DEVELOPMENT OF A HYBRID EXOSKELETON TO REDUCE MUSCLE STRAIN IN OIL PALM HARVESTING

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To my mother, Umme Kulsum and my father, Md. Tariqul Islam for their sacrifices support in every steps in my life.

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ABSTRACT

Oil palm harvesting is one of the biggest and highly developing agricultural sector throughout the world. Malaysia, the second top producer of palm oil in the world, with 17.32 million tonnes produced in 2016. Within 1960-2005, areas under oil palm plantation were increased from 54,000 hectares to 4.05 million hectares, which reflects a compound annual growth of 10.06%. In the same time period, palm oil production was increased from 94,000 tonnes to 15 million tonnes. In this area, oil palm harvesting is an essential part where a lot of workers are facing frequent body pain. Most common injuries experienced by workers are health, safety and ergonomic injuries. Long hours of manual works in awkward posture and handling load without any support are the reasons behind this pain. The aim of this study was to develop a hybrid exoskeleton exclusive for oil palm harvesting to reduce muscle strain. Iso-elasticity approach was used for gravitational compensation while DC linear motor was used for torque compensation and position control. EMG signal was used to check muscle strain due to harvesting work. As the signals were contaminated with some noises, it was not feasible for discussion. So, low pass filter has been developed using MATLAB DSP tools. Then the filtered data of each cases (i.e. without exoskeleton, with passive exoskeleton and with hybrid exoskeleton) was compared with each other. From the comparison, it can be seen that the overall muscle strain was reduced by 16% using passive exoskeleton and by 23% using hybrid exoskeleton. According to the results, it is evident that, the developed exoskeleton can be implemented in palm oil harvesting which will reduce the pain level of the workers at a significant rate.

ABSTRAK

Penuaian kelapa sawit adalah salah satu sektor pertanian terbesar dan termaju diseluruh dunia. Malaysia merupakan salah satu pengeluar kedua terbesar kelapa sawit diseluruh dunia, telah menghasilkan sebanyak 17.32 juta tan pada tahun 2016. Pada tahun 1960-2005, kawasan perladangan kelapa sawit telah meningkat dari 54,000 hektar hingga 4.05 juta hektar, iaitu bersamaan dengan 10.06% pertumbuhan tahunan kompaun. Dalam tempoh masa yang sama, pengeluaran minyak kelapa sawit juga telah meningkat dari 94,000 tan kepada 15 juta tan. Dengan ini, penuaian kelapa sawit adalah sangat penting dimana kebanyakkan para pekerja berhadapan dengan masalah kesihatan pada bahagian badan dengan kerap. Kecederaan yang paling sinonim dialami oleh pekerja adalah dari segi kesihatan, keselamatan dan ergonomik.Waktu bekerja yang lama dengan melakukan pekerjaan didalam postur badan yang terhad dan statik serta mengangkat barang-barang yang berat tanpa sokongan yang betul adalah punca yang menyebabkan kecederaan tersebut. Tujuan kajian ini dijalankan adalah untuk membangunkan eksoskeletal hibrid khusus untuk penuaian kepala sawit bagi mengurangkan ketegangan otot badan. Pendekatan "iso-elesticity" digunakan untuk pampasan graviti manakala DC motor tegar digunakan untuk pampasan tork dan juga kawalan kedudukan. Isyarat EMG telah digunakan untuk memantau ketegangan otot sewaktu aktiviti penuaian dijalankan. Oleh kerana isyarat telah terganggu dengan hingar, ini menyebabkan analisa dengan terperinci adalah sukar untuk dibincangkan. Dengan ini, penapis pas rendah telah dibangunkan dengan menggunakan "MATLAB DSP Tool". Data yang telah ditapis (sebagai contoh tanpa eksoskeletal, pasif eksoskeletal dan hibrid eksoskeletal) telah dibandingkan antara satu sama lain. Dari perbandingan tersebut, ketegangan otot bagi keseluruhan telah menurun sebanyak 16% dengan menggunakan pasif eksoskeletal dan 23% bagi hibrid eksoskeletal. Berdasarkan dari keputusan yang diambil, ini menunjukkan bahawa, eksoskeletal yang telah dibangunkan dapat dilaksanakandalam penuaian kelapa sawit yang dapat mengurangkan tahap kecederaan dan kesakitan pekerja pada kadar yang signifikan.

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CHAPTER 1

INTRODUCTION

1.1 Problem Background

World markets for edible oils are continuously increasing with time. Between 1980 and 2000, the global production of palm oil was increased from 4.5 million to 20.9 million tonnes per year which is 4.6 folds. Later this production became 30.4 million tones per year within 2010 [2]. This market will be doubled in the next twenty years which implies a doubling of the area under oil palm industries [3], since oil palm gives the highest yield of oil per unit of any crop [4]. Palm oil is produced from the fleshy orange-red mesocarp of the fruits of the oil palm tree (Elaeis guineensis), which contain 45% to 55% oil. The tree can grow up-to 20 to 30 meters and has an economic life span of 25 to 30 years. The female bunch can produce can 30–40 kg fruits [5]. The palm oil is important in the economic and socio-cultural activities of inhabitants around the plantation area. Palm is well used plant with less wastage as every part of the tree has economic importance [6]. The trunk is used as timber and a local fuel source for cooking. The ash produced from burnt dead trees is rich in potassium oxide, which is used in soap production [7]. The leaf rib is used for making fence and shed in local area. Moreover, the fibers are used to make rope [8]. Palm oil is not only used in domestic and international cuisines but also used for the preparation of a number of local products, for example, candles, soaps detergents, cosmetics etc [9]. Palm oil also a strong candidate for biodiesel production as biodiesel produced from palm oil has been found to have very similar fuel properties to petroleum-derived diesel [10, 11].

Malaysia, the second top producer of palm oil in the world with 17.32 million tonnes produced in 2016 [12]. Oil palm tree was first introduced in Malaysia in

1875, and from 1917 onwards the palm sector started its development to grow up into today's multi- billion Ringgit industry [13]. Within 1960-2005, areas under oil palm plantation were increased from 54,000 hectares to 4.05 million hectares, which reflects a compound annual growth of 10.06%. In the same time period, palm oil production was increased from 94,000 tonnes to 15 million tonnes.[14]. Nowadays, Malaysia is taking pro-active steps in strategizing the development of bio-fuel in the country. Therefore, the five leading producers of palm oil in Malaysia are currently producing the commodity through good and sustainable practices which is certified by Roundtable on Sustainable Palm Oil (RSPO) [15].

1.2 Problem Statement

Agricultural activities have always been associated with hazards and injuries. Most common injuries experienced by workers are health, safety and ergonomic injuries. It stems from many causes, such as the use of manual tools, incorrect working position, inadequate rest, overloading and lack of well defined training [16]. In oil palm plantation, palm fruit harvesting is one of the main tasks. Workers cut this fresh fruits branch (FFB) manually using a long pole, which has chisel in its end that weighs around 4-5 kg. During harvesting, workers keep looking up constantly which results in extreme neck and trunk flexion. The situation worsens during harvesting activity for tall trees. Figure 1.1 shows the general posture of cutting out the fruit from palm tree. In this figure, it is shown that, the knees and body is bent down while holding and pushing heavy long-armed sickle.

As a result, they feel extreme body pain. Generally, most of the workers have experienced pain due to their heavy work load. However, they may differ in terms of frequency of pain and pain level. There are 5 work units at oil palm plantation; fruit cutter, frond stacker, loose fruit collector, MTG drive and Badang driver. The pain experienced by oil palm workers according to work units is shown in Table 1.1. FFB cutters were having highest body pain, which is 37.5% of their working hour. It can be seen from Table 1.2 that, most of the cutters feel pain in upper body parts. This pain mainly occurs due to holding heavy load up for a long time in awkward posture.

Figure 1.1: Posture for Oil Palm Harvesting (FFB cutting)

Table 1.1: Pain experienced by workers according to the type of work

Work Unit	Body Pain			Total	
	Sometimes in pain	Frequent In Pain	Always In pain	Number	%
Cutter	21	6	6	33	37.5
Frond Stacker	8	3	0	11	12.5
Loose Fruit Collector	25	2	5	32	36.36
MTG Truck Driver	6	1	0	7	7.95
Badang Driver	4	1	0	5	5.68

Table 1.2: Body part's pain based on work units

Work Unit	Cutter	%
Shoulder (Left)	30	34.1
Shoulder (Right)	29	33.0
Elbow (Left)	15	17.0
Elbow (Right)	12	13.6
Upper Back	31	35.2
Upper Arm (Left)	24	27.3
Upper Arm (Right)	22	25.0

1.3 Hypothesis

This frequent body pain felt by the harvesting workers can be reduced if we can reduce the muscular strain

(i) by reducing some load of the pole with chisel felt by the workers,

(ii) by fixing working posture in correct form,

(iii) by supporting to lift up the load,

(iv) by giving support to hold the pole with chisel up for a long time.

Exoskeleton system can be a solution for this problem. By using gravitational compensation, exoskeleton system can decrease the felt load. It can also help workers to work in correct posture and to lower work related musculoskeletal disorders [17]. Exoskeleton system can minimize workload of the sholder flexor muscles during manual lifing/lowering [18]. Therefore, a suitable type of light weighted exoskeleton is needed that will provide support using gravitational compensation. At the same time, it must provide force while lifting the load up.

1.4 Objectives

The objectives of this project are:

(i) To design an upper back exoskeleton system to provide support and gravitational compensation for load.

(ii) To develop a light weighted exoskeleton system according to design which has degree of freedom required for oil palm harvesting work.

(iii) To attach suitable motor for providing external force to help lifting up the load.

1.5 Research scope

The skope of the research is stated below:

(i) An exclusive design of exoskeleton was used for oil palm harvesting.

(ii) Cheap, available spring, motor and materials were used to ensure affordability.

(iii) Light materials were used to avoid unwanted weight.

(iv) The testing steps were developed mimicking oil palm harvesting.

(v) The participant that took part in this research was healthy with no history of muscle disorder.

(vi) The muscle signals were acquired by using surface Electromyography (sEMG).

(vii) The data or signal processing was performed using MATLAB DSP tools.

1.6 Significance of Research

The significance of the research are stated as follows:

(i) The development of more suitable exoskeleton system for oil palm harvesting, keeping the required level of flexibility under consideration.

(ii) The approach of hybrid exoskeleton which uses advantages of both passive and active exoskeleton while omitting the limitations of each.

(iii)This exoskeleton can also be used to assist different types of work such as car assembly line, construction works, welding etc. which requires both static work and flexibility.

1.7 Organization

The thesis is organized has follows:

(i) Chapter 1: Introduction

(ii) Chapter 2: Literature review

(iii) Chapter 3: Research methodology

(iv) Chapter 4: Results and discussions

(v) Chapter 5: Conclusions and future works In Chapter 1, current oil palm industry is presented. It also includes the research objectives to be achieved in this work, problem statements, scope of work and also the significance of the research after identifying the problem faced in oil palm plantation. Meanwhile, Chapter 2 supports the argument on the proposed solution by elaborating reported works. Chapter 3 describes the proposed model and development used in this work. Obtained results will be analyzed in Chapter 4. In Chapter 5, the final chapter of this thesis, conclusions from the research findings using the proposed techniques are made.

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