Annual Sessions of IESL, pp. [661 - 666], 2019

A novel 3 -D printed wrist powered upper limb prosthesis using whippletree mechanism

K.P.L. Kumarage, W.H.S. Wickramarathan, V. Madhushan, V. Mugilgeethan, R. Neethan, T. Thanihaichelvan

Abstract- This study focuses on the development of a 3-D printed low-cost novel solution for upper limb amputees in Sri Lanka. Prosthetic devices available in Sri Lanka are declined by most patients with trans-metacarpal amputation due to the high cost and discomfort. Worldwide the 3-D printing technology has been recognized as a convenient solution for prostheses owing to its customizability and low cost. The adaptive grasp functionality in mechanical prostheses is important to effectively utilize the limited angle of the wrist. Wrist motion of healthy individuals and the limitations in wrist flexion occurring after amputation were studied. With the findings, a novel design was developed incorporating a modified whippletree mechanism. The prosthesis was printed and tested for adaptive grasp and comfort. In this testing, whippletree mechanism was used to improve the adaptive grasp through proper force distribution and a flexible material was introduced for wearable comfort. It was found that this kind of prosthetic hands will help the amputee to grasp complex shaped objects while providing good comfort.

Keywords: Trans-Metacarpal amputation, 3-D printing, Adaptive grasp, Whippletree mechanism, Prosthesis

1. Introduction

A prosthesis is an artificially made alternative for a limb lost through a congenital disability, accident, illness, or wartime injury. The primary function of a prosthetic device is to provide assistive support for patients with upper or lower limb amputation. The upper limb amputation can be categorized into seven levels based on the level of amputation [1]. They are partial hand amputation, metacarpal amputation, wrist disarticulation, below elbow amputation, elbow disarticulation, transhumeral amputation and shoulder disarticulation. In the northern part of Sri Lanka number of people suffer from upper limb amputation due to diabetes, birth defects and civil war [2]. Due to high initial cost and maintenance costs of advanced functional prosthesis amputees avoid their usages [3] [4]. One of the main prosthetic suppliers in the Northern Province is the Jaffna Jaipur Center for Disability Rehabilitation (JJCDR). JJCDR provides services and aesthetic prosthesis developed using Jaipur technology and polypropylene technology. From the time the organization was established in 1987, they have fitted 268 upper limb prosthesis and 6737 lower limb prosthesis for patients until May 2016 [2].

According to a study carried out involving American citizen, around 541,000 Americans suffer from upper limb amputations and this amount will be doubled by the end of 2050 [5]. Early methods of fabricating prosthesis limited its functionality and ability for customization. With the development of the rapid prototyping, specifically 3D printing in the last few decades the fabrication of prosthetics has become much more manageable. Three-dimensional printing is an additive manufacturing technique. Products are built up layer by layer instead of removing material from a large piece of material [6]. Using 3D printing made prosthetics customizable and lightweight while increasing functionality [7]. Additional to the advantages, there are also a few disadvantages of 3D printing as well, such as 3D printing is only possible with the limited number of materials. Acrylonitrile Butadiene Styrene (ABS) or Poly Lactic Acid (PLA) are considered as the most suitable material for 3D printing of prosthesis, focusing on the factors of cost and availability, toxicity, biodegradability and comfortability [8]. The functionality of the prosthetic hand is essential to the users to perform their day to day activities and their special requirements. Using a proper mechanism that can achieve the required functionality is one of the major concerns. The human hand is a unique tool, finding an alternative to it is very contrary.

Mr. K. P. L. Kumarage *Undergraduate, Faculty of Engineering, University of Jaffna.*

Mr. W. H. S. Wickramarathan *Undergraduate, Faculty of Engineering, University of Jaffna.*

Mr. V. Madhushan *Undergraduate, Faculty of Engineering, University of Jaffna.*

Mr. (Eng.). V. Mugilgeethan *B.Sc. Eng. (Hons) (Ruhuna), Lecturer of Mechanical Engineering, Department of Interdisciplinary Studies, Faculty of Engineering, University of Jaffna.*

Mr. (Eng.). R. Neethan *B.Sc. Eng. (Hons) (Jaffna), Postgraduate student, The State University of New Jersey, USA.*

Dr. (Mrs.) T. Thanihaichelvan *B.Sc. (Hons) (Jaffna), Ph.D. (UM, Malaysia), Senior Lecturer, Department of Interdisciplinary Studies, Faculty of Engineering, University of Jaffna.*