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Design and Fabrication of Sugarcane Harvesting Machine

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Abstract: ***Crop harvesting is a crucial component for any agricultural products production system. Sugarcane one of such products needs harvesting which is critical aspect governing the output yield of the product. Typically, manual harvesting is very labour extensive and labourious activity involving much expenditure, moreover the workers are exposed to stress, strain resulting in fatigue, also safety and health concerns prevail. Looking into the above aspects a project work is aimed to design and fabricate a sugar cane harvesting machine to reduce the farmers effort and to increase output of the product. This is a mechanical harvester simple in design, relatively affordable and low maintenance yet reducing harvesting losses. Application of this mechanical harvester of sugar cane will free large number of labour, minimize extraneous materials thereby reducing costs and improving the quality of cutting in turn reduce sugar loss.***

I. INTRODUCTION

India is one of the major agricultural countries in the world. Maharashtra being a major sugarcane cultivating state had majority of labours for harvesting of sugarcane manually, but that was the situation of 10-20 years back. Today, as the demand of sugarcane products like sugar has increased, the cultivation of sugarcane is also increased. But as there has been a shortage of labours for the sugarcane harvesting process, due to which sugarcane which is ready for harvesting is left as it is in the field and dried which affects its quality & quantity of sugar content in it due to delay in supplying to the sugarcane industry. The process of harvesting consists of cutting the cane from bottom, then cutting off its top leaves, making a bundle which consists of 10 to 15 canes each and then carrying it to the trucks and loading it. This entire process is time consuming and requires a lot of hard work and is tedious as it is done manually by labours. When we look at the world scenario, it is found that the fields of sugarcane are extremely huge compared to the Indian farms and hence they use machines for harvesting instead of labours as it is not possible by the labours to harvest the farm quickly. Therefore, labours for harvesting are very rare case. Therefore, it is seen that machines specially for sugarcane harvesting have been built & used and they have worked out to be quite successful. There have been attempts made to make use of these harvesters in India, however, the attempts turned out to be unfavorable to the small size farms and land quality of our farms. Hence, till today also very few sugarcane harvesters are used for helping in the process even though a need is arising due to scarcity of labourer's and an increase in demand for a faster and more profitable output of farmers. In India agriculture has facing serious challenges like scarcity of agricultural labour, not only in peak working seasons but also in normal time. Sugarcane is the world's largest crop 2010. As per Food Agricultural Organization (FAO) estimates it was cultivated on about 23.8 million hectares in more than 90 countries, with a worldwide harvest of 1.69 billion tons in 2010. Sugarcane harvesting is an agricultural machinery use to harvest and process sugarcane. Finally, complete content and organizational editing before formatting. Please take note of the following items when proofreading spelling and grammar:

II. HARVESTING PRACTICES

A. Burnt Cane Harvesting

In the burning process, fire is set in a confined predetermined field, which burns off leafy extraneous materials, including stalk tops and dry leaves. Pre-harvest burning burns off about 80% of cane leafy materials leading to 30% to 40% improvement in harvester productivity. Moreover, cane burning ensures a cleaner cane entering the mill, making the milling process more efficient. The reduced leafy materials lead to reduced waste in sugar production including adherent clay, sand, and mud contaminating the sugar.

B. Green Cane Harvesting

In the green cane harvesting process, canes are harvested without any preconditioning such as burning or removing leafy materials before harvest. A particular mechanical device is then used to separate leafy materials and discharge them into the field. From the perspective of soil nutrient balance and environmental effects, this process may provide a more sustainable option for sugarcane harvesting compared to burnt cane harvesting. The residues left in field could help to control weeds, reduce soil moisture loss, and decrease soil erosion. The residue also helps to improve nutrient cycling because organic matter contributes to the production of nutrients and nutrients contributes to grow healthy crops that add residues to soil. Thus, the residue improves soil fertility, and productivity.

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III. PROBLEM DEFINITION

It is noted that much research and development works done aiming towards new and improving or designing cutting and feeding mechanisms necessary to further increase cane recovery rate, and minimize extraneous materials and to improve cane cut quality for reduced sugar losses. But very few works focused on costs and human concerns. So, the team has taken an opportunity to focus in this area, and a project titled “Design and Fabrication of sugarcane harvester”, is planned.

IV. OBJECTIVES

This project work is aimed to design and fabricate a mechanical sugarcane cutting machine. To accomplish the job following are the objectives framed,

A. To design a mechanical sugarcane harvesting machine
B. To fabricate a prototype model of sugarcane harvesting machine

V. METHODOLOGY

The idea of the project is to design a crop harvesting machine which is productive and affordable to farmers. The design is simple and easy to disassemble and reassemble. The machine is powered with a 110cc petrol engine mounted on a chassis made of steel. The output shaft is horizontal hence pulleys, bevel gears are used to provide rotation in vertical direction. The machine is designed aiming for sugarcane harvesting which requires high cutting forces consequently the machine can also be used to cut other variety of crops.

A. The Work Comprises Of Two Sections
1) Design of machine elements like chassis, bevel gears, pulleys, and shafts
2) Fabrication of protype model based on the design

B. Design Of Machine Elements
The following are the components to be designed,
1) *IC Engine:* It Supply power to the cutters
2) *Chassis:* it is the strong base which supports all other basic components
3) *Pulleys:* these are required to transmit power from one shaft to another shaft
4) *Bevel Gears:* these are required to transmit power from horizontal shaft to vertical shaft
5) *Shaft:* it is a rotating element required for cutting process
6) *Cutters:* it is the actual part which cuts the sugarcane

C. Design Procedure
1) *IC Engine (TVS Vector):* The internal combustion engines are the engines in which the combustion of a fuel occurs with an oxidizer (usually air) in a combustion chamber that is an integral part of the working fluid flow circuit. In an internal combustion engine the expansion of the high temperature and high pressure gases produced by combustion apply direct force to some component of the engine. The force is applied typically to pistons, turbine blades or a nozzle.

The IC engine is selected based on the literature review and requirements, availability
The description of the engine is as follows,
a) Type: 2 stroke, single cylinder, Air cooled, petrol engine.
b) Speed: 1000rpm
c) Torque: 8Nm

2) *Shaft:* A shaft is a rotating member, usually of circular cross section, used to transmit power or motion. It provides the axis of rotation, or oscillation, of elements such as gears, pulleys, flywheels, cranks, sprockets, and the like and controls the geometry of their motion.
a) *Material:* Mild steel
b) *Diameter:*1 inch
c) Add calculation for shaft

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i) Design of horizontal and vertical solid shaft

$$\Theta = \frac{584\,T\,l}{Gd^4}$$

$$\frac{\Theta}{l} = \frac{584 \times T}{Gd^4}$$

$$0.25 = \frac{584 \times 8}{80 \times 10^9 \times d^4}$$

d = 0.02198 m = 21.98 mm

ii) Design of cutter shaft

$$\Theta = \frac{584\,T\,l}{Gd^4}$$

$$\frac{\Theta}{l} = \frac{584 \times T}{Gd^4}$$

$$0.25 = \frac{584 \times 8}{80 \times 10^9 \times d^4}$$

d = 0.02198m = 21.98 mm

3) Pulley: A pulley is a wheel on an axle or shaft that is designed to support movement and change of direction of a taut cable or belt, or transfer of power between the shaft and cable or belt.

a) Material: cast iron

b) Diameter: 2.5inch

c) Bore diameter: 1inch

d) Grooves: 2 in no

i) Design of Belt Drive 1

Output shaft speed = 1000rpm= n,

Torque= 8 N-m

$$p = \frac{2\pi NT}{60000} \text{.....kw}$$

P=0.838 kw = 1.123 hp

d1=Normal diameter of cast iron and mild steel pully =63 mm

center distance C = 370 mm

diameter of driven pully = 63 mm = d2

$$\frac{n1}{n2} = \frac{1000}{1000} = 1$$

Smaller diameter factor F_b = 1.14

$d_e = 63 \times 1.14 = 71.82\ mm$

velocity,

$$v = \frac{\pi dn}{60000} = 3.299 \text{ m/sec}$$

Length of belt = $2c + \frac{\pi}{2}(D+d) + \frac{(D-d)^2}{4c}$

=937.92 mm

(A type) Nominal pitch Length=950 mm

Nominal inside length =914mm

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Correction factor $K_L = 0.87 = F_c$

Angle of contact $\Theta = 2\cos^{-1}\left(\frac{D-d}{2c}\right)$

$= 2\cos^{-1}(0)$

$=180°$

Correction factor for angel of contact $f_0 = 1$

$i = \frac{NFa}{NFcFb}$

$= 2.24$

$i \sim 3$

power capacity ;

$N^A = V\left[\frac{0.45}{V^{0.09}} - \frac{19.62}{d_e} - \frac{0.765V^2}{10^4}\right]$

$N^A = 0.4294$ kw

(assume light duties oliv 10h to 16h – pg.no 322) From DHB

Correct center distance;

$$C = \frac{L}{L_1} - \frac{\pi(D+d)}{8} + \sqrt{\left\{\frac{L}{4} - \frac{\pi(D+d)}{8}\right\}^2 - \left(\frac{D-d}{8}\right)^2}$$

$$= \frac{938}{4} - \frac{\pi(63+63)}{8} + \sqrt{\left\{\frac{938}{4} - \frac{\pi(63+63)}{8}\right\}^2 - 0}$$

$= 370.04$ mm

Specification of V-belt;

The V-belt selected is A914

Width b = 13 mm

Thickness t = 8 mm

Tension calculations;

$P = \frac{(T_1 - T_2)V}{1000}$

$(T_1 - T_2) = \frac{0.838 \times 10^3}{3.299}$

$(T_1 - T_2) = 254.016$ N

$T_c = \frac{9810 \times 13 * 8 \times 3.299^2}{10^6 \times 9.81}$

$T_c = 1.132$ N

$\mu = \frac{0.35}{\sin(\frac{40}{2})}$

$\mu = 1.02$

$(T_1 - T_c) = e^{\mu\theta}(T_2 - T_c)$

$= 24.62\,(T_2 - T_c)$

$(T_1 - 24.602\,T_2) = -23.62\ T_c$

$= -23.62 \times 2.710$

$(T_1 - 24.62\,T_2) = -64.01$

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T_1 = 265.9N

T_2 = 11.89N

ii) Design of belt drive 2(cutter shaft)

Output shaft speed = 1000rpm= n,
Torque= 8 N-m

$$p = \frac{2\pi NT}{60000} \text{.....kw}$$

P=0.838 kw = 1.123hp
d1=Normal diameter of cast iron and mild steel pully =63 mm
center distance C = 610 mm
diameter of driven pully = 63 mm = d2

$$\frac{n1}{n2} = \frac{1000}{1000} = 1$$

Smaller diameter factor F_b = 1.14

$$d_e = 63 \times 1.14 = 71.82\ mm$$

velocity,

$$v = \frac{\pi dn}{60000} = 3.299 \text{ m/sec}$$

$$\text{Length of belt} = 2c + \frac{\pi}{2}(D+d) + \frac{(D-d)^2}{4c}$$

=1417.92 mm

(A type)
Nominal pitch length =1433
Nominal inside length = 1397
Correction factor $K_L = 0.96 = F_c$

$$\text{Angle of contact } \Theta = 2\cos^{-1}\left(\frac{D-d}{2c}\right)$$

$$= 2\cos^{-1}(0)$$

=180°

Correction factor for angel of contact $f_0 = 1$

$$i = \frac{NFa}{NFcFb}$$

$$= \frac{0.838 \times 1}{0.4294 \times 0.96 \times 1}$$

= 2.033
i ~ 2
power capacity ;

$$N^A = V\left[\frac{0.45}{V^{0.09}} - \frac{19.62}{d_e} - \frac{0.765V^2}{10^4}\right]$$

N^A = 0.4294KW
(assume light duties oliv 10h to 16h – pg.no 322) From DHB
Correct center distance;

$$C = \frac{L}{L_1} - \frac{\pi(D+d)}{8} + \sqrt{\left\{\frac{L}{4} - \frac{\pi(D+d)}{8}\right\}^2 - \left(\frac{D-d}{8}\right)^2}$$

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$$= \frac{1418}{4} - \frac{\pi(63+63)}{8} + \sqrt{\left\{\frac{1418}{4} - \frac{\pi(63+63)}{8}\right\}^2 - 0}$$

= 610.04mm

Specification of V-belt;

The V-belt selected is A1397

Width b = 13 mm

Thickness t = 8 mm

4) *Miter Gear:* Miter gears are a type of bevel gears that have equal numbers of teeth. The shafts are positioned at right angles from each other, and the gears have matching pitch surfaces and angles, with a conically shaped pitch surface.

a) Gear material: EN8 hardening by 450deg Celsius

b) Bore diameter: 1inch

c) No of teeth's: 16

Design of bevel gears

P=N=0.838kw,

n1=1000rpm,

n2=1000rpm,

shaft are perpendicular to each other therefore ∑=90°

Material =EN8 (hardening by 400°c)(Turning, milling and tempering at 400°c)

$\sigma_{d1} = \sigma_{d2} = 280$ Mpa ,

Θ = 90°,

A1 = A2 = 45°,

α=20° FDI,

Intermittent or 3h per day, Medium shocks, C_s=1.25

Gear ratio i = $\frac{n_1}{n_2} = 1$

Pitch angle of pinion $\delta_1 = \tan^{-1}\left(\frac{1}{1}\right)$

Pitch angle of Gear $\delta_2 = \tan^{-1}(1)$

Formative number of Teeth in a straight teeth bevel pinion

$$Z_{v1} = Z_{v2} = \frac{z_1}{\cos\delta_1} = \frac{16}{\cos 45} = 22.63$$

Lewis form factor for 20° FDI

$$y = 0.154 - \frac{0.912}{Z_v}$$

$$y_1 = y_2 = 0.154 - \frac{0.912}{22.63} = 0.114$$

Both the material are same, lets consider Weaker

a) Tangential tooth load = $F_t = \frac{9550 \times 1000 \times PC_s}{nr}$

Tangential tooth load of weaker member

$$F_{t1} = \frac{9550 * 1000 * N * C_s}{n_1 * r_1}$$

Pitch circle radius of pinion $r_1 = \frac{d_1}{2} = \frac{m * z_1}{2} = \frac{16m}{2} = 8m$

$$F_{t1} = \frac{9550 * 1000 * 0.838 * 1.25}{1000 * 8m} = \frac{1250.45}{m} \text{.....} \rightarrow \text{(i)}$$

b)Tangential tooth load from lewis equation

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$$F_t = \sigma_0 * C_v * b * \pi * y_2 * m * \left(\frac{R-b}{R}\right)$$

cone distance $R = \frac{m}{2} * \sqrt{Z_1{}^2 + Z_2{}^2} = \frac{m}{2} * \sqrt{16^2 + 16^2} = 11.31m$

For face width $\frac{R}{4} < b < \frac{R}{3}$

$\frac{R}{3} = \frac{11.31m}{3}$=3.77m

The face width of the bevel gear is generally taken as 10m or $\frac{R}{3}$ which ever is smaller.

As $\frac{R}{3} = 3.77m < 10m$,take face width b=3.8m

Therefore

$$F_{t1} = 280 * C_v * 3.8m * \pi * 0.114m * \left(\frac{11.31m-3.8m}{11.31m}\right)$$

$$= 253.03 * m^2 * C_v \ldots\ldots\ldots \rightarrow (ii)$$

Equating (i) & (ii)

i.e $\frac{1250.45}{m}$=$253.03 * m^2 * C_v$

Therefore $m^3 * C_v = 4.942 \ldots\ldots\ldots \rightarrow (iii)$

mean pitch line velocity of the weaker member

$$V_m = \frac{\pi * d_1 * n_1}{60000} = \frac{\pi * m * 16 * 1000}{60000} = 0.838m$$

Trial 1)Assume m=2

$$V_m = 0.838 * 2 = 1.675$$

Assume the teeth are finished with one cutters

velocity factor $C_v = \frac{3}{3+V_m} = \frac{3}{3+1.675} = 0.6416$

Consider (iii) $m^3 C_v = 4.942$

5.1328<4.952

Hence, suitable

module=2mm

C) Check for the Stress

Allowance stress σ_{all}= $(\sigma_{01} C_v)$= 280*0.4884

=136.752 N/mm^2

Induced stress σ_{ind}= $(\sigma_{01} C_v)_{ind}$ =$\frac{F_{t1}}{bmy_2 m(\frac{R-B}{R})}$

$$= \frac{\frac{1250.45}{2.5}}{3.8*2.5*\pi*0.114*2.5\left(\frac{11.31*2.5-3.8*2.5}{11.31*2.5}\right)}$$

=172.966 N/mm^2

As $(\sigma_{01} * C_v)_{ind} < (\sigma_{01} * C_v)_{all}$

The design is satisfactory

Therefore Module m=2 mm

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5) Checking

a) Dynamic load

According to buckingham's equation

Dynamic load $F_a = F_t + \frac{21*V_m*(F_t+bC)}{21*V_m+\sqrt{F_t+bC}}$

For $V_m = 1.675$

error=0.0906

Dynamic factor C=1067.95

Therefore , on solving , we get

$F_d = 3014.93N$

b)Wear load

According to buckingham's equation neglecting deflection effect ,wearload

$F_w = \frac{d_1 bQK}{\cos\delta_1}$

Ratio factor Q=$\frac{2z_{v2}}{z_{v1}+z_{v2}} = 1$

for safer design

$F_w \geq F_d$

i.e $\frac{d_1 bQK}{\cos\delta_1} \geq F_d$

on solving ,weget

K$\geq 8.76 \frac{N}{mm^2}$

Surface hardness for pinion =600BHN

Surface hardness for gear =600BHN

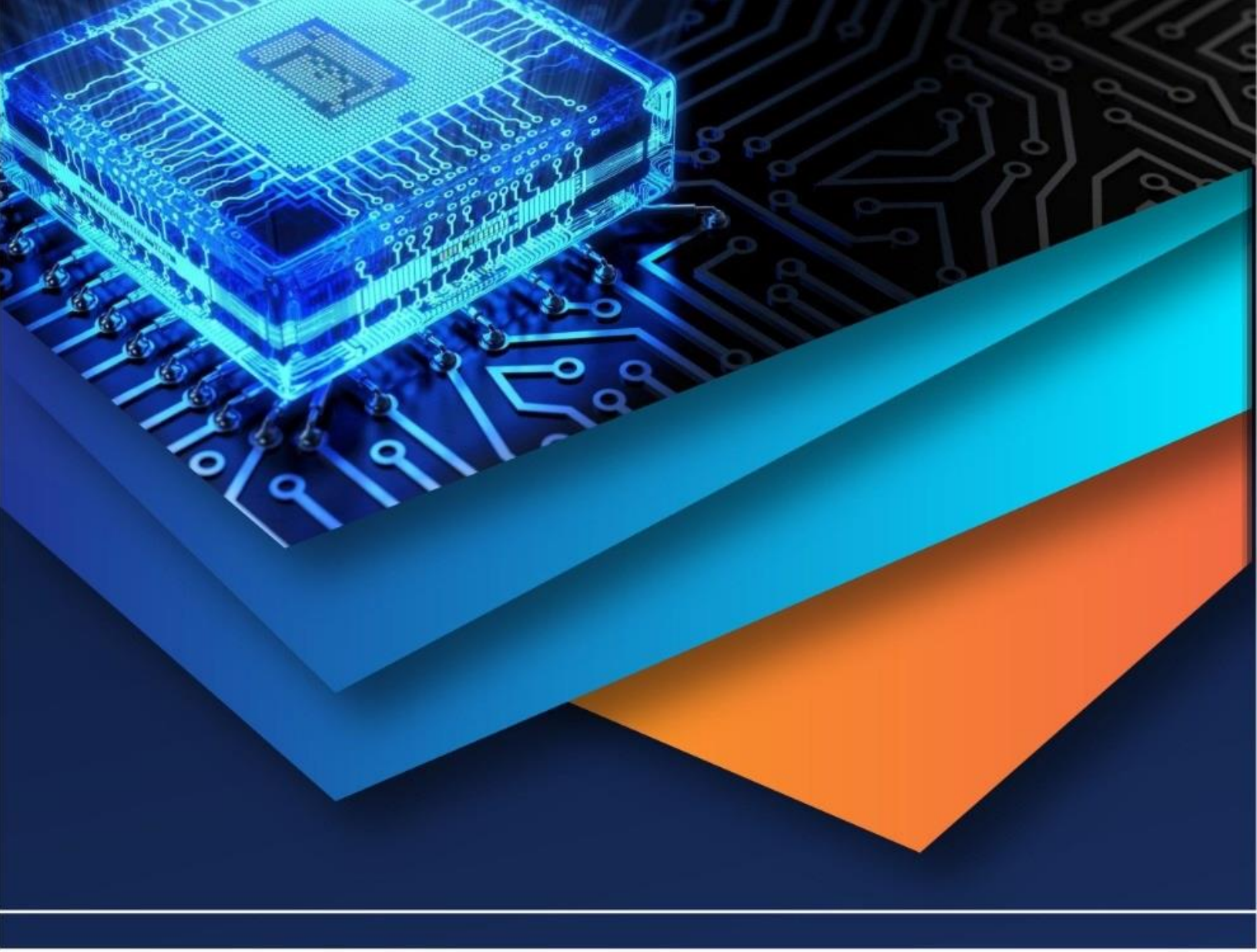
This type of harvester is low-cost, compact and portable useful to various sections of farmers.

VI. POSSIBLE OUTCOMES

With the design and fabrication of a portable mechanical sugar cane harvesting machine with minimum cost, Hurdles in harvesting of sugarcane will be reduced to much extent and possible outcomes are/

A. Number of labours are reduced
B. Cost of the harvesting will be reduced
C. Time of harvesting will be reduced
D. Easy to apply by any unskilled person

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