ASSESSMENT OF FORCE REQUIRED DURING CUTTING OIL PALM FRONDS

KHAIRUL AIMAN BIN ISHAK

UNIVERSITI SAINS MALAYSIA

2021

ASSESSMENT OF FORCE REQUIRED DURING CUTTING OIL PALM FRONDS

By:

KHAIRUL AIMAN BIN ISHAK

(Matrix number: 137817)

Supervisor:

Dr. Muhammad Fauzinizam Bin Razali

July 2021

This dissertation is submitted to
Universiti Sains Malaysia
As partial of the requirement to graduate with honours degree in
BACHELOR OF ENGINEERING (MECHANICAL ENGINEERING)

UNIVERSITI SAINS MALAYSIA

School of Mechanical Engineering,
Engineering Campus,
Universiti Sains Malaysia

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……………………Khairul…………………… (Khairul Aiman Bin Ishak)

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

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ACKNOWLEDGEMENT

I would like to praise and thanks to Allah SWT for giving me opportunity, blessings, help me endlessly and good health during the pandemic in finishing the thesis on my Final Year Project entitled Assessment of Force Required During Cutting Oil Palm Fronds. Greatest gratitude goes to the supervisor of the project, Dr. Muhammad Fauzinizam Bin Razali for the unvaluable guidance, knowledge and time he gave to me on supervise the entire project. It was a great honour to discover this project under his supervision as a lot of knowledge I have learned from him. My thankfulness and appreciation to Dr. Mohamad Ikhwan Zaini Bin Ridzwan for the guidance on completing the project. Also, to the team of the 'Sawit' project, Harisangar, Nor Maisarah and Nadiah Aqilahwati for their commitment on the project. Next, to the assistant engineer at School of Mechanical Engineering, Universiti Sains Malaysia, Mr. Amri, Mr. Baharom, Mr Halim and Mr. Zalmi for being so helpful in monitoring me running the project at the Vibration Lab and during the field trial. Lastly, I am indebted to my parents for their love, prayers and sacrifices in educating me for my future. Last but not least thank you to who have associated with my work but whose name did not find in this acknowledgement for the tremendous positive feedbacks given along with the continuous support received.

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LIST OF ABBREVIATIONS

α	Cutting tool edge
β	Oblique angle
S	Cutting angle
SCE	Specific cutting energy
SCF	Specific cutting force

PENILAIAN TENAGA DIPERLUKAN KETIKA MEMOTONG PELEPAH KELAPA SAWIT

ABSTRAK

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 itu benar. Dalam ujikaji ini terdapat 2 objektif utama kajian. Objektif pertama adalah untuk mengakaji hubungan antara ketinggian pelepah kelapa sawit (bawah 1 m, diantara 1 m dan 2 m, dan atas 2 m) dengan tenaga yang diperlukan untuk memotong pelepah dengan meggunakan pahat biasa. Seterusnya, untuk mengkaji hubungan antara reka bentuk sabit (sabit pelajak dan sabit biasa) dengan tenaga yang diperlukan untuk memotong pelepah kelapa sawit pada ketinggian lebih dari 2 m. Hasil ujikaji mendedahkan aktiviti memotong pelepah kelapa sawit untuk 3 ketinggian berbeza mempunyai pengaruh terhadap ukuran tenaga untuk kedua-dua subjek tidak berpengalaman dan berpengalaman di mana semakin tinggi pelepah kelapa sawit, semakin tinggi ukuran tenaga. Sementara itu, untuk akiviti memotong pelepah kelapa sawit melebihi ketinggian 2 m, hasil kajian mendedahkan yang sabit pelajak memerlukan lebih tenaga untuk memotong daripada sabit biasa untuk subjek tidak berpengalaman, tetapi untuk subjek berpengalaman, reka bentuk sabit tidak mempengaruhi ukuran tenaga diperlukan untuk memotong. Walupun demikian, hasil analisis terhadap bilangan potongan yang berjaya dan masa diperlukan untuk memotong pelepah menunjukkan sabit pelajak lebih baik daripada sabit biasa.

ASSESSMENT OF FORCE REQUIRED DURING CUTTING OIL PALM FRONDS

ABSTRACT

The major activity 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 true at all. In this experiment, there are 2 main objectives of the research. The first objective is to study the relationship between the heights of oil palm fronds (below 1 m, between 1 m and 2 m, and above 2 m) with the measurement of force to cut the fronds using the conventional chisel. Next to investigate the relationship between the designs of sickle (intervention ‘pelajak’ and conventional sickle) with the measurement of force to cut the oil palm fronds above than 2 m height. The experiment conducted revealed that cutting oil palm fronds on 3 different heights using conventional chisel has an influence on the measurement of force for both inexperienced and experienced subjects which the higher the level of oil palm fronds, the higher the measurement of force. Meanwhile, on cutting oil palm fronds above 2 m, the study revealed that using intervention ‘pelajak’ sickle required more cutting force than using conventional sickle for the inexperienced subject, while for the experienced subject the design of the sickle did not influence the measurement of cutting force. However, the analysis on the number of successful cuts and time taken to cut the fronds shows that the intervention ‘pelajak’ sickle was better than the conventional sickle.

CHAPTER 1

INTRODUCTION

1.1 Oil palm plantation in Malaysia

Oil palm (Elaeis guineensis Jacq.) plantation is one of the main industries in Malaysia and has become the second world largest palm oil producer behind Indonesia. In fact, Malaysia has produced 25.8% of the world's oil palm production and 34.3% of world exports for the year 2020 [1]. The plantation of oil palm in Malaysia is still growing until today, with 5.9 million hectares of land in Malaysia is under the plantation of oil palm and is expected to grow by 43% in the year 2025 [2].

A study revealed that 446,368 foreign workers were working in oil palm plantations which were 69% of the total workers in the plantations sector for the year 2010 [3]. Some of the oil palm plantations have an issue regarding the number of workers that they have to drag the harvesting works to 20 to 25 days because of the shortage of workers [4]. The delay in harvesting fresh fruit bunches may affect the quality of the fruits themselves. Plus, another issue that influences the oil palm industry was the high production cost which had risen to between 20% to 23% of the total production cost between 1980 to 2000 [5].

Thus, there should be a solution where the productivity of the harvesters can be increased by developing a new cutting tool. The new cutting tool that being developed should have the essential technical information to prove that it can reduce the burden on the harvesters.

1.2 Project background

Harvesting oil palm includes four main activities: cutting fronds and fresh fruit bunches, stacking the fronds, collecting loose fruits, and carrying harvested fruits to the location point. Conventional chisel and conventional sickle are the main tools that is used to cut the oil palm fronds and fresh fruit bunches. Until today, no other tools have surpassed them. Even there are efforts on producing the new cutting tools, the harvesters still prefer to use the conventional chisel and conventional sickle as they are cheap and effective.

Human power and manual handling are essential in oil palm plantation works. Harvesters are required to possess a high skill level on the harvesting activities such as lift up the pole and have enough strength to cut the fronds and fresh fruit bunches. As the harvesting activities require high energy, most of the harvesters are not able to maintain the momentum for an extended period. They usually spend 4 to 5 hours per day working productively before fatigue sets in. The age of the harvesters also may affect productivity.

Conventional chisel is a common cutting tool used by the oil palm harvester to cut oil palm fronds and fresh fruit bunches on oil palm tree between 4 to 7 years while the conventional sickle is recommended to be used by the harvester to cut oil palm fronds and fresh fruit bunches on oil palm tree older than 12 years old [6]. Conventional chisel also being used to prune the dead and dying oil palm fronds in order to reduce risk and enhance aesthetics [7].

Efforts on developing new cutting tools have been done since the cultivation of oil palm in Malaysia. Malaysia Palm Oil Board (MPOB) itself has introduced motorized cutter: Cantas and Cantas Evo which can improve the work productivity among the harvesters [8] as shown in Figure 1.2.1. These cutters applied the usage of motor, thus reducing the cutting force applied by the harvesters but will burden them in the cost factor due to high cost and service maintenance.

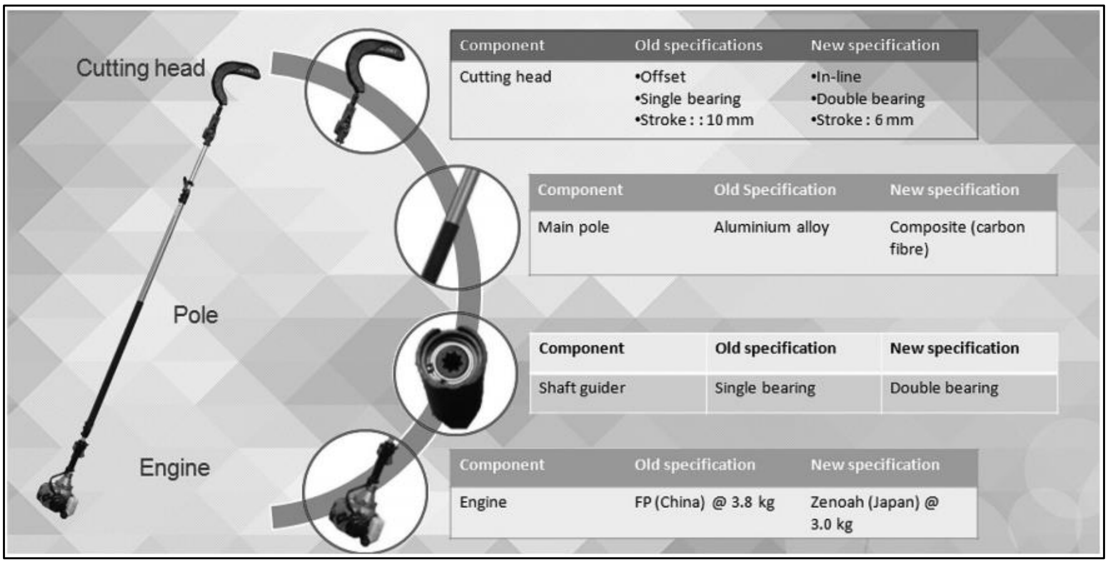


Figure 1.2.1 Comparison on Cantas (old specifications) and Cantas Evo (new specifications) developed by Malaysian Palm Oil Board (MPOB) [8].

There are also others cutting tools that being developed without using the motor such as 'pelajak' and inertial sickle as shown in Figure 1.2.2. These cutting tools applied some clearance between the sickle and the pole, thus can increase the momentum once the harvesters made a pull cutting force. However, most of the developers claimed that the tools they produced can improve the workers' productivity without published any relevant data regarding their claimed.

(a) (b)

Figure 1.2.2. (a) 'Pelajak' sickle produced by Teras Tegap Agro Sdn Bhd [9] and (b) Inertial sickle developed by Universiti Teknologi Mara Jasin [10]. Both are the new cutting tools that being introduced to reduce the burden on the harvesters during cutting oil palm fronds.

1.3 Problem statements

Cutting oil palm fronds using conventional chisel required push cutting technique while cutting oil palm fronds using conventional sickle required to use pull cutting technique. Both cutting techniques required the usage of a large amount of force.

Since there is still no other cutting tools that can suppress conventional chisel that usually being used to cut oil palm fronds on the lower height, the developing study must indicate the magnitude of force needed to cut the oil palm fronds on the different heights. This technical information is important to develop a new cutting tool. However, most of the developers did not acknowledge this information before develops a new cutting tool.

To develop a new cutting tool, the developer should provide technical information such as the improvement on the force required during cutting oil palm fronds using the new cutting tool. For an example, the intervention ‘pelajak’ sickle was claimed by the developer that the cutting tool can increase the productivity of the harvesters. However, there was no publication related to the technical information regarding the usage of the intervention ‘pelajak’ sickle. Plus, the developer should also include the analysis on the harvester’s performances on using the new cutting tools such as the number of successful cuts and time required to cut per frond.

1.4 Objectives of the study

There are 2 objectives of this study:

i. To measure the required cutting force to cut oil palm fronds on different heights using the conventional chisel.

ii. To measure the required cutting force to cut oil palm fronds above than 2 m height using different type of sickle designs (intervention ‘pelajak’ sickle and conventional sickle) and compare them with other published data.

1.5 Scope of the project

This study involved an experiment on the field test, where the technical information such as the magnitude of force needed to cut the fronds, time taken to cut per frond, and number of successful cuts using the cutting tools were observed. Regarding the previous study conducted by Abdul Razak Jelani et al. [11], the study was done inside the laboratory where there was no measurement regarding the human force. Thus, this experiment was focused on the magnitude of human force needed to cut the fronds using a conventional chisel, intervention ‘pelajak’ sickle, and conventional sickle. The design of the cutting tools was done on the SolidWorks software. The magnitude of force was measured by a S-shaped load cell and actuated through the LabView software. Finally, the measured data were analysed in the Microsoft Excel and SPSS software.

CHAPTER 2

LITERATURE REVIEW

2.1 Definition of cutting force

Cutting force is defined as the external force applied to the cutting tool to perform the material cutting. In a real cutting process, the force will be applied in the directions of X, Y, and Z components, but in this experiment, 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 (SCE). The cutting force is made up of two components: edge force and wedge force. According to Abdul Razak Jelani et al.[11], the edge force is the force applied on cutting the material that caused high local stress on the material in contact with or near the edge. Meanwhile, the wedge force is the force that is applied to separate the cut's sides to allow the cutting tool to pass through. Furthermore, there were studies in [11] and [12] that were similar to this experiment. Thus, similar terminology will be used in this experiment, as shown in Figure 2.1.1 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.

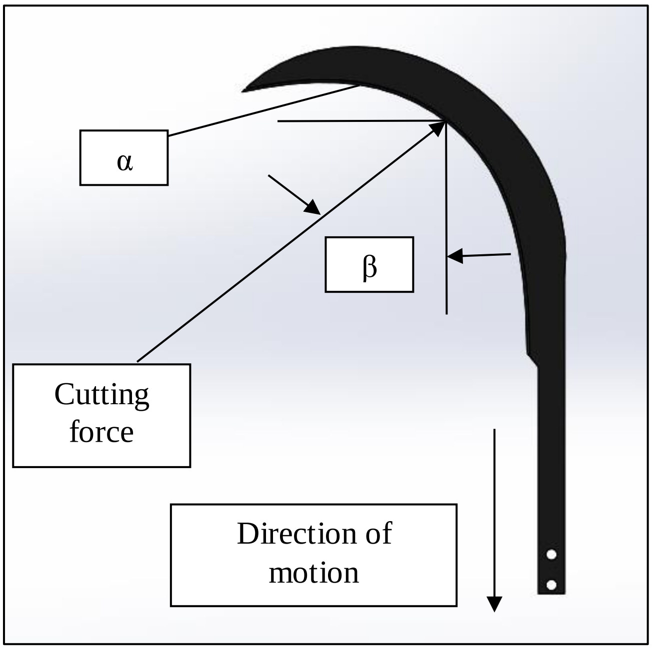


Figure 2.1.1. The schematic of sickle shows the cutting tool edge angle (α), oblique angle (β), direction of cutting force and direction of cutting motion [11].

2.2 Factors affecting the cutting force

There are several factors may be affecting on the measurement of cutting force on oil palm fronds. According to the works in [11] and [12], 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 frond. 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. While authors in [12] classified the fronds maturity to below 50 % moisture contents and above 50 % moisture content which was evaluated by eyesight. In common, the frond that has a moisture content below than 50 % is the dried frond and brownish.

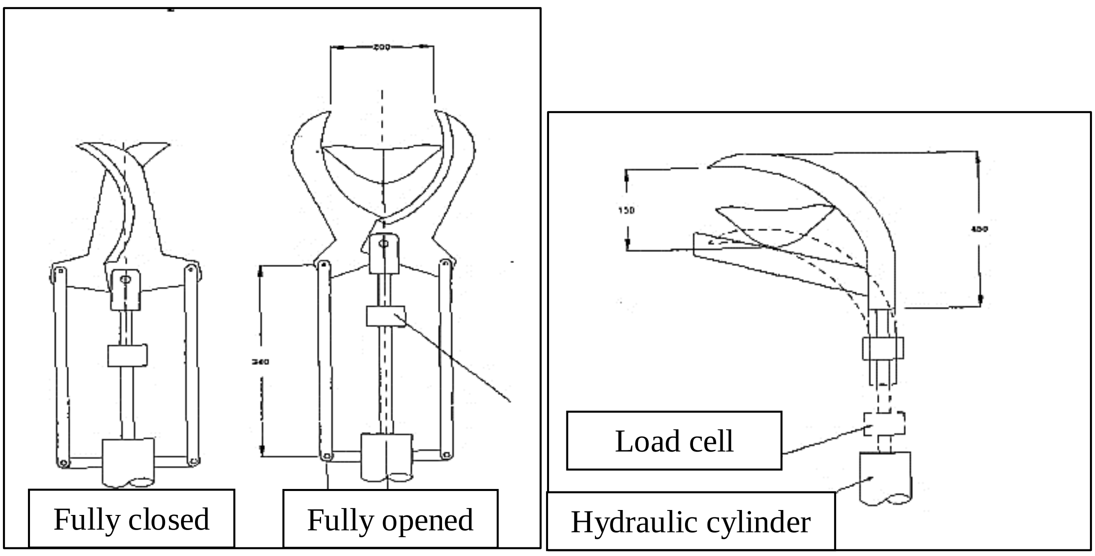
Studies by Abdul Razak Jelani et al. [11] concluded that increased the cutting angle will increase the magnitude of the cutting force. Three different cutting angles were tested on that experiment which was 45°, 60°, and 90°. As increasing the cutting angle from 45° to 90°, increased the maximum SCF 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 which the frond that located second below the ripe bunch required high force to cut compared to the frond that located second above the ripe bunch. As the frond becomes mature, the fibre inside the frond becoming harder.

The result revealed by Mohd Rizal Ahmad et al. [12] stated that cutting oil palm fronds on the angle of 45° contributed to the lowest cutting force compared to cutting angle at 30° and 60° and the highest cutting force measured was on cutting angle at 60°. On the influence of the frond maturity, the lower the frond moisture, the higher the measurement of cutting force. Based on the study, for moisture content more than 50%, increasing the cutting angle from 30° to 45°, had reduced the cutting force 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 45° had decreased the cutting force about 21%, and the cutting force was increased about 51% as the cutting angle increased from 45° to 60°.

2.3 Intervention cutting tools

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

Based on the research, a studied in [11] was done to observe the force and energy required to cut the oil palm fronds based on the 2 designs of the cutter. Figure 2.3.1 shows the claw cutter and sickle cutter that were used in the study. For the claw cutter, the blade was made up of carbon steel 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” with respect to the horizontal line.



(a) (b)

Figure 2.3.1. (a) Design of claw cutter and (b) design of sickle cutter [11].

The experiment revealed the maximum specific cutting force (SCF) for claw cutter and sickle cutter were 22.9 kg/cm^2 and 12.2 kg/cm^2, respectively. While the maximum specific cutting energy (SCE) for the claw cutter and sickle cutter were 115.5 $kg.cm/cm^2$ and 64.5 $kg.cm/cm^2$, 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 finish at about three quarters of the edge. This cutting method applies a higher oblique angle at 45° to 90° depends on the position of the material being cut. 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 just slide on the material and slowly penetrating it. Meanwhile using the claw cutter, it cuts the fronds by directly penetrating it without and slicing movement as the oblique angle is maintained at 24.4" at all position. Thus, 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 actuated by a 4-ton hydraulic cylinder and ran by a single-phase Enerpac Hydraulic pump set. The pusher road was maintained at a constant velocity of 0.6 m/s. Thus, it is found that there was no measurement of human force recorded in the experiment as the cutting force was done by the machine.

2.4 Motorized cutter

In the year 2017, MPOB has introduced a motorized cutter called Cantas to improve the productivity of the harvesters. However, the motorized cutter that utilizes a gasoline engine (petrol engine) had triggers some problems such as exhaust emission (smoke), vibration and heavy engine. Plus, there were some others issues regarding the price of fuel and spare part. Some smallholders' plantations that located far away from the petrol station also have a problem storing the fuel as it is flammable.

Thus, works in [13] and [8] were done on developing a battery-powered oil palm harvesting tool called Cantas Evo. The study concluded that the vibration level observed at the pole and throttle of the Cantas Evo was 1.3 m/s^2 and 0.8 m/s^2, respectively was far below the threshold level of 2.5 m/s^2, as suggested in [14]. Thus, it was indicating that the tool is safe to use within 8 hours of working per day. The battery durability test done revealed that the voltage of the motor reduced to 15.2 V from 20 V after 235 minutes of working (around 4 hours) at a depletion rate of 1.22 V per hour. The temperature measured on the motor was consistent at an average of 55°C during the operating time.

It was clear that the introduction of Cantas Evo can assist the harvesters in increasing their work productivity. The only drawback for the battery-powered cutter was the cost. Based on work in [13], an economic analysis was done based on the user perspective which includes the fixed cost for battery, motor, gearbox and pole, while the variable costs are labour, electricity for charging and maintenance. Table 2.4.1. shows the details of the calculation for the operational cost per tonne fresh fruit bunches (FFB) was done using the straight-line depreciation method. The cost per tonne calculated was RM 9.81 per tonne FFB. The assumptions considered in the calculation were as follows:

a) Machine selling price: RM 4000 [15]

b) Life span: 2 years

c) Performance: 6 tonne per day

d) Labour cost: RM 50 per day

Description	Calculation	Cost (RM per day)
Depreciation (price / life span × 300 days)	4000 / (2 years × 300 days)	6.67
Electricity for charging	2 hours × RM 0.22 / kWh × 2 sets	0.88
Repair and maintenance @ 10% per year of purchase price	10% × 4000 / 300 days	1.33
Labour cost	-	50
Total	-	58.88
Cost per tonne = total cost / productivity	(RM 58.88 per day) / (6 tonne per day)	RM 9.81 per tonne FFB

Table 2.4.1. Cost analysis based on user's perspective of battery powered Cantas Evo [13].

The cost per tonne of FFB on using the battery-powered cutter is higher compared to using the conventional cutting tools as suggested in [5], the analysis on harvesting cost for the smallholder's plantation in Johor, Malaysia in the year 2000 was RM 2.49 per tonne FFB which was 70% lower than using the battery-powered cutter. Hence, that is why most of the harvesters especially the smallholders' harvesters still using the conventional chisel and conventional sickle on oil palm plantation's works as they were much cost friendly.

CHAPTER 3

METHODOLOGY

3.1 Selection cutting tools

In this experiment, 3 types of cutting tools were used to cut oil palm fronds on 3 different heights: below 1 m, between 1 m and 2 m, and above 2 m. Conventional chisel and conventional sickle are the common cutting tools used by harvesters in the oil palm plantation. The intervention ‘pelajak’ was chosen in this experiment considering the information from the developers that claimed the cutting tool can make the harvesting work easier, plus increasing the work productivity compared to using the conventional chisel and conventional sickle [9].

3.1.1 Design of chisel

Figure 3.1.1 shows the design of the conventional chisel used by the subjects to cut oil palm fronds on the lower height. The chisel was made up of carbon steel and weighed 10.84 kg. The length and width of the chisel were 31 cm and 12.5 cm, respectively. An adaptor and S-shaped load cell were fixed at the middle of the aluminium pole with a distance of 23 mm from the edge of the chisel, while the total length of the cutting tool is 164 cm.

As the cutting force done by the edge of the chisel, the pushing force sensed by the load cell was recorded through the LabView software. The cutting force required to cut the fronds is equal to the resistance force given by the fronds.

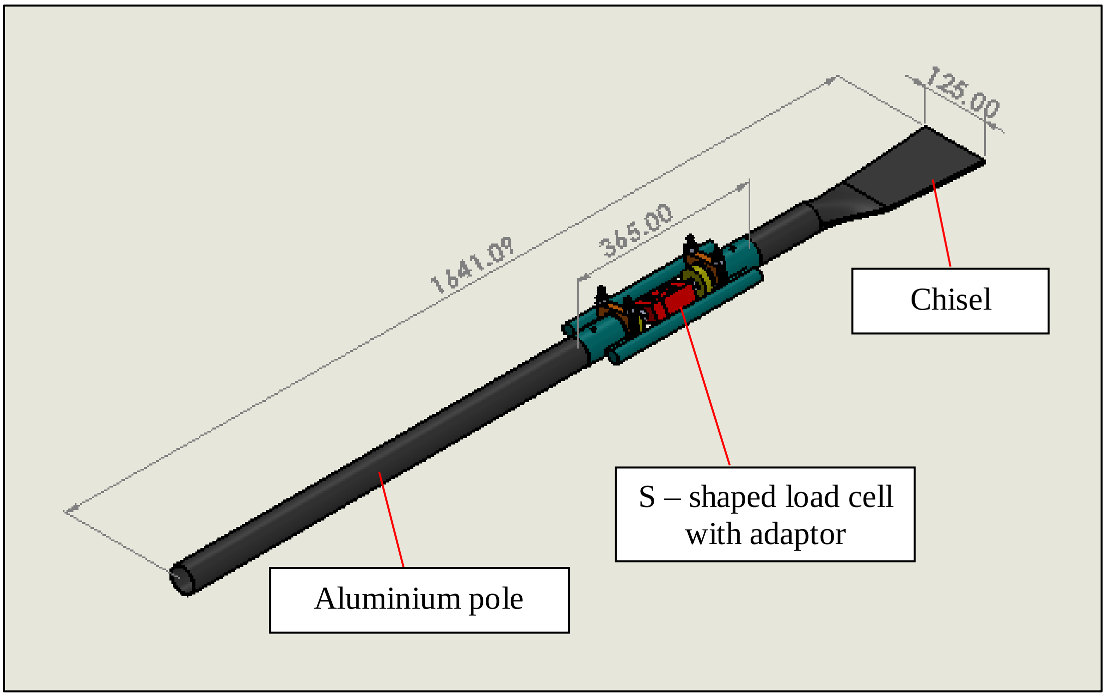


Figure 3.1.1. The conventional chisel used in the experiment. In the figure: S – shaped load cell with an adaptor was fixed to the aluminium pole. The dimensions' unit are millimetre (mm).

3.1.2 Design of sickle

Two types of sickle designs: conventional sickle (Figure 3.1.2) and intervention 'pelajak' sickle (Figure 3.1.3) were used in this experiment to observe their influence on the measurement of cutting force on the 2 subjects. The conventional sickle is the ordinary sickle made up of carbon steel and weighed 20.3 kg including the aluminium pole. The length and width of the conventional sickle were 62 cm and 37 cm respectively. U-clamped were used to fix the conventional sickle to the aluminium pole. The length of the aluminium pole used in this experiment was 336 cm. An adaptor with a S-shaped load cell were fixed at the aluminium pole to measure the magnitude of cutting force.

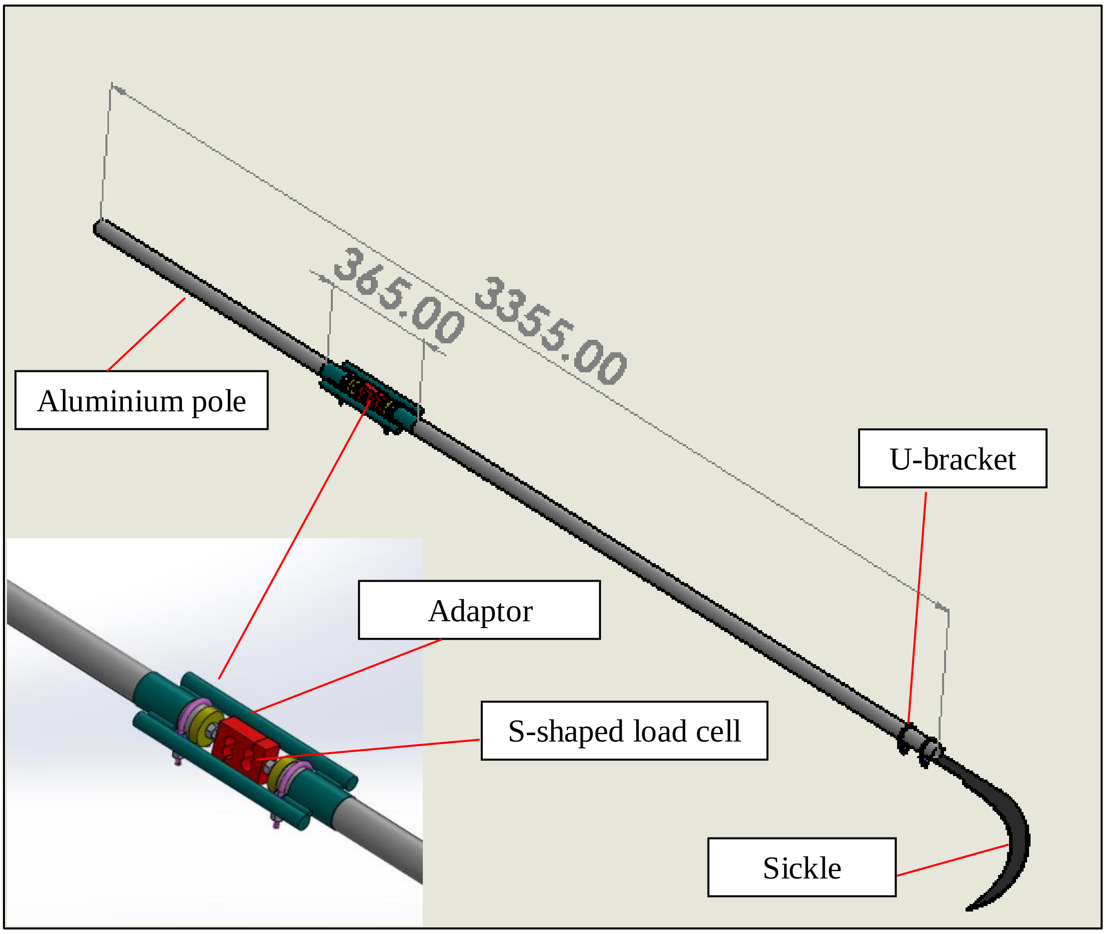


Figure 3.1.2. The sickle attached to the aluminium pole, S-shaped load cell and an actuator with the total length of 418 cm. Also in the figure is a S-shaped load cell with an adaptor fixed at the aluminium pole and the conventional sickle attached to the pole by U-bracket. The dimensions' units are millimetre (mm).

The intervention 'pelajak' sickle used the ordinary sickle as shown in Figure 3.1.3, just an additional part called 'pelajak' was fixed between the aluminium pole and the sickle. The 'pelajak' design has a clearance of 7.5 cm to create momentum once the harvester makes the pulling force. The overall weight of the cutting tool including the aluminium pole was 22.8 kg. The cutting force measured was sensed by the pulling force applied by the harvester to cut the fronds.

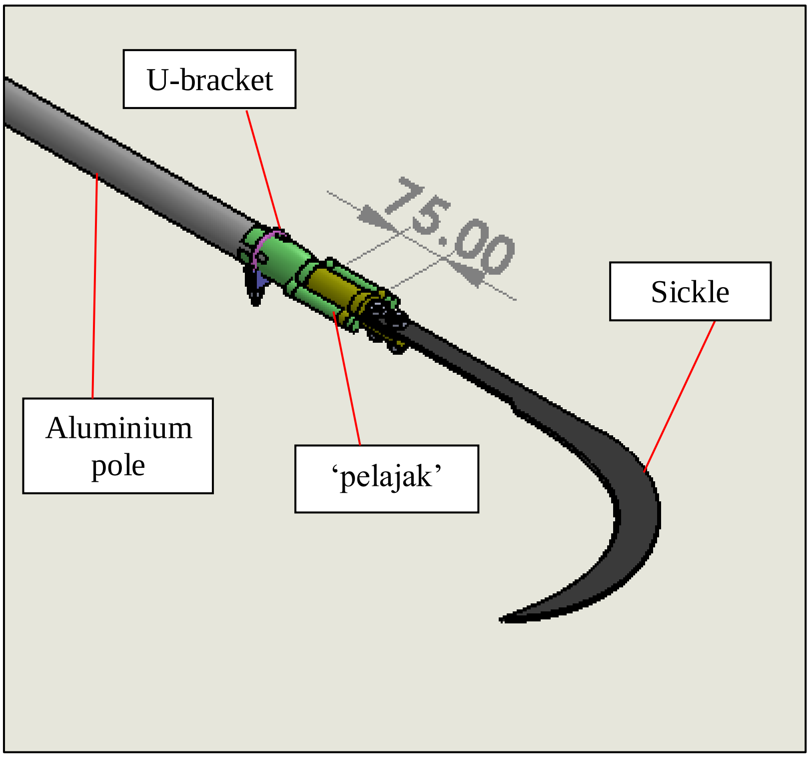


Figure 3.1.3. The sickle attached to the 'pelajak' that was used in the experiment to cut oil palm fronds above than 2 m. The dimension show is in the unit of millimetre (mm).

3.2 Experimental design

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 3.2.1. The tree was chosen as it has numerous fronds especially on the height below than 1 m. Plus, the height of the oil palm tree is 3 m which is reachable by the subject to cut the fronds using conventional chisel and intervention 'pelajak' sickle. There is a similar experiment that was done before by Abdul Razak Jelani et al. [11] which used a test rig to clamp the oil palm frond and the cutting tools were actuated with by a 4-ton hydraulic cylinder run by a single phase. However, in this experiment, the subjects were asked to replicate the cutting manually on the oil palm fronds in order to get the actual data of force measurement rather than attached the cutting tools to a machine.

Figure 3.2.1. The oil palm tree located at the compound of School of Chemical Engineering, Engineering Campus, Universiti Sains Malaysia. The oil palm tree has numerous of fronds on the lower level that can be cut using the conventional chisel in this experiment. 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, 2 subjects labelled as S1: inexperienced and S2: experienced, were given 5 tasks to be done in order to evaluate the magnitude of force required to cut the oil palm fronds. 1 day was allocated for each subject to complete all 5 tasks. Table 3.2.1 shows the 5 given tasks that were observed in this experiment.

Tasks number	Cutting tools used	Descriptions
1	Conventional chisel	Cut oil palm fronds below than 1 m height
2	Conventional chisel	Cut oil palm fronds between 1 m and 2 m height
3	Conventional chisel	Cut oil palm fronds above than 2 m height
4	Intervention 'pelajak' sickle	Cut oil palm fronds above than 2 m height

5	Conventional sickle	Cut oil palm fronds above than 2 m height

Table 3.2.1. The sequence of tasks that was followed during the experiment according to the cutting tools used.

The position of the force plate and the platform was determined by the subjects before carrying out the experiment. The force plate was used to record the ground force executed by the subjects when they made the cutting attempts on the fronds. The platform used to place the force plate on it and the position is shown in Figure 3.2.2. Due to each study task, the location and distance between the force plate and platform with the oil palm tree were set according to the suggestion from the subjects with approximately 0.8 ± 0.02 m. Subjects were required to stand still on the force plate and platform along with the experiment. The X-Sens's camera used to record the movement of the subjects and transform it into the avatar while the camera used to record all the activities in this experiment. The data from the X-Sens'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.

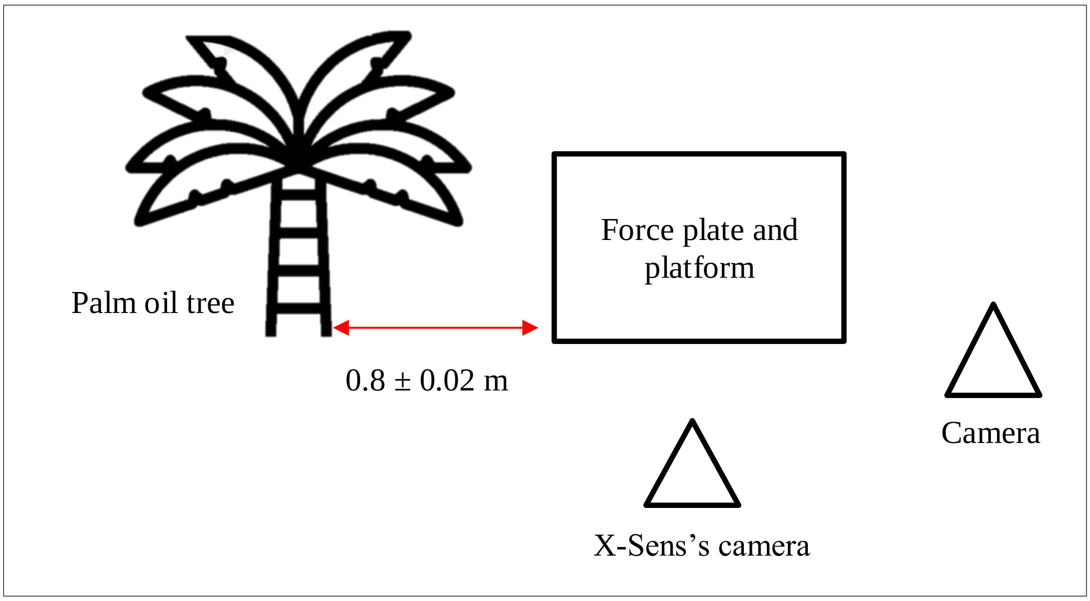


Figure 3.2.2. The design of position for the force plate, platform, X-Sens's camera and a camera.

3.2.1 Subject preparation

This experiment included 2 male harvesters as subjects to do the experiment as shown in Figure 3.2.3. The first harvester assigned as subject 1 (weighed 69.1 kg and height 171 cm) is an inexperienced harvester while subject 2 (weighed 84.5 kg and height 165 cm) is an experienced harvester. The inexperienced subject did not have any experience regarding the oil palm plantation works while the experienced subject works part-time on his oil palm plantation during the weekend and holiday with mean working hours 5 hours per week. Both subjects had signed an agreement form before doing the tasks in this experiment.

(a) (b)

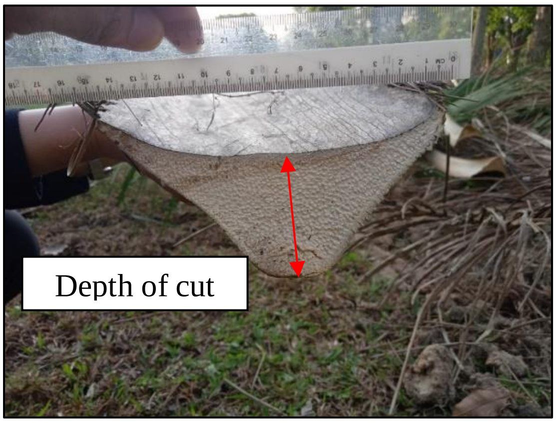
Figure 3.2.3. (a) S1: Inexperienced subject and (b) S2: Experienced subject completing the second task which is cutting oil palm fronds between 1 m and 2 m using conventional chisel.

3.2.2 Fronds cutting area

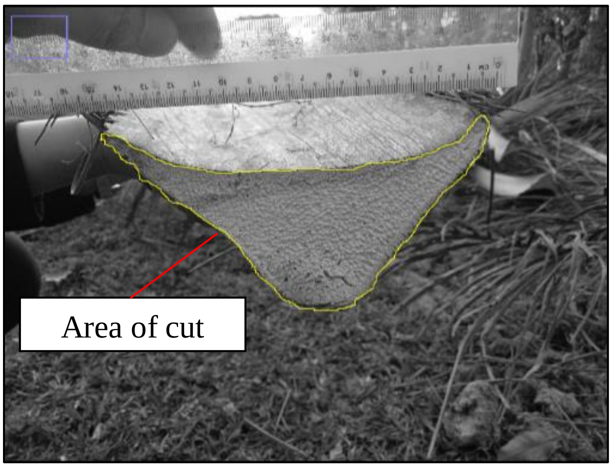
Fronds cutting area were measured using ImageJ software to calculate the maximum specific cutting force (SCF) and maximum specific cutting energy (SCE) for the tasks' analysis. 6 fronds that already being cut by chisel and 5 fronds cut by sickle were selected randomly to measure the cutting area, the width of cut and depth of cut. The samples taken show that the means cutting area for fronds cut by chisel and sickle were 31.01 ± 8.7 cm^2 and 61.66 ± 21.66 cm^2, respectively. Figure 3.2.4 shows the mean width of cut measured on the fronds that were cut by the conventional chisel, 10.84 ± 2.13 cm and the depth of fronds that were cut using the intervention 'pelajak' and conventional sickle. The mean value for the depth of cut fronds was 7.72 ± 2.39 cm.

The depth and width of cut on the fronds were taken considered on the direction applied by the subjects during cutting the oil palm fronds. It came to the observation that the subjects made the cutting attempt from the side of the targeted frond when used the conventional chisel. When the subjects used the intervention 'pelajak' sickle and conventional sickle, the cutting attempt was made in a downwards direction for ease of cutting.

(a)



(b)



(c)

Figure 3.2.4. (a) The measurement on the width of cut using the chisel, (b) measurement of the depth of cut using the sickle and (c) measurement of oil palm frond's cutting area. The ruler in the image was used as the reference on measuring the dimension of the fronds.

3.3 Measurement of cutting 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 3.3.1. 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.

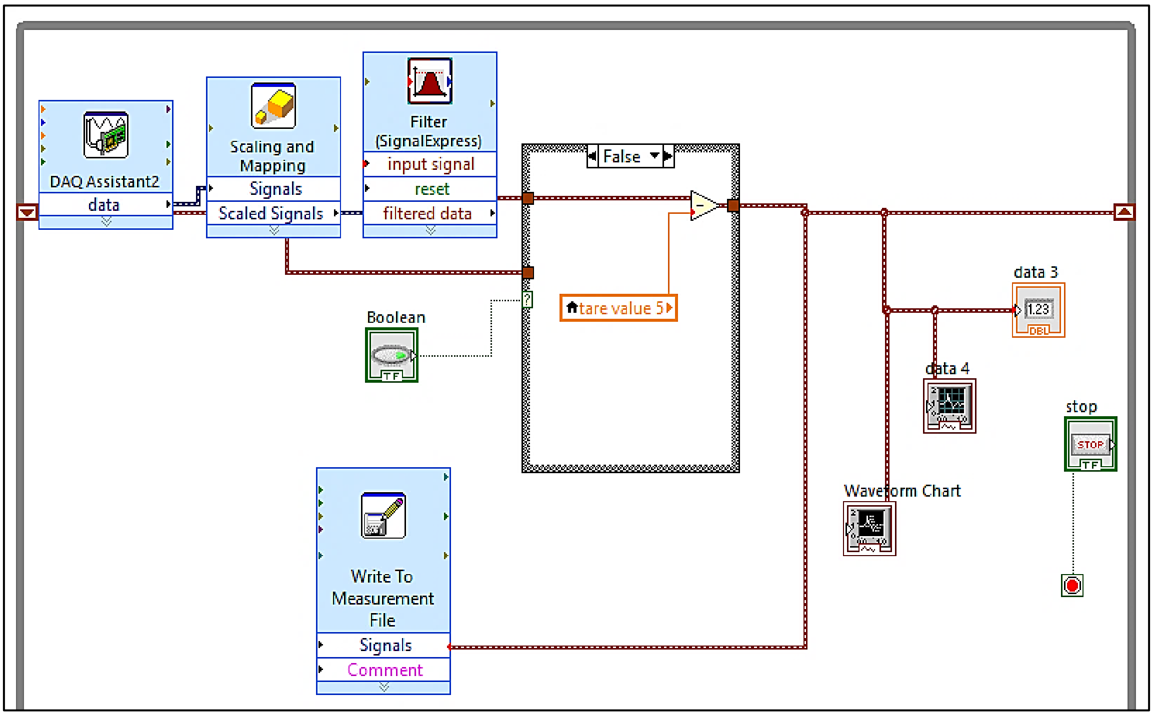


Figure 3.3.1. The layout on the LabView on measuring force from the load cell. In the figure consists of DAQ assistant, scaling and mapping, filter, write to measurement and display blocks.

The graphical interface for defining the measurement task and channels for customising 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 0.5 ms. 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 ($y = 23.42 x$). 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.

3.4 Statistical analysis

Statistical data analysis was performed using IBM SPSS Statistics software. Descriptive statistics were used to obtain the mean and standard deviation for each task. One way ANOVA (analysis of variance) and independent samples T-test were used to determine the significant difference between the compared tasks. The ANOVA analysis compared the means of groups between 3 different classes: measurement of cutting force using conventional chisel for fronds below than 1 m, fronds between 1 m and 2 m, and fronds above than 2 m height. While the T-test used to compare means values for measurement of cutting force using intervention ‘pelajak’ sickle and conventional sickle. Any variable with a p value < 0.05 was considered to have a significant level.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

Analysis of variance (ANOVA) on the maximum cutting force was done to indicate the significant difference of the cutting force required to cut the oil palm fronds on 3 different heights (below than 1 m, between 1 m and 2 m and above than 2 m height). While T-test was done on the maximum cutting force to identify the significant difference in the maximum cutting force required to cut the oil palm fronds above than 2 m using 2 different sickle designs (intervention 'pelajak' sickle and conventional sickle).

Other analyses such as maximum specific cutting force (SCF), maximum specific cutting energy (SCE), impulsive force, number of attempts per frond and time required to cut per frond were done to observe the interactions on cutting oil palm fronds using conventional chisel between 3 different heights and cutting oil palm fronds above than 2 m using two different sickle designs. The results displayed on a mean ± standard deviation basis for the analysis.

4.2 Measurement of force using chisel

The raw data for measurement of force using conventional chisel for subject 1 (S1: inexperienced) when cutting fronds at a height of below than 1 m is shown as in Figure 4.2.1. The graph shows the overall raw data of force measurement against time from the standby position, execution cutting position and finishing position. In the standby position, the subject was required to stand still while holding the conventional chisel beside him and the calibration of the load cell was done to set the initial zero reading. At first, the load cell recorded weight on the top part of the conventional chisel was 10.84 ± 0.36 kg. The subject was given 5 minutes to execute the cutting right after the calibration had completed. The peaks in the graph are the maximum pushing force exerted by the subject while the valley is the maximum pulling force exerted by the subject. In several cutting attempts, the edge of the chisel was stuck at the oil palm frond that required the subject to make a hard pulling force.

Table 4.2.1 shows the observed maximum cutting force made by the inexperienced subject on cutting the fronds using the conventional chisel. The highest force recorded was on cutting fronds above than 2 m and the lowest cutting force was on the fronds below than 1 m height.

S1: Inexperienced	
Oil palm fronds' heights	Maximum cutting force (N)
Below than 1 m	493.14
Between 1 m and 2 m	496.16
Above than 2 m	523.84

Table 4.2.1. The measurement of maximum cutting force for inexperienced subject on cutting fronds using the conventional chisel