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Design and Fabrication of Casuarina Harvesting Machine*

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Abstract

Agrotech – a developing field which is essential for agriculture. Casuarina Equisetifolia is a widely grown species used for the production of paper and firewood. Casuarina grows up to 12 feet in height in a span of 3 to 4 years. They are rigid and hard. This makes harvesting of Casuarina difficult. It consumes more time, money and manpower. Our harvesting machine reduces all of these. Our machine is equipped with two chainsaw blades at the front sides which are run by a 2 HP motor. It provides high rpm for effective cutting of trees. The dual blade enables cutting of two trees at same time. It is equipped with a front shield for protecting the driver. Overall an acre of Casuarina can be harvested in a few hours thus saving time, money and manpower. Our machine can also be used to harvest crops like sugarcane and bamboo by adjusting the position of the blades by simple alteration mechanism in order to produce a low cost harvesting machine for the farmers.

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Keywords: Agrotech, Casuarina Equisetifolia, Harvesting machine, Chain saw, 2HP motor, Sugarcane, Bamboo.

1.0 Introduction

1.1. General

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Most people think of agriculture as cow's milk and bread. But did you know it’s impossible to get in a car and drive on a paved road without agriculture being involved? Almost all sports have some component that originates with agriculture. The same is true in medicine, publishing, education and recreation. Agriculture is defined as the science, art, or practice of cultivating the soil, producing crops, and raising livestock and in varying degrees the preparation and marketing of the resulting products. There are many types of farms and ranches, including dairy farms and farms that grow vegetables. In addition, there are fish farms (aquaculture), mushrooms, herb farms and tree farms. Farmers and ranchers produce many products, not just plant crops and meat. The primary purpose of agriculture is to produce the food we eat. However, non-edible parts of plants and animals are used to make additional products we use every day. In addition to food, agriculture provides fiber, housing and biofuels. In fact, agriculture connects to your life every single day and in every single way.

As urbanization increases around the globe and as technology becomes the hearts and souls of people, fewer recognize the importance of agriculture and its need for humans to thrive. There are fewer agricultures today and one of the main need for agriculture is man-power which we lack today. As the need for more food increases across the globe, demand for agriculture is more than ever [6]. For producing more food, agriculture needs to develop to keep up with the demand. Here is technology comes into play. Harvesting is a major part of agriculture which requires man-power and time. Hence harvesting machines are used.

The mechanization of agriculture not only reduces the overall cost of production but also increases the total agricultural yield. Through mechanized farming, many countries in the world are reaching the upper limits of their cultivable land. The increasing use of agricultural machinery, equipment and fertilizers coupled with better irrigation facilities, together revolutionizes the agricultural sector.

Harvesting, the gathering of a ripened crop, is the most important stage of the cultivation process. In the past, when harvesting was done manually, a substantial portion of the crop was wasted. But, with the introduction of harvesting machines, harvesting has become cheaper and easier than ever. Harvesting machine not only saves the time but also reduces the quantity of waste to a great extent.

1.2. Harvesting

Harvesting machinery or equipment is a mechanical device used for harvesting. There are several types of harvesting machines which are generally classified by crop. Reapers [4,1] are used for cutting cereal grains, threshers for separating the seed from the plant; whereas corn or maize harvesting is performed by employing a specially designed mechanical device ' mechanical corn pickers' [4]. A typical harvesting machine comprises of a traveling part, a reaping part, and a baler part. Harvesting machines are also used for controlling the production of weeds [6]. Machines like field choppers, balers, mowers, crushers and windrowers are the common examples of this category. A forage harvester is used for cutting and chopping of almost all silage crops.

1.2.1. Types of Harvesting Machineries

Following is a brief description of major harvesting machines used all around the globe:

- Crop Harvesting Machine:

The mechanical device which harvests forage crops cultivated in upland/paddy field and forms roll bale simultaneously was developed, is termed as crop harvesting machinery. It comprises of traveling, reaping and a baler part [6]

- Root crop Harvesting Machine:

Traditionally root crops are harvested with diggers and digger-pickers. Nowadays, several machines are available in the market. Modern sugar-beet harvester is one of the most popular examples of the root crop harvesting machine [7]

- Grain Harvesting Machine:

This machine is used to harvest grains, the edible brans or fruit seeds of a cereal-crop [4]

- Threshers**:**

First invented by the Scottish mechanical engineer Andrew Meikle, threshers or threshing machine is used for the separation of grain from stalks and husks [6].

- Vegetable Harvesting Machine**:**

Nowadays, machines are also available for the harvesting of vegetables. These 'vegetable harvesting machines', are quite common among the global vegetable farmers [4,7].

2.0 Literature review

2.1. Casuarina Equisetifolia

Casuarina equisetifolia is an evergreen, dioecious or monoecious tree 635 (60) m tall, with a finely branched crown. Crown shape initially conical but tends to flatten with age. Trunk straight, cylindrical, usually branchless for up to 10 m, up to 100 (max. 150) cm in diameter, occasionally with buttresses [1]. Bark light greyish-brown, smooth on young trunks, rough, thick, furrowed and flaking into oblong pieces on older trees; inner bark reddish or deep dirty brown, astringent. The branchlets are deciduous, drooping, needlelike, terete but with prominent angular ribs, 23-38 cm x 0.5-1 mm, greyish-green, articles 5-8 mm long, glabrous to densely pubescent, dimorphic, either deciduous or persistent. Twigs deciduous, entirely green or green only at their tips [1]. Casuarina is from the Malay word ‘kasuari’, from the supposed resemblance of the twigs to the plumage of the cassowary bird. One of the common names of Casuarina species, ‘she-oak’, widely used in Australia, refers to the attractive wood pattern of large lines or rays similar to oak but weaker. The specific name is derived from the Latin ‘equinus’, pertaining to horses, and ‘folium’, a leaf, in reference to the fine, drooping twigs, which are reminiscent of coarse horse hair [1].

2.2. Tree Management

A planting density of 2500 stems/ha is commonly used but some farmers plant up to 8 000-10 000 stems/ha [6] when fuel wood and small poles are the required product. Casuarina equisetifolia is a poor self-pruner. Pruning is necessary up to 2 m to make plantations accessible for maintenance. Casuarina equisetifolia is not fire resistant and protection is necessary. It coppices only to a limited extent and best results are obtained when cut young. Timely thinning is essential as Casuarina species trees demand light. For timber production, an intermediate thinning will be required for stems to develop. Young trees are susceptible to competition from weeds, especially grasses. They are susceptible to drought until their roots reach the groundwater table, which may take up to 2-3 years after planting [1].

Casuarina equisetifolia has a lifespan of 40-50 years and displays fast early growth. Under favorable conditions, early growth rates are about 2 m/year in height and the trees have good form in cultivation. On favorable sites, it can yield an annual increment of 15 cubic m/ha of wood in 10 years [6]. In India, plantations using 1 x 1 m or 2 x 2 m spacing on 6-15 year rotations yield 50-200 t/ha. Dry weight per tree ranges from 15 to 25 kg at 3 years of age, depending on site quality. In South China, where an estimated 1 million hectares in shelterbelts along the coastal dunes have been established since 1954, heights of 7-8 m and diameters of 5-7 cm are achieved in about 4 years. The rotation period ranges from 4-5 years for fuel wood and 10-15 years for poles. Mean annual increments usually fall in the range of 4-5 cubic m/ha per year [8,11].

3.0 Design and Fabrication

3.1. Model of the machine frame

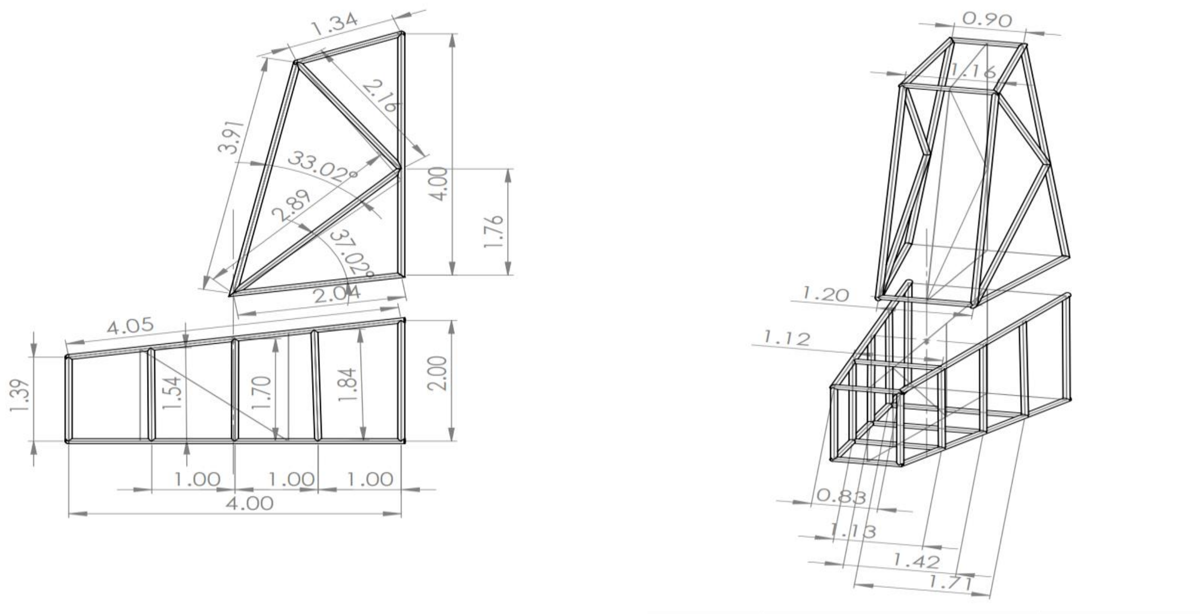

Figure 1. (a) Side view of the Frame; (b) Isometric view of the Frame

3.2. Design Calculations

3.2.1. Motor Torque [3]

Speed of the motor, N=1970rpm

Power of the motor, P=1.47KW

T=60P/2πN = (60*1470) / (2π*1970) =<u>7125N-mm</u>

3.2.2. Speed of the Pulley [3]

Diameter of smaller pulley, d1 = 100mm

Speed of the pulley, n1 = 1970rpm

Diameter of the larger pulley, d2 = 118mm

Speed of the larger pulley, n2 = d1*n1/d2 = (100*1970)/118=<u>1669.49rpm</u>=n3 (Both pulleys of same diameter)

3.2.3. Speed of sprocket

Speed of the sprocket, n4 = <u>1669.49rpm</u> =n3 (Pulley and sprocket on same shaft)

3.2.4. Pitch of the Chain

Distance between three rivets = 17mm

Pitch, p = 17/2 = 8.5mm

3.2.5. Chain Speed [5]

Drive shaft speed, Rpm = 1699.49rpm

Number of teeth on the sprocket, t=7

Pitch, p=17mm

Chain speed = (1699.49*7*17)/ (60*1000) = 3.37m/s

3.2.6. Cutting Force Required To Cut Casuarina [4]

F_c=-7.37+A1+15.61φv-2.6φv^3+1.3ρ+0.2V_c+A2

Where,
γ_F = Rake angle (rad)

ρ = Cutting edge dullness (μm)

φv = Angle

m_c = Moisture content (%)

a_p = Thickness of cutting layer (mm)

D = Average wood density (Kg/m^3)

T = Temperature of wood (℃)

A1 = $a_p(0.38D - 224.5\gamma_F)$

= 5(0.38*100-224.5*0.61) = 305.696
A2 = m_c(0.3* φv-0.1T)

= 35.6(0.3*0.287-0.01*24.1) = -5.64
F_c= 310.878N

3.2.7. Cutting Force of the Chain Saw [6]

Power to the chain saw, P=1.47KW

Cutting velocity, V_c=3.37m/s

Cutting force, F_c=P/V_c =1470/3.37 = 436.20N

The cutting force of the chain saw is greater than the cutting force required to cut the casuarina tree. Thus the above proposed design is safe for harvesting casuarinas trees.

4.0 Experimental Setup

4.1. Design Layout

The body of the machine which is the frame is made of high strength steel in order to withstand high loads. The cross section of the frame structure is 6ft height and 4ft length and width at the front and back is 1ft and 2ft respectively. The electric motor which is mounted vertically at the rear part of the machine in order to transmit power to the cutting saw. A double headed pulley of diameter 100 mm is attached to the shaft of the motor. From the pulley on the motor two other pulleys are connected to the left and right positions at a center distance of 360 mm in an incline position. Both the pulleys are of same diameters and are connected by a V-Belt of B45 type [3]. The pulleys are supported by a stepped shaft whose ends are attached with the bearings. At the top of the shaft pulley is connected and exactly 4 inches from the ground the sprocket is connected and to which the guide bar and the chain is also attached. The guide bars are supported by a square tube from the frame in order to withstand loads. The whole setup is designed in a way that the machine cuts the tree from a distance of 4 inches from the ground and it is supported by three wheels which can carry a maximum load of 500 kg [10,11].

4.2. Working Principle

When the motor is switched on, it rotates at an rpm of 1970 and the pulley attached to it also rotates at the same rpm. Then the power is transferred to the other pulleys by the V-Belt so, that the sprocket and the shaft rotates as the pulley on the shaft rotates. Now the chain saw rotates at the speed of the sprocket (i.e.) around 3200rpm. This machine is specially designed to cut two trees within a time period of 10 sec. The feed to the machine is given manually (i.e.) a man should enter into the machine and should give manual feed in order to perform the cutting operations. The main reason to design a machine of 6ft height is to provide safety for the person inside the vehicle. While cutting the trees even if the tree falls on the guide bars the cutting action continues because the blades can withstand a maximum load of 200kg.Thus the above designed machine reduces the time and cost of harvesting casuarinas trees.

Figure 2. (a) Full view of the Harvesting Machine; (b) Motor and Pulley setup; (c) Blades used in the Machine

5.0 Conclusion

Casuarina equisetifolia is one of the difficult crops to harvest [1]. Harvesting Casuarina requires more time, money and manpower. An acre of field contains nearly 5000 trees. Workers require a wage of 5000 for every day they work on the casuarina fields. Using this harvesting machine, we can cut an acre of trees within a few hours, this significantly saves money manpower and time. Using our harvesting machine, we can cut down two trees at a single time. This doubles the speed of harvesting the crops. We have provided necessary protections to prevent kickbacks and to protect the driver from the falling trees that are cut down. Nearly 2000 people die per year from chainsaw kickbacks. This can be avoided by using our machine. Our machine is an excellent choice for harvesting Casuarina instead of manual labor which takes up more money and time [9]. In the era of technology, our machine is a boon to the farmers.

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