Design and Fabricate the Prototype of a Motorized Cutter for Harvesting Palm Fruit

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Abstract : A new harvesting pole, specifically developed for palms trees, was designed, developed and tested. It comprises three sections, the engine, extension and replaceable sickle/chopper, 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 replaceable sickle/chopper pole has been designed based on the ordinary sickle and chopper widely used in Malaysia palm estates. This innovation introduced new mechanism concept of small chain saw engine as a source of mechanical force to cut the frond and fruit bunch. The replaceable system was designed and located at the end of the pole for easily detachable manually. While the threaded steel used to link the engine systems and replaceable sickle/chopper system can be easily replace for higher tree.

Keyword – Harvesting Cutter, Fruit Frond Bunch, Sickle

1.0 INTRODUCTION

This project is focusing on the design and manufactures the prototype of a motorized cutter for cutting the palm frond besides harvesting the palm fruit. The reason that leads to this idea is very much related to the dependency of our country to foreign worker. As everybody aware, numbers of Malaysia youth work in the agriculture field such as palm estate keep reducing every year. In order to cater the demands in this field, Malaysia government depend on the foreign worker to fill the gap left by Malaysia citizen.

In Rancangan Malaysia Ke-9 (RMK9), agriculture becomes the new focus area that can lead to many advantages and benefits especially to our economy, politics and social. Palm fruit is one of the focus area where there is still les contribution from researchers and manufactures to develop it. There are few problems arise such as how to maximizing the profit, how to increase productivity and how to reduce the cost. One of the important activities in palm fruit is harvesting. This harvesting operation requires 60% of total labour where some of the workers are foreigner. Hire foreign workers will impact on increasing the social problem in our society and money draining out to other country. The idea is to reduce dependency on workers in harvesting. This new invention seems to be the solution and help to increase productivity. Hence, reduce the cost and generate more profit.

2.0 Design Concept

Before proceed with design and fabrication, several criteria need to be identify such as easy to fabricate, low cost and flexible enough to perform saveral task with minor adjustment. Designing process begin with selection of available standard part, motor to supply the power for cutter and raw materials to fabricate the components.

There are several concept being considered before end up with finalised design. The main constraint here is to identify how to transmit the rotary movement to the linear movement. A few concept that being studied are the movement bevel gear. However, this concept does not fit with the project since it required big area to place both bevel gears. Another way is by using cam mechinism. But this idea is not a good solution since it needs an extra spring to push the sickle backward. Cam mechanism only capable to produce forward force. At last, the idea of using piston and crank shaft concept is selected since it fulfill the criteria set earlier.

This new invention of mechanical cutter use the chain saw as a source of power. Then the movement of piston and crank shaft in car engine is adapted into this mechanical cutter. Its use to transmitted the rotational movement from the engine to the sickle. At the bottom part, the flywheel is attached to the chainsaw. The force will transfer by the cranks into the rod. The pole is attached to the engine and inside the pole, there are combination of rod and linear bearing. Its used to transfered the force from the engine to the sickle. The pole for this mechanical cutter is flexible which can be adjusted to the certain length for the shaft. At the top part, the movement of shaft make the sickle move in pole's axis. At the same time the sickle can be replace with chissel to cut the frond at the lower height. This linear motion generate rapid vibration of sickle along the pole's axis. This vibration mechanism is use to cut the palm fruit bunch. Figure 1 below show the process flow of the project starting from concept design untill repair and modification.

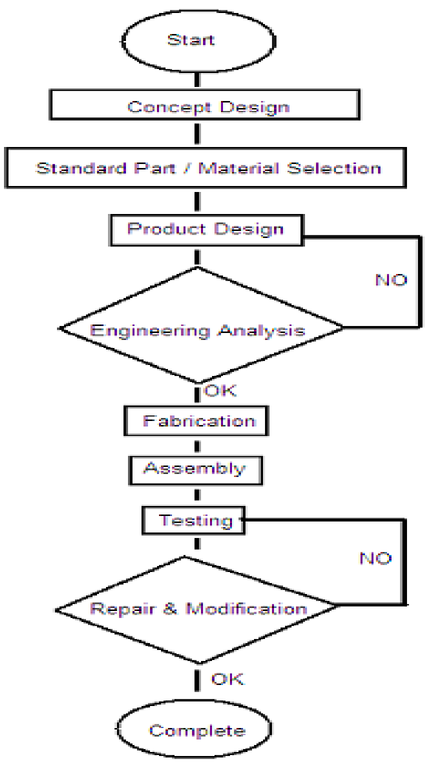

Figure 1 : Process Flow

3.0 Product Design and Fabrication

Product design of being visualized using solid base software SolidWork Ver2005. It begin with design process. The base plate was designed using reverse engineering method by acquiring the dimension of the holes location form the chain saw using vernier height gauge and caliper. This design consist of 15 parts all together inclusive of seven (07) standard parts. The ideas of using standard part is to reduce the cost and speed up the completion time. All of the fabricated components used Aluminum as a material since it give several advantages such as light in weight, cheap, strong and easy to fabricated except for base plate that hold most of the load and required extra strength.

Figure 2 : Crank System of Prototype

In the fabrication process, milling, lathe, EDM wire cut and several other machines were used. Quality of each component fabricated are monitored and controlled. All the component dimension measure after the fabrication process must within the general tolerances of ±0.1mm. With this kind of result it will avoid any difficulty during the assembly process.

The first test was done without sickle but it not run as expected. The crank got stuck at the entrance of the pole. However, after a minor adjustment it functions successfully.

4.0 ANALYSIS

This machine can be represented four-bar mechanism which is simple and most common linkage. It is a combination of four links, one being designated as the frame and connected by four pin joints. Since four-bar mechanism has only one degree of freedom, it is constrained or fully operated with one driver. The pivoted link that is connected to the driver or power source is called the input link. The other pivoted link that is attached to the frame is designated as output link. The connecting arm couples the motion of the input link to the output link. This four-mechanism usually used as a mechanism for the window glass cleaning machine (David et ac., 2005).

Table 1: Bill of Material

Parts	Qty	Description
Chain Saw	1	Std. Part
Base Plate	1	Mild Steel
Flywheel	1	Aluminum
Crank	1	Aluminum
Stud Rod	1	Std. Part
Sickle	1	Std. Part
Fastener	1	Std. Part
Linear Bearing	1	Std. Part
Bearing Housing	1	Std. Part
Aluminum Pole	1	Std. Part
Cover	2	Std. Part
Sickle Shaft	1	Aluminum
Connector Rod	1	Aluminum
Back Pole Holder	1	Aluminum
Front Pole Holder	1	Aluminum

An important part in mechanism analysis is a degree of freedom amount. Number degree of freedom is name as mobility, F. When the configuration of the mechanism is defined by positioning one link, the system has one degree of freedom. By using Gruebler's Equation (David et. al 2005):

$$F = Degree\ of\ Freedom = 3(n-1) - 2j_p - j_h$$

Where:

n = total number of links in the mechanism
j_p = total number of primary joints (pins or sliding joints)
j_h = total number of higher order joints(cam or gear joints)

Figure 3 : Finish Assembly Product

Mechanism with one degree freedom usually called as constrained mechanism. Mechanism with zero or negative degrees is identified as locked mechanism that unable to move from a structure. Mechanism with more than one degree of freedom is under unconstrained mechanism that needs more than one driver to precisely operate. By this equation, the mechanism for the cleaning machine can be classified (David et al., 2005).

The mobility of the machine can be calculated with four links and four primary joints. Therefore,

$$n = 4,\ j_p = 4,\ j_h = 0$$

$$F = Degree\ of\ Freedom = 3(n-1) - 2j_p - j_h$$
$$= 3(4-1) - 2(4) - 0 = 1(constrained\ mechanism)$$

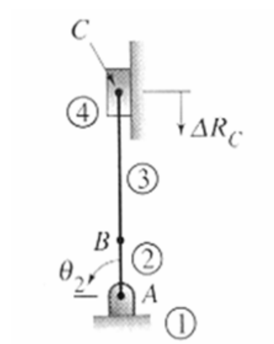

Figure 4 : Mechanism Diagramme

Dimension: AB = 60mm, BC = 80mm,
N = 3000rpm

$$\Delta\theta = \theta\left(\frac{1rev}{360°}\right) = 30°\left(\frac{1rev}{360°}\right) = 0.08333\text{rev}$$

$$\Delta t = \frac{\Delta\theta}{\omega} = \frac{0.08333}{3000}(60) = 0.001667\,\text{sec}$$

$$\theta_1 = \sin^{-1}\left(\frac{AB\sin\theta}{BC}\right)$$

$$= \sin^{-1}\left(\frac{60\sin 30^\circ}{80}\right) = 22.0243^\circ$$

$$\theta_3 = 180^\circ - (\theta + \theta_1) = 180^\circ - (30^\circ - 22.0243^\circ)$$

$$= 127.9757^\circ$$

$$R_c = \sqrt{[L_1^2 + L_2^2 - 2(L_1)(L_2)\cos\phi_2]}$$

$$= \sqrt{[80^2 + 60^2 - 2(80)(60)\cos 127.9759^\circ]}$$

$$= 126.1235\text{mm}$$

Velocity, v, of the machine can be calculated as:

$$v_i = \left[\frac{\Delta R_{i+1} - \Delta R_{i-1}}{2\Delta t}\right] - \left[\frac{\Delta R_{i+2} - 2\Delta R_{i+1} + 2\Delta R_{i-1} - \Delta R_{i-1}}{12\Delta t}\right]$$

$$= \left[\frac{29.1724 - 0}{2(0.0033)}\right] - \left[\frac{47.0850 - 2(29.1724) + 2(0) - 0}{12(0.005)}\right]$$

$$= 6.832722\text{mm/s}$$

Acceleration, a, of the machine can be calculated as;

$$a_i = \left[\frac{\Delta v_{i+1} - \Delta v_{i-1}}{2\Delta t}\right] - \left[\frac{\Delta v_{i+2} - 2\Delta v_{i+1} + 2\Delta v_{i-1} - \Delta v_{i-1}}{12\Delta t}\right]$$

$$= \left[\frac{10.33633 - 0}{2(0.0033)}\right] - \left[\frac{8.91835 - 2(10.33633) + 2(0) - 0}{12(0.005)}\right]$$

$$= 0.3326\text{mm/s}^2$$

5.0 RESULT

Table 2 showed the displacement, velocity and acceleration of the machine. All the value inside the table has been calculated using an equations above. This figure will be used to plot the graph of Displacement Curve, Velocity Curve and Acceleration Curve .

Table 2: Calculated Result

Crank Angle (°)	Time (sec)	Displacement (mm)	Velocity (mm/s)	Acceleration (mm/s ²)
0	0	0	0	0.1681
30	0.001666667	13.8764909	6.832722	0.3326
60	0.003333333	29.1723747	10.33633	0.0579
90	0.005	47.08497378	8.918346	0.2217
120	0.006666667	69.1723747	4.873131	0.2561
150	0.008333333	77.79953935	1.5329	0.1271
180	0.01	80	0	0.0944
210	0.011666667	77.79953935	-2.7055	0.1558
240	0.013333333	69.1723747	-5.7237	0.195
270	0.015	47.08497378	-9.1227	0.1393
300	0.016666667	29.1723747	-10.0156	0.1125
330	0.018333333	13.8764909	-5.9148	0.3647
360	0.02	0	0	0.1537

Figure 4 showed Displacement Curve graph, the maximum distance that can sickle move is about 80 millimeter. At maximum distance, the angle of crank is 180 degree. After it reaches the maximum distance, the sickle will moved to the initial position which is at angle 360 degree.

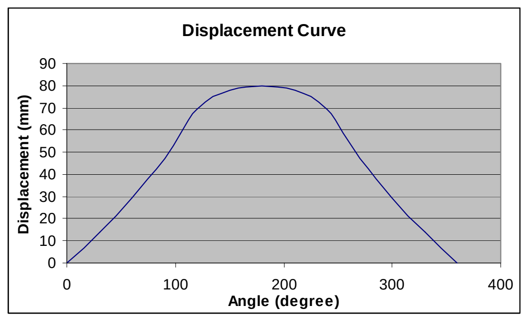

Figure 4: Displacement Curve

Figure 5 showed Velocity Curve graph, the maximum velocity that can sickle move is about 10 millimeter per second. The sickle will achieve the maximum velocity when the crank angle at 60 degree.

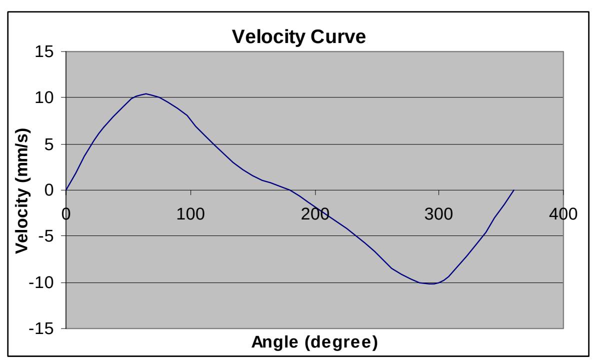

Figure 5: Velocity Curve

Figure 6 showed Acceleration Curve graph, the maximum acceleration ensued after the sickle fully harvests the palm fruit. For this machine, the maximum acceleration which is about 0.3647 mm/s^2 happens when the angle of crank is about 330 degree

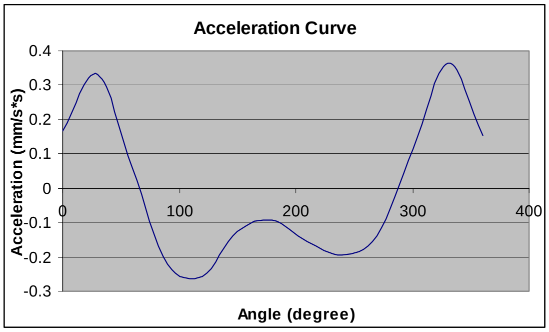

Figure 6: Acceleration Curve

6.0 DISCUSSION

From Displacement Curve graph, the maximum displacement for sickle to moved is about 80mm. With this distance, the palm fruit can be harvested because the diameter of the fronds of palm fruit usually within 50-80 mm.

Sickle displacement is not the only factor that influences the harvesting palm fruit process. According to Jelani [2] the factor in harvesting palm fruit is depend on the velocity of the sickle. Combination of velocity and the sharpness of the sickle will cut off the fruit frond and make it fall down due to gravitational effect.

From the Velocity Curve graph, it been discovered, the maximum velocity this sickle can reach is 10 millimeter per second. Jelani in his article, *Reaction Force and Energy Requirement for Cutting Oil Palm Fronds by Spring Powered Sickle Cutter* [2] mention the velocity that enables the sickle to harvest the palm fruit is about 8 to 15 millimeter per second. The value obtains from the analysis proof that this machine capable to harvest the palm fruit.

7.0 CONCLUSION

The prototype developed is able to meet the requirements of the harvesting process and fulfill the criteria that have been listed in the beginning of the project such as ease of fabrication, low cost, flexibility and last but not least multi functional.

There are few problems arise during fabrication, assembly and testing. In order to assure the machine functions smoothly there are some factors that should be considered. For example, in fabrication, the tolerance and the parameter need to be measure correctly. Machining technique and fabrication also need to select properly. During the testing phase, another problem discovered where the torques generate by the chain saw engine is not capable to supply enough force to move the sickle. This requires the steel stud screw to be changed with aluminum shaft so that the components become lighter and to function.

In future development, the machine performance may be increase especially the force supply by the chainsaw. Large engine will produce high revolution per minute and increase the movement of the sickle. Once this prototype has satisfied the need of its function, the development can be extended to the next stage which is mass production and commercialization

8.0 REFERENCES

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