ANALYSIS OF DESIGN OF INTERVENTION OIL PALM SICKLE

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ANALYSIS OF DESIGN OF AN INTERVENTION OIL PALM SICKLE

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DECLARATION

This work has not previously been accepted in substance for any degree and is not being concurrently submitted in candidate for any degree.

Signed……………………………………… (Muhammad Adib Haikal bin Awang Mansor)

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STATEMENT 1

This thesis is the result of my own investigations, except where otherwise stated.

Other sources are acknowledged by giving explicit references.

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LIST OF SYMBOLS AND ABBREVIATIONS

α	Cutting tool edge
β	Oblique angle
S	Cutting angle
SCE	Specific cutting energy
SCF	Specific cutting force
r	Radius of edge roundness
UTM	Universal Testing Machine

ANALISIS REKA BENTUK SABIT INTERVENSI PELAJAK KELAPA SAWIT

ABSTRAK

Salah satu aktiviti utama dalam perladangan kelapa sawit ialah menuai hasil kepala sawit, yang memerlukan tenaga yang tinggi terutamanya ketika memotong pelepah kelapa sawit. Sejak penanaman kelapa sawit di Malaysia, pelbagai usaha telah dilakukan untuk mencipta alat pemotong yang terbaik. Kebanyakan alat pemotong yang dicipta oleh pengeluar didakwa mampu mengurangkan beban ke atas penuai, namun tidak semua dakwaan disokong oleh sebarang maklumat dan kajian. Pelajak adalah sebuah alat yang dibuat sebuah syarikat, Teras Tegap Agro Sdn. Bhd. Alat pemotong ini memberi pelepasan di antara sabit dan juga galah, yang mana meningkatkan momentum apabila penuai menggunakan daya tarikan memotong. Dalam eksperimen ini, terdapat empat objektif utama penyelidikan. Objektif pertama adalah untuk mengkaji kesan proses pemotongan terhadap ketajaman sabit. Seterusnya, melakukan ujian daya statik pada sabit intervensi ‘Pelajak’ dan mengkaji kesan sudut pelepah ke atas pelbagai parameter. Yang ketiga ialah menyiasat penguatan daya dengan intervensi sabit ‘Pelajak’ berbanding sabit konvensional. Akhir sekali, projek ini bertujuan untuk menjalankan kajian parametrik dan mengkaji kesan pelepasan ke atas intervensi ‘Pelajak’ sabit dalam daya yang dihasilkan. Eksperimen yang dijalankan menunjukkan bahawa ketajaman sabit berkurangan sebanyak 44% selepas 12 proses pemotongan dan peratusan menjadi lebih tinggi apabila hanya luas sabit yang kebanyakannya terlibat dalam proses pemotongan diambil kira pada 132% pengurangan. Sudut pelepah juga mempengaruhi kawasan pemotongan, daya pemotongan maksimum yang diperlukan, dan masa yang diambil

untuk memotong pelepah manakala ia tidak menjejaskan kerja yang dilakukan untuk memotong pelepah. Eksperimen ketiga mendapati sabit intervensi 'Pelajak' menguatkan 77% daya berbanding sabit konvensional. Pada ujian lapangan walau bagaimanapun, data menunjukkan hanya peningkatan sebanyak 23% pada kekuatan untuk intervensi 'Pelajak' sabit berbanding sabit konvensional. Kedua-dua keputusan masih menunjukkan perbezaan yang signifikan secara statistik antara daya yang dihasilkan dan sabit yang digunakan. Ujian akhir mendedahkan bahawa pelepasan pada sabit 'Pelajak' memang menjejaskan hasil daya. Nilai daya berkurangan apabila kelegaan berkurangan.

ANALYSIS OF DESIGN OF AN INTERVENTION OIL PALM SICKLE

ABSTRACT

One of the major activities in an oil palm plantation is oil palm harvesting, which demands a lot of energy, especially when cutting the oil palm fronds. Since the beginning of oil palm cultivation in Malaysia, attempts have been made to develop better cutting equipment. Most of the cutting tools developers claimed that the built cutting tools can help to reduce the burden on the harvester, however not all the claims are supported with any data and research. 'Pelajak' is a device produced by a company, Teras Tegap Agrotech Sdn. Bhd. (TTASB). This cutting tool provided some clearance between the sickle and the pole, which increased momentum when the harvesters applied a pull cutting force. In this experiment, there are four main objectives of the research. The first objective is to study the effects of the cutting process on the sickle sharpness. Next, to perform the static force test on intervention 'Pelajak' sickle and study the effects of frond angle on various parameters. The third one is to investigate the amplification of force by intervention 'Pelajak' sickle relative to a conventional sickle. Finally, this project aims to conduct parametric study and study the effects of clearance on intervention 'Pelajak' sickle in the force produced. The experiment conducted revealed that the sickle reduced by 44% in sharpness after 12 cutting process and the percentage becomes higher when only the area of sickle that is mostly involves in cutting process is considered at 132% of reduction. The frond angle also affects the cutting area, maximum cutting force required, and the time taken to cut a frond while it does not affect the work done on cutting the frond. The third experiment found that the intervention 'Pelajak' sickle amplified 77% of force compared to a conventional sickle. On the field test however, the data show only an increase of 23% on force for the intervention 'Pelajak' sickle relative to the conventional sickle. Both results still

show a statistically significant difference between the force produce and the sickle used. The final test revealed that the clearance on the ‘Pelajak’ sickle does affect the force produce. The value of force decreases as the clearance is reduce.

CHAPTER 1

INTRODUCTION

1.1 Oil palm plantation in Malaysia

Oil palm (Elaeis guineensis) was first introduced to Malaysia as an ornamental plant in 1870. It has become an essential commodity crop in Malaysia. Since 1960, the planted area has increased at a rapid pace. In 1985, 1.5 million hectares were planted with palm trees, which increased to 4.3 million hectares in 2007. As of 2011, the total planted area was 4.917 million hectares [1]. Oil palm plantation is one of Malaysia's primary industries, and the country has become the world's second-largest palm oil producer. Malaysia, in actuality, has produced 25.8% of global oil palm production and 34.3% of global exports for 2020[2]. The oil palm plantation in Malaysia is continuously expanding today, with 5.9 million hectares of land under oil palm plantation in Malaysia, and it is predicted to grow by 43% by 2025 [3].

Because of labour scarcity, several oil palm estates have had to delay harvesting by 20 to 25 days [4]. The quality of the fruits may suffer due to the delay in harvesting fresh fruit bunches. Furthermore, the high production cost, which had climbed to between 20% and 23% of total production cost between 1980 and 2000, influenced the oil palm sector [5].

As a result, a solution to increase harvester productivity should be devised, such as developing a new cutting tool. The new cutting tool should include all the necessary technical data to demonstrate that it can help harvesters work more efficiently.

1.2 Project background

Cutting fronds and fresh fruit bunches, stacking the fronds, collecting loose fruits, and bringing collected fruits to the location are the four basic actions involved in oil palm harvesting. The main instruments used to cut the oil palm fronds and fresh fruit bunches are a regular chisel and a conventional sickle as shown in Figure 1.1. Despite efforts to develop new cutting instruments, harvesters choose the traditional chisel and sickle because they are inexpensive and effective. They have yet to be exceeded by any other tool.

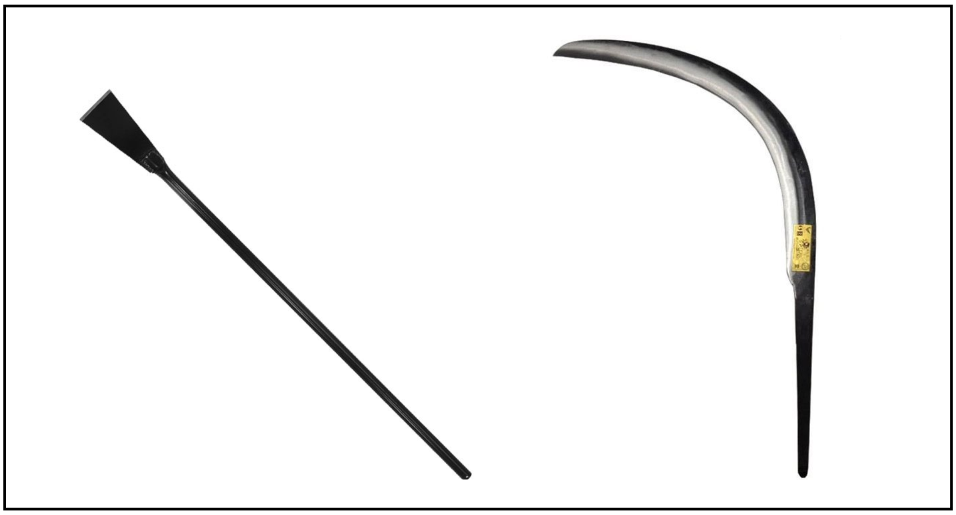


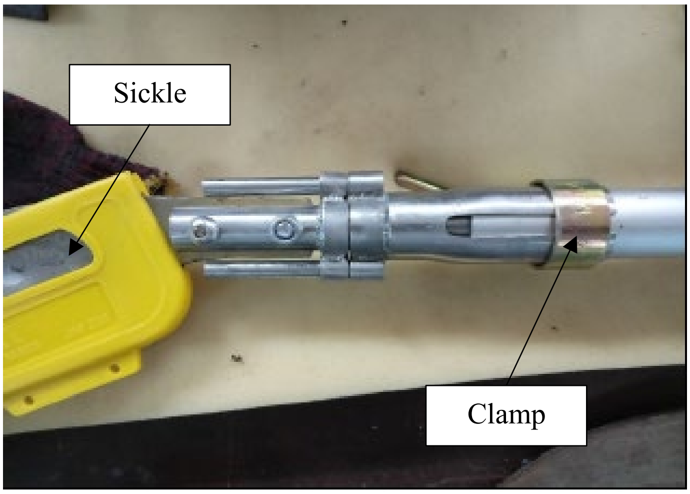
Figure 1.1 A conventional chisel and sickle.

1.2.1 Teras Tegap Agrotech Sdn. Bhd. (TTASB)

Teras Tegap Agrotech Sdn. Bhd. (TTASB) is a wholly Bumiputera-owned company and operates in the state of Melaka. The company has created a harvesting tool which is an innovative sickle called the SABIT TERAS. TTASB stated on their website that SABIT TERAS is very practical, economical, and effective as well as efficient [6].

SABIT TERAS comes with a device called 'Pelajak' sickle, as shown in Figure 1.2. This cutting tool provided some clearance between the sickle and the pole, which increased momentum when the harvesters applied a pull cutting force.

(a)



(b)

Figure 1.2 (a) 'Pelajak' sickle produced by Teras Tegap Agro Sdn Bhd, and (b) Pelajak attached to the sickle and pole. A clamp is used to secure the pelajak to the aluminium pole

1.3 Problem statements

A sickle is essential for cutting oil palm fronds and fresh fruit bunches (FFBs). It is attached to a bamboo or aluminium pole and is used to collect the oil palm fruit bunch from a three-meter-tall tree. When the tool's weight and the cutting force required are considered, a significant amount of physical effort is required to control the cutting tool. This study will examine the efficacy of Teras Tegap Agro Sdn Bhd's 'Pelajak' sickle. The intervention sickle will be able to boost cutting force while requiring less force from the operator. The design will be enhanced to increase the cutting force's amplification.

To develop a new cutting tool, the developer should provide technical information such as the improvement in the force required while cutting oil palm fronds using the new cutting tool. The developer should also include the analysis of the harvester's performance in using the new cutting tools, such as the number of successful cuts and the time required to cut per frond. For example, the developer claimed the intervention 'pelajak' sickle that the cutting tool could increase the productivity of the harvesters. However, there was no publication related to the technical information regarding the usage of the intervention 'pelajak' sickle. This study evaluated one of the designs of the intervention sickle that are available in the market. The data such as the cutting force and force produced when some parameter is manipulated(clearance of ‘pelajak’) is essential for the tool developer to improve their design.

1.4 Objectives of the study

The objectives of this study are:

i. to study the effects of the cutting process on the sickle sharpness
ii. to perform the static force test on intervention ‘Pelajak’ sickle and study the effects of frond angle on various parameters
iii. to investigate the amplification of force by intervention ‘Pelajak’ sickle, and
iv. to conduct a parametric study on the effects of clearance of intervention ‘Pelajak’ sickle on the force produced.

1.5 Scope of the project

This study involves designing and fabricating tools to assist in testing the intervention sickles, which were then evaluated in a field trial and lab, where technical data such as the sickle sharpness, the amount of maximum force required to cut the fronds, the time required to cut per frond, the work done and the cutting area utilizing the cutting instruments were recorded. This research will concentrate on using an intervention 'Pelajak' sickle and a few other intervention sickles that will be designed. The cutting and assisting tools were designed using SolidWorks 2020 software. An S-shaped load cell was used to measure force, which was then actuated using the LabView 2021. Finally, the measured data were analyzed using Microsoft Excel 365.

CHAPTER 2

LITERATURE REVIEW

2.1 Cutting force

The cutting force is the external force applied to the cutting instrument to cut the material. Force will be delivered in the directions of X, Y, and Z components in an actual cutting process. However, only force applied along the cut line (X direction) will contribute to the data of cutting force, specific cutting force (SCF), and specific cutting energy in this experiment (SCE). There are two parts to the cutting force: edge force and wedge force. The edge force, according to Abdul Razak Jelani et al.[8], is the force applied to cut the material that causes high local stress on the material in contact with or around the edge? On the other hand, the wedge force is the force used to separate the cut's sides so that the cutting tool can pass through. Some experiments were similar to those in [8] and [9]. As a result, in this experiment, similar terminology will be utilized, as indicated in Figure 2.1, and as follows:

a) Cutting tool edge angle (α) – The angle between the two faces of cutting tool.

b) Oblique angle (β) – The angle at the cutting edge toward the cutting direction.

c) Cutting angle (S) – The angle between the edge of cutting tool and the longitudinal axis of material being cut.

d) Specific cutting force (SCF) (N/m^2) – Cutting force per fronds cutting area.

e) Specific cutting energy (SCE) ($N.m/m^2$) – Cutting energy defined as combination of cutting power which includes total blade movement starting from when it touches the cutting material until the end of cutting process.

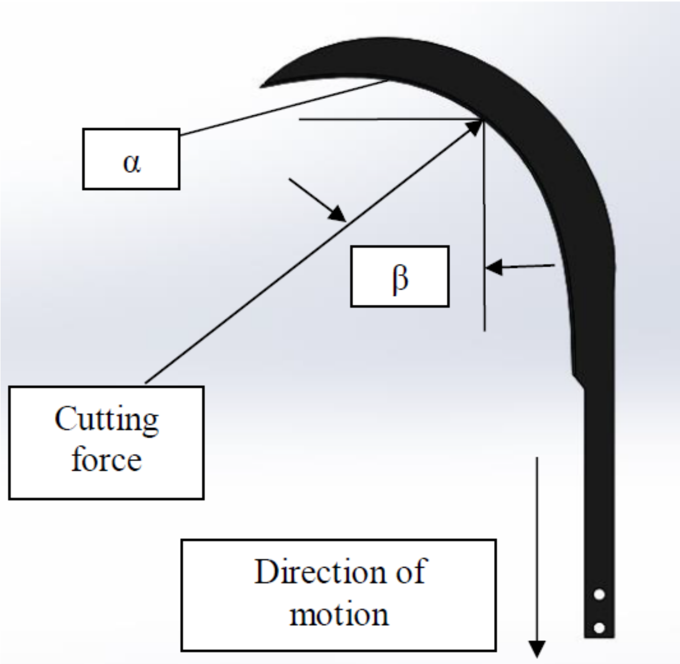


Figure 2.1 The schematic of sickle shows the cutting tool edge angle (α), oblique angle (β), direction of cutting force and direction of cutting motion [10].

2.2 Factors that affect the cutting force

Several factors may affect the measurement of cutting force on oil palm fronds. According to the works in [10], cutting angle and frond maturity were the factors that may affect the measurement of cutting force. The cutting angle was measured between the edge of the cutting tool and the longitudinal axis of the material being cut. For frond maturity, there was no specific measurement as authors in [11] classified the frond maturity based on the placement of the front. The most matured is the second frond located below the ripe bunch, the second matured frond is located above the ripe bunch, and the least matured frond is the second frond above the ripe bunch. At the same time, authors in [11] classified the fronds' maturity as below 50% moisture contents and above 50% moisture content which was evaluated by eyesight. In common, the frond with a moisture content below 50 % is the dried frond and brownish.

Studies by Abdul Razak Jelani et al. [10] concluded that increasing the cutting angle will increase the magnitude of the cutting force. Three different cutting angles were tested in that experiment which were 45°, 60°, and 90°. Increasing the cutting angle from 45° to 90° increased the maximum SCF by around 24% and 111% for the sickle cutter and claw cutter design. For the frond maturity, the matured the frond, the higher the cutting force required to cut the oil palm fronds. The frond located second below the ripe bunch requires high force to cut compared to the frond that is located second above the ripe bunch. As the frond becomes mature, the fiber inside the frond becomes harder.

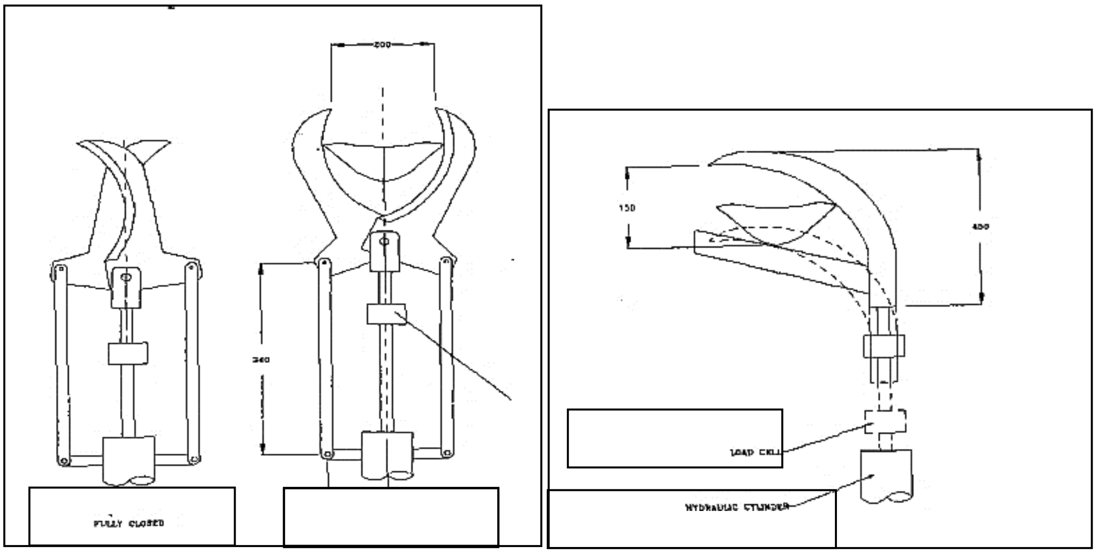
On the influence of the frond maturity, the lower the frond moisture, the higher the cutting force measurement. The result revealed by Mohd Rizal Ahmad et al. [11] stated that cutting oil palm fronds at the angle of 45° contributed to the lowest cutting force compared to cutting angles at 30° and 60°, and the highest cutting force measured was on cutting angle at 60°. Based on the study, for moisture content of more than 50%, increasing the cutting angle from 30° to 45° reduced the cutting force by about 20%, while increasing the cutting angle from 45° to 60° increased the cutting force by about 29%. While for frond moisture content less than 50%, increasing the cutting angle from 30° to 60°.

2.3 Intervention cutting tools

Several cutting tools are available in the market to be used as the harvester, such as chisel, sickle, chain saw, rotating disk, etc. Even though the conventional chisel and conventional sickle are still the favourite cutting tool among the harvesters, the effort to develop new cutting tools are not stopped until right now as the governing bodies responsible for the promotion and development of the palm oil industry in Malaysia, Malaysian Palm Oil Boards (MPOB) have made several studies on producing the new cutting tools.

2.3.1 Sickle cutter and claw cutter

Based on the research, a study in [11] was done to observe the force and energy required to cut the oil palm fronds based on the two designs of the cutter. Figure 2.2 shows the claw cutter and sickle cutter used in the study. The blade was made of carbon steel for the claw cutter and weighed around 0.6 kg with a thickness of 3 mm. The length and width of the cutter were 31.7 cm and 15.5 cm, respectively. The edge angle (α) was designed at 10° and its oblique angle (β) was kept constant at 24.22” in all positions. Two blades were joined by a pivot that was connected with a hydraulic pusher rod to enable the blades to perform the cutting. For the sickle cutter, a counter-shear part was fixed to the conventional chisel, 15 cm from the tip of the sickle at 15” concerning the horizontal line.



(a) (b)

Figure 2.2 (a) Design of claw cutter and (b) design of sickle cutter [11].

The experiment revealed that the claw cutter's maximum specific cutting force (SCF) and the sickle cutter were 22.9 kg/cm² and 12.2 kg/cm², respectively. While the maximum specific cutting energy (SCE) for the claw cutter and sickle cutter were 115.5 kg.cm/cm² and 64.5 kg.cm/cm², respectively. This indicates that the sickle cutter required 47% less maximum SCF and 76.5% less maximum SCE.

A sickle cutter applies the slicing method as the cutting starts from the bottom side of the cutting edge and finishes at about three-quarters of the edge. This cutting method applies a higher oblique angle at 45° to 90°, depending on the cut material. The angle approach 90° at the bottom of the cutting and get smaller at the end of the cutting point. Those, the force required to cut the fronds is not high as the cutting-edge slide on the material and slowly penetrates it. Meanwhile, using the claw cutter cuts the fronds by directly penetrating them without slicing movement as the oblique angle is maintained at 24.4" at all positions. Thus, it will require a higher cutting force.

However, the experiment was conducted in a laboratory setup where the test cutters were installed on a designed test rig. The test cutters were activated by a 4-ton hydraulic cylinder and run by a single-phase Enerpac Hydraulic pump set. The pusher road was maintained at a constant velocity of 0.6 m/s. Thus, it was found that there was no measurement of human force recorded in the experiment as the cutting force was done by the machine.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This project is the continuation of previous research done by Ishak[12] titled “Assessment of Force requirement During Cutting Oil Palm Fronds.” The research compares the traditional sickle and the intervention ‘Pelajak’ sickle. On the other hand, as stated in the objectives, this project aims to analyze the efficacy and design an improvement to ‘Pelajak’ sickle produced by Teras Tegap Agro Sdn Bhd. where the sickle will go through various tests and experiments that will be explained in the next section.

3.2 Sickle Sharpness Measurement

The test is conducted in the School Microscopy and Micro Analysis laboratory. In this experiment, the sharpness of the sickle is measured to study how the sickle sharpness is affected every time the sickle goes through a cutting process. Since there is no exact way to determine how sharp a sickle is, an optical 3D measuring instrument (Alicona Infinite Focus G5) is used to determine the radius of edge roundness. The sickle is firstly sharpened with a whetstone. The sickle is marked with 11 lines, as shown in Figure 3.1. The gap between the lines is 50 cm except for lines three until nine, where the gap is reduced to 25 cm as that is where the sickle is expected to be primarily involved in the cutting process. Hence, the number of lines is denser there.

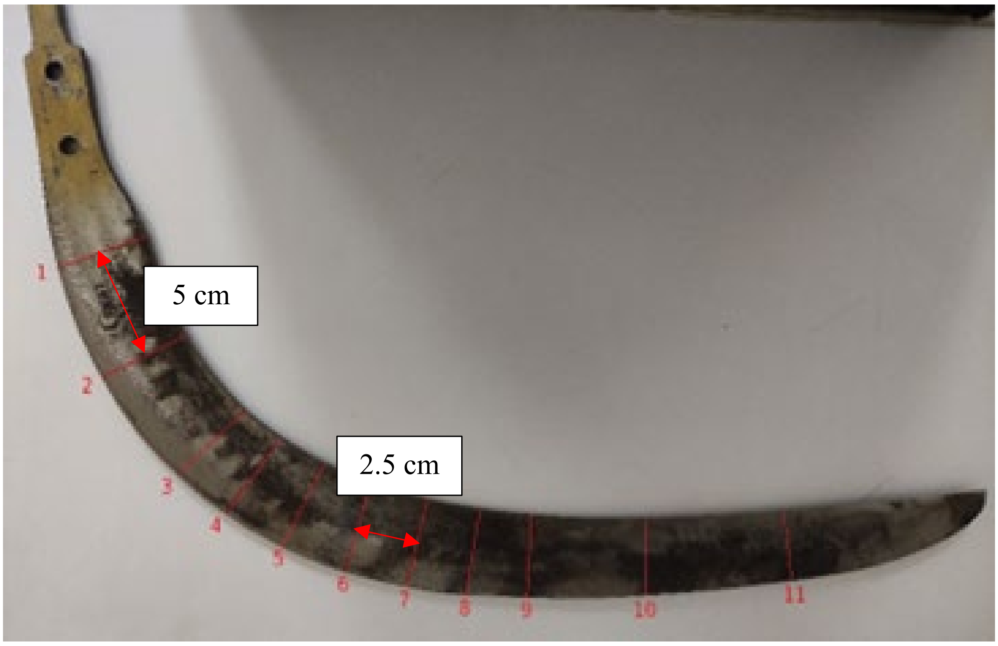
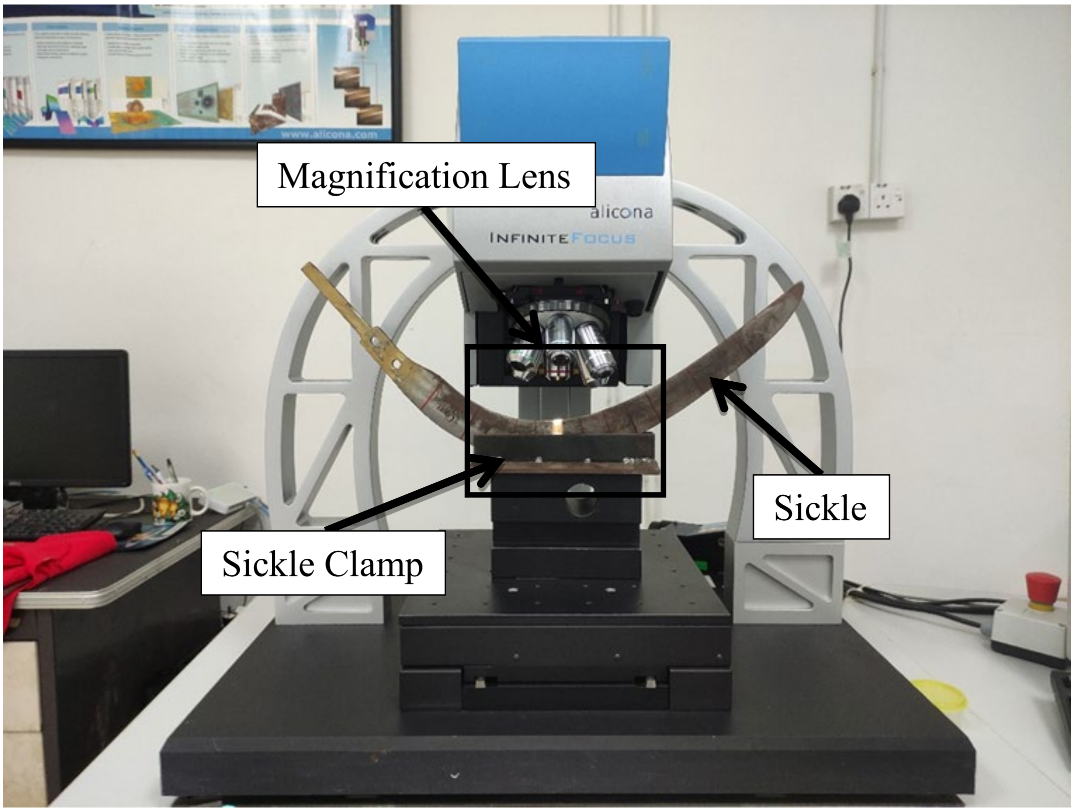
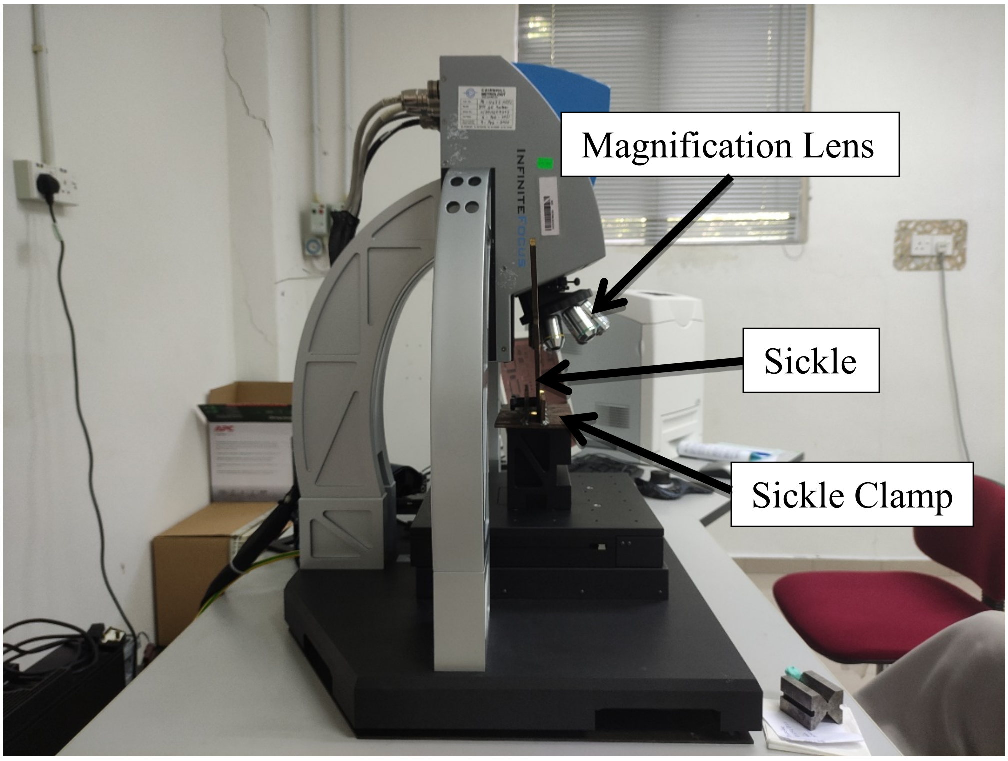


Figure 3.1 The sickle used in this experiment marked with 11 red lines.

The sickle is clamped onto the fabricated 'Sickle Clamp' for Alicona Infinite Focus, as shown in Figure 3.2. The sample of results is measured using 20x magnification and Mean Profile Extraction Mode to get the r value (Radius of edge roundness) using IFM software 3.5.1.5. The sharpness is determined from the radius of the edge roundness of the sickle on each line. The average of the 11 lines is then calculated to get the mean radius. The experiment is repeated after the sickle went through the 'Static Force Test' to get the sharpness of the sickle after it was used.



(a)



(b)

Figure 3.2 (a) The front view of the full setup. The sickle is attached to a sickle clamp and placed under the magnification lens. (b) The side view of the full setup.

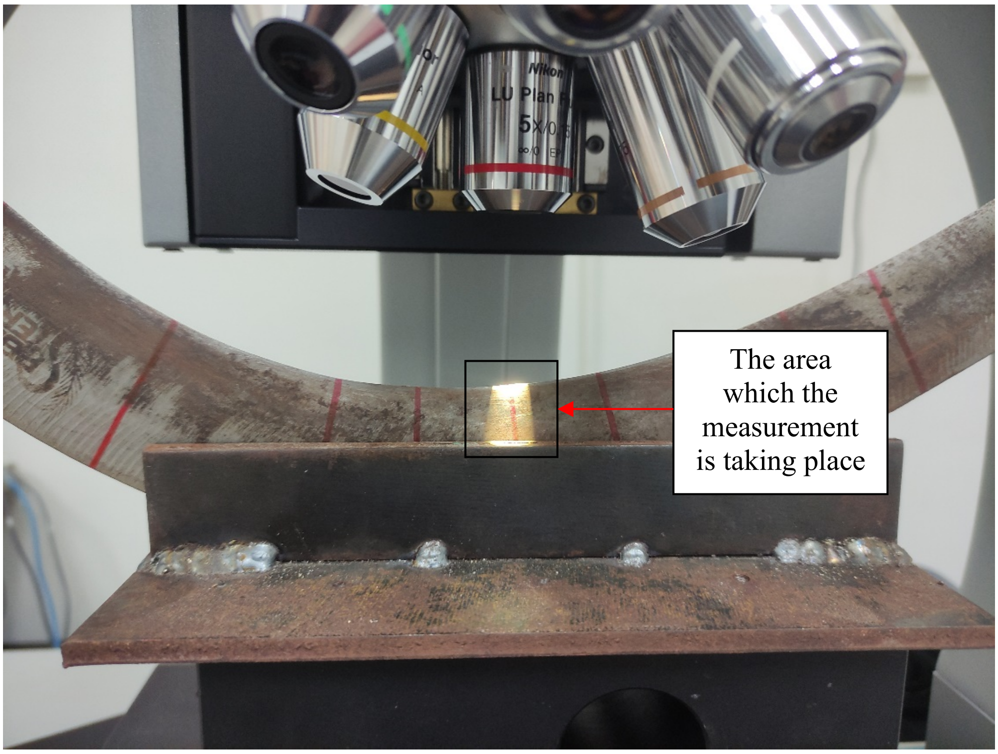
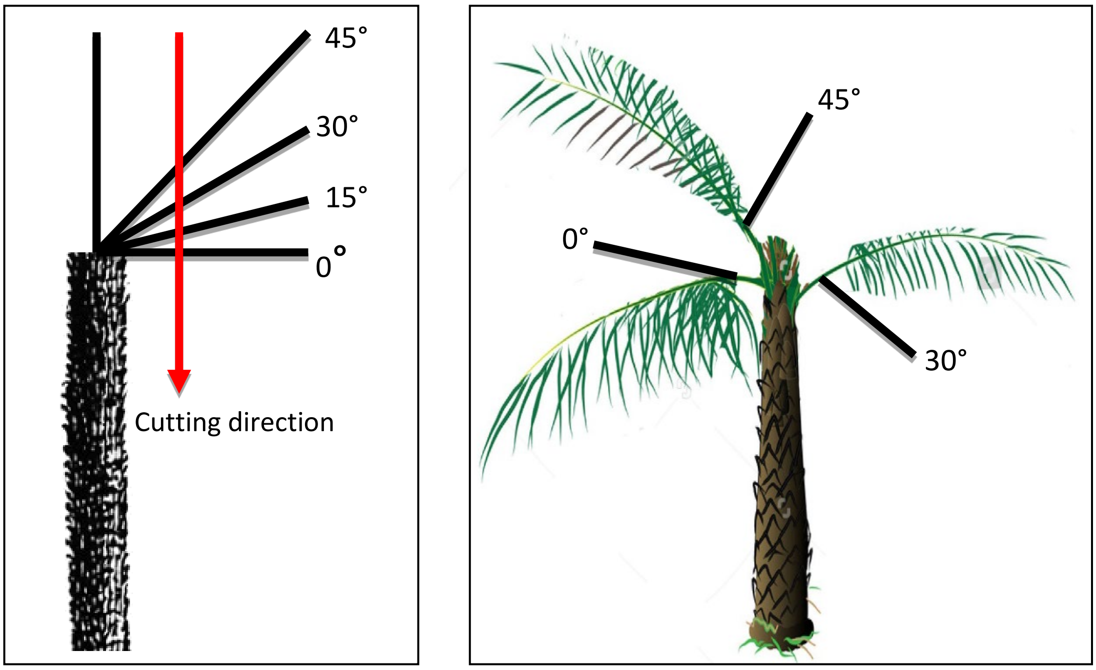


Figure 3.3. Magnified view of the setup. In this example, the measurement edge roundness is taking place at Line 5.

3.3 Static Force Measurement

This experiment is designed and mainly focused to study the effects of frond angle on the cutting area, static force, time taken, and energy required to cut a frond without the use of intervention sickle. The oil palm has different angle as shown in Figure 3.4 (b), and this test is conducted to find out whether the angle of fronds affect parameters mentioned above.



(a) (b)

Figure 3.4. (a) Cutting angle and direction for the experiment, and (b) example of frond angle relative to the sickle cutting direction.

The test is conducted in Applied Mechanic Laboratory in Mechanical Engineering School, Universiti Sains Malaysia, using UTM (Universal Testing Machine) by Instron (Instron 3382) with a maximum capacity of 100 kN to obtain force against displacement graph. A freshly cut frond will be clamped onto a 'Frond Clamp' with an adjustable angle, and the angle is set to 45°. The angle is determined using an Android application called Protractor. The 'Frond Clamp' with the frond clamped to it is then attached to the UTM at the bottom part of the machine, and a

‘Sickle Clamp’ with a sickle is attached to the upper part of the UTM.

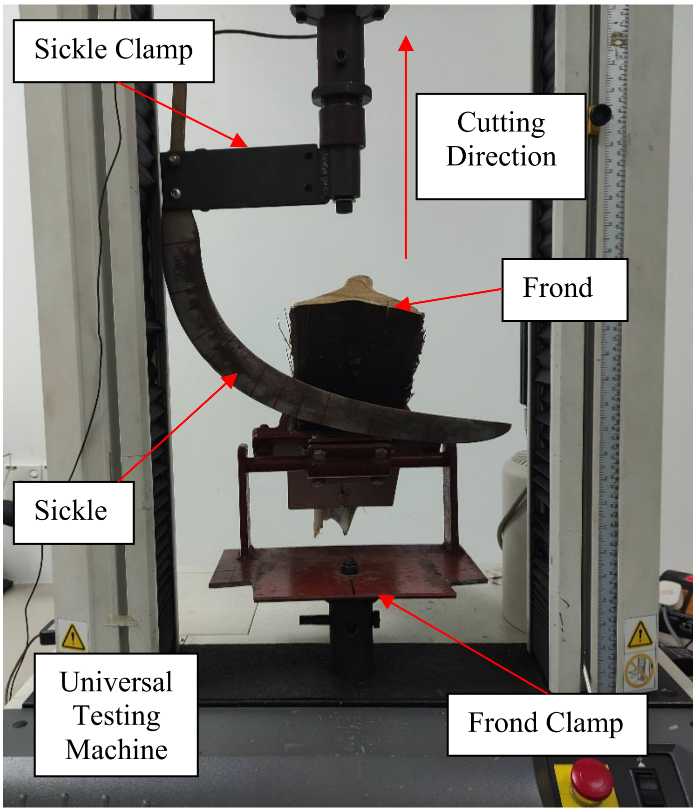


Figure 3.5 Front view of the full experimental setup for static force measurement (45° angle).

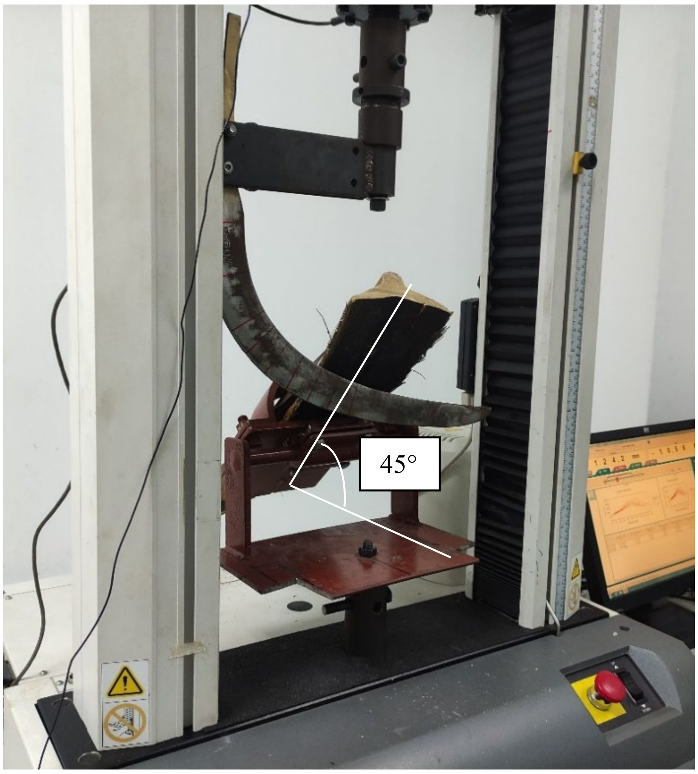
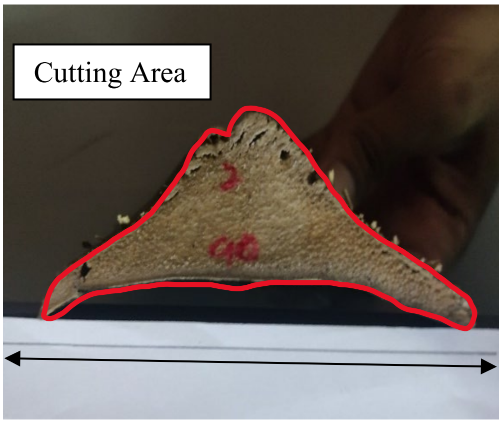


Figure 3.6 Side view of the full experimental setup for static force measurement

After the whole setup is completed, the test is run. The sickle will slowly move upward according to the displacement rate of 20 mm/s until the frond is entirely cut three times. The test is repeated with different angles (0°, 15°, and 30°), and each angle is repeated three times to get the mean value. The maximum cutting force, the work done, the time taken to cut the fronds, and the cutting area are compared for each angle to study the effects of the frond's angle.

3.3.1 Fronds cutting area

Fronds cutting areas were measured using ImageJ 1.8.0 software for the Static Force Measurement test. Twelve fronds already cut by sickle were selected to measure the cutting area. Figure 3.7 below shows a photo of a sample going through the editing process to obtain the cutting area's size. The frond cut surface must be parallel to the camera and the scale. The photo is edited in Photoshop 2020 to isolate and remove the background to make it easier to calculate the area in ImageJ 1.8.0 software.



(b)

(b)

(c)

Figure 3.7 (a) The top view of the cutting area, with the scale (b) edited image using Photoshop and (c) edited photo in ImageJ. The area is determined using the scale through the software.

3.4 Amplified Force Measurement

The intervention 'Pelajak' sickle is tested and used to measure the force required to cut a frond using a sickle with a load cell attached to it. The frond is clamped horizontally to a table/bench clamp, as shown in Figure 3.8. A frond holder is placed between the clamp and the frond to ensure the frond is held firmly and protect the frond's outer surface from the clamp grip. The test is then run with five cutting attempts to obtain the mean maximum cutting force and repeated using a conventional sickle to compare the difference.

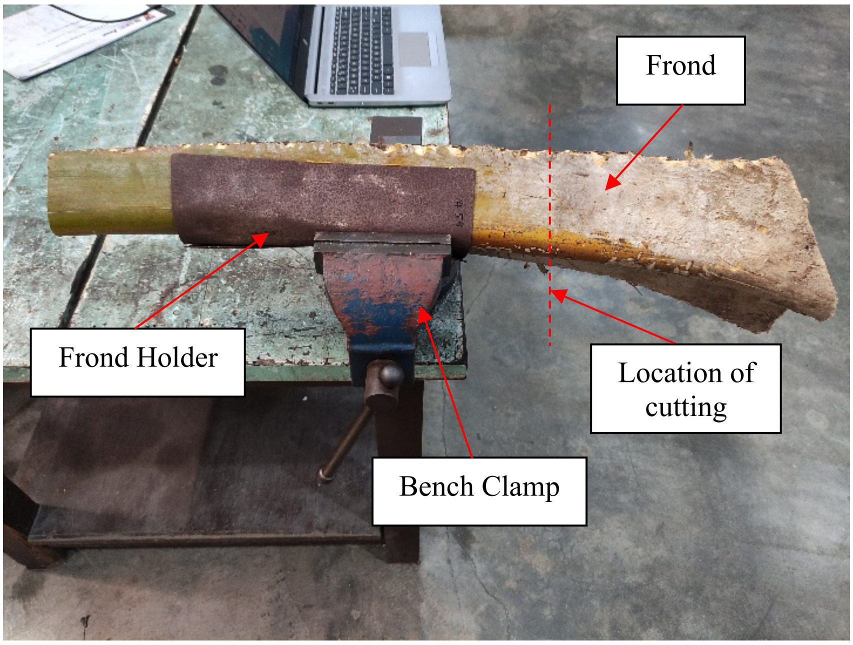


Figure 3.8. The frond is tightly clamped onto a bench clamp.
The Frond Holder is used to hold the frond more firmly.

Figure 3.9 shows the side view of the full experiment setup. The distance of the load cell from the frond and clamp is 2.3 m and the distance between the subject is 3 m as labelled in the figure. The details of the load cell and measurement of force is explained in the next section.

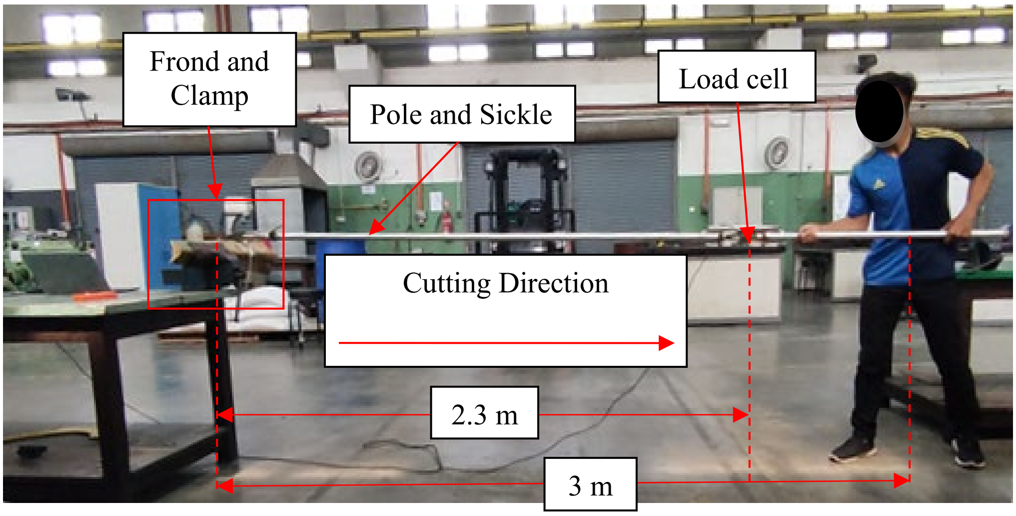


Figure 3.9 The side view of the full experiment setup for amplified force measurement test.

3.4.1 Measurement of force

Raw data of force measurement for each task were recorded on the LabView software and export into Microsoft Excel for display and analysis as shown in Figure 3.10. The raw data including the measurement of force on the standby posture which the subject hold the cutting tool in an upright position, then calibration was done to set the zero reading on the load cell and execution posture where the subject carried out the given task.

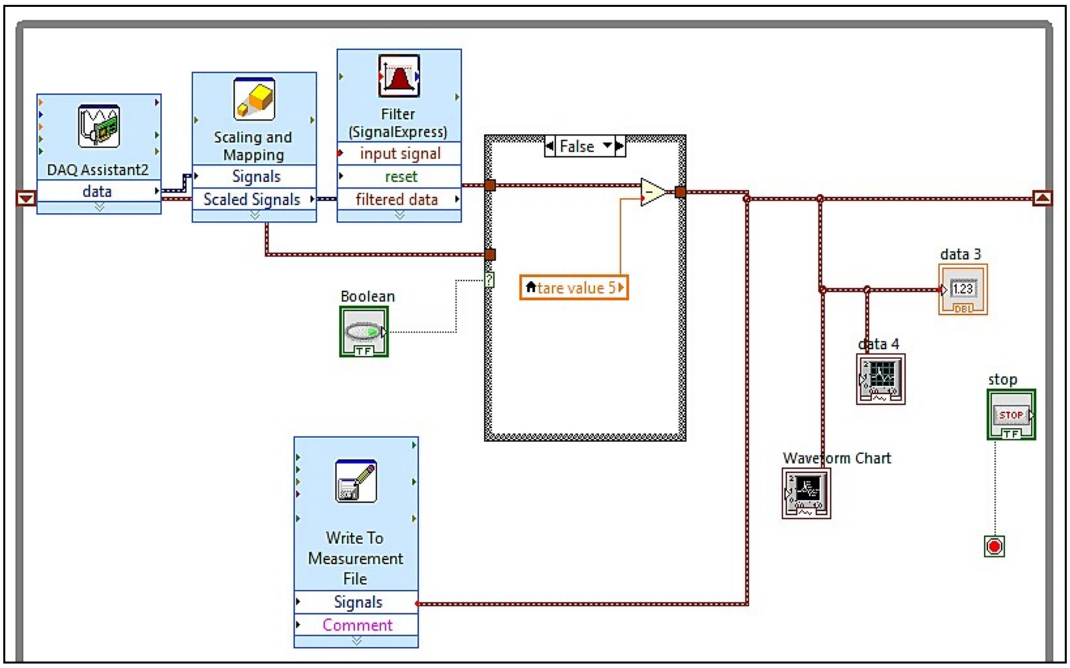


Figure 3.10 The layout on the LabView on measuring force from the load cell. In the figure consists of DAQ assistant, scaling and mapping, filter, write to measurement and display blocks.

The graphical interface for defining the measurement task and channels for customizing timing, triggering, and scales without programming is known as DAQ assistant or data acquisition assistant. The acquisition mode was set to continuous mode at a rate of 2000 Hz. As per setting, the load cell recorded the force measurement at a time gap 0.5ms. The scaling and mapping block used to change the amplitude of the signal by scaling or mapping the signal. In this experiment, the scale and mapping were set on the linear mode which the signal is based on the straight line ($y = 4.3x$). Next is the filter block which works on filtering the time signal using an infinite impulse response (IIR). The filter was used to remove and attenuate the unwanted frequencies from a signal using inverse Chebyshev topology. Write to measurement file block used to export the filtered signal (measurement of force from the load cell) to the Microsoft Excel. Lastly, the display blocks used as a display interface to monitor the signal (force against time) during the experiment.

3.5 Field Trial for Amplified Force Measurement

The experiment was done on an oil palm tree at the compound of the School of Chemical Engineering, Engineering Campus, Universiti Sains Malaysia, as shown in Figure 3.11. This experiment has the same objective as the test in 3.4, Amplified Force Measurement. Still, the difference is that the test in 3.4 is conducted in the laboratory. In contrast, this experiment was conducted on the outside, on a real tree, and eight subjects were tested instead of one in 3.4 test. The tree was chosen as it has a height higher than 3 m which is reachable by the subject to cut the fronds using a conventional sickle and intervention 'pelajak' sickle. This is a similar experiment that was done before by Ishak[12]. However, in this experiment, eight subjects, instead of 2 asked to replicate the cutting manually on the oil palm fronds. The subjects are 22 years old on average, with average height of 167.4 ± 3.40 cm, 60.95 ± 12.04 kg average weight and only one of them have the experience in pruning palm tree. Another difference in this experiment is that the subjects were not required to cut the frond until it gets fully cut. Instead, they were required to perform only five cutting attempts for each task. This is because this experiment does not focus on how the design of the sickle affects the performance of subjects like Ishak[12] did when he studied the sickle's design by the number of successful cuts and the number of attempts per frond and cutting time per frond.

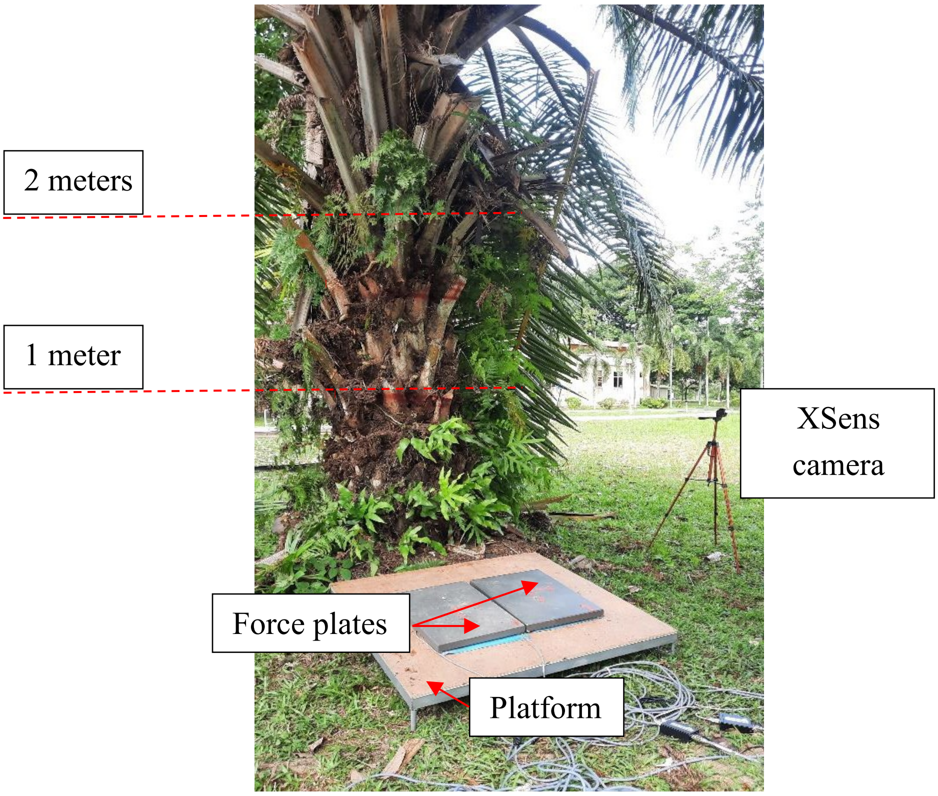


Figure 3.11. The oil palm tree located at the compound of School of Chemical Engineering, Engineering Campus, Universiti Sains Malaysia. In the figure, force plate and platform were located next to the oil palm tree as suggested by the subject for ease of cutting using conventional chisel.

In this experiment, the eight subjects were given two tasks to evaluate the magnitude of force required to cut the oil palm fronds. The first task is to cut oil palm fronds above 2 m in height using the intervention ‘pelajak’ sickle, and for the second task, the subject is asked to do the same task as the first one but using a conventional sickle.

Triaxial force plates (Bertec Corporation, Columbus, OH) was used to record the ground force executed by the subjects when they made the cutting attempts on the fronds. The subjects determined the position of the force plate and the platform before experimenting. The platform used to place the force plate on it and the position is shown in Figure 3.12. Subjects were required to stand still on the force plate and platform along with the experiment. The XSens's camera was used to record the movement of the subjects and transform it into an avatar. The study utilized IMU from Xsens Technologies, (Enschede, The Netherlands) called Xsens Motion Tracker Awinda (MTw). It consists of 17 sensors to be attached at subject's body as in figure for full body measurement as shown in Figure 3.11. In contrast, the camera recorded all the activities in this experiment. The data from the XSens's camera and the force plate will not be covered in this study as it was included for a different study carried out by my team members.

Figure 3.12 One of the subjects equipped with IMU sensors to the body.