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Trend of Harvesting of Oil Palm Fruit; The Mechanisms, and Challenges

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Abstract:

Demand for oil palm has increased over the years due to increase in population, and an increase in the demand for biofuels as alternative sources of energy. With this increase in demand for oil palms as well as technological advancement comes the different harvesting methods that are being employed. The harvesting methods employed by farmers can be associated with the form of farming carried out; small scale farming or plantation farming. This paper, however, tends to consider the trend in harvesting processes of oil palm over the range of different farming sizes. The harvesting processes identified were the traditional method, manual method, Ckat and Cantas method, harvesting machines and climbing robots. This paper also considered the mechanisms of these various oil palm fresh fruit bunch harvesting processes and the challenges associated with them. It is believed that for there to be a massive improvement in mechanization and industrialization of oil palm, improving the harvesting process is unavoidable.

Keywords – **Harvesting, Oil Palm, Mechanization, Agriculture**

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1. INTRODUCTION

The oil palm is an enduring yield that began in the tropical rainforest of West Africa. The development of oil palm spread to South America in the sixteenth century and to Asia in the nineteenth century. There is an expansion in the development of oil palm across America, Asia and Africa and one of the explanations is the more extensive utilization of palm oil biodiesel as an elective energy source. The interest for oil palm is additionally fortified as more nations build up orders on the utilization of biofuels. Another main consideration that added to this expansion is an increasingly quick ascent in per capita human utilization of vegetable oils in the previous 30 years than some other food as vegetable oils are utilized for food, feed squander and mechanical utilization [1]

Even though oil palm is the most profitable palatable oil crop (multiple times the following generally gainful), it is one of the least noteworthy food crops that today, for the most part, is notmechanically reaped. It is evaluated that 500 Million US dollars of oil palm have been lost because of the wasteful reaping methods presently utilized. Physically, there are a few stages associated with reaping palm oil fruit. For short youthful palms (1-3.5 m tall), a sharp level cutting edge connected to the furthest end of a steel pipe is utilized to cut the fruit. For more seasoned, taller palms (3.5m or taller), a sharp edge (generally the size and state of a hand Scythe cutting edge) joined to the furthest end of a long (13+m) customizable shaft is utilized. The shaper conveys the shaft upstanding. It is truly burdening to raise and lower the shaft due to its length.

80% of the production of oil palm in developing Africa countries comes from dispersed smallholders who harvest semi-wild plants and use manual processing techniques. An example is Nigeria where several million smallholders are spread over an estimated area of 1.65 million hectares, in contrast to Malaysia (2nd world producer of palm oil) that uses plantation mode of production for large scale monoculture production under unified management [2].

- **General Challenges ofOil Palm Fruit Harvesting**

The oil palm tree which is the most productive edible oil crop has a productive cycle between its 4th year to its 30th year and in this period it can grow up to 12.192m tall [3]. The available traditional and manual harvesting mechanism becomes difficult to use when the tree has grown to a specific height. These methods have both ergonomic and safety issues and in cases where harvesters are not available, the trees are abandoned or cut down, leading to wastage of the oil palm. Also, during the rainy season, the bark of the oil palm tree becomes very slippery and the climbers experience difficulty in climbing. In the long term if these risks are not minimised it may tilt the balance of sustainability. Furthermore, there had been cases of child labour and unsafe working conditions, especially among smallholders.

With the continuous increase in the population of the world (about 1.08% annually), there is a correlative increase in the demand of oil palm as a consumption product, exportation product as well as its demand as a source of energy, there is need to match the production rate of palm oil with its demand. One of the ways of accomplishing this is to harness optimally the palm fruits available, to reduce wastages due to ineffective harvesting methods. Also considering the ergonomics and safety issues associated with the traditional and manual harvesting methods of palm fruit especially trees above 3.5m, there is a need to develop safer harvesting methods.

2. OIL PALM HARVESTING PROCESSES

Harvesting Fresh Fruit Bunches (FFB) account for up to 60% of the total work in palm fruit processing and about 50% of the production cost [4].

- **Traditional Method of harvesting FFB**

Mechanism

This method is generally implemented among the small scale FFB harvesters. For short trees within arm-reach, conventional tools such as cutlass or chisel are used to cut the fronds first before cutting the FFB. For taller trees of about 9m, either the single rope and cutlass (SRC) or the double rope and cutlass (DRC) methods are used in which the harvester manually climbs the palm tree using the rope which is tied around the tree and his torso and when within arm-reach, the harvester uses cutlass to cut the fronds and the FFB[5].

Challenges

This is not safe as there is a risk of falling which may lead to impairment and possibly death. Also, there is a shift of occupational option among the young people in these developing countries from farming to white-collar jobs, hence the number of harvesters available to harvest the oil palm is not enough for the massive farming process.

Fig.1: Traditional harvesting of palm FFB.

- **The manual method of harvesting FFB**

Mechanism

The manual harvesting of FFB also known as the bamboo pole and knife (BPK) method is usually used for short trees of height below 3m in which the harvester stands on the ground while the pole and knife are raised to the tree crown in order to harvest the fruit [5]. The BPK method was modified by replacing the bamboo pole with an aluminium pole, known as the aluminium pole and knife (APK) method.

The harvesting process involves the following steps [4]:

- Search for the FFB on trees
- Adjust the length of aluminium or bamboopole and knife
- Position the pole's knife for pruning
- Perform pruning
- Position the pole's knife for the harvesting of the FFB
- Collect the FFB brunches
- Move the harvesting tool to another tree
- Repeat the process.

Challenges

This process of harvesting FFB is simple and faster than the traditional method but there is the difficulty of harvesting as the height of the tree increases beyond 5.5m. This is because a pole above twice the height of the user will be difficult for the user to manoeuvre[4] since two activities will have to be carried out: lifting the pole upright and cutting the fronds and the FFB, hence high skill is required and strength [6]. This can lead to work-related injuries as a result of ergonomics problems, slippage of the pole from the hand of the harvester [5].

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Fig. 2: Aluminium Pole and Knife method of harvesting FFB.

Ckat and Cantas method of harvesting FFB

Mechanism

The Ckat method of harvesting FFB involves the use of a mechanical chisel which comprises of a cutting head, pole and two-stroke engine of 1.3hp. It is about 1.5m long and weighs about 5.0kg[1]. The Cantas, on the other hand, comprises of a C-sickle, a telescopic pole, and two-stroke engine of 1.3hp and are used for palm trees of less than 4.5m[1]. It was developed by the Malaysian Palm Oil Board (MPOB)[7]. Cantas method of harvesting FFB was developed to overcome the labour cost problem associated with harvesting FFB in which the engine powers the cutter, and with the help of a switch controlled by the fingers of the operator, cutting takes place by first cutting the bunch before cutting the FFB[8].

The productivity of this method is equivalent to two or three human harvesters and one of the main factors that affect productivity is the operator's skill[4]. There have been several models of Cantas from Canta 3 to Canta 6 base on the height of palm tree they can be used for[9].

Challenges

Though this method has more advantages than the manual and traditional methods, it still has its disadvantages such as the vibrations the worker will be exposed to as canta vibrate as high as 300 cycle min $^{-1}$. Also, the average model of canta with a maximum height of 6m weighs approximately 9kg and this put strain on the worker and lead to muscular-skeletal disorder[4]. Also, the cost of a canta of the maximum height of 4.5m is approximately 1,300 US dollars[10], which is not economical for small scale palm oil producers.

Fig. 3: Ckat method of harvesting FFB.

Fig. 4: Canta method of harvesting FFB.

- **Harvesting Machines**

Mechanism

Mechanization of harvesting of palm FFB has been a challenge over the years because of some factors that surround the nature of Palm trees such as the varying ground level of the plantation, the height of the palm tree, the weight and sizes of the palm FFB and the fronds, the low tonnage per hectare to be harvested, movement of the harvester from one palm tree to another is difficult and consumes time and fuel etc. [1]. The harvesting machines can either be the wheel type or the track type.

One of the harvesting machines that was developed was the scissor cutting mechanism machine. This is a tracked type vehicle with a 500kg loading capacity that is powered by a 31.5hp diesel engine. The track wheel contributes less compaction to the ground and offers good traction for both rough and soft terrains [1]. The scissors cutting mechanism is driven by the hydraulic power source which generates enough force to cut through the fronds and the FFB.

Another mechanized harvester is the blade cutting mechanism harvester. This harvester is similar in structure to the Scissor cutting mechanism harvester, except for the addition of the Fruit catching mechanism (FCM) that is attached to the arm alongside the cutter blade. During the harvesting process, the operator drives the harvester along the harvesting path using a joystick control. Once the FFB is sighted, the operator will extend the arm to the palm crown using the required joystick control, grab the FFB with the FCM and then cut the fond and the bunch using the blade cutter, then the FCM drops the FFB in the bin [1].

String cutting mechanism harvester is another type of mechanized harvester in which cutting is obtained by the continuous rotation of the string at a rapid speed. The tension in the string wire is controlled by the extension of the hydraulic actuator. The cutting process is achieved by placing the string under the fronds or the FFB and applying upward cutting force. Usually, for the continuous cutting process, strings are knotted together to form a loop and due to the excessive force and lack of bonding strength on the knot, the wire loop may snap during cutting [4].

Generally, the advantage of the mechanized harvesters over other harvesters is high tonnage output of the formal over the latter, although the capital cost of the mechanized harvester is higher than the manual harvesters. One of the ways of compensating for the high-cost disadvantage of the mechanized harvesters is by extending the working hours of the machine.

Challenges

The disadvantage, however, is that the mechanized harvesters are limited on the reachable height they can be used for because increasing the length of the boom leads to increase in the weight of the prime mover and the actuator. Similarly, longer boom leads to less stability of the machine which may be detrimental to the operator and the tractor [4]. Also, the capital cost of the mechanized harvester is approximately 13,500 US dollars [11], which makes it uneconomical for small scale farmers to use. Similarly, this operator of this harvester requires approximately 2 weeks of training before operating the harvester and the harvesting time (which is made of activities such as positioning of the cutter, cutting the fond, setting the scissors mechanism to cut the FFB, cutting the FFB, and bringing it down) takes between 2.5 to 3.5 minutes. [1].

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Fig. 5: Scissors cutting mechanism harvester.

➢ **Climbing Robots Harvesters**

The introduction of climbing robots in the harvesting of oil palm fruits is to replace some human activities (such as adjusting the length of APK or BPK, positioning the pole's knife for pruning, performing pruning, positioning the APK or BPK for the harvesting of FFB, harvesting the FFB). There is a progressive study on the development of climbing robots and they are aimed at attaining heights above the cantas harvesters [4] thereby increasing the production yield as more palm trees will be accessible. Also, these harvesters will reduce the safety hazards and ergonomics issues attached to harvesting FFB both in the traditional and manual methods. However, some factors limit the use of climbing robots such as adverse climbing surface (wet and dry conditions), habitants of plants and insects, great variation in the trunk diameter across the length of the trunk, etc.

Fig. 6: Blade cutting mechanism harvester.

Fig. 7: Palm tree harvesting robot.

Challenges

1. Challenges in Locomotion Processes of Climbing Robots

Locomotion aspects of climbing robots are the major issues in the design of climbing oil palm harvesting robots.

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Climbing robots possess the unique characteristic of sustaining their bodies against gravity while moving in 3D environments. Hence, the following requirements should be observed to design climbing robots[12]:

- The lightness of weight, which is followed by low energy consumption, to increase the autonomy and payload of the auxiliary equipment.
- High mobility, which enables the climbing robots to move over various environments with different geometries of trees
- A reliable grasping mechanism for climbing on various surface types.

Types of Locomotion Processes

i. Legged Locomotion

Legged robot locomotion mechanisms are often inspired by biological systems (animals), which are very successful in moving through a wide area of harsh environments[13]. Climbing robots can employ legged locomotion which has from two up to eight legs that are equipped with vacuum suction cups, grasping grippers, or magnetic devices at the end of the feet. These devices for attachment enable strong and stable adhesion to the surface. Since they usually have a lot of degrees of freedom, they can move over rough surfaces and cracks and are capable of good obstacle avoidance. A greater number of legs of a climbing robot lead to a greater supporting force in the environment, which increases the capacity in terms of the payload and safety. However, an increase in the number of legs also increases the control complexity and the size and weight of the robot at the same time. Also, they require complicated control systems because of the use of harmonic gait control and have the disadvantage of low speeds of motion due to discontinuous movement[12].

Fig. 8: Legged Locomotion

ii. Locomotion Based on Translation

This is one of the simplest locomotion for robot and it uses a translational mechanism with an appropriate attachment device.The control strategy and process to operate translational climbing robots are not complicated due to the easy movement that comprises of sticking-moving-sticking.However, there are a few disadvantages such as the large size that hinders them from being used in a narrow space and also, the movement is discontinuous and the speed is low[12].

iii. Cable-driven Locomotion

The cable or tether driven locomotion is a mechanism in which a cable system that is equipped with a trolley on the crown of structure can make vertical and horizontal movements and sustain the robot body at the same time[12].

iv. Wheel-Driven and Tracked Locomotion

Wheel-driven climbing robots climb vertical planes by combining wheels for translation and rotation and vacuum pumps or magnets for surface attachment. Therefore, they move continuously and subsequently, their speed can be improved considerably. For using suctional force for attachment to the surface, some wheel-driven climbing robots

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have an air gap between the base and the surface to be driven over though the suctional device must not completely adhere with a high degree of friction; therefore, a particular kind of sealing is required that will allow the robot to pass over small obstacles. Such robots cannot handle large obstacles and their payload capacity is small [12]. Although the production cost is lesser compared to the track locomotion, they have high speed since they need lower torque, they are lightweight which is a critical property of harvesting robots [14].

Tracked climbing robots have a similarity to wheel-driven climbing robots in that both move with a rotational mechanism. However, using a chain-track as the locomotive mechanism, tracked climbing robots are better able to avoid obstacles and adhere to the surface[12]. In palm tree climbing,the chosen locomotive mechanism needs to be able to conform and to adapt to the extremely uneven surface of the tree trunk and a tracked locomotive mechanism with a large surface is suitable for this application because the large surface allows it to easily traverse over frond stubs. Using track over other locomotive mechanisms prevents it from getting stuck in recesses formed in between old frond stubs. In this case, the track has to be made from a flexible, tough and durable material. Also, it needs to have a high coefficient of friction to the surface of the trunk. With help from the active-gripping mechanism, the track can enable the robot to climb in wet and dry conditions as well[4]. Although, the climbing process is slow and has a higher weight [14].

Fig. 9: Wheel locomotion.

Challenges in Adhesion Mechanism of Climbing Robots

Robot designers must consider not only locomotive, as in all mobile robot systems, but also adhesion aspects, which are the two major issues in the design of climbing robot[12].

Types of Adhesion Mechanism of Climbing Robots

i. Adhesion Mechanism using Suction and Propulsion

Vacuum suction, which is the most commonly used adhesion method, can be widely adopted for less rough surfaces because it enables strong attachment to the surfaces regardless of materials such as glass, ceramics tiles, and cement. The major disadvantage that is related to this adhesion mechanism is that any gap in the seal can cause the robot to drop. Therefore, this type is usually used in relatively smooth nonporous and non-cracked surfaces. The use of more than one suction cup, as in the tracked locomotive mechanism, maybe a solution to prevent the loss of pressure and adhesive force due to surface irregularities. The vacuum can be generated through the Venturi principle or a vacuum pump that is either on-board or external to the robot[12].

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ii. Magnetic Adhesion Mechanism

Magnetic adhesion, including permanent magnetization or electrical magnetization, are suitable for attaching to only ferromagnetic surfaces though they are highly desirable due to their inherent reliability. However, since a magnetic adhesion mechanism does not require time to generate a sufficient adhesive force, unlike suction-based adhesion, it enables fast locomotion. Magnetic adhesion using permanent magnets has another advantage in that there is no need to spend energy on the adhesion process. Regarding applications, it can be applied at the ends of the legs of legged climbing robots or combined with wheels or tracks for moving along ferromagnetic surfaces. The disadvantage of this adhesion mechanism is they are limited to only ferromagnetic surfaces[12].

iii. Gripping Equipment Adhesion Mechanism

Gripping mechanisms for adhesion have been suggested to enable climbing robots to travel along 3D complex environments, while other adhesion mechanisms are usually applicable for climbing on flat walls and ceilings. Those gripping mechanisms are usually attached to parts of structures, through careful control of the grasping forces[12].

iv. Biomimetic Adhesion

Recently, a great number of researchers have focused on the sticking ability of geckos. They adhere to surfaces using patches of microscopic hairs that provide a mechanism for dry adhesion through van der Waals forces. Since the dry adhesion is mainly due to molecular forces, geckos can attach to almost any surface, whether wet or dry, smooth or rough. In the last decade, a group of climbing-robot researches have sought to employ biomimetic adhesion with nanofabrication techniques. Similar to permanent magnetic adhesion mechanisms, climbing robots that use biomimetic adhesion do not need the energy to stay on the surface or pressure differences to climb. However, they have a few disadvantages, such as a very low payload and sensitivity to surface conditions involving dust[12].

v. Thrust Force Adhesion Mechanism

After the robot has made contact with the structure to climb, thrust forces generated by the thrusters guarantee the adhesion to the wall, while the actuated wheel move the robots on the surface[15]. The thrust force adhesion mechanism uses negative pressure technique in the form of a brushless DC motor ducted fan. As the motor spins at high speed, the blades inside ducted fan are driven to rotate coaxially by the motor's output torque. Then the robot can adhere on the surface, due to an air discharge and a differential pressure formed between the external atmospheric pressure and the sealed chamber pressure [16].

Challenges inEnd Effector and Cutting Tool of Harvesting Robots

The cutting tool of harvesting robot must have high degrees of freedom to enable it to manoeuvre and adjust its angle to cut because higher manoeuvrability of the cutting tool allows access to densely packed fronds [4].

Types of End Effector of Harvesting Robots

i. End effector with grippers

These are designed specifically to pick the oil palm FFB on the ground and carried it to the trailer. The gripper is designed similar to the human hand and fingers, using a double-acting hydraulic cylinder to open and close the gripper. The end effector is developed to operate as fast as possible without damaging the fruits.

ii. Two-Finger End Effector

Another development is the design of the two-finger gripper with a cutting tool specifically to grip and cut the oil palm frond and FFB from the tree. The cutting tool is mounted at the end of the gripper.

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Types of Cutting Tool of Harvesting Robots

i. Reciprocating Cutting Tool

The reciprocating saw mimics the back and forth motion of a common hacksaw. The gearing system inside the reciprocating saw will cause the saw blade to move back and forth across the material[17]. Replicating the harvesting steps perfumed by the human workers is the best way for a robot to eventually match the efficiency of its human counterpart[4].

ii. Rotary Cutting Tool

Rotary saw cutting is a cutting method which is versatile and effective for a variety of industrial applications. The advantages of using the rotary saw method are faster cutting times, closer tolerances, better finishes, less kerf, easier tool changes, better tool life, and an overall wider range of applicability[17].

3. CONCLUSION

The trends in the harvesting process of oil palm FFB has been considered, in terms of their harvesting mechanisms and challenges for each of them. It is important to note that the challenges of some of these processes are life-threatening as in the case of the traditional and manual harvesting methods. Also, the cost of some of the processes is high especially for small-scale farmers found in developing countries as in the case of Ckat, Cantas and harvesting machines.

In view of moving with the current trend in technology, the use of climbing robots is encouraged as they come lots of benefits such as no risk to life, safety, long useful life, etc. Hence these paper considered the various challenges in the use of climbing robots as oil palm FFB harvesters and provided different alternatives that can be used to suit this purpose.It is believed that this project will help in reducing the risk associated with palm fruit harvesting (which may be human risk or damage to land), the harvesting time, the long run harvesting cost, and consequently improve access to palm trees that were not accessible before thereby improving the production rate of oil palm.

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