FEASIBILITY ANALYSIS OF OIL PALM HARVESTING USING FIBER LASER SYSTEM

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By

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Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Master of Science

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December 2019

Chairman : Professor Mohd Adzir bin Mahdi, PhD
Faculty : Engineering

Malaysia is currently experiencing a labour shortage in oil palm plantations, estimated to account for 46 % of the total industrial workforce. The industry is striving to increase worker productivity by adopting new technologies using a variety of work methods. One of the possibilities is laser cutting technology. Experimental design and methodology of developing a pulsed-fiber laser for cutting oil palm fronds had been discussed in this chapter. The main idea was to characterize and optimize the quality of the laser cutting using two different focus lenses i.e. 250 mm and 63 mm and a jig holder. This section focuses on characterizing the laser beam that was produced and its quality in cutting frond samples by looking at speed of laser beam (mm s^{-1}), frequency (kHz), power (%), and time taken to complete the task of cutting. The results indicated the best cutting speed was at a speed of 1 mm s^{-1} with the optimum of frequency is 5000 kHz. In this research, the optimum cutting power was 50W, which was equivalent to 2 mJ of energy. Under this optimum condition, the time taken to cut fronds was 3 – 5 minutes. It can be concluded that the pulsed fiber laser technology can cut bio-materials such as oil palm frond. However, to declare it as one of the harvesting methods still require further investigations owing to its power limitation that cannot reach the standard time of harvesting.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia
sebagai memenuhi keperluan untuk ijazah Master Sains

KAJIAN KEMUNGKINAN PENGGUNAAN LASER GENTIAN SEBAGAI ALAT PENUAIAN SAWIT

Oleh

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Malaysia kini mengalami kekurangan tenaga buruh di ladang kelapa sawit, dianggarkan ia menyumbang kepada 46 peratus daripada jumlah tenaga kerja mahir. Industri perladangan sawit berusaha bagi meningkatkan produktiviti pekerja dengan memperkenalkan teknologi baru yang menggunakan pelbagai kaedah kerja. Salah satu kemungkinannya adalah penggunaan teknologi pemotongan laser. Reka bentuk dan metodologi eksperimen untuk mengembangkan laser serat berdenyut ini adalah untuk memotong daun kelapa sawit. Idea utama adalah untuk mencirikan dan mengoptimumkan kualiti pemotongan laser dengan menggunakan dua kanta fokus yang berbeza iaitu 250 mm dan 63 mm serta dibantu oleh pemegang jig. Bahagian ini memfokuskan kepada ciri-ciri laser yang dihasilkan dan kualitinya dalam pemotongan sampel dengan melihat kelajuan laser beam (mm s^{-1}), kekerapan (kHz), kuasa (%), dan masa yang diambil untuk menyelesaikan tugas memotong. Hasil kajian menunjukkan kelajuan pemotongan terbaik dari segi bagaimana laser memotong sampel adalah 1 mm s^{-1} dengan optimum frekuensinya adalah 5000 kHz. Kuasa pemotongan yang optimum dalam penyelidikan ini telah disahkan menggunakan 100% daripada jumlah sistem kuasa ia setara dengan 50W atau 2 mJ tenaga. Ini dapat disimpulkan bahawa teknologi laser gentian berdenyut boleh memotong bahan bio seperti pelepah kelapa sawit tetapi untuk mengisytiharkannya sebagai kaedah penuaian adalah jauh dengan had sumber kuasa yang sedia ada dalam kajian ini tidak mencapai waktu pemotongan yang baik dalam operasi penuaian.

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This thesis was submitted to the Senate of the Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows:

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LIST OF ABBREVIATIONS

CAD	Computer-Aided Design
CO_2	Carbon Dioxide
CW	Continuous Wave
CPU	Central Processing Unit
ER	Erbium
FFA	Free Fatty Acids
FFB	Fresh Fruit Bunches
GDP	Gross Domestic Product
GIS	Geographic Information Systems
GPS	Global Positioning Systems
LIDAR	Light Detection and Ranging
MPOB	Malaysian Palm Oil Board
ND	Neodymium-Doped
OSA	Optical spectrum analyzer
PORIM	Palm Oil Research Institute Malaysia
TM	Thulium
UAV	Unmanned Aerial Vehicle
UPM	Universiti Putra Malaysia
YAG	Yttrium Aluminum Garnet
YB	Ytterbium

CHAPTER 1

INTRODUCTION

1.1 Background

Oil palm plantations produce fresh fruit bunches (FFB) as their primary output. A hectare of plantation yields an average of 20 tonnes of FFB in a year [1]. Good estate management generally will produce FFB above the mean value. Malaysia is targeting to increase the national FFB yield up to 25 tonnes per hectare per year by implementing good plantation management practices across all estates around the country. Among good estate management practices is by improving the harvesting and other activity.

Malaysia is currently experiencing labour shortage in the oil palm industry. The precarious and repressive nature of the work with extremely low wages make it a less appealing career option to locals. Hence, oil palm workers are usually being sourced out from neighbouring countries like Indonesia. However, as of recently, Indonesia has been active in expanding their oil palm industry as well which triggered the labour shortage for Malaysian oil palm plantation industry. Therefore, the implementation of machines in oil palm plantation operations is necessary to overcome the issue. An example to this is by adopting new technologies. MPOB, as the Malaysian Research Institution has made significant breakthroughs in developing machines and tools which some of them have been successfully been commercialized like the Aluminium harvesting pole (Zirafah and Hi-Reach), Motorised Cutter (Ckat and Cantas) Mechanical loader (Grabber), FFB infield transporter (Beluga and Rhyno) and Loose Fruit Picker for loose fruit collection.

1.2 Fundamental of Oil Palm Harvesting

Many different tools have been developed for harvesting oil palm. It started with a bamboo pole which has now evolved to an aluminium pole with a sickle or a chisel attached to one of the ends for cutting fronds. Over the past years, the Malaysian Palm Oil Board (MPOB) has been actively investing on research and development of machines and tools to improve the field operation's efficiency. There are many inventions which have been commercialised and introduced to the industry. 'Cantas', for example, has been proven to increase productivity in harvesting FFB and also to reduce worker's fatigue.

This machine conserves the workers' energy during the cutting operation, thus prolonging their working hour and allow efficient harvest of FFB from palms less than 4.5 m high. Using Cantas, an operator could harvest 560 to 750 FFB day^{-1}. Cantas was well accepted by the operators due to its high efficiency, ergonomic design, ease of operation and it is being comfortable handle [2].

Figure 1.1 : Oil Palm Motorised Cutter (Cantas)

For tall palms, the mechanical harvesting machine has a good potential of replacing the manual operation. The important role of the grapple to hold and bring down the bunch has been proven that the machine can operate effectively [3].

Figure 1.2 : Mechanical Harvesting machine

1.3 Problem statement

Over the years, several technologies for cutting oil palm fronds and fresh fruit bunch (FFB) have been designed, developed and tested. Most of the technologies developed are directed towards mechanical concepts such as pneumatic and hydraulic circular saw, chainsaw cutter and shear-type cutter. However, the technologies were not well taken up by the industry due to its bulkiness in size, difficulty, and requires high capital which have prompted the industry to look into new approaches.

1.4 Objectives

The aim of this research study is to explore the potential of fiber lasers as an alternative technology to cut oil palm fronds. The specific objectives are as follows:

1. To optimize the laser cutting system using a 250 mm and 63 mm focus lens by manipulating power, speed and frequency.
2. To optimize the laser cutting system by varying power, speed and frequency.
3. To emulate the actual frond during cutting process in the field by implementing a customized jig holder and test with optimized laser parameters.

1.5 Scope of Study

The scope of this study focuses on the potential of pulsed fiber laser as a method of cutting oil palm during harvesting. The laser system with an operational wavelength of 1064 nm will be used throughout the study. The samples used in this study are oil palm fronds. The study will begin by identifying the optical properties and characteristics of the sample oil palm frond to ensure that the wavelength of the emitted laser energy can be absorbed by the sample of fronds. A preliminary test was conducted to identify the various parameters used in this study such as speed of laser beam (mm s^{-1}), frequency of pulsed laser (kHz), and power of the system (%).

These parameters can be manipulated to give the desired cutting result. Two optical focus lenses will be used and compared in this laser system. The lens that produces optimum cutting performance will be used in another test using a jig holder. The jig holder is a to simulate the position and weight of fronds during harvesting. The expected result using this laser system is to achieve precise cutting at a similar, if not shorter, cutting time when using the conventional method. Figure 1.3 shows a flowchart to better explain the work scope.

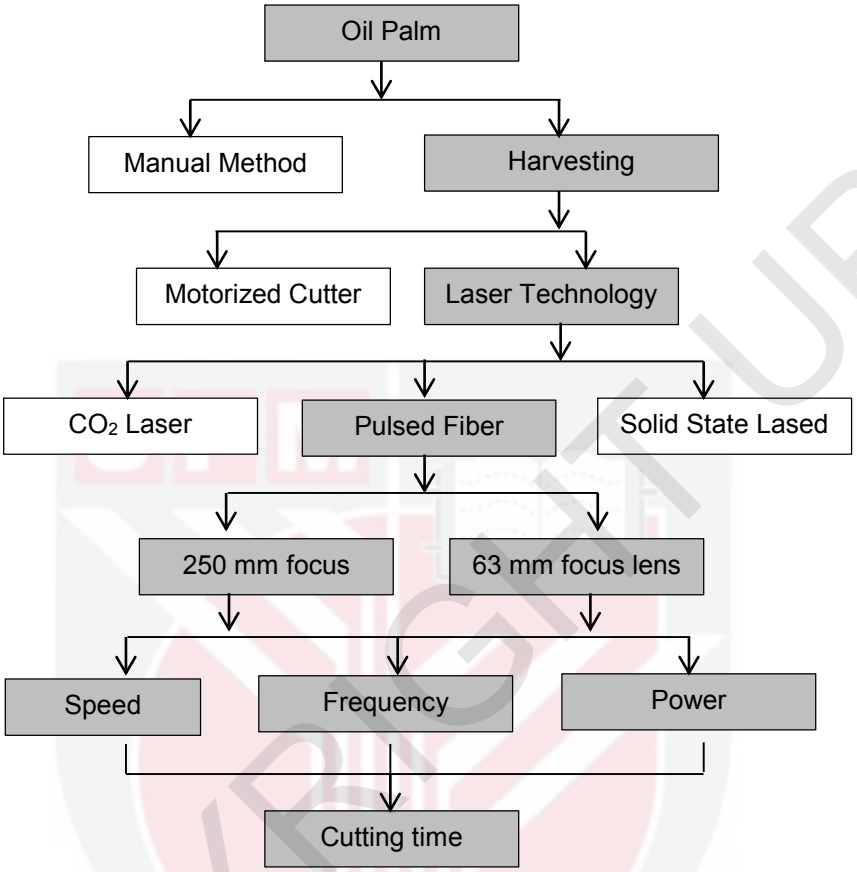

Figure 1.3 : Chart showing scope of the study

1.6 Significance of the study

The oil palm industry is among the few industries that guarantees the nation a high rate of return on capital investment, especially for an oil palm producing country like Malaysia. Thus, seeing labour shortage as a potential critical hindrance to the continuation of oil palm production, there is a dire need of finding appropriate technology to compensate the labour loss and maintain production rate and efficiency. This study proposes the implementation of pulse fiber laser technology that has yet, to the best of my knowledge, to be proposed for oil palm frond cutting. Success of this work will offer the industry an alternative that is capable of making precise cuts, use less man energy which would boost production efficiency, and requires less mechanical parts thus less maintenance. Hence, the work is worth exploring and may contribute greatly to the advancement of oil palm harvesting technology.

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