UNIVERSITI PUTRA MALAYSIA

DESIGN AND DEVELOPEMENT OF OIL PALM TRIMMER

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Approval Sheet

This project report, entitled "Design and Development of Oil Palm Trimmer" prepared and submitted by Ahmad Shafie Bin Samsuri (189569) in partial fulfilment of the Bachelor of Agriculture and Biosystems Engineering with Honours is hereby accepted.

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Abstract

Currently, the cutting of Oil Palm Frond (OPF) using a sickle attached to a long pole is still widely practiced. To advance the state of current harvesting method, MPOB has introduced a new technology, which is a mechanized cutter, Cantas. The mechanize cutter operate using a small engine and vibrating sickle to cut the OPF and fruit bunch on tree. This project continues development in the field of mechanization of oil palm frond cutter. The focus is on using a different type of cutting tool, instead of using a sickle. A rotary cutting tool is introduced in this project. The most suitable cutting tool is the large straight router bit; because, the ability of this cutting tool is better when compared to other tested cutting tools bit. Moreover, the cutting angle during cutting of OPF are studied and the result shows that a 30-degree angle is the most suitable as the cutting speed is much faster compared to others. Furthermore, this project's prototype will be used with a robotic system in future development. The housing of cutter prototype is working properly during the experiment. Besides that, this prototype is powered by an electrical source compared to previous technology, using a small engine as power source.

Abstrak

Sebelum ini, pemotongan pelepah sawit menggunakan sabit dipasan pada galah Panjang, akan tetapi dengan bantuan teknologi, MPOB telah mencipta pemotong pelepah mekanikal. Pemotong pelepah mekanikal menggunakan enjin kecil sebagai punca kuasa dan getaran pada sabit akan memotong pelepah dah tandan buah. Projek ini akan meneruskan penyelidikan dan pembangunan dalam pemotong peleah sawit mekanikal. Focus utama adalah menggunakan alat pemotong yang berlainan dimana ia menggunakan alat pemotong yang berputar. Alat pemotong yang sesuai adalah 'straight router bit' yang besar kerana kemampuan untuk memotong pelepah sawit adalah yang terbaik daripada yang lain. Selain itu, sudut pemotongan juga dicari dalam projek ini, sudut yang sesuai adalah sudut bersudut 30. Hal ini kerana kelajuan pemotongan pada paksi ini adalah yang terpantas berbanding yang lain. Tambahan pula, prototaip ini juga digunakan bersama robot pemotong pelepah dan ia berfungsi dengan baik semasa ujian dilakukan. Prototaip ini juga menggunakan punca kuasa elektrik berbanding teknologi lama yang menggunakan enjin sebagai punca kuasa.

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List of Abbreviation

OPF	Oil Palm Frond
MPOB	Malaysian Palm Oil Berhad
mm	Millimetre
s	Seconds
“	Inch
Rpm	Rev per Revolution
T	Time
L	Length
W	Watts

1 Introduction

1.1 Overview

Palm Oil industry is one of the main industries that helps Malaysia economic become better and stable. Estimated area planted for oil palm for 2017 are about 5,811,145 hectares and each hectare's average production of Fresh Fruit Bunch (FFB) about 17.89 tones which is the total production of Fresh Fruit Bunch (FFB) are 103 mega tones. Average price in year 2017 of FFB are about RM 606.00 per ton and the total gross profit are RM 62.418 billion (MPOB). Statistics shown by Malaysia Palm Oil Berhad (MPOB, 2017) prove that Palm Oil industry are one of the largest industries in Malaysia and provide a large number of job opportunities either for locals or foreigners

1.2 Mechanization in Oil Palm Estate

Labour are very important in oil palm industry because workers requirement is very high demand either in upstream or downstream section. The labour shortage already occurs in Malaysia; thus, the foreign workers are increase as they work in this industry. Depending on foreign worker are not best solution as it only in a temporary and not fixed. Decreasing the human needed in the industry are using the mechanization concept to eliminate the shortage of labour (A. Rahim, et all; 2010). The mechanization concept is using the technology to help and decrease the human labour as the mechanization concept using less worker to operate but provide a good output in term of production. In early years plantation of palm oil in Malaysia, harvesting and pruning process are using the manual tools which is sickle or chisel. However, the technology become advance year by year and mechanize

cutter are introduced to the palm oil industry. There are several mechanize cutter develop by many parties and the most famous are made by MPOB introduced in 2007; called as Cantas, Cantas designed for harvesting FFB and cutting fronds or pruning. A small petrol engine is attached at the bottom of cutter pole and cutting knife are attached the top of cutter pole (A. Razak, et all; 2016).

1.3 Problem Statement

A C-sickle shape used in Cantas is adapted from sickle used in the conventional pole-sickle harvesting tool used in manual operation. However, most of the knife used in motorized cutter are almost same and there is no development for the cutting knife. Current tools faced several problems during cutting operation; this include vibration produced when the engine is started. Vibration can cause several effects such as the bolt and nuts might loosen due to vibration; and Musculoskeletal Disorder. M. J. Griffin and M. Bovenzi state that, the effect of vibration on hand can cause vibration-induced white finger and Raynauld's phenomenon. Besides that, power transmission shaft uses in the tools also become some burdens as it increases the weight of the tools. A. Razak & et all (2017) mentioned that Cantas sales decline at 2012 as the frequent breakdown, heavy and high vibration was the caused this tool to become less favourable.

1.4 Objectives

The aim of this study is to develop a new mechanized cutter utilizing a new cutting tool bit for pruning of Oil Palm Frond (OPF) in field. The purpose is to minimize and if possible to eliminate the problems faced by operators of Cantas. The weight and vibration of the system have to be reduced. The scope of study was to use a milling cutter as a new type of cutter and utilizes DC motor as power source. The more specific objectives would include;

- To identify the suitable milling cutter
- To develop jig to be used in the prototype
- To test the prototype on laboratory and field

2 Literature Review

2.1 Harvesting and Pruning in Oil Palm Estate

Harvesting and pruning are the main activities involve in palm oil estate operation. Without those activities FFB on tree are unable to harvest and excess fronds growing at the tree will caused the palm oil growth slower. Harvesting activities usually occur once or twice per month however pruning activities occur depends the condition of the trees.

Harvesting are the process of cutting FFB from the oil palm trees and obtain a maximum amount and high quality of oil. A high fatty acid at the FFB will produced low quality of oil and the best fatty acid are between 2 - 3 % (produced high quality oil). High level of fatty acid also caused the price of oil decrease due to crude oil processing took longer; thus, decrease the market price. Several caused of high fatty acid are FFB are too ripe, unripe FFB, some wound on fruit during harvesting, FFB kept more than 24 hours and dirt quantity are high during collecting process (Taman Pertanian Universiti, Univesiti Putra Malaysia, 2012).

Pruning is important to promote more efficient of fertilizers use and create an easily accessible plantation. During pruning; more fronds are better for production, dead or dying leaves contain nutrients that needed to be recycled, and palm are tall it will be harder to perform a good harvesting as there are many fronds. Hence, the goals of pruning are; enable palms receive maximum amount of sunlight, ensure no waste of nutrients in dead or dying

fronds, enable perfect harvesting, create a good plantation area, preserve good soil and nutrients quality, and pruned fronds able to decompose faster (Akvopedia, 2016).

2.2 Mechanized Oil Palm Cutting Tools

Razak & et all (2008) describe that, Cantas was a motorized cutter develop by MPOB for harvesting FFB at below 4.5 m height of palm oil tree. They mentioned Cantas is a mobile cutter powered using a 1.3 HP petrol engine attached below of the cutting pole. Moreover, they also state that the productivity of this tools is about 560 - 750 bunches per day with 9.50 - 12.6 tones/day where the average bunches weight is 17 kg. Compare to manual cutting tools, the productivity are about 250 -350 bunches per day or 4.20 - 6.00 tones/day which half productivity of Cantas. One Cantas able to cover two or three human harvesters thus estate operation able to reduce labor needed in harvesting process up to 50%.

Motorized chisel or also known Ckat was develop by MPOB to harvest FFB for short palm height. Early development of motorized cutter, MPOB invent a Cantas cutter however the tools are suitable for tree height below 5 m. Moreover, a 2 m tall tree are not suitable to use a Cantas for cutting process thus Ckat was introduced to prevent the problem. Ckat was a motorized cutter that have a same design with Cantas but instead of chisel, sickle was used in Ckat (A. Razak & et all, 2008).

A. Razak & et all (2017) mentioned MPOB was introduce an oil palm motorized cutter called Cantas for palms 5 m harvesting height and able to double up harvesting output compare to manual harvesting. They also mentioned that there are some weaknesses such

frequent breakdown, heavy and high vibration thus Cantas Evo was introduced to overcome those problems. The weight of Cantas Evo reduced to 31% and vibration produced are reduced to 95% than previous version. Besides that, this cutting tool able to reach oil palm tree up to 7 m height. The maintenance cost also reduced by 90 % thus RM 3000 were cut for per machine.

2.3 Palm Oil Frond Mechanical Properties

W. Alnuami & et all (2015) stated that research on palm frond strength is important in design of oil palm frond chopping machine. They also mentioned this paper are study of variation palm oil fronds strength in penetration, shear, and compression of two different level of moisture content and two variations of maturity. The result of their study is penetrative, shear and compression forces are highest at the stalk while those forces decrease to the middle of fronds and lastly at tip of the fronds. Moreover, maturity effect on all forces are in small scale compared to moisture level effect. When the moisture content decrease, penetrative forces increase but compressive forces decrease.

There are some problems due to the lack of effective and efficient design in development of oil palm pruner and harvester machinery in the field. Designing process needed an early data and information of mechanical and physical properties of oil palm frond and stem fruits. Result of this paper prove that tool machinery was been advantageous by the physical properties of the plant which is total weight of frond and leaf that supported the process of cutting (Y.I Intra,H. Mayulu and P.A.S Radite; 2013).

R. Bulan, T. Mandang, W Hermawan & Desrial (2015) stated that factor of development of palm oil waste utilization technology are the physical mechanical properties of palm oil frond. Pressing machine and chopper machine design needed the information of average dimension of palm frond to analyse the maximum pressure break off point. Moreover, the maximum compression strength is high at 20 years-palm fronds compare to 5 years-palm fronds.

3 Methodology

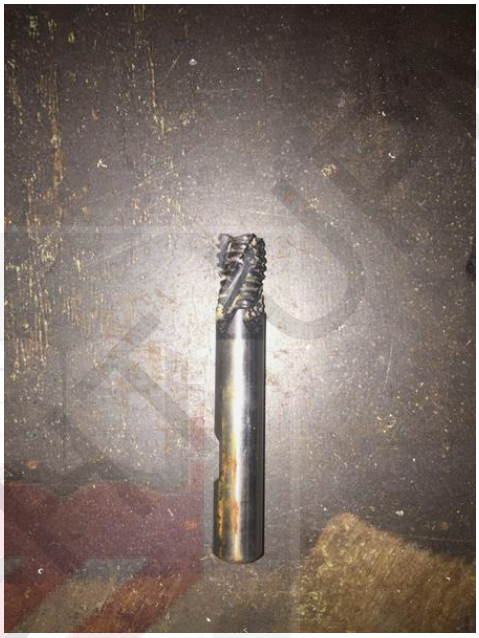
3.1 Cutting Tool Bits Selection

The selection of cutting tool bits are to determine which of the tool bits are best for cutting the OPF. As the concept of the trimmer are using rotary cutting, we decided to use cutting tool bits that usually used for milling machine operation. The purpose of the cutting tool bits in milling machine operation are to be used for cutting the material or making a shape of the material. Besides that, those tools are also to be used to make a hole, chamfer and many more.

Several cutting tool bits was chosen for this experiment; which is include rough end mill bit, end mill bit, saw bit, straight router bit. Moreover, coconut grinder also been choosing to test the ability of this grinder to cutting the OPF. Other than that, to test the tool bits, hand drill was chosen to provide a rotational movement to those bits. The specification of this hand drill includes:

Manufacture	**Bosch**
Model	**GSB 10 RE**
Speed	**Up to 2600 rpm**
Power	**500 W (input), 250 W (output)**

Table 3.1-1: Specification of Hand Drill

Tool bits	Specification	Cutting Tool
Rough end mill	Total Length: 65 mm Flute Length: 20 mm Diameter: 10 mm	
End mill	Total Length: 80 mm Flute Length: 30 mm Diameter: 10 mm	

Tool Bits	Specification	Cutting Tool
Saw bit	Total Length: 85 mm Flute Length: 55 mm Diameter: 6 mm	
Small straight router bit	Total Length: 60 mm Flute Length: 26 mm Diameter: 7 mm	

Tool Bits	Specification	Cutting Tools
Large straight router bit	Total Length: 100 mm Flute Length: 75 mm Diameter: 25 mm	
Coconut grinder	Total Length: 90 mm Diameter: 70 mm	

Table 3.1-2: Specification of Selected Tool Bits

3.2 Design of Cutter Machine

Hand drill was chosen to be used as power source and provide rotational movement of the tool bits. However, some modification needed as to perform the testing of OPF cutting. Set of housing needed to design that fit with the hand drill and the hand drill also have some modification; where, the switch at the hand drill grip holder was move out from the hand drill. The switch will be place at the housing so switching on or off will be easy and faster.

The cutter machine will have several parts but differentiate with two groups; as one parts groups include the housing of machine and other part groups include the angle jig. The housing will place the hand drill inside it, the purpose is to hold the hand drill in proper way when doing the experiment. The angle jig is to be used for changing the angle of the housing; where it important to keep the angle when cutting the OPF. The angle was set into four different angles; which is 0, 15, 30 and 45 degree.

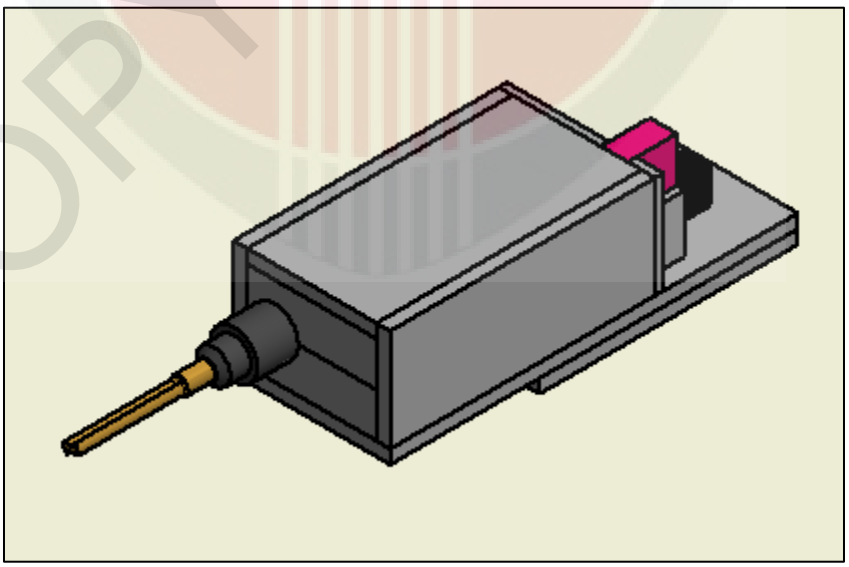


Figure 3.2-1: Design of Trimmer Machine

3.3 Cutter Fabrication

All the part that been design will be fabricate as it needed to be assembly. Material used for all the parts are made of aluminium, as it will give enough strength to hold the hand drill and cutting the OPF during experiment. Milling machine is used to shaping the material, where the milling bit will cut the material into specific dimension. Besides that, milling machine also used to make a hole for screw as screw will combine all of the parts.

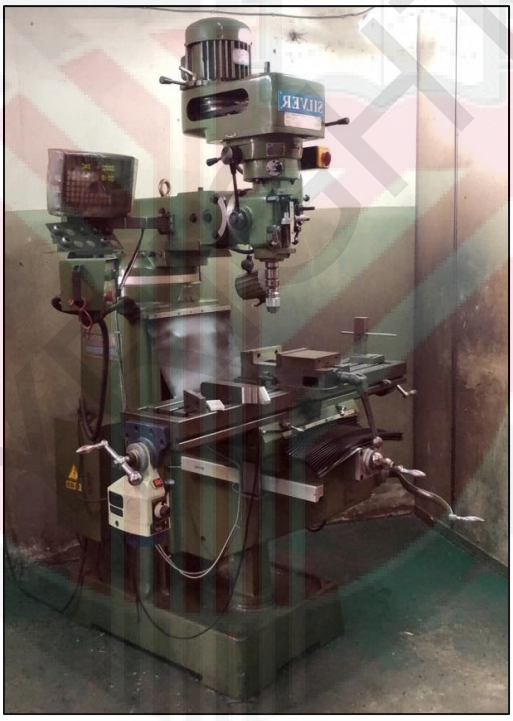


Figure 3.3-1: Milling Machine

3.4 Cutter Assembly

After all of the parts was fabricate, the assembly process is done. Every part will assemble together using screws. Hand drill will be place into the housing and housing parts will close the hand drill. The switch also will be place with the housing, the position is outside from the hand drill and it will be easy to operate the switch. Moreover, the angle jig parts also will be attached with the housing and the location is below the housing of hand drill.

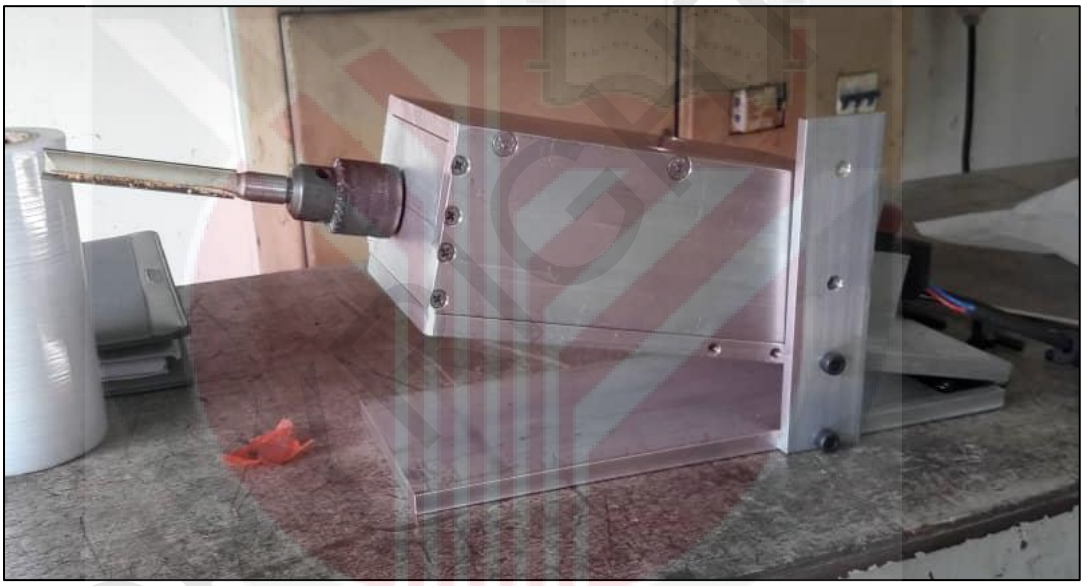


Figure 3.4-1: OPF Trimmer Machine

3.5 Angle of Cutting Determination

A test of cutting of OPF will be made where it will be tested using four different angles of cutting. The angle of cutting include 0, 15, 30 and 45 degree where all the angle is vertical angle. The purpose of using different angles are to determine which angle are the best for cutting the OPF. Besides that, the test also to determine cutting speed; which are the angle have fastest cutting time.

The experiment setup is including the OPF will place with clamp; the clamp will hold the OPF when cutting operation are held. The cutter machine will be place in front of the clamp, which is to cut the OPF horizontally. Both clamp and cutter machine will be placed at a table where at clamp side, the clamp will not move while at cutter machine side the table will move horizontally. The parameter needed to take during testing are the size of OPF and time taken of cutting operation for each different angle.

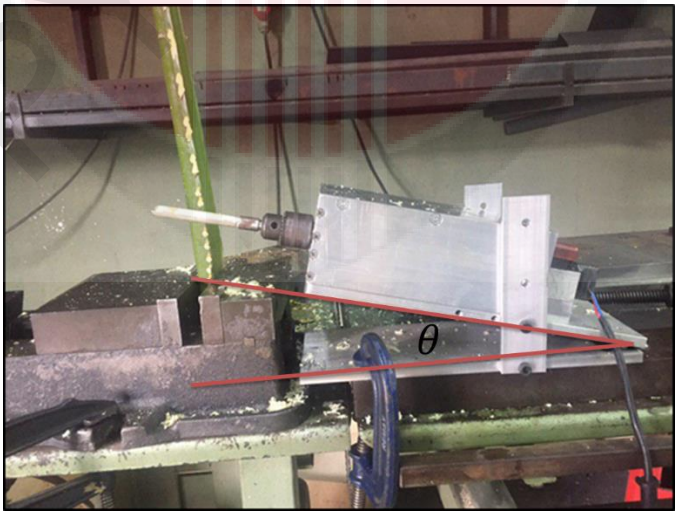


Figure 3.5-1: Experiment Setup

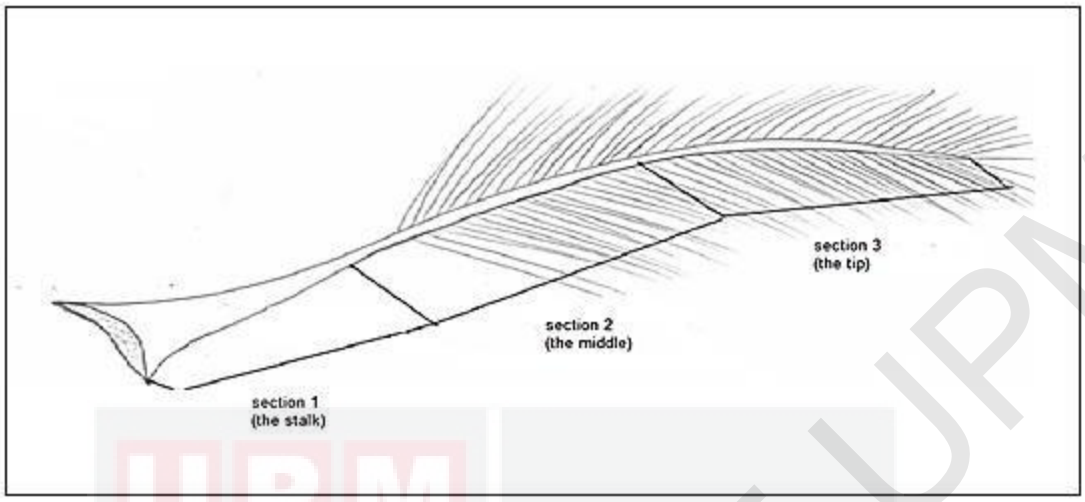


Figure 3.5-2: Sections in OPF

The experiments need fresh OPF from the oil palm tree, the OPF was cut few hours before the experiment are conducted. In OPF, there are three sections as stated on Figure 3.5-2 above. This includes stalk, middle and tip of frond. The stalk of frond is located at the trunk of oil palm tree and this location where the cutting operation are located. Since the experiment are held at workshop, the frond are cut and there are some difficulty to obtained full frond; the stalk are cut about 4 – 6 cm from trunk.

4 Result and Discussion

4.1 Cutting Tools Selection

4.1.1 Saw Bit

Saw bit originally used in wood cutting in wood industries. Basically, this type of cutter is to drill a plywood to make a hole and used to make a horizontal cutting the plywood. The bit has two different types of flute which is at the bottom end of the bit are drilling flute and the middle of bit are side cutting flute. For the experiment, saw bit were chosen to test cutting on the palm oil frond with selection of bit's size are 6 mm diameter and 84 mm length. Figure below shows the saw bit selected. Compared between end mill and rough end mill, the saw bit has a very difficult to cut the OPF and large amount of vertical force are high during cutting the OPF. Moreover, this type of cutter is suitable for cutting wooden board as the wooden board have a small thickness compare with OPF

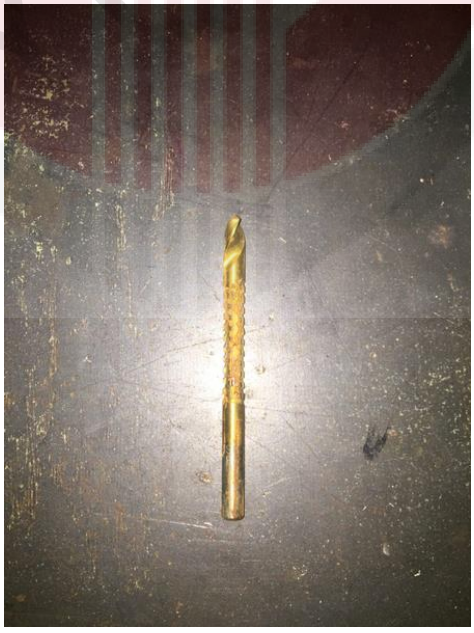


Figure 4.1-1: Saw Bit

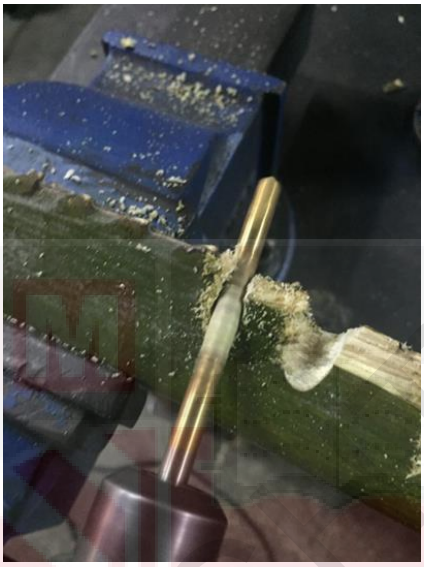


Figure 4.1-2: Cutting OPF Using Saw Bit

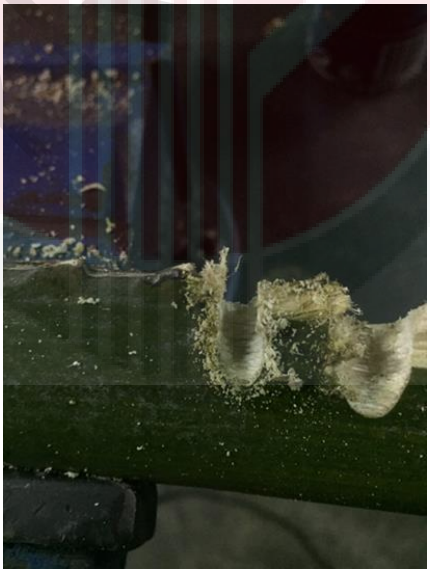


Figure 4.1-3: OPF After Cutting Using Saw Bit

4.1.2 End Mill Bit

End mill bit used to cut a material into various size or shapes. Usually, end mill bit was use in metal working task attached to milling machine. The bit cut the material with rotation and remove layer of material until desired size of the material. At the end of the bit, the knife will cut the material and chip from material removed with help the flute geometry. For this experiment, the bit was chosen and cutting oil palm frond will be cut using the flute of the end mill bit. The size was chosen are 10 mm diameter, 81 mm length, and 4 flutes type. Figure below are the end mill bit that used for the experiment. At highest speed, the cutter cut the OPF not efficient as this type of cutter are for cutting material using the bottom end of the cutter. The side of cutter quite sharp but cutting the OPF is very difficult as the tooth not cut the OPF.

Figure 4.1-4: End Mill Bit

Figure 4.1-5: Cutting OPF Using End Mill Bit

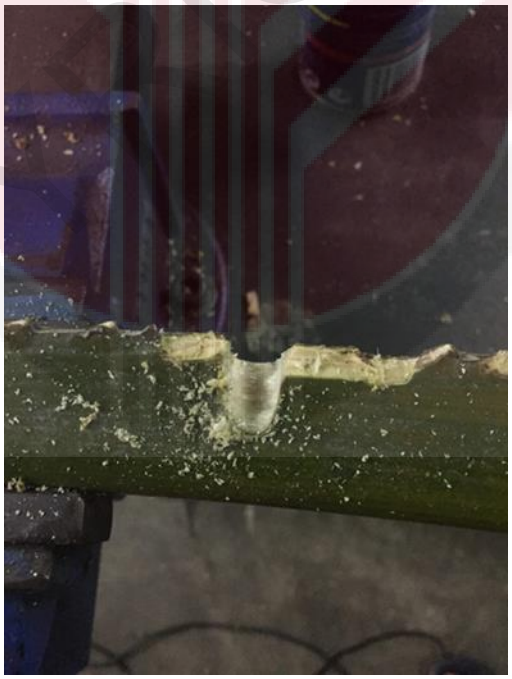


Figure 4.1-6: OPF After Cutting Using End Mill Bit

4.1.3 Rough End Mill Bit

Rough end mill bit has a same function with end mill bit but the tooth of the bit slightly different than end mill bit. Comparing with end mill bit, the tooth has a wavy shape while end mill bit has a clean-straight tooth. The purpose of wavy tooth is to increase the cutting efficiency, but the cutting precision might be decrease. Usually, in metalworking task; this type of bit was used in the beginning of process then continue with different type of milling bit. The specification of this type bit that used in the experiment are 10 mm diameter, 65 mm length and 4 flutes type. Below is figure of chosen rough end mill bit. At high speed, the cutter cut better than end mill. However, this type of cutter is also not suitable to cut the OPF at vertical position. Besides that, the chip of OPF also stuck between the flutes; thus, cutting efficiency is not high.

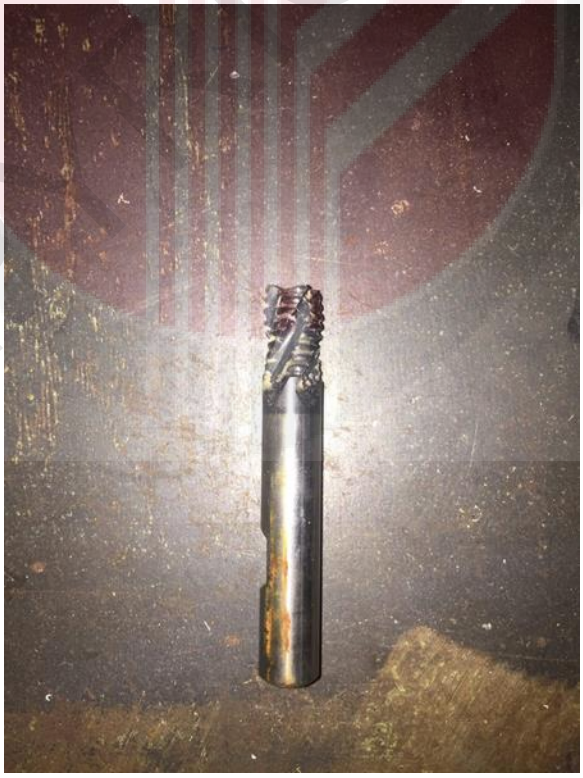


Figure 4.1-7: Rough End Mill Bit

Figure 4.1-8: Cutting OPF Using Rough End Mill Bit

Figure 4.1-9: OPF After Cutting Using Rough End Mill Bit

4.1.4 Straight Router Bit

Straight router bit is a bit with straight flute compare bit from mentioned above. Usually, this bit used in woodworking such as cutting woods or shaping wood into desired shape. The flute consists with carbide knife and rotation of the bit will cut the wood. For this experiment, the bit was choose with different sizes which is 1" and ¼" diameter; the length for both bit are 4" and 2". Figures below are the straight router bit selected for this experiment. This small straight router bit is suitable to cutting the OPF at high speed. The result of cutting is the OPF can be cut into two pieces. However. The are some limitation as the cutter are quite small diameter and short length. Thus, cutting the bigger or wider OPF might be difficult and not able to reach longer side of OPF. Ability to cut the OPF is very good as the diameter and length of cutter are larger and longer compare with smaller size of straight router bit. However, there are some difficulty during starting the cutting process; because, the cutter not able to stay at same position and need a high force to hold properly during the cutting process.

Figure 4.1-10: Large Straight Router Bit

Figure 4.1-11: Small Straight Router Bit

Figure 4.1-12: Cutting OPF Using Small Straight Router Bit

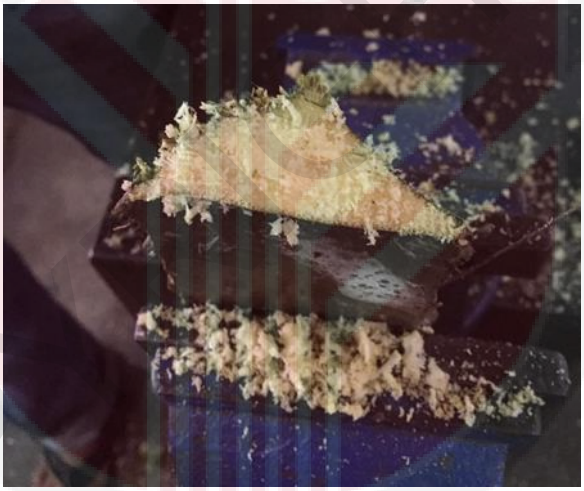


Figure 4.1-13: OPF After Cutting Using Small Straight Router Bit

Figure 4.1-14: Cutting OPF Using Large Straight Router Bit

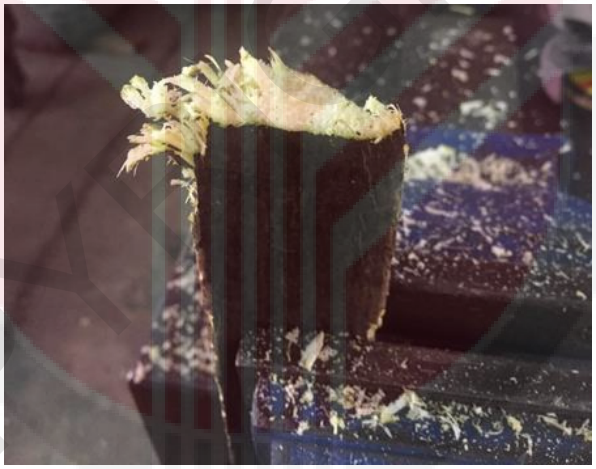


Figure 4.1-15: OPF Atrer Cutting Using Large Straight Router Bit

4.1.5 Coconut Grinder

Coconut grinder are use in the grinder the coconut fibre inside the fruit. The fibre will give a coconut milk where it used for cooking purpose. The shape of grinder a oval shape where sets of torn are welded with the grinder. The torn will scrapping the fibre when the grinder are rotate, and the fibre will be removed from the coconut. The grinder is tested to cut the OPF and the result shows that the ability are very low as the OPF is not cut into two pieces. This is because the torn are covered with fibre, the contact between torn and OPF are almost none. Thus, the cutting ability are very low compare to other cutting tool bits.

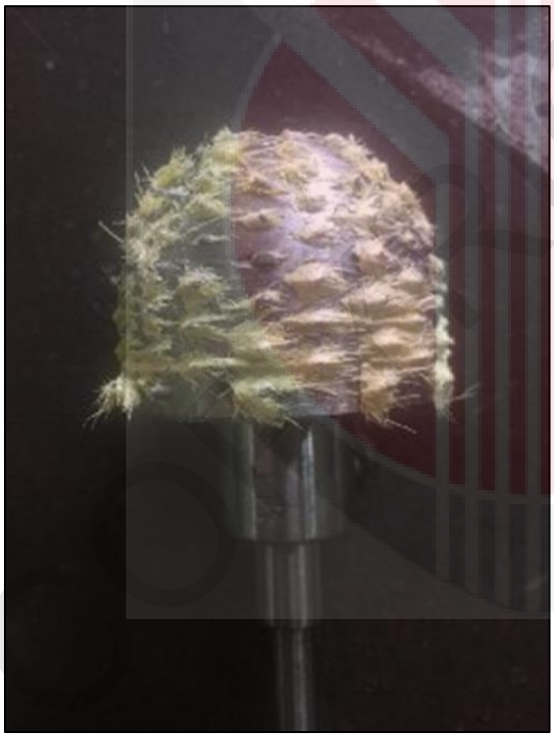


Figure 4.1-17: Coconut Grinder

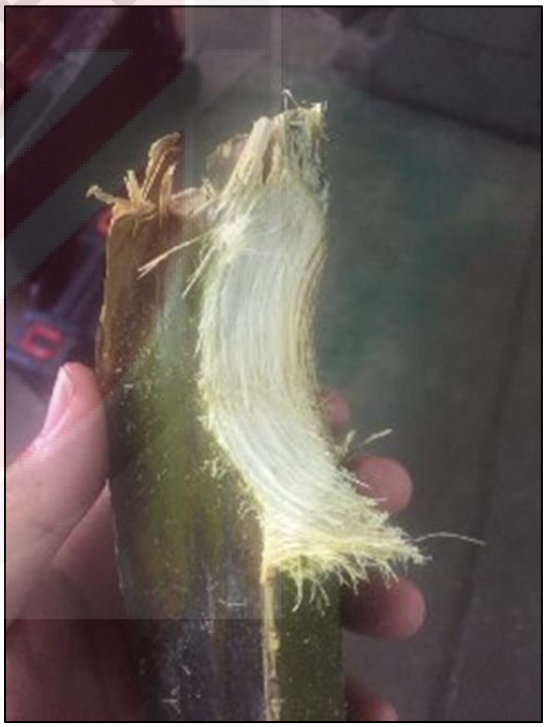


Figure 4.1-16: OPF After Cutting Using Coconut Grinder

4.2 Pugh Selection Matrix of Cutting Tools

	End Mill	Rough End Mill	Saw Bits	Straight Router (Small)	Straight Router (Large)	Coconut Grinder
Stability	+	+	-	+	-	+
Chip Production	-	-	-	+	+	-
Cutting Time	-	-	-	+	+	-
Cutting Force	-	-	-	-	+	-
Total +	1	1	0	3	3	1
Total -	3	3	4	1	1	3
Total Score	-2	-2	-4	2	2	-2

Table 4.2-1: Pugh Selection Matrix of Cutting Tools

Table 4.2-1 is a Pugh Selection Matrix of Cutting Tool and the purpose is to identify which cutter tool bits are suitable for the experiments. However, there are four criteria needed to fulfil the best cutter tool bits. The criteria selected for selection includes stability, chip production, cutting time and cutting force. During cutting test of OPF using hand drill, all of the cutter are observed base on those criteria, if the criteria are achieved for selected cutter tool bits; sign '+' are given while sign '-' vice versa. Total of both sign will be sum up and the most total score will be the best cutter tool bits.

4.2.1 Stability

Stability are important during cutting operation of OPF; because, it will affect the cutting efficiency. The term of stability when choosing the best cutting bit are when in the beginning of cutting operation, the bit is hold properly to the OPF and the cutting machine are moving to other side of cutting direction. This is important as if the cutting machine is not in proper stability, the cutting tool might damage.

Based on observation during testing each of cutting tool bits; end mill, rough end mill, small router and coconut grinder are in good stability. However, large router and saw bit are lesser stability compared to others. 5 of the good stability cutting shows that during in the early cutting operation; the cutting machine are not moving to other side of cutting direction but 2 of the cutting bits shows that the machine will moving a little bit to other side of cutting direction.

4.2.2 Chip Production to Comparison of Chip Removal Capacity

Cutting a material using milling bit will produce the chips. Chips are the scrap material that removed during the cutting process. The chips can be different shapes or sizes depends on the cutting speed, type of bits, sizes and tooth.

During the experiments, four types of bits was chosen to perform cutting the oil palm frond. The cutting process of all its produce wood chips which is the fibre from the frond. However, the wood chips are stuck between flutes and the efficiency of cutting are decrease as the region between flutes full of wood chips. Since the chips stuck, the cutting process become slower as contact between tooth knife to the material become decrease. As results, the more the chips stuck between the flute caused the ability of cutting material become lesser and slower. Figure below shows the comparison of wood chips stuck on the bits

Figure 4.2-1: Various Cutting Tools

Based on figure above, the volume of wood chips stuck on the flutes are different for each types of bits. The saw bits show the most wood chips covered on the region between flutes; thus, the result of the cutting process is the longest time taken to cut. Between end mill bit and rough end mill bit, the wood chips stuck are the most for rough end mill; because, the wavy tooth might be the reason the volume of wood chips stuck are higher. Last but least, straight router bit is the most lesser volume of wood chips stuck on the region between flutes. Comparing both sizes, the chips stuck on the flutes are almost the same and different compare to other type of bits. Based on results, cutting process using straight router bit are the most fast and easier compare to other types of bits. This shows that the lesser wood chips stuck between flutes, the better the cutting process.

4.2.3 Cutting Time

Term of cutting time for selecting the right cutting tool bits are time taken to complete the cutting operation are faster or less time taken. Cutting time are important; because, the productivity of cutting operation can be major factor as if the cutting time are slow, the productivity will slow and affect the operation of palm oil estate. Thus, faster cutting time will gives the estate increase their field operation productivity.

All the cutting tool bits was tested by cutting the OPF and time taken for each cutting tool bits are compared. The results show that both small and large router bit are faster compared to other cutting tool bits. However, cutting time of each cutting tool bits are affected from another criteria; which is include chip production. As the fibre chips stuck between the flutes of cutting tool bits, ability to cut the OPF fibre are become lower; because, chips stuck on the flute affect the contact of flutes with OPF. Since both of straight router bit are lesser wood chip stuck between flutes; it shows that both have faster cutting time.

4.2.4 Cutting Force

Force are important during cutting the OPF; because, if the force is high, the ability to cutting the OPF will be low as energy required to supply right amount of force are increase. Term of cutting force for selecting the suitable cutting tool bits are horizontal force acting to the OPF. Since the cutting operation are set to be vertical cutting position, horizontal force is important in this situation. The higher the force, the higher the energy needed to supply; thus, small amount of force acting to the OPF are required.

After all cutting tool bits were tested, the result shows that only large straight router bit are use a small of force during cutting testing. Other than that, the amount of force is high when cutting the OPF. Reason of amount of force are high this is because it affected from wood chips stuck between flutes. When space between flutes compacted with wood chips, the contact of flutes to the OPF are lesser thus, cutting force is high due the amount horizontal force acting to OPF from cutting machine are increase. As both router bit has lesser wood chips stuck between flutes, the horizontal cutting force acting to the OPF are lesser; thus, energy use is lesser.

4.3 Vertical Cutting Angle

Degree	Length, L (mm)	Time, T(s)	Length / Time (mm/s)	Average (L) (mm)	Average (T/s)	Average (L / T) (mm/s)
0	42.6	9	4.7	37.4	8.0	4.7
	36.7	8	4.6			
	33	7	4.7			
15	40.2	12	3.4	36.4	10.3	3.5
	36	10	3.6			
	33	9	3.7			
30	34	11	3.1	40.0	13.0	3.1
	47	15	3.1			
	39	13	3.0			
45	30	7	4.3	31.7	8.0	4.0
	32	8	4.0			
	33	9	3.7			

Table 4.3-1: Data on Vertical Cutting Angle

Four degree of cutting angle was tested for the experiment. Figure above shown the data collected during the experiment. Three sample for each angle was used to determine the parameter required. The parameter collected for this experiment are distance or the length of the OPF and time to complete a single cutting operation. Moreover, each length and time are taken its average value and the cutting speed and average cutting speed are calculated with length divide by time. This data was tested using large straight router bit because this cutter tool bits are the most suitable.

4.3.1 0 Degree

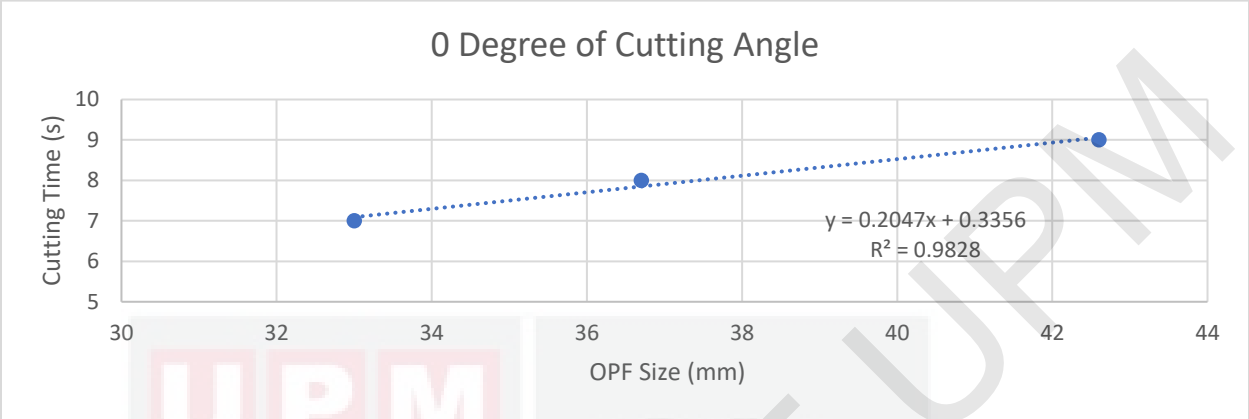


Figure 4.3-1: Graph of 0 Degree Cutting Angle

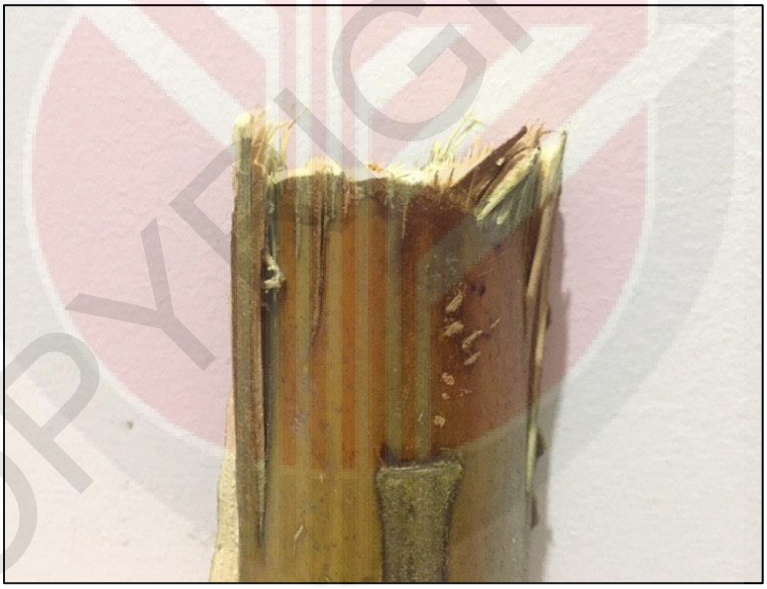


Figure 4.3-2: 0 Degree Cutting On OPF

4.3.2 15 Degree

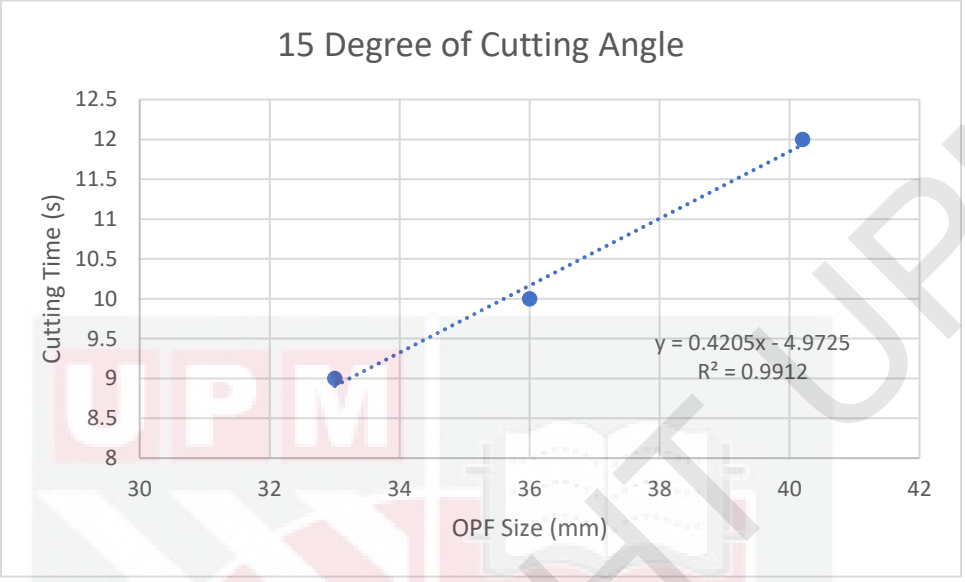


Figure 4.3-3: Graph of 15 Degree Cutting Angle

Figure 4.3-4: 15 Degree Cutting On OPF

4.3.3 30 Degree

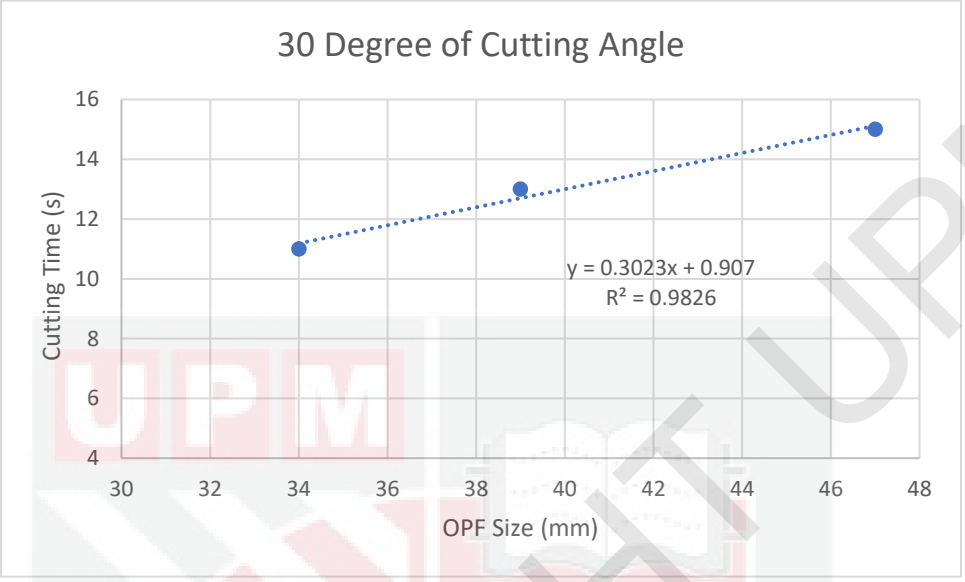


Figure 4.3-5: Graph of 30 Degree Cutting Angle

Figure 4.3-6: 30 Degree Cutting On OPF

4.3.4 45 Degree

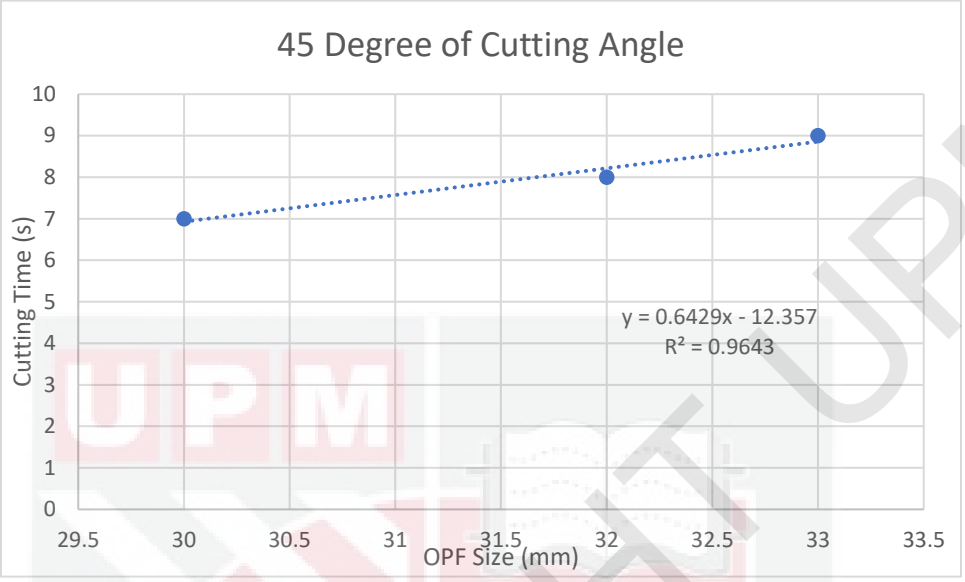


Figure 4.3-7: Graph of 45 Degree Cutting Angle

Figure 4.3-8: 45 Degree Cutting On OPF

4.3.5 Comparison Between Cutting Angles

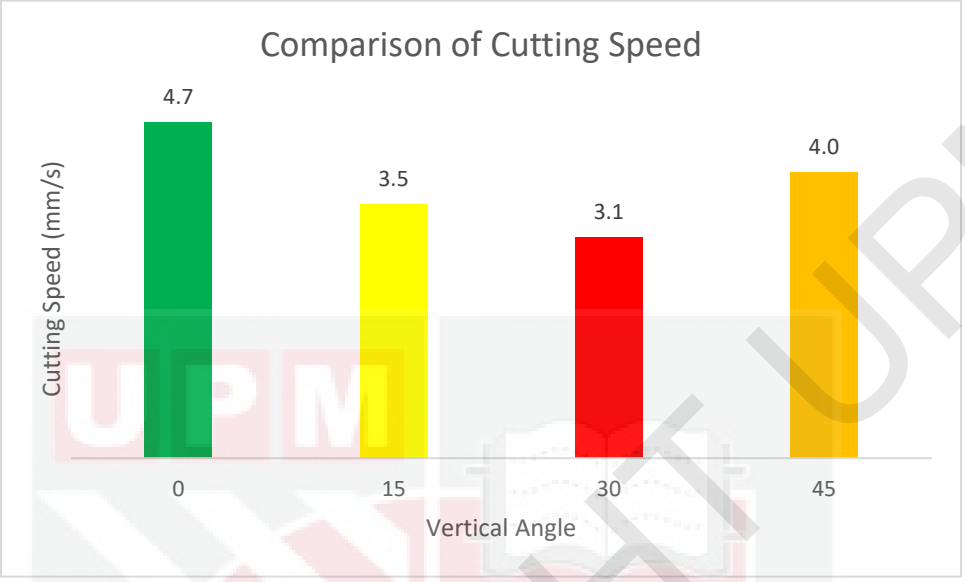


Figure 4.3-9: Various Speed Between Cutting Angle

Figure 4.3-1 until 4.3-8 shows the graph of OPF length with time taken to cut the OPF and OPF condition after cutting for each different cutting angle. The graphs also include an equation where we can predict the cutting time with different length of OPF. Since the higher the age of oil palm tree, the length of OPF are increase. Thus, a higher time taken for cutting OPF will be increase when the OPF length increase. Besides that, the condition of OPF after cutting are different when using a different cutting angle. It shows that the piece of OPF after cutting have same angle with the cutting angle when cutting the OPF. Based on Figure 4.3-9, the graph of comparison of cutting with different cutting angle shows that using 0 degree cutting angle are the most fastest cutting speed while 0 degree is the slowest among others cutting angle.

5 Conclusion and Recommendation

5.1 Conclusion

As conclusion, all of three objectives are achieved by completing this project. The objectives include finding the suitable cutting tool for cutting the OPF, develop and assembly the cutting jig that use for the prototype and testing the prototype. Various type of cutting was tested for this experiment, the most suitable cutting tool are large straight router bit; because, it has the most cutting speed compare to others and the ability to cut OPF are better compared to others. Moreover, the jig was developed and assembly to make a new functional prototype that used for cutting the OPF. The jig holds properly the hand drill and cutting the OPF is work fine. Furthermore, testing the protype to cut OPF with different cutting angle are achieved as 0 degree of vertical angle are the most suitable angle for cutting the OPF.

5.2 Recommendation for Future

In engineering, a small improvement of previous technology considered as a new development. A research and development are important in agriculture machinery and equipment as the technology helps the farmer to reduce their time and energy. Besides that, technology helps to improve the operating efficiency. As this project idea are using the different cutting tool compare to previous cutting tool, this project might have potential and provide a small contribution for next research and development. As recommendation for future, a next idea is to build a smaller cutter prototype as it important because it will reduce the weight of cutter prototype. Besides that, a new jig for hold the OPF and cutter prototype are needed as currently, efficiency to hold OPF and cutter prototype are not in high condition. Lastly, force determination when cutting the OPF are highly recommendation for future project; because, current project only focus on finding best cutting tool and cutting angle.

References

1. Alnuami, W., Janius, R. B., & Ahmad, D. (2015). Factors Affecting the Mechanical Strengths of Oil Palm Fronds, *4*(3), 138–149.

2. Bulan, R., Mandang, T., & Hermawan, W. (2015). Physical and Mechanical Properties of Palm Frond for the Development of Palm Oil Waste Chopper and Pressing Machine Design, *6*(2), 117–120.

3. Din, A. K. (2017). Overview of the Malaysian Oil Palm Industry. *Malaysian Palm Oil Board*, *i*, 1–4. https://doi.org/10.1017/CBO9781107415324.004

4. Griffin, M. J., & Bovenzi, M. (2002). The diagnosis of disorders caused by hand-transmitted vibration: Southampton Workshop 2000. *International Archives of Occupational and Environmental Health*, *75*(1–2), 1–5. https://doi.org/10.1007/s004200100271

5. H, S. P. H. (2008). Poster · June 2008, (November 2016), 2–4. https://doi.org/10.13140/RG.2.2.22291.68646

6. Intara, Y. I., Mayulu, H., & Radite, P. a. S. (2013). Physical and Mechanical Properties of Palm Oil Frond and Stem Bunch for Developing Pruner and Harvester Machinery Design. *International Journal of Science and Engineering*, *4*(April), 69–74.

7. Jelani, A. R., Ahmad, M. R., Azaman, M. I. H., Gono, Y., Mohamed, Z., Sukawai, S., … Kushairi, A. (2018). Development and evaluation of a new generation oil palm motorised cutter (cantas Evo). *Journal of Oil Palm Research*, *30*(2), 276–288. https://doi.org/10.21894/jopr.2018.0015

8. Jelani, A. R., Hitam, A., Jamak, J., Noor, M., Gono, Y., & Ariffin, O. (2008). Cantas ™ - A tool for the efficient harvesting of oil palm fresh fruit bunches. *Journal of Oil Palm Research*, *20*(DECEMBER), 548–558. https://doi.org/10.1093/cercor/bhs383

9. Shuib, A. R., Ramdhan, M., & Deraman, M. S. (2010). Enhancing Field Mechanization in Oil Palm Management. *Oil Palm Bulletin*, *61*(November), 1–10. Retrieved from http://palmoilis.mpob.gov.my/publications/OPB/opb61-Rahim.pdf

10. (Alnuami, Janius, & Ahmad, 2015; Bulan, Mandang, & Hermawan, 2015; Din, 2017; Griffin & Bovenzi, 2002; H, 2008; Intara, Mayulu, & Radite, 2013; Jelani et al., 2018, 2008; Shuib, Ramdhan, & Deraman, 2010)