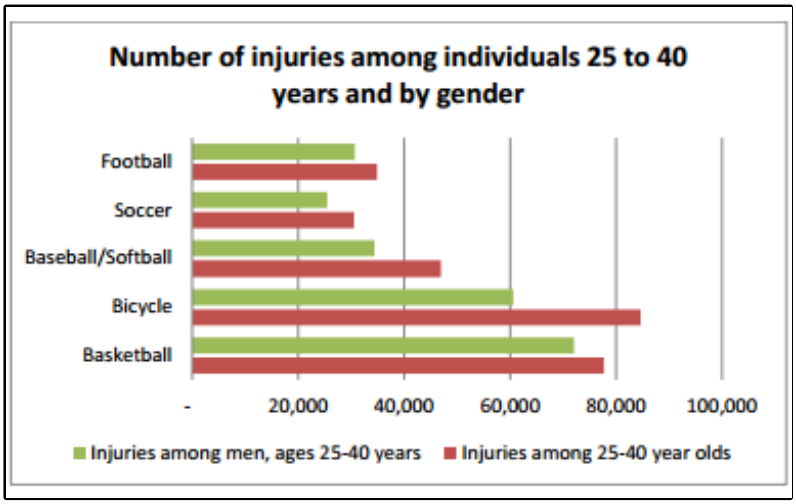

Figure 1.2: Number of injuries at the age of 25 to 40 years and by gender

1.3 Problem Statement

Most of the patient with several sicknesses such as stroke, injury on the lower limb and some elder people cannot walk in a proper way due to their joints' injury. These sicknesses may cause lots of inconvenient in their daily life especially when their lower limb cannot move well in a proper motion. Thus, this motion study with the used of bionic leg using hydraulic actuator is proposed to overcome the problem faced. These would benefit them and provide a more comfortable, reliable and convenient in their daily life. Besides, previous study on pneumatic actuator on the bionic legs had some limitation as well. In term of compression, the pneumatic cylinder is not always possible to get the uniform and constant piston speeds of compressed air. Besides, pneumatic cylinder only

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able to withstand 600 to 700KPa (6 to 7 bar) only compare with hydraulic cylinder which is able to withstand more load. Thus, in order to improve the efficiency of the pneumatic actuator, this project was proposed. Hydraulic cylinder can provide constant force and it is flexible whereby it can be stores under pressure for long periods. Hydraulic cylinder able to transfer huge amounts of power too. The hydraulic cylinder pressure can be controlled until the best pressure is selected depend on the load needed. For instance, pneumatic cylinder unable to withstand high load for the patient that had heavy weight and the pressure inside the pneumatic cylinder may not be constant flow which may cause the improper movement of the bionic leg. However, hydraulic cylinder may overcome this situation because the fluid flows in the hydraulic cylinder incompressible. Other than that, hydraulic cylinder is accurate for the control motion of extend and retract in term of its position.

1.4 Objective

1. To derive mathematical modelling of bionic leg in term of kinematic analysis.
2. To design the motion of bionic leg in application of hydraulic actuator for stand and sit position.
3. To analyze the overall performance in term of accuracy and reliability on the bionic leg using hydraulic actuator for rehabilitation application.

1.5 Scope

1. Derivation of mathematical modelling focus on the hydraulic actuator of one leg with two degree of freedom in term of kinematic analysis.
2. Stand and sit position with the use of two hydraulic actuator which include hip and knee parts on one leg is analyzed.
3. The analysis performance on hydraulic actuator done in experimental lab is discussed about time taken for hydraulic actuator to extend, retract and its velocity with different pressures, accuracy on hydraulic cylinder stroke position with the use

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of limit switches and flex sensor as well as synchronization of two cylinder movement.

4. The analysis performance on accuracy done on hardware in term of the knee and hip rotation angle in stand and sit position with the used of limit switches.
5. This project focus on using the FluidSIM as computer simulation on hydraulic cylinder with forces provided and Arduino UNO R3 as microcontroller to actuate the hydraulic cylinders.

1.6 Significant of study

This proposed motion study of bionic leg using hydraulic motor will provide lot of opportunity and beneficial for the people who in difficulty of the walking especially for the elder people or people who had injury on the lower limbs. This study may improve the previous study which using pneumatic actuator by replacing it with hydraulic actuator in order to obtain high accuracy performance for rehabilitation purpose.

1.7 Report outlines

Chapter 1 discussed about the project background regarding the related project, problem statement, objectives, scope of research and significant of study. Chapter 2 was the literature review with its theory and the related on the previous work of research or study. Comparison on the review was done too. Chapter 3 discussed about the research methodology. Flow chart, K-chart, derivation of mathematical modelling in term of kinematic analysis, experimental design and implementation on hardware were done. Chapter 4 was the result obtained with the discussion for the experimental design, comparison on derivation of mathematical modelling in term of kinematic analysis in theory with result for the implementation on hardware. Chapter 5 was the conclusion for this project with the recommendation.

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