DESIGN A NEW BIONIC ARM TO ASSISTS PARALYZE ARM

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ABSTRACT

Based on the statistic, stroke is one of the largest killers in Malaysia only after heart disease and cancer where an estimated 40,000 people in Malaysia suffer from this type of disease. Another statistic shows 12 to 53 new spinal injuries per million inhabitants in the developed countries per year. These injuries lead to disability of human body parts including paralyzed arm. In order to assist paralyzed arm sufferers, studies have been conducted to improvise the development of bionic arms. Based on the problem statement, previous studies on bionic arm had some limitation to users. Moreover, previous study has also shown that the design of bionic arms is lacking in engineering characteristic. The objectives of this project are to derive the mathematical model of bionic arm using kinematic analysis and formulate joint torque and to design and validate the bionic arm in term of structural strength and torque. This proposed motion study is to provide opportunity and benefit for the patient who are suffering from paralyzed arm. Next, the methodology of the project started with kinematic analysis and mathematical model of bionic arm and validation by Robotics Toolbox MATLAB Software. Then, the formulate joint torque of bionic arm by static forces in manipulator is analysed. After that, the bionic arm was designed and analyzed by SolidWorks simulation. Finally, Maximum torque was simulated by SolidWorks Motion. As the result, the joint angle configuration on kinematics calculation and MATLAB Simulation both have obtained$[1,0,0]$,$[-1,0,0]$, $[0,-1,0]$ and $[0.5,0.5,0]$. Then, SolidWorks Simulation obtained factor of safety, where the value is 34 and 14 for whole part testing and 772, 155, 4, 1273, 15 and 8 for by part testing. After that, the calculated result of formulate torque is 19.14Nm, 19.14Nm, 11.05Nm, 4.458Nm and 4.458Nm. Meanwhile, the results of SolidWorks Motion are 66.75Nm, 66.31Nm, 37.71Nm, 0.04Nm and 5.22 for dynamic motion method and 66.94Nm, 66.27Nm, 37.78Nm, 0.04Nm, and 5.21Nm for static motion method. For the conclusion, the derived kinematic model for bionic arm has been validated by MATLAB Simulation. Then, all analyzed structure strength parts are safe. Finally, the type of motor could be determined based on resulted maximum torque.

ABSTRAK

Berdasarkan statistik, strok merupakan pembunuh nombor satu di Malaysia selepas sakit jantung dan barah dimana dianggarkan 40,000 rakyat Malaysia menghidap penyakit ini. Statistic lain menunjukkan 12 dari 53 kecederaan tulang belakang setiap sejuta penghuni di negara membangun setiap tahun. Kecederaan ini telah menyumbang kepada kecacatan bahagian tubuh badan termasuklah ketidakupayaan tangan. Untuk membantu pengidap ketidakupayaan tangan, kajian telah dilakukan untuk memperbaiki pembangunan tangan bionik. Berdasarkan penyataan masalah, kajian lepas terhadap tangan bionic mempunyai keterbatasan terhadap pengguna. Tambahan pula, kajian lepas juga telah menunjukkan reka bentuk tangan bionic kekurangan ciri-ciri kejuruteraan. Objektif projek ini adalah untuk menerbitkan model matematik tangan bionik menggunakan analisis kinematik dan memformulasi sendi daya kilas dan untuk mereka bentuk dan mengesahkan model tangan bionik dari sudut struktur kekuatan dan daya kilas. Sasaran kajian ini adalah menyediakan peluang dan kebaikan untuk pesakit yang mengidap ketidakupayaan tangan. Seterusnya, metodologi projek telah bermula dengan analisis kinematik dan model matematik tangan bionik dan telah disahkan oleh perisian Robotics Toolbox MATLAB. Kemudian, memformulasikan daya kilas tangan bionik dengan daya statik dalam *manipulator*. Selepas itu, tangan bionik telah direka bentuk dan dianalisis dengan simulasi SolidWorks. Akhirnya daya kilas maksimum telah disimulasikan dengan SolidWorks Motion. Dan keputusannya, kedua-dua *konfigurasi* sudut sendi pada pengiraan kinematik dan simulasi MATLAB telah mendapat $[1,0,0]$,$[-1,0,0]$, $[0,-1,0]$ and $[0.5,0.5,0]$. Kemudian, keputusan simulasi SolidWork telah mendapat darjah keselamatan diamana nilainya 34 dan 14 untuk ujian keseluruhan bahagian dan 772, 155, 4, 1273, 15 dan 8 untuk ujian separuh bahagian. Selepas itu, keputusan yang telah dikira untuk memformulasi daya kilas adalah 19.14Nm, 19.14Nm, 11.05Nm, 4.458Nm and 4.458Nm. Manakala keputusan SolidWorks Motion 66.75Nm, 66.31Nm, 37.71Nm, 0.04Nm dan 5.22 untuk kaedah pegerakan dinamik dan 66.94Nm, 66.27Nm, 37.78Nm, 0.04Nm, dan 5.21Nm untuk pegerakan statik. Kesimpulannya, model kinematik yang telah diterbitkan untuk tangan bionik telah diasahkan oleh simulasi MATLAB.

Kemudian, semua struktur kekuatan yang telah dianalisis adalah selamat. Akhirnya, jenis motor boleh ditentukan berdasarkan keputusan daya kilas maksimum.

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CHAPTER 1

INTRODUCTION

1.1 Project Background

Recently, a lot of researchers are developing artificial arm which can closely resemble the function of a human arm. Bionic arm is applicable to various field such as the military and medical. In the medical field, this technology is mostly applied to help patients who are suffering from paralyzed arm resulted from stroke, upper limb injury and old age factor. These inabilities may cause inconveniences for them to perform daily routines. There are various types of bionic arm. Many research were conducted to improve on the development of bionic arm. A bionic arm is a complex piece of engineering. It requires deep understanding of the knowledge and process to successfully build a bionic arm. In order to help patients with paralyzed arm, the study of bionic arm is introduced. The motion study of a new bionic arm design to assist patients with paralyzed arm was proposed to overcome and improve the situation for real life application. Hopefully, this will help to improve the life of the sufferer, provide more comfort and ease their daily activities. The bionic arm also is designed to be ergonomic so that the users of the bionic arm are comfortable and safe.

1.2 Motivation

Bionic engineering is a method to study the living system with the intention to apply the principles to the design of an engineering system. The bionic arm is used in the medical field as a rehabilitation robot. The users are able to improve the movements and functions of their arm using this bionic arm.

Based on the National Stroke Association of Malaysia (Nasam) statistic, stroke is one of the largest killers in Malaysia only after heart diseases and cancer. At another edge, stroke is one of the contributors to severe disability, and year by year an expected 40,000 people in Malaysia suffer from this disease. In the year 2005 alone, 17909 stroke sufferers were admitted into public hospitals all over the country. By the year of 2020, this statistic is expected to rise to 25,000 per year. On top of that, a study conducted by Dr. Tan Chong Tin, the senior consultant at the neurology clinic of University Malaya Medical Center suggested that 70% of stroke patients who recuperated from stroke stopped taking parts in social activities, 30% are in need of assistance and 15% passed away within a month. [1]

According to The Neurosurgical Association of Malaysia (NAM), there are 12 to 53 new spinal discomfort per million inhabitants in the developed countries per year. At a certain time in the United States only, 721 to 906 people are suffering from spinal cord injury per million populations. The new spinal cord injury is predicted to increase in Malaysia. For instance, in the Neurosurgical service in Sarawak General Hospital, a case of spine injury is reported every month for patients with head injury. These patients usually are young and a ratio of two thirds of these happen to a person less than 30 years of age. However, it varies from country to country. About 20 to 57 percent of people diagnosed with spinal cord injury have injuries elsewhere. [2] These injuries lead to the disability of human body parts including paralyzed arm

1.3 Problem Statement

Some patients who are suffering from stroke, injury on the upper limb, and some older patients are unable to move their arm and hand normally. This problem causes limitations for patients to perform their daily activities as they cannot move their upper limb properly. Therefore, the need for a new motion study to design bionic arm as assistive technology to overcome the problem is vital. This study may be beneficial for patients who lost abilities to move their arm by providing more comfort, convenience, and self-reliability in their daily life.

Previously, the design and functions of a bionic arm were limited. For instance, many of the bionic arms only function as an assisting tool for rehabilitation therapy. The patients mainly used the bionic arm during therapy sessions, but they did not always wear it all day long to perform daily routines at home. Thus, it is vital that the design for this new bionic arm serves not only for therapy purposes, but is also used to assist patients in moving their hand just like a healthy person all day long.

Other than the aforementioned disadvantages, the design of previous bionic arms were lacking in engineering characteristics such as the absence of ergonomics implementation on bionic arm. Consequently, it caused injury, discomfort, and was unsafe to the user of bionic arm. Other than that, previous bionic arms were also not portable as it was attached to the wheelchair or it was too big and heavy to carry, thus limiting the mobility of the user. In order to overcome this problem, this project is proposed to design an ergonomic and portable bionic arm.

1.4 Objective

The objective this project are:

1. To derive the mathematical model of bionic arm using kinematic analysis and formulate joint torque.
2. To design and validate the bionic arm in term of structural strength and torque.

1.5 Scope

This project will focus on supporting system of an 80kg able-bodied user suffering with the disability to move the arm. The bionic arm is design to be an exoskeleton robot where it will be actuated by an electrical actuator available on the market. In this project, the kinematics of the bionic arm manipulator will be derived. Besides, the exoskeleton arm will be designed in three dimensions by using SolidWorks Software. Apart from that, the upper limb exoskeleton will be analyzing the performance of the bionic arm in term the structural strength and torque requirement.

1.6 Project Significance

This proposed motion study of a new bionic arm design to assist paralyzed arm will provide opportunities and benefits for patients who are suffering from paralyzed arm especially those resulted from stroke and spinal cord injury. This study may improve on previous bionic arms by focusing on ergonomic design.

CHAPTER 2

LITERATURE REVIEW

This chapter is dedicated for preliminary reviews for the research method of bionic arms making approach. The literature review will clarify sustainability associated with this research study. This chapter will review exoskeleton as mechanism in bionic arm robot. Then, the anatomy of the upper limb is discussed thoroughly. Next, the explanations of actuators, sensors, power transmission, material, ergonomics mechanism, and microcontroller are clearly discussed throughout this chapter.

2.1 Introduction

According to the American Heritage Dictionary of the English Language, Bionic is defined as the Application of biological principles to the study and design of engineering systems, especially electronic systems. [3] Referring to the Oxford Advance Learner's Dictionary, exoskeleton is defined as a hard outer covering that protects the bodies of certain animals. [4] Exoskeleton robots are an actuated skeleton-like, external supportive structure robots applied to human. There are many functions of exoskeleton such as, extending or powering human performance as applied in military equipment or rehabilitation process of impaired function. Other than that, exoskeleton is also used as an interface that creates physical

contact with an illusionary physical environment or object. These haptic devices are usually referred to as kinesthetic interfaces. Other possible applications are in gaming and advanced fitness equipment. [5] Exoskeleton robots are also applied in training human motor skills. For example, it is used in the rehabilitation of arm functionality or gait after a stroke. [5]

2.2 Limb

Limb is a jointed or prehensile, appendage of human body. The limb is divided into the upper and the lower limb. In human anatomy, the upper and lower limbs are commonly referred as the arms and the legs. According to Basic Human Anatomy website, a lower limb has four major parts: a girdle formed by the hip bones, the thigh, the leg, and the foot. Its main function is to support the weight of the body, adapting to gravity, and locomotion. As for the lower limb, it is customary to include regions that are transitional between the limb and the trunk, especially the gluteal and inguinal regions. [6] The human upper limb can be separated into shoulder joint, upper arm, elbow joint, forearm, wrist joint and hand. The upper arm is linked to the torso by the shoulder joint. Then, the forearm is connected to the upper arm through the elbow joint, and forearm and the hand link the wrist joint. The human upper limb can be simplified as a spatial linkage mechanism composed of several rigid links connected through revolute pairs according to the human anatomy and mechanisms. The skeletons are links, and the revolute pairs represent the joints. The upper limb consists of seven main independent degree of freedom, and they are the shoulder flexion and extension movement, the shoulder abduction and adduction movement, the shoulder medial and lateral rotation movement, the elbow flexion and extension movement, the forearm pronation and supination movement, the wrist flexion and extension movement, the wrist abduction and adduction. [7] And the kinematical model of the human upper limb is shown in Figure 2.1.