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Structural Design and Mechanism Analysis of Palm Oil Harvester

(Analisis Reka Bentuk Struktur dan Mekanisme Penuai Buah Kelapa Sawit)

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ABSTRACT

Plantation of palm oil in Malaysia is one of the top contributor of the economy. In order to match the supply of palm oil fruit with demand, different harvesting methods are used such as the existing motorized cutter. Although it can reduce the harvesting time and the number of labors involved in harvesting process, the tight arrangement of oil palm fronds and long manually adjusted harvesting pole may cause the inconvenient to the labors. Therefore, this project studies the design of a circular cutter and automatically adjusted telescopic pole with rotational mechanism. The concept development of harvester is based on the scientific study on the limitations, customer requirement and engineering characteristics of existing harvesters. It is followed with the selection of best design of harvester that can solve the problems that faced by labors in existing harvester. The analysis of rotational speed, deflection and bending moment for different components in the palm oil harvester. The design of harvester is done with the aid of CAD software in form of part detail design, orthographic view and exploded view. With the rotational cutting mechanism, the harvester can easily reach and harvest the oil palm fresh fruit bunches from the bottom of the bunches.

Keywords: palm oil; harvesting process; circular cutter; rotation mechanism; fresh fruit bunches

INTRODUCTION

Palm oil is one of the most rapidly expanding equatorial crops in the world and Malaysia is one of the largest oil palm producing countries in Southeast Asia (Koh and Wilcove, 2008). The oil palm fresh fruit bunches (FFB) need to go through some processing unit operations before it produces as a palm oil product. There is difference in the level of mechanization for each unit of operation. However, the most important and primary stage is harvesting of oil palm FFB from oil palm tree. At earlier stage, the traditional method was used in harvesting process. The oil palm harvesting involved the cutting of FFB by harvester and allowing it to fall to ground by gravity. It was done manually as the chisel in Figure 1 was used for young palms.

FIGURE 1. Chisel for young palm

Realizing the problem, a motorized cutter which named as Cantas has been invented and developed by Malaysia Palm Oil Board (MPOB). The Cantas can be used to cut the frond and FFB from oil palm tree efficiently as it is powered by a 1.3 hp petrol engine (Jelani et al. 2008). The vibration method is used in designing the operational mechanism of Cantas whereby the vibration action is transferred to vertical direction so that the cutting operation can be performed vertically (MPOB, 2016). However, there are limitations on the cutter and mechanism of the oil palm harvester. Hence, this project will focus in designing and analyzing of an oil palm harvester for better operational efficiency.

Being one of the biggest producers and exporters of oil palm fruit, Malaysia aims to fulfil the growing global need. The rise in demand of oil palm fruits increases the work load of labour in oil palm estate as the harvesting of oil palm FFB is the vital stage of overall process. Although the motorized cutter, Cantas can reduce the harvesting time, the harvesting process of oil palm fruits normally still associated with high prevalence of ergonomic injuries (Ng et al. 2013). One of the reasons is the difficulty in cutting some of the fronds and brunches of oil palm, as the fibre bundles consist of cellulose. Labors might need to use some energy to shove the fronds and brunches physically during the harvesting of oil palm fruits. The tight arrangement of oil palm fronds and FFB on the tree also causes the difficulty in placing the sickle accurately.

The manually adjusted pole in the oil palm harvester causes the inconvenience to the labours as they need to change the height of poles manually due to various height of oil palm tree. The length of the pole is considered too long if they need to carry it for whole day long. Besides, they need to find a suitable position during harvesting process so that the oil palm FFB could be harvested accurately (Chun et al. 2021). Therefore, an oil palm harvester will be designed and analysed to solve these problems and provide higher operational efficiency. The objectives of this project are to design a circular cutter with rotational harvesting mechanism onto an oil palm harvester and to develop a structure of automatically adjustable telescopic pole in the oil palm harvester.

In order to design an oil palm harvester with better mechanism, some researches on the oil palm tree and its fresh fruit bunches (FFB) are carried out. The history and invention of oil palm harvester since the early stage of a century are also studied. Different harvesting methods used in Malaysia as well as its mechanism are determined as it is a way to generate some ideas on designing the oil palm harvester. Other harvesting and cutting tools are also identified and studied in term of its components and mechanism.

Oil palm is a monoecious crop as both of the female and male flowers grow on the same tree. However, the flowers grow in different spikes and produce in different time. For several months, the oil palm will only produce male flowers. After few months, it will produce female flowers. The female flowers will be fertilized by male flowers and turned into a cluster of oil palm fruits. The oil palm grows in bunches and varies in weight from 10kg to 50kg as the FFB of oil palm consists of more than a thousand individual fruits. The oil palm FFB in Figure 2 is found to grow in three major stages from week 0 to 5, week 6 to 14 and week 15 to 14 (Kasim et al. 2014).

FIGURE 2. Oil palm fresh fruit bunches (FFB) (Source: ArgiFarming, 2015)

The primary stage of the processing of oil palm is the harvesting process which involved the cutting of oil palm FFB from palm trees as well as pruning task. The harvesting process is carried out by cutting the exposed punch stalk while the pruning process is performed by cutting the oil palm frond that located at the trunk base. Each of the palm trees is visited for harvesting every 10 to 15 days as FFB ripen throughout the whole year.

A curved knife which attached to a long bamboo or aluminum pole or galvanized iron (GI) hollow metal pole is used in Malaysia. The knife can be categorized into two types which are chisel and sickle. For chisel, it is usually used for young and shorter palms which the height is within 0.5 meters to 3 meters above ground as shown in Figure 3. It can be done by slipping the chisel between the leaf and stem to cut off the FFB. It needs to throw the chisel at high speed to frond or FFB of oil palm. For sickle, it is used for taller palms which the height is over 3 meters as shown in Figure 4. The harvesting and cutting are done by slicing method by pulling the sickle downward.

FIGURE 3. Traditional harvesting methods with chisel
Source: Indian Institute of Oil Palm Research, n.d.

FIGURE 4. Traditional harvesting methods with sickle
Source: Henkel 2013

According to Balu N. et al. (2018), other competitive in oil production field have improved their cost competitiveness in term of planting material and processing technologies. Thus, in order to expand the oil palm industry in Malaysia, some improvements should be done on the productivity, mechanization and so on. Although many operations have been mechanized and automatized, there are still consists of limitations due to the slow in practicing and adopting the new machines by labours.

The motorized cutters popularly known as Cantas /Ckat in Figure 5 are developed by MPOB. These motorized cutters are designed and invented by Haji Razak

Jelani and other designers. The cutter that attached to the Ckat is chisel while the cutter for Cantas is sickle. According to Jelani et al (2008), Cantas advanced II is a hand held cutter that can be used to harvest the FFB at height that less than 4.5m. For the telescopic pole, it consists of telescopic shaft, bearing, basic pole and extension pole (Jelani et al. 2003).

FIGURE 5. Cantas and Ckat
Source: Jelani et al. 2018

However, there are difficulty in harvesting of FFB and might influenced the efficiency of harvesting operation (Jelani, 1997). Besides, the vibration method in the mechanisms is also the issues that lead to ergonomic risks to labors. According to Salleh et al. (2013), the vibration that transmitted to labors hands and arms in the regularly or frequently exposure during harvesting of oil palm FFB can lead to the risk of hand arm vibration syndrome (HAVS).

CONCEPT GENERATION

In order to design an oil palm harvester with higher operational efficiency, the Cantas that developed by MPOB is chosen as a datum. The Cantas with the weight of 6.5kg is a motorized cutter that designed with a sickle. It can be used to harvest the oil palm FFB from the tree that less than 4m height. The telescopic pole with length 1.6m to 2.4m is installed with vibrator and it is powered by 1.3hp petrol engine with two strokes. The petrol engine is used to generate the vibration mechanism for creating the great speed in cutting process of the Cantas (Kusuma, G. and Vidhan, S.T, 2015).

The morphological chart is chosen to generate ideas in designing the conceptual design of oil palm harvester. Different characteristics and options such as power source, location of motor and the connection of motor to cutter are focused as the main part of the harvester. Besides, the parts or components like pole, handle, cutter, as well as security belt are also determined. Different conceptual designs of oil palm harvester are generated and drawn by combining different characteristics and options that investigated in morphological chart.

CHOSEN CONCEPT

Five concepts design been generated from the morphological chart. Based on the Pugh concept selection, the best concept design for the oil palm harvester is concept design 3 as in Figure 6. This is because it consequences with the consideration of engineering criteria and customer requirements. The concept design 3 also gets higher final score than other designs with 5 points in addition and only 2 point in subtraction. Therefore, design 3 is chosen for further discussion in this project as it has the highest potential to become a quality product.

In the selected oil palm harvester, the diesel engine is used as power source. This is because it can be used to generate power in better efficiency for the rotational movement of cutter and extension of the telescopic pole. Both of the movements are done by the rotational forces from the motors. The diesel engine is connected to two motors which one is attached near to the cutter and another is near to the telescopic pole. The motor that used to generate movement for cutter is located near to the cutter to reduce the energy loss. The rotational movement is generated by the motor to move the inclined teeth circular blade.

On the other hand, the wire that used to connect the motor with engine is kept inside the long pole. The retractable cord is attached in the engine housing in order to control and roll up the wire when the pole is retracted to shorter length. Furthermore, another motor is attached near to the engine housing and used to control the telescopic pole. The telescopic pole is extended and retracted by the rotational movement of the internal thread shaft that guided by the motor. The threaded nut is installed in the pole and allowed the threaded rod to turn in and out to generate the linear motion. Besides, the components such as safety guard, handles and security belt are also installed in the oil palm harvester in order to increase the safety and bring convenience to the labours.

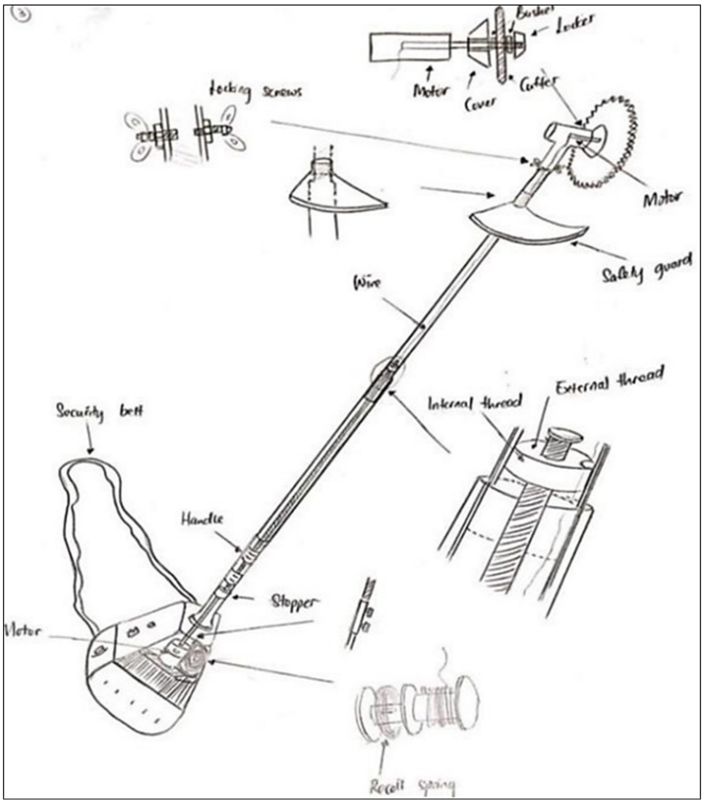

FIGURE 6. Concept design 3

ANALYSIS AND SIMULATION

Few analyses are carried out before the confirmation of components that need to be used in designing the harvester. These analyses are used to ensure those components used can work properly. the strength of cutter and the poles that used to build the oil palm harvester are also analysed in this section.

Cutter is the main component of the oil palm harvester as it is the tool that used to cut the fronds and harvest the oil palm FFB from the tree. The inclined teeth circular blade is designed as in Figure 7 to cut the oil palm FFB effectively and easily. There is only one cutter used in designing the harvester which the cutter is started up by motor that attached near to the cutter. The arrangement and size of the cutter are determined in this section to ensure it can work properly in harvesting process. With the consideration of size of oil palm fronds and its FFB, the alloy steel cutter is designed with the diameter of 17cm and thickness of 1cm with 40 teeth.

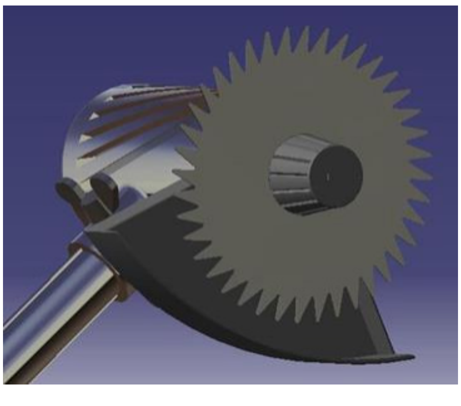

FIGURE 7. Cutter of palm oil harvester

The results shown that the maximum and minimum values of the von misses stress are 7.55 MPa and 0.755 MPa respectively as shown in Figure 8.

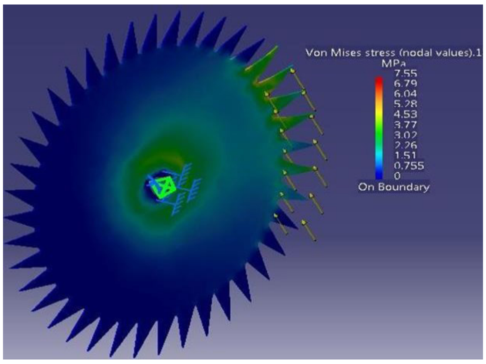

FIGURE 8. Von misses stress of cutter

The telescopic pole is designed and combined by using three circular poles (main pole, middle pole and end pole) with different dimension as shown in Figure 9. The strength of the poles is depending on the length and material that used in designing the poles. This is because poles with longer length are easy to defect and break. Therefore, the aluminium is chosen to design the poles as it is resistance in corrosion and good in strength. Besides, the deterioration of the poles can be noticed easily as the ductile material is used for the poles.

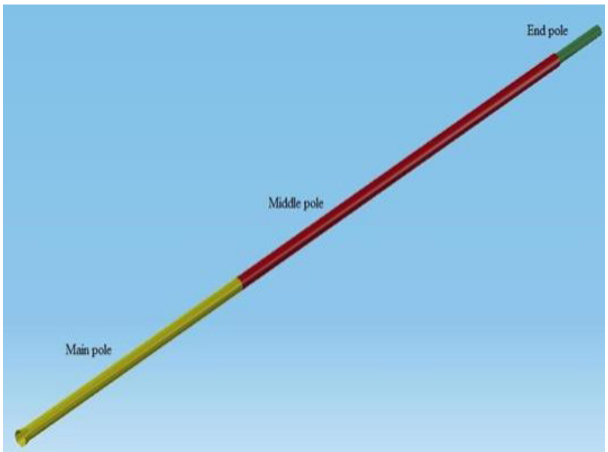

FIGURE 9. Telescopic pole of harvester

The results determined from CATIA which are von misses stress. The 1m main pole with 40mm outer diameter and 30mm inner diameter is analysed. For the von misses stress, the main pole gets the maximum and minimum values with 8.87 MPa and 0.0386 MPa respectively as shown in Figure 10.

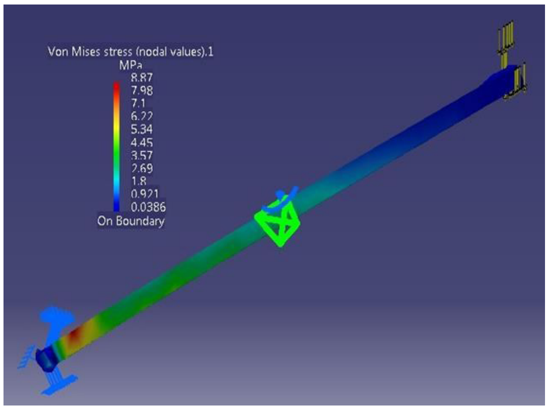

FIGURE 10. Von misses stress of main pole

The 1.5m middle pole with the outer diameter of 40mm and inner diameter of 32mm is also analysed in the load analysis. The middle pole gets the values of maximum 0.32MPa and minimum 0.032 MPa for the von misses stress as in Figure 11.

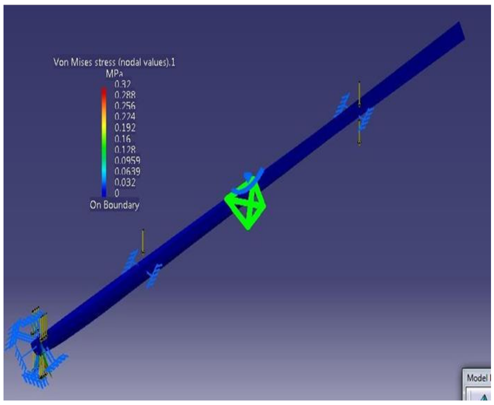

FIGURE 11. Von misses stress of middle pole

In addition, the end pole with 1.5m length, 32mm outer diameter and 28mm inner diameter is analysed. The results of the von misses stress of end pole are determined and get 0.0446 MPa for maximum and 0.0045 MPa for minimum as in Figure 12.

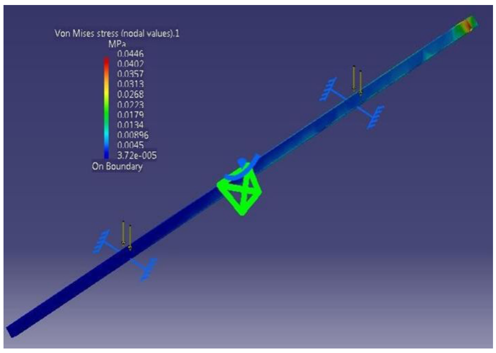

FIGURE 12. Von misses stress of end pole

In short, this means that the poles can withstand the forces that applied on the harvester. This also shown that the deflection may occur at the end of pole due to the lack of stability at the top end of harvester. However, there are only 8.87 MPa for the maximum von misses.

CONCLUSION

Due to the rapid expansion of palm oil plantations in Malaysia, there's a need to integrate novel technologies into the harvesting process to keep pace with the rising demand. A recommended solution involves the introduction of an oil palm harvester equipped with a circular cutter and a self-adjusting telescopic pole, operated through a rotational mechanism. The aims of this study have been effectively fulfilled, as it also encompasses the assessment and definition of the structure of both the cutter and telescopic pole within the oil palm harvester.

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DECLARATION OF COMPETING INTEREST

None.

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