Design and Fabrication of a Multifunctional Robot for Harvesting Areca nut

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Abstract. The main crops grown in south Indian states like Karnataka and Kerala are areca nut and coconut. Skilled labours are essential who can manually climb up the tree for spraying pesticides on the crown and harvest areca nut. Since these tress are very tall so for a successful harvest yearly it is necessary to climb a minimum of five times. The farmers have to climb using their muscle power. Skilled tree climbers especially for areca nut and coconut trees have become very scarce. Also the existing climbers are finding it difficult to spray the insecticides effectively. Thus there is an immediate need to fabricate a device to automate the process of harvesting areca nut to address efficiency, safety and cost effectiveness. This paper proposes a novel design and fabrication of a multifunctional robot for harvesting areca nuts and spraying pesticides. It provides an alternate for traditional manual method. The robot uses a kind of rack and pinion mechanism to move up and down the tree. The movement of the robot is controlled by using an aurdino circuit based remote control. It regulates the wheels of the robot through motors in which the rack is considered as the trunk of the tree and pinion is considered to be the wheels. It operates by using Double Pole Double Throw (DPDT) switch. The connectivity of the remote and motor is ensured by Bluetooth connection. Specific designed sprayer or a cutter are mounted on the frame of the robot for proper harvest of areca nut.

1. Introduction

The major civilization in the rural areas of south India states like Karnataka and Kerala mainly depend on agriculture for their livelihood. Mostly are areca nut and coconut trees are grown in these places. Skilled labourers who are capable of climbing the tree manually are required for spraying and applying insecticides on the crown and for a proper yearly harvest. Such a process might apparently look easy but in reality it is extensively laborious and dangerous. Approximate height of an areca nut trees are of 60-70 feet and for a successful harvest it is essential to climb the trees a minimum of twice for the preventive spray against fungal disease, and thrice to harvest the areca nut yearly. Only skilled or properly trained labourers can carry out these farming operations. For an acre consisting of 550 trees usually a labourer climbs a minimum of 100 to 150 trees which involves a lot of physical exertion. This is the major reason because of which the younger generation of labourers are losing interest and thus it is creating a tremendous implications for areca nut cultivation. Generally the spraying of insecticides are often done in monsoon, while the harvest time is in summer. As day by day skilled tree climbers are becoming scarce thus there is a need for a device or mechanism to address automation, efficiency, safety and cost effectiveness. The design of the device should be simple and effective enough for people to operate and should also appeal to the majority. In some past literatures areca nut tree climbers uses rope and pulley mechanism for climbing [1]. A special type of knife is used to cut the areca nut. The machine can be operated from the ground. It reduces the risk in climbing the tree manually. The design is very simple making it easy for operation by unskilled labour and also maintenance for this machine is low. But this is not completely automated and requires some manual input. Also it is time consuming. Another literature addressed a triangular base frame areca nut tree climbing and spraying machine [2]. It consists of a triangular base frame with three stepped DC motors. The tension for gripping the tree is exerted by spring loaded mechanism and nylon rollers are used to achieve the required friction. To balance the stability of the structure in motion is difficult. The spring loaded mechanism used is not an efficient design. A product was developed [3] which had two units RH and LH. The downward movement is created as the climber steps on the pedal of RH unit, also through it the steel wire rope is stretched and it subsequently locks the areca nut tree. Now by pulling the handle attached to climb one step up the tree the LH unit is lifted up and the same process is repeated to create the climbing mechanism and to reach the required height. The pedal of RH unit is pushed down to descend the tree and the handle of LH unit is also pulled down alternatively till the bottom of the tree. The main objective of this design is to reduce the effort required to climb the tree. The product makes use of pedal mechanism consist of a T-gripper assembly which locks the areca tree, a box -beam assembly which acts as a supporting member. This process is also not completely automated. In present days the climbing methods that are been used by the farmer are rope climbing method and rectangle wooden seat climbing method. Rope climber is economical and simple in design which consists of rope of length one meter twisted to the shape of the sandal, the user wears this sandal and climb the tree manually. In rectangle wooden seat climber the user hangs the wooden seat on his back and climbs the tree manually, once he reaches the tree top he ties the wooden seat to the tree and rest on the seat to harvest the areca nut. Although this two methods are simple and economical. It is not safe and cause physical strain to the user.

In summary although many device were invented to climb the areca nut tree it was not economical and user friendly. This project aimed to overcome these deficiencies by developing a multifunctional robot for arecanut farming. This research aims to overcome the difficulties from climbing, cutting the bunch of arecanut and spraying pesticides on single tree to multiple trees. The crops on the tree and its position can be observed with the help of camera attached to the mechanism. It can be the future scope of this present work.

2. Working methodology

The basic principle of friction has been used to design and fabricate the multifunctional robot with arecanut harvesting and spraying pesticides. It considers the forces which is generated because of the relative lateral motion between the two surfaces in contact. A base frame with three wheels which are geared with high torque motor comprises the basic parts of the machine. The machine with “L” shape hinges [4] are on each links which ensures proper movement of links with the tree size variation. A hydraulic pump used provides sufficient grip between the wheel and the tree with variation in size [5]. The frame of the arecanut tree climber can be opened up and held across the tree for proper functioning. The tree climbing machine is obtained from 12V battery through which drive motors are charged. Controlling of the motor is done by the remote. On switching on the drive motor the shaft starts rotating which in turn rotates the wheels. The friction between the drive wheel and the bark of the tree helps in rising up along the length of the tree [6]. The tension springs and grippers on the wheel helps in maintaining the contact friction between the wheel and tree [7]. The wheels made up of nylon are only in contact with the tree, thus preventing the bark of the tree from any damage. The drive motor is switched OFF by the remote control unit upon reaching the top of the tree and the tension created in the spring retains the machine at the required height. Now for spraying pesticides the motors for controlling the nozzle attachment is switched ON with the help of the remote.

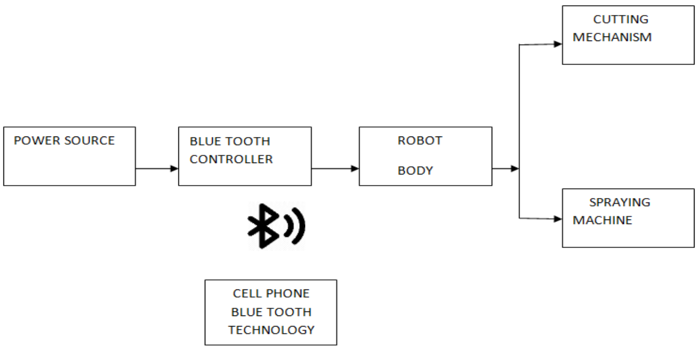

Fig 1. Schematic representation of the complete methodology

The motor unit is capable of rotating in 360˚. To spray pesticides to the crop a guide way motors with nozzle is mounted on top and rotated to the required position. The guide way motors are switched OFF after the nozzle is positioned near the areca nut. The pesticides is sprayed by switching ON the wiper pump motor. The whole setup is being brought back after the pump is stopped by changing the polarity of the switch such that the drive motor rotates in opposite direction there by making the wheels rotate in opposite direction. The setup is removed from the tree after reaching the ground and then attached to the next tree for spraying. During harvesting the cutting blade along with the basket mechanism can be mounted in place of the sprayer [8]. Once the robot reaches the top of the tree the blades cut the crown and the harvest is collected in the basket. This is then bought back to the ground and attached to the next tree. This ensures safe handling of the arecanuts ensuring less wastage.

3. Design calculations

3.1 Design of Frame

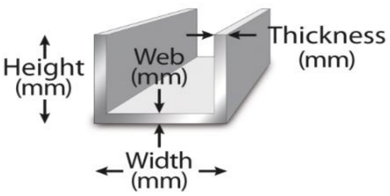

Fig 2. Square angle frame

Frame design;

For a square angle mild steel channel having dimensions;

$b = 25$ mm, $d = 25$ mm, $t = 3$ mm.

Consider the maximum load on the frame to be 20 kg,

Then,

Max. Bending moment = force*perpendicular distance

$$= 20*9.81*400 \tag{1}$$

$M = 78480$ N-mm

We know that [4],

$$M/I = \sigma_b/y \tag{2}$$

where,

M = Bending moment

I = Moment of Inertia about axis of bending that is;

y = Distance of the layer at which the bending stress is considered (We take always the maximum value of y, that is, distance of extreme fiber from N.A.)

E = Modulus of elasticity of beam material

$$I = \frac{25*25^3}{12} - \frac{19*19^3}{12} \tag{3}$$

$I = 21692$ mm^4

$$\sigma_b = \frac{M*y}{I} \tag{4}$$

$$\sigma_b = \frac{78480*12.5}{21692}$$

= 45.22 N /mm^2

3.2 The allowable shear stress for material

$$\sigma_{all} = S_{yt}/f.o.s \qquad \text{(f.o.s- factor of safety)} \tag{5}$$

where, S_{yt} = yield stress

$S_{yt} = 210$ MPa.

And f.o.s is factor of safety is taken = 2

So,

$$\sigma_{all} = 210/2$$

$$\sigma_{all} = 105 \text{ MPa}$$

Comparing above we get,

$$\sigma_b < \sigma_{all}$$

i.e. 45.22 < 105 N/mm²

Hence, design is safe

3.3 Design of shaft

$$M/I = \sigma_b/y \tag{6}$$

Bending moment=force*perpendicular distance

=5*9.81*450

Bending moment =22072.5Nmm

For, diameter =15mm,

$$I = 2483.78 \text{ mm}^4 \tag{7}$$

Therefore, we get

$$\sigma_b = 66.64 \text{ N/mm}^2$$

Thus, $\sigma_b < \sigma_{all}$

Hence, design is safe.

3.4 DC Motor

Motor specifications used;

Voltage = 4 volt

Current rating <= 13 amps

Speed= 100 rpm

Electrical Power is given by;

$$P = I * V \tag{8}$$

$$P = 250 \text{ Watt} \quad \text{(rated)}$$

Torque of motor is given by;

$$P = 2\Pi NT/60 \tag{9}$$

$$T = 23.8 \text{ N-m}$$

(high torque).

4. Results

The robot is estimated to climb the tree accurately for the harvest of the areca nut. For analysing the mechanism and to get a complete picture we have performed a finite element analysis in ANSYS.

4.1 Static analysis

The determination of the effects of non-time varying loads on structures and their components are determined by static structural analysis [9]. The results help to verify the fitness of a structure under a given load and boundary conditions. A static analysis calculates the displacements, stresses, strains, and forces in structures or components caused by loads that do not induce significant inertia and damping effects.

Fig 3**.** 3D model of Areca nut harvester in ANSYS

We have used a Hex Dominant Meshing Method in ANSYS**,** where a free hex dominant mesh is created. A majority of hex type cell is being used which contains mostly a combination of tet and pyramid cells with majority of hex type. Hex dominant meshing reduced element count. The total number of element is 59548

Statistics	
Nodes	64908
Elements	34322

Fig 4**.** 3D meshed model of Areca nut harvester

Boundary conditions are given as a rigid type of connection. It restrains the member in all translations and rotations. The mechanism has been subjected to a load of 10 kg as shown in the Fig 5. For a static load the maximum equivalent stress has been estimated to be around 9.577e-9 around the joining part of the links which is less than the yield stress thus making the design to be safe. But those are also the and optimization techniques can be used to reduce the stress concentration factor.

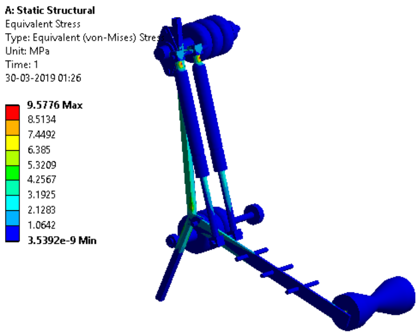

Fig 5. Maximum equivalent stress is 9.5776e-9 MPa

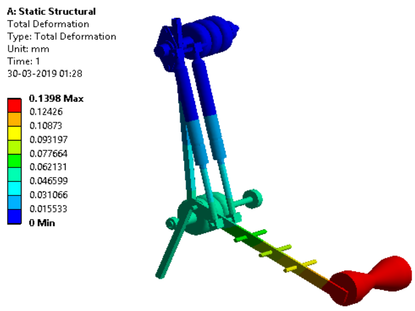

Fig 6. Maximum total deformation is 0.1398

4. Conclusion

The robot is roughly estimated to take about 1.30 to 2.0 minutes to climb 40-45 feet trees. From the simulation result it have been found that the maximum equivalent stress is 9.5776e-9 MPa which is less than the yield stress. Thus it can be concluded that the proposed design is safe. The mechanism will be able to spray pesticides and harvest areca nut with good accuracy, less effort and minimal human involvement. It is portable and easy to operate. The operation is economical.

Fig 7. Fabrication of the mechanism

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