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The Potentials of Laser Cutting Technologies for Oil Palm Harvesting

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ABSTRACT

Malaysia is currently experiencing a labour shortage of labours in oil palm plantations, estimated to account for 46% of the total industrial workforce. At present, efforts are being made to increase the productivity of workers by utilising a wide range of intensive mechanisation technologies. Laser technology is a new approach as a tool for oil palm harvesting. Malaysian Palm Oil Board (MPOB) and Universiti Putra Malaysia (UPM) researchers are now focusing on the possibility of cutting frond and oil palm bunches stalk using fibre-pulsed lasers based on their high efficiency, small size and low divergence beams. The pulse regime can also be manipulated to produce high energy pulses, which enables the cutting operation to be conducted effectively. This paper reports the preliminary results of the potential use of laser technology in oil palm harvesting.

ABSTRAK

Malaysia pada ketika ini sedang mengalami kekurangan tenaga buruh di sektor perladangan sawit yang dianggarkan sebanyak 46% daripada jumlah tersebut. Pada masa ini usaha untuk meningkatkan produktiviti pekerja dengan menggunakan pelbagai teknologi mekanisasi sedang diperluaskan. Teknologi laser merupakan satu pendekatan baru sebagai alat penuaian sawit. Penyelidik MPOB dan UPM kini memberi tumpuan kepada kemungkinan penggunaan fibre-pulse laser untuk memotong pelepah dan tandan sawit berdasarkan kecekapannya yang tinggi, saiznya yang kecil, dan lencongan cahaya yang rendah. Rejim nadi boleh dimanipulasikan untuk menghasilkan denyutan tenaga tinggi yang membolehkan operasi pemotongan dijalankan dengan berkesan. Kertas kerja ini melaporkan keputusan awal potensi penggunaan teknologi laser ini dalam penuaian sawit.

Keywords: oil palm, harvesting technology, laser cutting.

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INTRODUCTION

Malaysia is currently experiencing a labour shortage in oil palm plantations, estimated to account for 46% of the total industrial workforce. This is due in part to the demanding nature of the estate work and the growing number of other attractive alternative job opportunities in other industries. The lack of mechanisation options in plantations creates an overreliance on manual labour for all key activities. The industry is striving to increase worker productivity by adopting new technologies using a variety of work methods. Mechanisation is an important approach to improve workers' productivity.

The Malaysian government has targeted to reduce the number of foreign workers in the oil palm sector by 110 000 in 2020; it can be achieved through mechanisation technologies that increase labour productivity, especially in harvesting activities. Most of the oil palm harvesting technologies developed over the past few years was focusing on mechanical cutting concepts such as rotating disc, circular saw, chain saw and shear type (Razak *et al.*, 2003). However, these technologies have not been fully utilised by industry for a number of reasons, including large machine sizes, poor handling, complex operations, high capital costs, and low efficiency.

Harvesting Technology

A few decades ago, harvesting techniques using bamboo as a harvesting tool have been developed, and aluminium is currently used as a pole for a sickle or chisel. The development of technologies is parallel to the increase in oil palm plantation in Malaysia and many harvesting technologies have been developed to date. Harvesting is an important activity in oil palm plantation and is estimated for about 60% of the total labour force.

Over the past years, Malaysian Palm Oil Board (MPOB) was developing machines and tools to improve efficiency of field operations. Many inventions have been commercialised and introduced to the industry. The use of Cantas (*Figure 1*) has been proven to increase the productivity of harvesting FFB, and reduce workers' fatigue. This machine conserves the energy of workers during the cutting operation, thus prolonging their working hours. It can effectively harvest palm tree FFB below 4.5 m. Using Cantas, an operator can harvest 560 to 750 FFB day^{-1}, Cantas is well accepted by the operators for its high efficiency, ergonomic design, ease of operation and comfortable handling (Razak *et al., 2008*).

*Figure 1. Oil Palm Motorised Cutter (*Cantas*).*

For the tall palm, the mechanical harvesting machine (*Figure 2*) has a good potential of replacing the manual operation. The machine is able to perform all the necessary functions effectively and as of manual operation. The important role of the grapple in holding and bringing down the bunch has proven that the machine can operate effectively (Ramdhan and Rahim, 2014).

Figure 2. Mechanical harvesting machine.

Although some of the technologies developed are practical, several technical issues and capital as well as maintenance costs have prompted the industry to look into new approaches. One of the possibilities is laser cutting technology. It is hoped that by using laser technology, tall palm trees can be harvested more easily.

Laser Technology

Laser cutting technology is a new approach that can be further researched in the oil palm industry. Laser technologies have been widely used in the manufacture of metal cutting (Liu *et al.,* 2011). Niyibizi *et al.* (2013) stated that types of lasers described were: carbon dioxide laser (CO_2), solid state laser, and fibre laser. For each type, the type of active medium (atomic gas or solid state), the emission wavelengths, main applications, recent trends, the main competing technology and market price comparisons of various systems were discussed in detail (Niyibizi *et al.,* 2013). Liu *et al.* (2011) revealed that the device using 30 W, 980 nm fibre laser energy could achieve an energy transformation efficiency of 49%, which is several times higher than that of the most commonly used technology lasers.

According to Liu *et al.* (2011) the laser technology is capable of cutting agricultural materials such as tomatoes stalk cutting, based on two essential aspects. One is that the power density of focusing spot of this device is determined by both laser beam quality and properties of focusing system. It should be understood that this laser cutting method is based on the concept of burns and ablation and is different from machines that use blade. The factors affecting efficiency of laser cutting are diameter of surface, laser power, focal length and angle during cutting. Lawson (2009) analysed the laser market industry where the most active industrial laser technology product sector is fibre lasers with at low- and high-output power levels. However, the research and application of laser cutting technology in biomaterials have not been fully revealed.

Oil Palm Fronds Optical Characteristic

Dawson *et al.* (1998) investigated the optical properties and characteristics of oil palm fronds. This frond has similarities to other vegetation leaves. Looking into the leaf composition, water contributes the most to the leaf weight. The remainder of the leaf weight is 'dry matter' and consists mainly of cellulose, lignin, protein, starch and minerals. The optical absorbance of these constituent increases with increasing concentration, thereby reducing the reflectance and transmittances of the leaf. A model was developed to illustrate the absorption spectra of the vegetation leaf as shown in *Figure 3*. It has major absorption features of around 1.45 μm, 1.95 μm, and 2.5 μm which are mainly due to water absorption peak. In *Figure 4*, the absorption spectra of protein, lignin, cellulose and chlorophyll are shown, respectively.

The optical properties of oil palm frond can be further studied by using the Dawson model as a reference. The frond composition consists mainly of cellulose (31%), hemicelluloses (17%), lignin (23%), and others (water moisture, chlorophyll and protein) (Ahmad and Tsuyoshi, 2012).

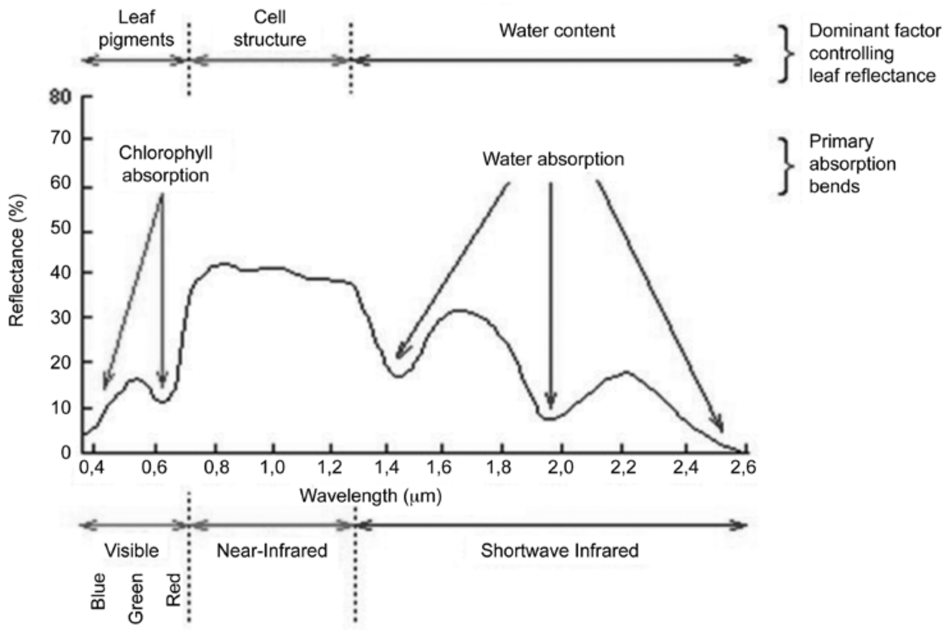

Figure 3. Leaf reflectance model as proposed by Dawson.

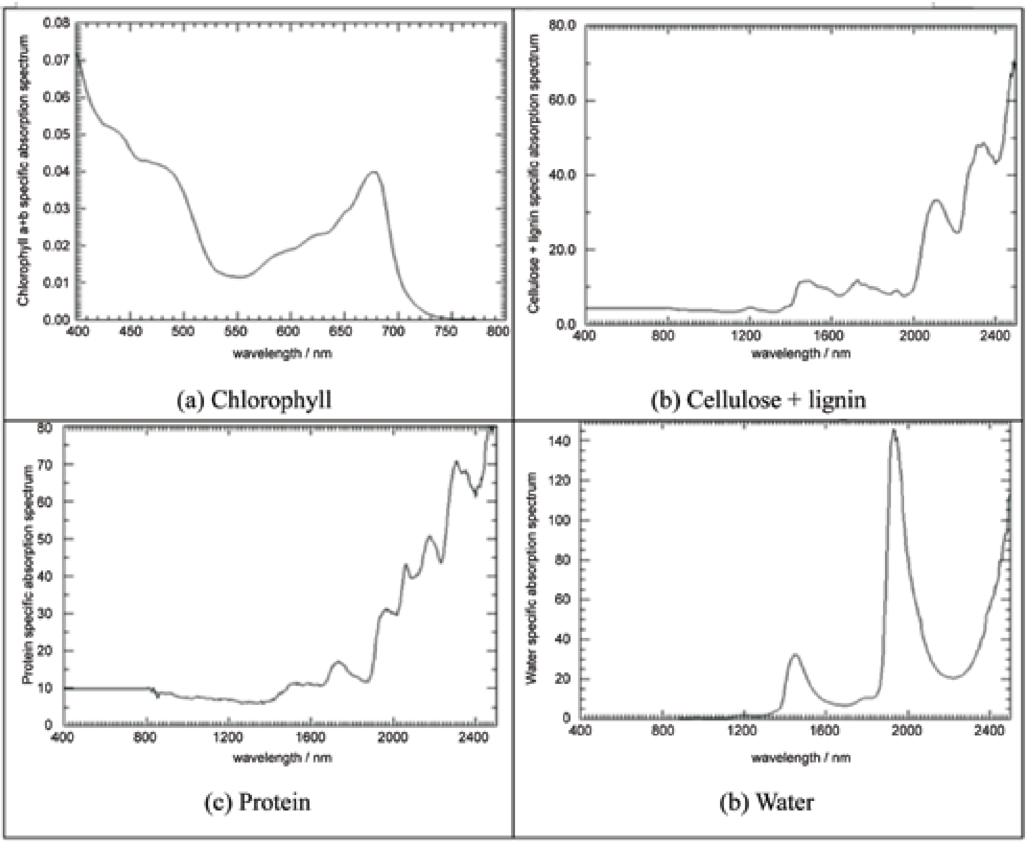

Figure 4. Leaf absorption spectrums of (a) chlorophyll, (b) cellulose and lignin, (c) protein and (d) water, using Dawson model.

Transmission Experiment

A systematic study was carried out to understand the spectroscopy properties of the oil palm frond. A wideband supercontinuum laser system was used to investigate the absorption characteristics of the oil palm frond at different laser wavelengths (*Figure 5*). The preliminary result of the absorption experiment is shown in *Figure 6* where the oil palm fronds can absorb the energy from the laser.

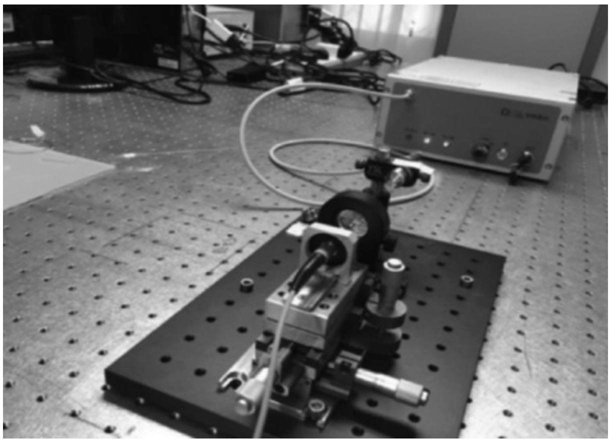

Figure 5. A wideband supercontinuum laser system.

Fundamental Research

A study was carried out at 1064 nm wavelength using the pulse fibre lasers to investigate the feasibility of laser technology for cutting frond samples. The study focuses on utilising the next generation fibre laser to explore the capability in ablating and cutting the oil palm fronds.

Methodology of research. The equipments' used in this study are pulse fibre laser system, laser scan head and a computer (*Figure 7*). The experiment was carried out at the Laboratory in UPM and MPOB for frond cutting.

Pulsed fibre laser technology. The fibre lasers are superior to other lasers because of their high wall plug efficiency, small size, and low divergence beam. Another attractive feature of fibre laser is its ability to operate in a pulse regime and generate pulses with intense energy. Pulsed fibre laser will be used in this method with pulse width ranging from sub nanosecond up to a few microseconds (*Figure 8*).

The pulse fibre laser is suitable for cutting biomaterials. The reason for selecting pulse laser is that energy is channelled via a temporal pulse profile different from a continuous wave (CW) beam, resulting in frond burning due to continuous energy being channelled (*Figure 9*). The pulse fibre laser with an average power of 20 kW from the system can significantly ablate the fronds.

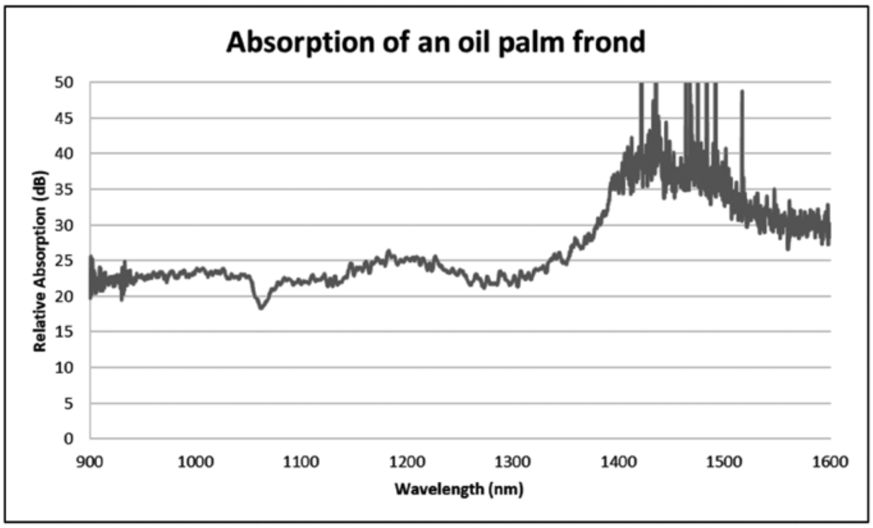

Figure 6. The laser absorption of an oil palm frond.

From the understanding of the absorption peaks theory, when the high energy laser beams are directed at the fronds, the energy will be absorbed by the cellulose, converting the high energy laser pulses to thermal energy in a short burst, leading to material removal (ablation and cutting). Theoretically the laser can cut bio-materials such as leaf and frond. The laser technology can be used in any environment without significant impact on living plants (Juergen *et al*., 2002). However, the main factor to be considered when using the laser technology is the safety of users.

Laser cutting experiment on oil palm frond. In order to demonstrate the effectiveness of using pulsed fibre laser to cut oil palm frond, a pulsed fibre laser system (*Figure 10*) capable of emitting an average power of 50W and having a pulse energy beyond 1

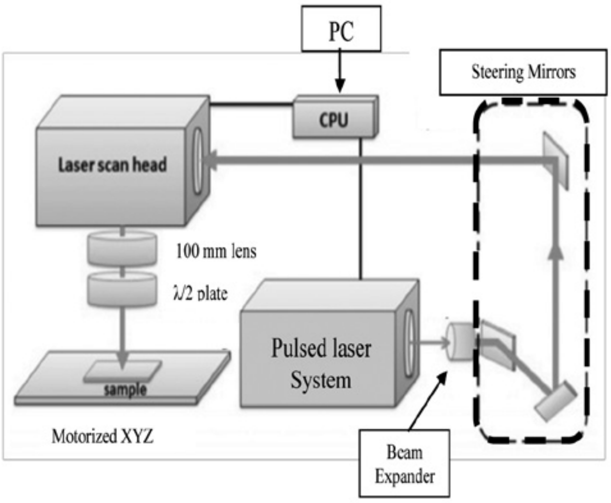

Figure 7. The diagram of installation of the laser system equipment.

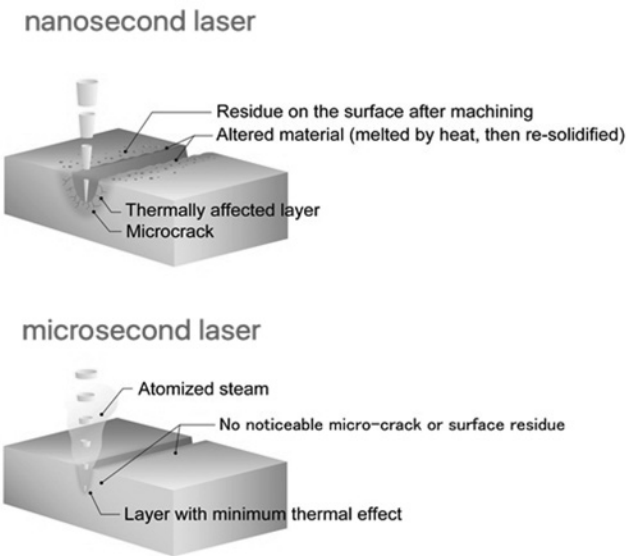

Figure 8. The advantages of pulse fibre laser for pulse ranging from sub nanosecond to microsecond.

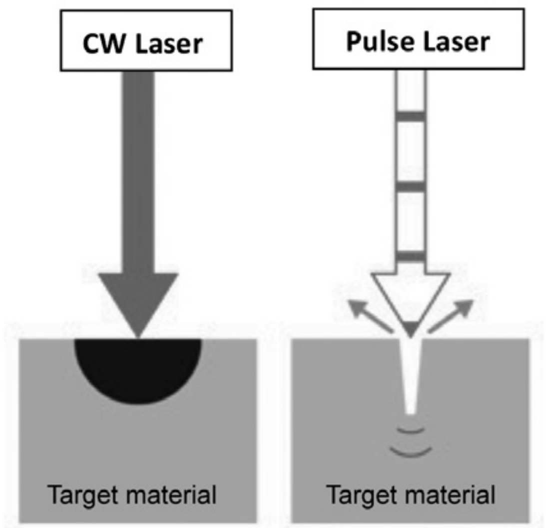

Figure 9. The difference between CW laser and Pulse Laser cutting.

mJ was used. The efficiency parameter is measured based on the frequency of laser pulse regime, laser speed, and power used. In this experiment, the frequency of pulse regime has been is set from 50 to 5000 Hz and the movement of laser speed between 1 and 100 mm s^{-1}. The power range used is set from 30% to 100% which is equivalent to between 15W and 50W. The frond samples (*Figure 11*) were used in various sizes with different thicknesses and widths. In this preliminary study, the time and depth of laser cutting on the samples were taken and analysed. This is important because it determines the efficiency of the laser when cutting the sample and building the prototype.

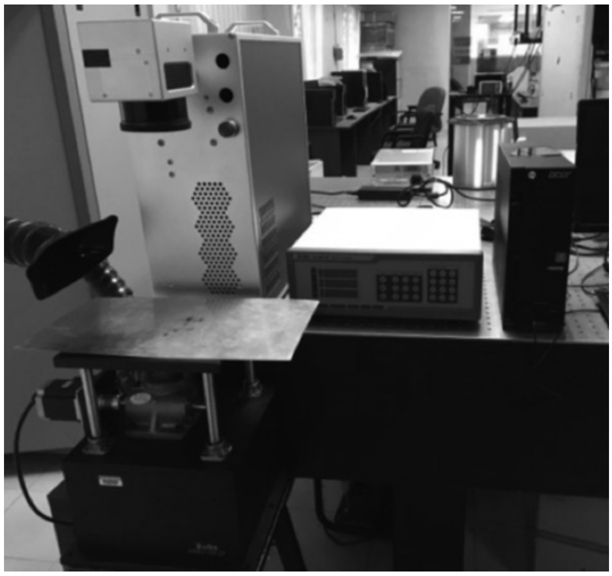

Figure 10. The pulse fibre laser system with an average power of 50W.

Figure 11. The sample of fronds with different sizes.

The Preliminary Results

The result showed the capability of the laser to cut frond samples (*Figure 12*). The deepest cutting has a cutting efficiency of 1 mm s^{-1} in the frequency range of 1500 to 3000 Hz (*Figure 13*). Pulsed fibre lasers have an average power of 100% of the power system, which is equivalent to 50W. The frequency actually reflects the pulse energy and speed of the laser emission as important factors affecting the cutting efficiency of the pulse laser system.

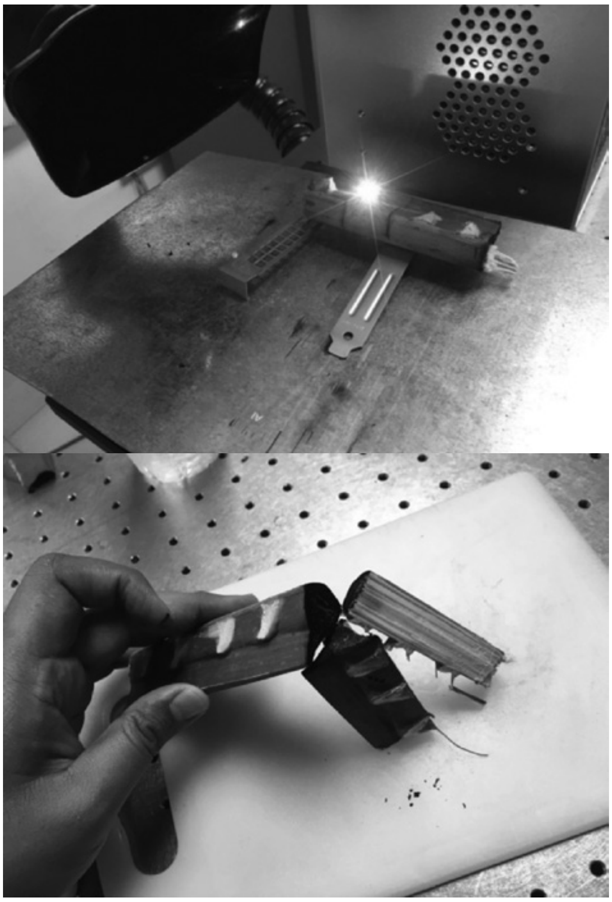

Figure 12. The laser cutting experiment on palm fronds.

The working principle of lasers on oil palm fronds is by initiating laser beam on the surface of the material and linear movement of the laser. The laser pulse frequency is set according to the suitability of time and power. The frequency of laser pulse and the travelling time will affect the depth of cutting (*Figure 14*).

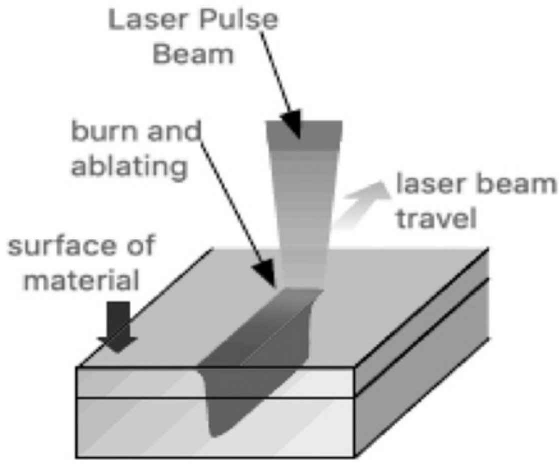

Figure 14. The movement of laser cutting on oil palm frond surface.

The preliminary findings showed a positive sign that the laser technology can be implemented in oil palm harvesting. The safety aspects must be applied to the prototype as well as to the users. The cost of building a prototype may be high but with the demand of new technologies, the expected price of a pulse fibre laser system can be reduced.

CONCLUSION

The laser technology has the potential to improve the oil palm harvesting, but many parameters must be considered, especially on safety issues. With the positive results conducted by MPOB and UPM, it is hoped that the laser cutting technology in oil palm harvesting can be realised in the future.

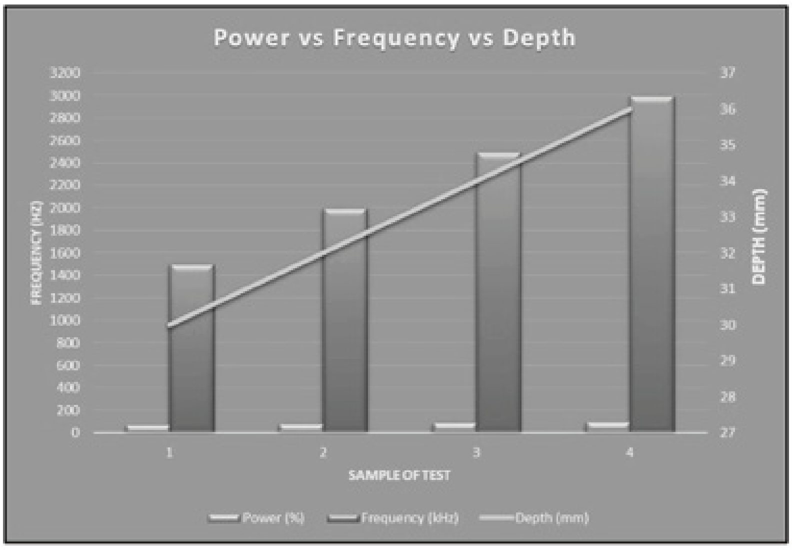

Figure 13. The comparison of different frequency with average power and speed reflect cutting depth.

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