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Design and Fabrication of IoT-Based Sugarcane Harvesting Bot

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***Abstract*—This paper presents the design, build, assembly, and commissioning of an IoT-Based Sugarcane Harvesting Bot. Harvesting machine development is the major goal of this project. Agriculture is the foundation of over 85% of the Indian economy. This project is an investigation into the aspects of sugarcane harvesting machines as well as economical harvesting, with the goal of lowering labour costs and worker fatigue. The main frame, engine, gearbox, counter shaft, horizontal shaft, vertical shaft, cutter, handle, and ground wheel made up the harvester. Power is transferred from the engine of the sugarcane harvester to the cutter and ground wheel through the countershaft, horizontal shaft, and vertical shaft with the use of a bevel gear. In comparison to the conventional way of harvesting, it was discovered that the sugarcane harvester provided 0.1401 ha/h of average effective field capacity and 77 percent field efficiency with the lowest labour needs.**

Index Terms: **Agricultural need, impact on modern machines, cultivation and harvesting techniques.**

I. INTRODUCTION

India is the greatest producer of sugarcane in the world, and demand for sugar and its by products is now on the rise[1]. The three states that produce the most sugarcane are Maharashtra, Uttar Pradesh, and Karnataka[2]. All tropical and subtropical nations in the globe get their sugar from sugarcane, a member of the Poaceae family. In India, sugarcane is grown on an area of around 4 million hectares and produces 300 million tonnes of sugar annually[3]. Moreover, it should be simpler to operate and maintain[4]. The gear box, connection, frame, cutter frame, counter shaft, horizontal shaft, vertical shaft, cutter, and ground wheel were the machine's key components[5]. The frame supported all of the machine's component pieces. This frame had the wheel mounted to it [6]. It was attached to the frame, which powers the cutter as well as the wheels by a gear and chain mechanism[7]. The goal of this research is to create a low-cost, more effective of the sugarcane harvesting equipment with a straightforward mechanism for cutting the cane[8].

II. METHODOLOGY

The primary goal of autonomous sugarcane cutting is to shorten harvesting time while lowering operational costs and enhancing efficiency. Despite the early costs, huge businesses are economically advantageous. The sugarcane in the storage chamber will be able to be changed by the bot. Mechanical, electrical, and electronic, as well as computer systems, make up the project.

III. SUGARCANE HARVESTING METHODS

In India, there are primarily two kind of sugarcane harvesting methods. Both strategies have several benefits and drawbacks.

a. Manual Harvesting Methods

Manual harvesting methods shows have harvesting is done manually. This approach uses human effort to complete the harvesting process. The flame process is when this procedure begins. Just the dried leaves are consumed by the fire; the remaining sugarcane is secure. Next the employees begin cutting the sugarcane just a little bit above the ground, while cutting, knives are utilized. According to the report, trained personnel can cut around 500 kilos in one hour. So, it can be determined that hand harvesting requires 3 days to thoroughly clear a single acre of land and costs between 30,000 and 40,000 INR. The hand harvesting method has the following drawbacks.

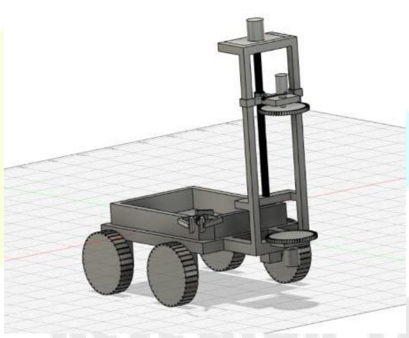
- Time commitment
- Worker shortage
- Inability to complete task
- Worker tiredness

b. Mechanized Sugarcane Harvesting Methods

The majority of foreign nations use automated harvesting techniques to gather sugarcane. Large-scale production will be more successful using this method. Its production will be more expensive, costing between 3500 and 4000 Rupees per hour. One acre of land may be harvested in 6-7 hours. This technique follows and calls for some specification.

- Large initial outlay
- Expensive operation
- Only applicable to massive production
- Skilled labour is necessary

IV. FABRICATION OF BOT



V. ASSEMBLY

The design of this work is more compactable, and it looks like a trolley with a basket in a shopping complex. Controllers such as Arduino and linear actuators are mainly used to fabricate. In the electrical part, the ultrasonic sensor senses the ground level. There are two ultrasonic sensors. One measures the ground-level measuring sensor and sends the feedback signal to the Arduino. The Arduino controls the linear actuator. The DC motor has the capacity to run at 600 rpm and has a torque of 4.5 kg. The motor is coupled with the linear actuator. The DC motor is coupled with a circular cutter that has a 220mm diameter. A 24V battery is used as a power source for the complete setup. The battery has a current value of about 7 amps. When the machine is taken into the field, the ultrasonic sensors start to send signals to the Arduino, and the linear actuator varies its height depending on the ground level. Figure 1 represents the electrical and mechanical setup and also the programming sequences of the model. It covers the main characteristics of the harvesting equipment and explains the overall scope of the work in clear terms.

VI. MAIN FUNCTIONALITIES

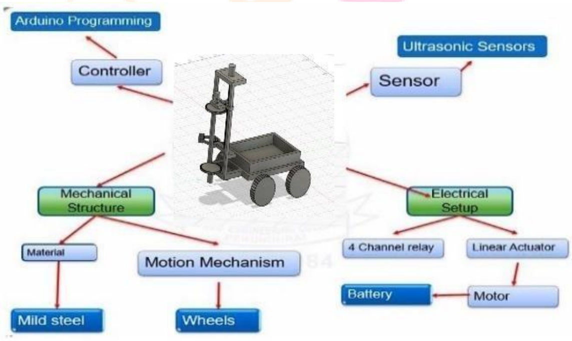


Fig. 1: Sugarcane Harvesting Bot workflow

Figure 1 shows all the basic accessories used in fabricating the product. The portable device may be utilized by even illiterate people, increasing productivity. It is made up of a mechanical structure, sensors, an electrical component, and a controller component. All the components will be incorporated, and the final product will be a new mechatronic system design. The electrical section consists of interfacing an ultrasonic sensor, a 4-channel relay, and a DC series motor with an Arduino UNO. The sequence of operations to be performed is programmed in Arduino UNO through the Arduino IDE. The mechanical portion consists of wheels, a linear actuator, a metal cutter, and mild steel. The process of making the mechanical part consists of drilling and welding.

VII. DESIGN CALCULATION

Maximum shear stress of sugarcane should be found to find the torque.

$$\tau = 3.6 \text{ Mpa}$$

$$\tau = 3.64 \text{ N/mm}^2$$

$F = Ꞇ \times A$

$F = Ꞇ \times \pi / 4\, d^2$

$F = 1767$ N

$Mt = F \times r$

$Mt = 44178$ Nmm

The lead screw's motion and efficiency are determined.

For screw :

$d = 20$ mm

$s - p = 3$ mm

For Collar :

$\mu = 0.15$

For Length :

$p = 10N$

$L = 100$ mm

Step 1 :

$dp = (d – 0.5p)$

$= 20 – (0.5 \times 3)$

$= 18.5$ mm

$\tan\beta = 3/\pi dp$

$= 3/(18.5) = 0.05$ [$\tan\beta = \mu = 0.15$

$\beta = 2.95°$

Collar Friction :

$M_f = p \times dr_{rd} / 2 \times \mu$

$= (0.15)\, p(d/2)$

$= 0.15 \times 25p$

$M_f = 3.75\, p$

Step 2 :

$M_f = p \times dp/2 \tan(\beta + c) + M_f$

$= p(18.5)/2 \tan((2.95) + (8.531)) + 3.75$

$= 1.85p + 3.75p$

$M_f = 5.6p$ Nmm

Step 3 :

$M_t = F \times L$

$= 100 \times 10$

$M_{tp} = 1000$ Nmm

$M_{te} = M_t + M_f$

$1000 = 5.6p$

$p = 178.5$ N

Efficiency, $\eta = p \times s / 2\pi M_{te}$

$= (176.5 \times 3 / 2\pi \times 1000) \times 100$

$\eta = 8.5\ \%$

The maximal bending moment acting at one location is determined by computing the bot's bending moment.

$\sum Fy = 0$

$Ra + Rb = 88.29$ N

$\sum MA = 0$

$Rb = 31.883$ N

Moreover, we consumed the resistance force as 0 & acceleration of 0.5 m/s^2 at the max power and thickness is calculated.

$F_{total} = 68$ N

Min.power output = total × V max of motor

Vmax → for rover assumed 1.5m/s

$p_m = 102$ w

To assure the bot's locomotion and gripping mechanism, calculations for the wheel and gripper are made.

Diameter = 80mm =0.03m

Radius = 40mm = 0.04m

circumference = $2\pi r$

= 0.25 m

Top speed = 1.5 m/s

= 90m/min

Max wheel RPM = speed/circumference

= 360 rpm

Torque :

$p = 2\pi\, Nt / 60$

$T = (102 \times 6) / (2 \times 3.14 \times 360)$

= 0.29Nm

Gripper Calculation :

$w = 0.5$ kg $= 0.5 \times 9.81$

= 4.91 N

nf = 2 (no.of contact)

$\mu = 0.3$

Gripping force,

$Fg = W/nf \times \mu$

$Fg = 8.18$ N

Gripping servo :

$21 \sin \theta = 20 \sin (63.63)$

$\theta = 58.4$

$P = Ax = 12$ N

$Ay = RN$

$Ax = Bx = 12$ N

$Ay = By$

The gripper servo is to find the link and axis of the gripper and how it holds the sugarcane.

Gripper Servo :

W = 0.055 Kg

Gripper Weight = 0.2 Kg

Sugarcane Weight = 0.5 Kg

D = 70 mm

$\sum Mb = -2.501 \times 35 - 686.7 + M = 0$

M = 0.7742 Nm

Moment = 0.774 Nm

$\sum MA = 0$

$M = 1.962 \times 150 + 774.235$

M = 1.068 Nm

Dynamic Calculation :

$L = K - P$

$K = K1 + K2$

$p = p1 + p2$

Link : 1

$K1 = ½ [mlvl²]$

$V1 = dx/dt$

$x1 = L1 \cos \theta1$

$y1 = L1 \sin \theta1$

$x1^{1} = -L1 \cos \theta1\ \theta1^{1}$

$y1^{1} = L1 \sin \theta1\ \theta1^{1}$

$v12 = (x1^\wedge1^\wedge2 + y1^\wedge1^\wedge2)$

$K1 = ½\ m1\ L1^{2}\ \theta1^{1\wedge2}$

$p1 = m1gh = m1\ g\ L1 \sin \theta1$

Link 2 :

$x2 = L1 \cos \theta1 + L2 \cos (\theta1 + \theta2)$

$y2 = L1 \sin \theta1 + L2 \sin(\theta1 + \theta2)$

$x2^{1} = -L1 \sin \theta1\ \theta1^{1} - L2 \sin (\theta1 + \theta2)(\theta1^{1} + \theta2^{1})$

$y2^\wedge1 = L1 \cos \theta1\ \theta11 + L2 \cos(\theta1 + \theta2)(\theta11 + \theta21)$

$v2^\wedge2 = (x1^\wedge2 + y1^\wedge2)$

$v2^{2} = L1^{2}\ \theta1^{1\wedge2} + L2^{2}\ (\theta1^{1} + \theta2^{1})^{2} + 2L1L2(\theta1^{1} + \theta2^{1}) \cos \theta2\ \theta1^{1}$

$K2 = ½\ m2V2^{2}$

$K2 = ½\ m2\ L1^{2}\ \theta1^{1\wedge2} + ½\ m2L2^{2}\ (\theta1^{1\wedge2} + \theta2^{1\wedge2} + 2\ \theta1\ \theta2) + m2\ L1\ L2 \cos \theta2\ \theta1^{1}$
$+ m2\ L1\ L2 \cos \theta2\ \theta1^\wedge1$

$P2 = m2\ gh$

$= m2g\ L1 \sin \theta1 + m2g\ L2 \sin(\theta1 + \theta2)$

$K = ½\ m1\ L1^{2}\ \theta^{1\wedge2} + ½\ m2\ L1^\wedge2\ \theta1^{1\wedge2} + ½\ m2\ L2^{2}\ (\theta1^{1\wedge2} + \theta2^{1\wedge2} + 2\ \theta1\ \theta2^{1})$
$+ m2\ L1\ L2 \cos \theta2\ (\theta1^{1\wedge2} + \theta1^{1}\ \theta2^{1})$

$P = P1 + P2$

$L = K - P$

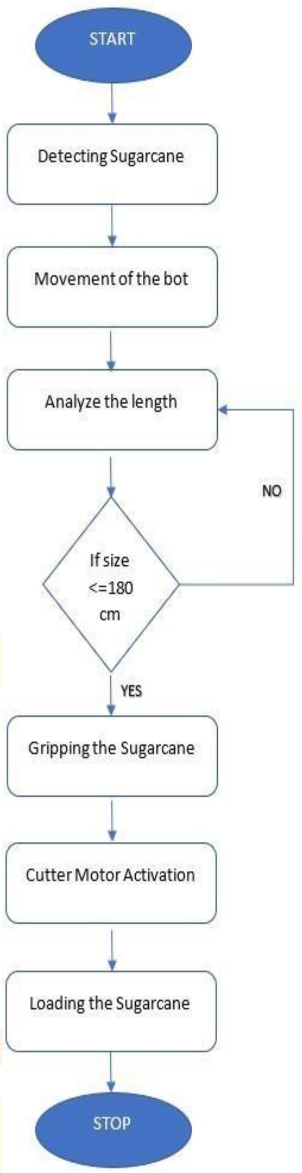
$r1 = d/dt\ (\partial L/ \partial \theta1^{1}) - \partial L/ \partial \theta1$

r1 = 7.93 Nm

$r2 = d/dt\ (\partial L / \partial \theta21) - \partial L/ \partial \theta2$

r2 = 1.16 Nm

VIII. FLOW CHART



IX. FEASIBILITY STUDY

Feasibility studies seek to identify the advantages and disadvantages of the planned or current business logically and objectively, as well as the possibilities and risks that are the surrounding circumstances, the necessary resources, and ultimately the likelihood of achievement. The following list includes the work's feasibility studies. It is clear from the cost estimation table 1 that the development will make it possible to produce the suggested design at a modest scale. The estimated cost to construct the portable Sugarcane harvester with all its attachments is Rs. 16306.

Table 1. Cost Estimation

S No	Components	Quantity	Cost
1	MG995 Servo motor	04	1648
2	Nema 17 stepper motor	03	2250
3	Wheel	04	800
4	Battery	01	2700
5	U Clamp	04	80
6	DC Motor	02	540
7	L293D Motor Driver Board	02	260
8	Ultrasonic sensor	02	198
9	Lead Screw	01(200mm)	430
10	Mild Steel	10 Kg	1300
11	Welding work	-	1800
12	Miscellaneous	-	1800
13	Fabrication Work (Drilling, Grinding, Cutting)	-	2500
Total			16306

X. CONCLUSION

We introduce the "IoT-Based Sugarcane Harvesting Bot" project, in which the system functions adaptably by using appropriate input. The sugarcane stalks can be roughly sliced using this pattern. Harvesting time and personnel expenses are cut in half when compared to manual sugarcane harvesting. Compared to hand harvesting, it yields the best results in the least amount of time.

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