Design, Fabrication and Testing of New Invented Spring Sickle Pole "ZappIt®" for Palm Harvesting

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***Abstract:** A new harvesting pole, specifically designed for palms trees, was designed, developed and tested. It comprises three sections, the locking, extension and spring sickle, which were joined through an aluminum pole. The pole can be adjusted to certain length to reach different height of tree. It is built using standard circular rod with cross section diameters of 50 mm. This newly invented spring sickle pole called "ZappIt®" has been designed based on the ordinary sickle widely used in Malaysia palm estates. ZappIt® introduced new mechanism concept of spring compression as a source of mechanical force to cut the frond and fruit bunch. The locking system was designed and located at the bottom of the pole for manual hand operated. While the threaded steel used to link the locking systems and spring sickle system.*

***Keywords:** Harvesting Cutter, Fruit Frond Bunch, Sickle*

1. INTRODUCTION

The previous method of harvesting, the criteria of design and the recommended design are the issues frequently mentioned in the literature (D.A. Adetan, L.O. Adekoya and K. A. Oladejo Department of Mechanical Engineering). The palm fruit is a tree without branches but with many wide leaves at its top. It has become the world's number one fruit crop because of its unparalleled productivity. Generally, for fruit crops, the majority of the mechanical harvesting systems utilized today are shake-catch systems (Futch et al., 2006). Each tree is visited for harvesting every 10 – 15 days as fruit bunches ripen throughout the whole year (Kwasi, 2002). The stalks of the palm fronds underlying a bunch are first cut, after that the stalk of the bunch is cut off to allow it fall freely onto the ground. Harvesting schedule will depend on the ripening of fruits as observed on plantations (Owolarafe and Arumughan, 2007). When a fruit is fully ripe, it loosens itself from the bunch and drops on the ground or it becomes easily detachable.

Locally, short trees within arm-reach are harvested using either the cutlass or the chisel to cut the bunches and fronds. On the other hand, very tall trees above 9 m in height are harvested using high technology machinery. There are two methods in harvesting which is the single rope-and-cutlass (SRC) or the double rope-and-cutlass (DRC) method. The SRC method is more common because it is relatively much faster though less safe (Ironbar, 1981). In this method, the harvester manually climbs the tree by the use of a rope tied around the tree and his torso. When arm-reach of the crown, the harvester uses a cutlass to cut the fronds and bunches. Medium-height trees beyond arm-reach up to a height of about 9 m are harvested using the bamboo pole and knife (BPK) method. In this method, a Malaysian knife, which is a curved knife with the sharp edge along its convex side, is attached to the end of a bamboo pole. The length of the pole depends on the average height of the trees on the plantation plot to be harvested. The harvester stands on the ground while the pole and knife are raised to the tree crown in order to harvest the bunches.

Yet another method is the Aluminum pole and knife (APK) method. In this method, a 40 mm diameter aluminum tube replaces the bamboo pole of the BPK method. It works very well and even faster than the BPK method for trees of height below 5.5 m. Above this height, bending of long harvesting poles that carry relatively heavier cutting knives on top constitutes a very serious problem as it becomes very difficult to engage the stalks of palm fronds and bunches. Indeed, a lot of time and energy (and therefore production cost) goes into oil palm harvesting. Such an enormous amount of energy is required for harvesting oil palm that even cutting a single frond alone, using the sickle cutter (the Malaysian knife), could require the exertion of a force as much as 18,048 N for the most matured frond (Jelani et al., 1999).

Harvesting from the older trees took more man-days. The situation, most likely, has not changed today because harvesting is still being done manually. Many attempts have been made to reduce the drudgery of the harvesting of oil palms. Webb (1976) worked on an oil palm tree climbing cycle. Test results showed that the cycle was not efficient for palm trees and it was not comfortable for the harvester to use. A lot of energy and time was required by this method. Pierce and Cavalieri (2002) opined that improving labour productivity, health and safety represents a major opportunity for reducing production costs. Also, the report by Adetan and Adekoya (1995) further established that because climbing before cutting substantially reduced the SRC harvesting rate and that much risk (including fatal falls) is involved in climbing, the pole-and-knife method is both faster (more productive) and safer than the rope and- cutlass method. Thus the report recommended that research effort should preferably be directed towards improving the pole-and-knife method by redesigning the harvesting pole to reduce its weight, minimize bending and increase the ease of its transportation.

2. Preparation

In order to fulfill the objective of this project, some preparations are needed. The search of the standard parts and capability of available machines need to be confirmed. Standard part such as long spring, ball bushing and threaded stud are few crucial items needed before the prototype can be fabricated. While the lathe machine is require in fabricating the prototype. Other tools such as M12 hand tap is also needed in producing the thread. Furthermore, appropriate size of aluminum pole need to be defined so that it can be fitted nicely with the ball bushing. Two inch diameter aluminum had been selected as a material for the main pole. Some standard part such as long compression spring is imported from Japan. Other standard part such as ball bushing was bought from MISUMI standard parts and solid aluminum bar 6061 with 75 mm diameter from local supplier.

3. Product design

Manual sickle consist of aluminum pole and being tight with the sickle at the end of it. Lengths of the pole depend on the height of the trees. Normally, sixty feet length of aluminum pole is available in the market. It will be cut to the required size in order to suit the height of trees. For the trees that have more than sixty feet height, two different diameter poles will be joined together using C-clip. In some cases this pole can be used telescopically where smaller diameter pole is placed to the bigger diameter pole from the top to the bottom. The sickle knife attached at the end of pole by tied it tightly using elastic rope or rubber. In order to cut the frond or fruit bunch, large downward force is required by pulling the poles manually.

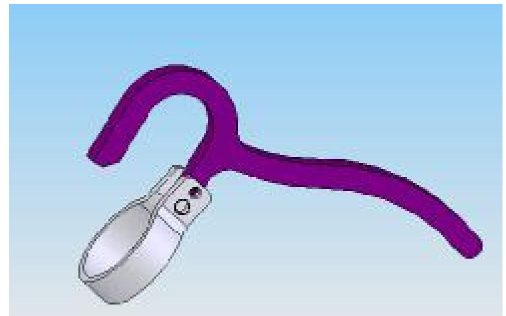

Figure 1 :Hand Lever sub-assembly

The basic design concept of the product is very simple where the compression spring will provide the force to pull c-shape sickle downward and then cut the frond or fruit bunch. The sickle used is the same as a normal one used nowadays. This sickle will be attached to the sliding shaft by three Allen Head Screws at the one end of pole. This aluminum sliding shaft carried the compression spring and link by ball bushing with the threaded stud inside the main pole. It is attached to the stopper that joined with the pusher at the bottom of pole. Lever will act as locking devices for the stopper once being push upward against the compression spring. Once lever is pushed, the sickle that attached to the sliding shaft will moved down and cut the frond or fruit bunch.

Figure 2 : Sub-assembly of the Pole & Stud

There are three main sub assembly which is hand lever, poles with stud and sickle & sliding shaft assembly. Figure 1 show the sub-assembly of the hand lever. It consists of two components, lever and locking ring. These components are design to be flexible and moveables to ensure easy assemble and match with the stopper shaft inside pole. The hand lever will attached to the ring using dowel pin and this ring will be assembled to the pole using single locking screw. Lever can be easily pulled down to release the locking mechanism and will be returned to the original position (locking) due to the compression spring mechanism at the bottom of it.

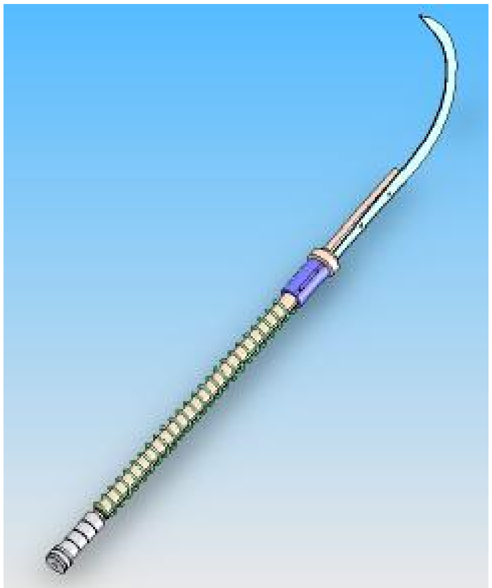

Figure 3 : Subassembly of the Sickle & Sliding Shaft

Pole and stud assembly as shown in figure 2 consist of five components which are pole, stud screw, stopper shaft, pusher and connector. The threaded stud was attached to the stopper shaft using tap screw holes. Then it is joined to the pusher shaft which was the aluminum pole that have smaller diameter from the main poles. Connector is assembled to the threaded stud to prevent it from bending and at the same time act as connector in order to get longer stud. All of these sub assembly will be placed inside the main aluminum pole with 60mm diameter. This sub-assembly then will be joined with the assembly of the sickle and sliding shaft.

Figure 3 shows the sub assembly of the sickle & sliding shaft. It consists of 6 components; sickle, sliding shaft, fix shaft, compression spring, ball bushing and slider joint. Sickle will be attached to the sliding shaft outside the pole. The fix shaft made of steel will be forced into the aluminum pole and act as a top stopper for the compression spring which located inside the aluminum pole. Slider joint will be assembled to the sliding shaft trough the thread fabricates on it. It acts as a bottom stopper for the compression spring and connector between sliding shaft and the stud screw. Ball bushing is installed between Slider Joint and aluminum pole. It is used to reduce friction while operated. This standard part provide anti friction movement for sliding shaft and aluminum pole.

4. Fabrication

There is an improvement in term of material usage between ordinary pole and this new design. The project aim to obtain the effective factor that can increase the productivity and reduce fatigue of the user. So, the product must be designed to have less weight and easy to use. Most of the parts have been made from aluminum except for a few standard components. Table 1 show the part lists, type of material and dimensions of each component.

Table 1 : Part lists

	Part	Material	Dimension (mm)	Remark
1	Hand Lever	Aluminum	12x150x75	Fabricate
2	Ring	Aluminum	85x15x75	Fabricate
3	Pole	Aluminum	Ø30x2000	Standard part
4	Stud Screw	Mild steel	M12x1500	Standard part
5	Stopper Shaft	Aluminum	Ø27x200	Fabricate
6	Pusher	Aluminum (pipe)	Ø25x500	Standard part
7	Connector	Aluminum	Ø28x50	Fabricate
8	Sickle	Steel		Standard part
9	Sliding shaft	Aluminum	Ø50x800	Fabricate
10	Fix stopper	Mild Steel	Ø20x75	Fabricate
11	Compression Spring	Spring Steel	Ø25x400 (2 units)	Standard part
12	Ball Bushing	Steel	Ø25x75	Standard part
13	Slider Joint	Aluminum	Ø25 x 100	Fabricate

Various type of machining processes are used to fabricate the components of this pole.

Figure 4 : Hand Lever

Part 1: Fabrication of Hand Lever

	Operation description	Tools
Step 1	External profile	Wire cut machine
Step 2	6H7 hole	Drilling machine, Centre drill, Drill bit Ø5.8, Reamer 6H7

Complicated profile of the Hand lever is produced using wire cut machine. Drawing from AutoCad software used to generate the programming and cutting operation performed by Sodick wire cut. While 6H7 hole is used to allowed rotation movement of the component and release the sickle. Drilling machine is used to drill and ream the part.

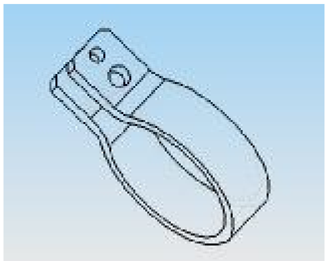

Figure 5 : Lever Ring

Part 2: Fabrication of Lever Ring

	Operation description	Tools
Step 1	External Profile	Wire cut machine
Step 2	6H7 hole	Drilling machine, Centre drill, Drill bit Ø5.8, Reamer 6H7
Step 3	M8 tap holes	Drilling machine, Centre drill, Drill bit Ø7.2, Tap M8 with holder

This component also used wire cut machine to cut the external profile. It required closed tolerance to the pole diameter so that it can hold the Lever rigidly. Drilling machine is used to drill the hole before manually tapping to get M8 thread hole.

Figure 6 : Stopper shaft

Part 3: Fabrication of Stopper Shaft

	Operation description	Tools
Step 1	Turning	Lathe machine,
Step 2	M10 hole	Lathe machine, Centre drill, Drill bit Ø8.8, Tap M12 with holder

Stopper shaft act as stopper by engage the lever at the groove. The external profile is produced using CNC lathe and the program generate manually on the DMG Fanuc controller CNC lathe machine. Again, Lathe machine is used to produce M10 hole. First center drill being performed with 8.8mm diameter and rotation speed of 1000rpm. The thread is produce manually using M10 tap.

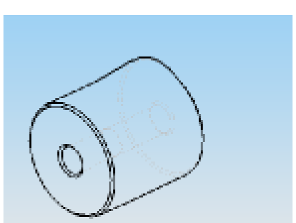

Figure 7 : Connector

Part 3: Fabrication of Connector

	Operation description	Tools
Step 1	Turning	Lathe machine
Step 1	Tap M12	Lathe machine, Centre drill, Drill bit Ø10.5, Tap M12 with holder

Lathe machine is used to machine the outside diameter and to get actual length of Connector. This is not a critical dimension part because the diameter is 28mm with the tolerance +-0.5mm. The function of this part is to prevent the stud from bending and allow the length being extended. M12 tap hole is fabricated on the Connector using lathe machine.

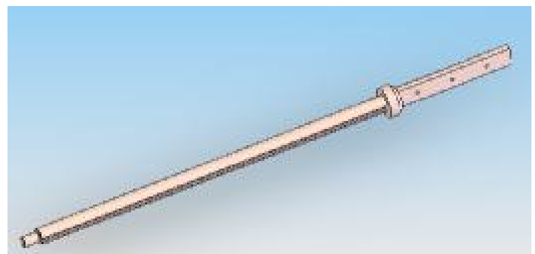

Figure 8 : Sliding Shaft

Part 3: Fabrication of Sliding Shaft

	Operation description	Tools
Step 1	Turning	Lathe Machine
Step 1	Flat surface	Milling
Step 1	Tap M10	Milling machine, Centre drill, Drill bit Ø8.8, Tap M10 with holder

Sliding Shaft is important part that connects the sickle to the stud. This part is assembled with sickle, spring, ball bushing and stopper. It consists of flat surface with three M10 tap holes at the top, 6mm wide groove and one M10 tap hole at the bottom. The flat surface used to facilitate the sit for sickle while the 6mm groove will allow the pin to slide on it and prevent the sickle form rotating. Outside profile of this part is made using lathe machine while the flat area and three M10 holes being machine using milling machine.

Figure 9 : Fix Stopper

Part 3: Fabrication of Stopper Shaft

	Operation description	Tools
Step 1	Turning	Lathe machine,

Step 2	Drilling Ø26.0	Lathe machine, Drill Ø10, Ø15, Ø20 & Ø26
Step 3	Slot	End Mill Ø6
Step 4	Tap M6	Milling machine, Centre drill, Drill bit Ø5, Tap M6 with holder

Required outside diameter and length of the Stopper shaft is achieve through lathe machine. The process continues to drill 26mm diameter holes. Pilot drill of 10mm is used at the beginning of the process. Then followed by 15mm, 20mm and final dimension of 26mm. Milling machine is used to mill slot and M6 tap hole in one setting.

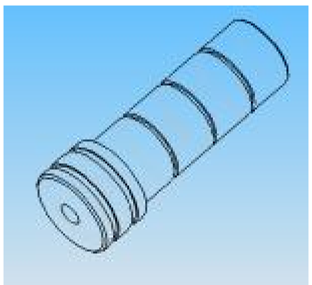

Figure 10 : Slider Joint

Part 3: Fabrication of Stopper Shaft

	Operation description	Tools
Step 1	Turning	Lathe machine
Step 1	M12 Hole	Lathe machine, Centre drill, Drill bit Ø10.2, Tap M12 with holder
Step 1	M10 external thread	Lathe machine, Dies M10

Figure 11 : Complete Design

Main function for this component is to join the Sliding shaft with the Stud. Ball Bushing and groove on this part is used to store the lubricant. For Slider Joint, CNC lathe is used to produce the external profile and holes for tapping. The program is generated manually on the DMG Fanuc controller of the machine. Manual method is used to produce threaded holes at both ends.

5. Product Testing and Modification

All the components in this product are assembled correctly before performing the testing process. During the first tried, hand lever is not well function and need to be redesign. The lever is too closed to the pole. When it is pressed, the stopper can't be released.

Figure 12 : Modified Ring and Hand Lever

Extra heavy load spring used for this prototype is too strong. It caused difficulty to press the lever. By changing to the medium load spring the problem can be overcome. However, another problem occur where it can't achieve the load required 18 048N in order to cut the mature palm frond [Jelani et.al,1999] .

Figure 13 : Sickle in spring actuated condition

<u>Spring Load calculation method :</u>
N (load) = N/mm (spring constant) x F (Deflection)

Max. deflection (F) for SWM spring 24% length (L).
L for this spring = 300 mm
Spring constant = 65.3 N/mm
Deflection 24% x 300 = 72 mm

Maximum N (load) = 65,3 N/mm x 72 mm
= <u>4677 N</u>

6. CONCLUSION

The machining processes that have been done are turning, drilling and tapping. The sequence of the processes is important to get a good quality of work and reduce machining time. In machining process, there are certain parts should be emphasized. Drilling a large holes required proper selection of drill bit size. Hole with 26mm diameter can't be drilled directly. It needs to be drilled step by step from the small drill bit size. In this case, drill started with 10mm diameter and increase by 5 mm for next operation. This method can avoid damage to the tool and work piece due to the bulk removal of material in one cutting. Excessive heat also can be reduced and prevent the material become harden due to coolant effect.

In taping operation, holes size must be within the recommended size. If require tap size is M8 with the pitch of 1.25, hole must be at least 6.65mm or bigger size drill bit. Manual tapping require gentle and careful movement, it is very easy to break if excessive force applied during the process.

Figure 14 : Complete prototype

Testing have ben conducted at the nearest palm estate. Most of the trees are between 6 to 10 feet height. This prototype capable to cut only 5 pieces small and young frond. In order to make it well functioned, the pole needs to be put the ground to compress the spring and lock the stopper to the lever.

In near future, further improvement can be identified to improve the functionality at the same time can be produced at minimum cost.

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