Design, Fabrication and FEM Analysis of Multipurpose Cutting Machine for Agricultural Uses

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ABSTRACT

Agriculture is the backbone of India's economy, employing over 60% of the population and contributing 8.4% to the GDP. However, traditional farming practices are labor-intensive, leading to delays and workforce shortages. To address these challenges, a multi-purpose agricultural cutting machine has been developed to enhance efficiency and productivity. Despite technological advancements, high costs and limited accessibility hinder the widespread adoption of automation in rural farming communities. A 3D model of the machine was designed using SolidWorks 2021, followed by Finite Element Analysis (FEA) to assess stress distribution and deformation in critical components. The Finite Element Method (FEM) ensures the reliability of the machine by minimizing potential failures before implementation. Prioritizing simplicity, cost-effectiveness, and user-friendliness, this innovation provides small-scale farmers with a sustainable and efficient solution to modern agricultural challenges. This project focuses on three key automation processes: Sugarcane Seed Cutting, where a motor-driven gearbox transforms rotary motion into reciprocating motion for precise cutting; Groundnut Stripping, which employs a rotating shaft and cylinder to separate groundnuts from plants efficiently; and Straw Cutting, where rotating blades mounted on a circular ring finely chop straw using a belt-driven motor.

Keywords: *Sugarcane Seed Cutting, Groundnut Stripper, Solid Works, ANSYS, Finite Element Analysis, Static Structural Analysis**, etc.***

1. INTRODUCTION

Agriculture is a cornerstone of the Indian economy, providing a livelihood for nearly two-thirds of the population and occupying approximately 43% of the country's land area. Contributing 16.1% to India's GDP, the sector is vital but faces numerous challenges, particularly labor shortages during peak seasons. Factors such as the migration of workers to cities, the appeal of non-farm jobs with higher wages, and the declining social perception of agricultural labor have worsened this issue. Additionally, rapid urbanization has reduced available farmland, making agricultural mechanization essential to improving efficiency and productivity. Integrating modern farming techniques and machinery offers a viable solution to address these concerns.

India is a major producer of key agricultural commodities such as sugarcane, straw, and groundnuts. With an annual production of approximately 300 million tons, sugarcane plays a significant role in India’s agricultural economy. Traditionally, sugarcane planting requires manual cutting into smaller segments, each containing 2-3 seeds, before sowing in moist soil. This process is labor-intensive, involving nearly 4 million farmers and a substantial portion of the rural workforce. Similarly, straw cutting, particularly for maize and jowar, is essential for producing livestock fodder. After harvesting, maize straw, which typically measures 150-200 cm in length, must be cut into smaller pieces for animal feed. Manual cutting is slow and tedious, necessitating mechanization to increase efficiency. Groundnut cultivation also relies heavily on manual labor, with 20-30 workers per acre needed to separate groundnuts from plants, making the process both time-consuming and labor-intensive.

To address these challenges, this project aims to develop a multi-purpose cutting machine that integrates three key agricultural processes: sugarcane seed cutting, groundnut stripping, and straw cutting into a single, cost-effective system. This innovation will significantly enhance agricultural efficiency while reducing labor dependency, making farming more sustainable for small-scale farmers.

To ensure the reliability and durability of the machine, Finite Element Analysis (FEA) is employed in the design phase. The Finite Element Method (FEM) is a computational technique used to model mechanical stress in agricultural machinery. It is particularly effective in simulating the structural behavior of complex components, accounting for varying material properties, intricate geometries, and dynamic forces. FEM analysis involves creating a mesh of nodes, with higher density in areas expected to experience greater stress, such as joints, corners, and potential fracture points. By applying FEM to agricultural equipment, engineers can predict stress distribution, deformation, and failure risks before production, reducing the likelihood of mechanical failure in the field. The use of FEM in mechanized farming equipment enhances performance, durability, and efficiency, contributing to the advancement of modern agricultural practices.

2. PROBLEM STATEMENT

- **Labor Shortage** – Agriculture faces a severe labor shortage, especially during peak seasons, due to increased migration to cities and better-paying non-farm jobs.
- **Time-Consuming Traditional Methods** – Manual planting, harvesting, and processing of crops like sugarcane and groundnuts require excessive time and labor, reducing overall productivity.
- **High Cost of Mechanization** – Advanced agricultural machinery is often expensive, making it unaffordable for small and marginal farmers.
- **Limited Awareness and Implementation** – Despite technological advancements, many rural farmers lack awareness and access to modern agricultural equipment.

- **Land Scarcity Due to Urbanization** – The rapid expansion of urban areas reduces arable land, increasing the need for efficient farming methods.
- **Mechanical Failure Risks** – Agricultural machinery must be optimized to prevent failures that could lead to financial losses and downtime.
- **Need for Optimization and Simulation** – There is a necessity to develop and test agricultural equipment using Finite Element Analysis (FEA) to improve durability and performance before field deployment.

3. LITERATURE REVIEW

Prof. Dipak U. Adhapure, et al [1]. In this paper, we have studied the one alternative to reduce the mass and improve the quality of seed for sugarcane would be to plant excised axillaries nodes of cane stalk, popularly known as node chips. These node chips are less bulky, easily portable, and more economical material. The node chip technology holds great promise in the rapid multiplication of new sugarcane varieties: The problem of establishment and initial growth could be addressed by the application of appropriate plant growth regulators and essential nutrients. Construction of the sugar cane eye cutter is a simple pedal-operated machine used in this sugar cane node cutter. Through the development of a sugarcane node cutting machine, slicing the inter-node is made possible, sugarcane stalk can be utilized which is considered as waste in the traditional method.

Krishna Prasad et al [2]. In this paper, the semi-automated sugarcane node chipping machine is fabricated and assembled as per the proposed design. Through the development of the sugarcane node cutting machine, slicing the inter-node is made possible, so that nearly 1.8 tons of sugarcane stalk can be utilized which is considered waste in the traditional method. With the development of the sugarcane node cutting machine, the workload on the labor is reduced and productivity increased. The sugarcane node cutting machine based on the required consideration and objective is made ready with all the required connection and support on the mild steel frame. The outcome of the fabricated machine is to separate the buds from the sugarcane stalk. In the traditional way of plantation, nearly 3 tons of sugarcane is used for plantation per acre. The sugarcane with 2 to 3 buds known as seed is planted continuously. In this traditional method, nearly 1.5 tons of useful sugarcane stalk is being wasted per Acre for plantation.

Suraj S. Magdum et al [3]. In that machine, we are using a platform, hemisphere chipping knife of GI pipe, and roller follower with a simple harmonic motion belt drive used for speed reduction. It is used to chip out the node from sugarcane for sowing purposes. Most of the machines available are using flat cutters that separate the node. But in this project, two two-hemisphere chipping knives provide gentle cutting of nodes without extra loss of sugarcane during sowing. G 1 cutting Blades are used to cut the buds. The blade tip used is sliding which will give a smooth cutting and increase the blade life. The cam and roller follower transmit the rotary motion of the gear shaft into a reciprocating motion of the cutter. The machine is powered by an electric motor. Cutting speed can be calculated as per our motor and reduction gearboxes. A large number of buds can easily be chipped off in this way in a short period. They are using two cutters to double the capacity of a single bud chipper machine. With this sugarcane bud chipper machine, we can separate 30 buds of pieces within one minute time, away that it can handle various sugarcane sizes and diameters.

Sanjay Patil et al [4] studied that Sugarcane planting with traditional methods is costly and time-consuming, and necessary compression of buds in the field is not achieved easily because of stalk planting in sugarcane. In the traditional planting method, great human forces and a high volume of sugarcane stalks in a hectare are required. To solve this problem and mechanize sugarcane planting, we suggest the application of a machine vision system and Image Processing methods to identify nodes from sugarcane and to plant it as a seed by planting machines.

Ashish S. Raghtateet. al [5] designed and fabricated a groundnut sheller machine. It is very cheap and five experiments were performed with peanuts. Since this machine is made for small businessmen or farmers, therefore the work carried out by this machine is less. The decocting process of groundnut by this machine is more economical and faster than the manual process or any other process. "GROUNDNUT SHELLER MACHINE" will save a tremendous time, energy manpower, and financial input of the project, reducing the cost and time considerably which is the backbone of the present world economy.

Javeed Basha et. al. [6] have fabrication and performance tests of an ultraportable crop cutter. To increase the productivity and profit. How to reduce costs and how to solve the problem comes from workers. It is fabricated for cutting various crop varieties during the time of cutting.

Adarsh J Jain et. al. [7] has designed and fabricated a machine whose production capacity is more & machine gets operated on 1 H.P. electric. The fresher and smaller farmer or businessman can start a business by investing less capital. Groundnut decorticator consists of a feed hopper with a flow rate control device, shelling unit, separating unit, and power system.

Abel Roy J. et. al. [8]. In this research work was made to investigate the cutting energy and force required for the pigeon pea crops. The commercially available blade has been attached to the lower end of the arm of a pendulum-type dynamic tester which cut the stalk at 900 to the stalk axis with knife velocity ranging between 2.28m/s to7.23 m/s the diameter of the stem at 42.6 % (wb to) to moisture content. The cutting force I directly proportional to cross cross-sectional area "The stem cutter was designed.

Research gap –

After the study of the various aspects of the agriculture machines, the application & different theories related to the development of sugarcane seed cutting, straw cutting & ground-nut stripper agriculture related machines are also discussed in the previous section. Agriculture has been the backbone of the Indian economy and culture and it will continue to remain as such for a long time in the future.

To farmer safety while using the agriculture machine, we need to analyze how much stress, strain & deflection will be sustained while operating the machine, so we need to simulate and analyze the machine using a CAD model & ANSYS software for stresses, strain analysis, Safety factor & Static structural analysis and to investigate the stresses and deformations induced in the parts well before product development to avoid failure in the later phase of field evaluation.

4. RESEARCH METHODOLOGY

A. Design Calculations:

a. Sugarcane Seed Cutting

The force required to cut the bud of sugarcane F= 400N Bud cutting frequency = 23/min
Leather Belt specification:
ρ= 0.95 g/cm³
μ=0.35
t=5 mm
Permissible stress:
σ= 2.45 N/mm²
Centre distance of pulley = 25 cm
width of belt= 13 mm
thickness=5 mm
Worm gear specification:
Speed ratio:- N2/N1= 30:1
So N2=N1 x30
So N2-23 x30
So N2-690
Pully:-D2=10 cm
V=TD2N2/1000*60
V=(π×10×100x690)/1000*60
V= 3.611m/s

Length of belt:-
L=2C+ ((D1+D2))/2+ (D2-D1)2/4C
L=2×250+ (π(64.28+100))/2+ (100-64.28)2/(4×250)
L=759.1955mm
a 180-2 sin-¹(D2-D1)/2C
a 180-2 sin ¹(100-64.28)/(2×250)
a=171.806°
a=171.806/180×T
a=2.997 rad
The volume of the belt:
V=LXBXT
V=100×13/10×5/10
V-65 cm3/m

Mass of belt:
m=0.95×65 gm
m=0.95×65/1000 kg
m=0.06175kg
mv²=0.06175 × 3.6112
mv²=0.80522
e(μxa)= e(0.35×2.997)=2.854
(T1-mv2)/(T2-mv²)= e(uxa)-2.854
(T1-0.80522)/(T2-0.80522)= e(uxa)=2.854

Max permissible stress in the belt:
0= T1/A
T1= o XA
T1= 2.45 ×5×13
T1= 159.25N

So, T2= 55.798N
P=(T1-T2)XV
P=373.5 W

Torque Calculation
Torque formula:
P= (2*3.14*N*T)/60
where P stands for Power, N stands for Speed, and T stands for Torque. Torque in the motor before speed reduction,
P= (2*3.14*N3*T3)/60
373 = (2*3.14*1400* T1)/60
Hence, T3 = 2.54 (Nm)
We know that,
T3x N3 = T2x N2
Hence, T2 = (T3 x N3)/N2
thus, T2 = (2.54 x 30) T2 =5.08 (Nm)
Assuming the transmission efficiency is 82% hence, T2=5.08x 0.82
Hence, T2 = 4.16 (Nm)

For gearbox :
T2x N2= T1x N1
4.16x 700 Tlx 23
T1= 126.6 (Nm)
Design of shaft:
Total vertical load acting on the pulley:
Wt = T1+T2 +W
= 159.25 + 55.798 +2
= 217.048 N

Bending moment acting on the shaft:
M = Wt x L
= 217.048 × 50
= 10852.4 N-mm

Twisting moment acting on the shaft:
T = 4160N – mm
Equivalent twisting moment:
T_{e} = root(2, (M ^ 2 + T ^ 2))
overline 2) 4^ 2 +4160^ 2) = sqrt[2] (10852.4^ 2 +
=11622.40 N-mm
t = 250N / m * m * 2
sigma yt
for = 4
tau yt =0.5* sigma yt =125 N/mm^ 2
tau_{w} = 125/4
=31.25 N/mm^ 2
tau_{w} = 16T_{e} / pi * d ^ 3
d = (16 x 11622.40)/π x 31.25
=12.37 mm
=13 mm
As we are using 25mm dia. Shaft. So our design is safe.

Cutter Design:
Tyt = 125 N/mm² F= the average force for punching from the literature and the experiment is 400 N.
Tyt = F/A
= 400/2 x (D²/4)
= 400/2 × (25²/4)
= 0.4076 N/mm²

Since, t<<ty
Hence design is safe under shear.

b. Straw Cutting
This part of the machine will cut straw, grass, maize plant and paddy plants etc., among these all the maize plant having more strength.
So the machine requires more power to cut this maize plant. The force required to cut maize plants is 243 N. Now the calculation for
power required for straw cutting operation is given below,
Torque = force × distance
Force = Force required to cut maize plant in N
Distance = 47.5/2 (47.5 is the radius of the pulley on which the blade will be placed)
= 23.75 cm
Torque = 243 × 23.75= 5771.25 × 10-2 Nm
Power (P) = (2 × π × N × T)/60= (2 × π × 150 × 5771.25× 10-2)/60
P = 906.54 W
By considering loss,
Efficiency of belt = 85%
P = 906.54/0.85
= 1066.52Watts
P = 1 HP

c. Groundnut Stripper
Cutting energy = 147 mJ/mm2
Power (P) = 147 × Area
P = 147 × (π × d2)/4
P = 147 × 9.62
(By considering the diameter of groundnut rubber blades is 3.5 mm)
P = 1414.30mJ
P = 1.414 J
This power is for only one groundnut plant, so by considering nearly a bunch of
30 groundnut plants the power is given below, also by taking belt efficiency as 85%l.
P = 1.414 × 30
P = 42.42 J
But, 1J/s = 1 W
P (J) = 42.42 J
P (W) = (42.42 × 480) / (60 × 0.85)
P = 399.24 Watts
P = 0.54 HP
According to power calculation maximum power required is 1 hp. So, the motor is purchased at 1.50hp, because the standard available motor is of that value.

d. Grass stem cutter (DC)

- Voltage V=12 V DC
- Current I=2 Amps (max)
- Speed N=10,000

1. Power Calculation (Electrical Input Power):
We calculate input power using the formula:
Pin=V×I
Pin=12×2=24 Watts
So the input power is 24 Watts.

2. Torque Calculation:
To find the torque, we use the relation between power, torque, and angular speed:
P=τ⋅ωP
Where:

- P is power in watts (24 W)
- ω is angular velocity in radians per second
- τ is torque in Nm

First convert RPM **to rad/s:**

$$\omega = \frac{2\pi \cdot \text{RPM}}{60} = \frac{2\pi \cdot 10000}{60} \approx 1047.2 \text{ rad/s}$$

Now calculate torque:

$$\tau = \frac{P}{\omega} = \frac{24}{1047.2} \approx 0.0229 \text{ Nm}$$

So, the output torque is approximately 0.023 Nm.

3. Mechanical Work Done (on Grass Stems):
The motor operates at full power for 10 seconds while cutting a bundle of grass stems:
Energy used=P×t=24×10=240 Joules
That is the energy available to perform mechanical work i.e., to cut the stems.

B. Components Required

Power Source (Motor):

- The electric motor is an electric machine used to convert electrical energy into mechanical energy, for smaller loads such as in domestic applications.
- Although traditionally used in fixed-speed services, induction motors are increasingly used with variable frequency drives in variable speed services. Power of motor= 1 hp. Speed of motor 1400 rpm.

Gearbox:

- A gearbox is used to reduce shaft speed and control rotational movement, increasing torque by lowering the output shaft speed.
- This mechanical advantage enhances torque while reducing speed. Some gearboxes, like helical and worm gear systems, transmit output power efficiently. A worm gearbox, smaller than a spur gear, has its shafts positioned at 90° to each other. With one revolution of the worm, it advances a single gear tooth.

Shaft:

- A solid shaft rotating at 1440 rpm is assumed to be made of mild steel. A Shaft is a rotating element, usually circular in cross-section, line shaft is used to transmit power from one shaft to another, or from the machine which produces power, to the machine which absorbs power.

V-Belt Pulley:

- To transmit power from the motor to the cutter blade shaft this V pulley is used. V belt drive arrangement is used to transmit power from the motor to a shaft which is connected to the cutter mechanism.
- The use of V-belts in multiple, allowed drives with a much variable range of power capacity than ever before obtainable using single belt drives.

Universal Joint:

- A universal joint is a joint or joint that connects rigid shafts whose axes are inclined relative to each other. It is commonly used on shafts that transmit rotary motion.
- It consists of a pair of hinges placed close together, oriented at 90 ° to each other, connected by a transverse axis.

Pedestal Bearing:

- It has two Pedestal bearings that are extensively used for furnishing support for a rotating shaft with the help of compatible comportments.
- It's used for long shafts taking intermediate support.

Clutch:

- Clutch is used to allow motor power to be applied gradually when a groundnut stripper is starting out it is operated manually by lever. It is connected to the shaft.

High Speed DC Motor & Cutter Blade :

- The cutter /Blade is attached to High power RPM motor. Enough to cut crops.
- It has RPM up to 10000 apro.

- With the help of high speed motor , we can easily harvest the crops.
- As cutting of crop is more easy & low cost for farmers with this technique.
- The cutter blade is size upto 6 inch , easily to cut big crops also.

C. Schematic Diagram

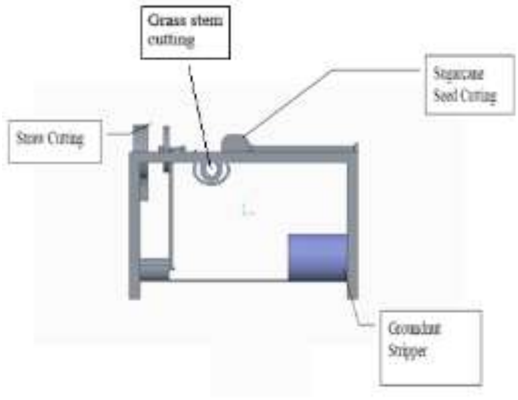

Fig1. Schematic Diagram

Designed and built a machine, where it is possible to perform the following operations,

Sugarcane seeds cutting; Groundnut stripping; Straw cutting.

The different parts of this machine will be mounted on a sturdy frame. The wheels will be attached to this frame, so that it can move around the farm and it is a multipurpose cutter, to work in different conditions.

a. Sugarcane Seed Cutting

When the single-phase motor is activated, it operates at 1400 rpm, which is reduced to 700 rpm via a belt and pulley drive.

This speed is further reduced to 23 rpm by a gearbox with a 1:30 worm and worm wheel ratio. The gearbox is connected to a cam that converts rotary motion into reciprocating motion for the cutter.

As the cutter advances, it cuts the sugarcane, which is manually fed. During the return stroke, the cutter releases sugarcane sprouts, which are collected in a collector. This system efficiently converts rotational motion into reciprocating motion for the cutting process.

b. Groundnut Stripper

It consists of hollow cylinder with a rod welded on its periphery. The electric motor which is connected to the external power supply transmitted to the shaft.

The rotating shaft is mounted on the roller cylinder. Groundnuts are supplied in a rotating blade that will separate the groundnut from the plants and shelling.

c. Straw Cutting

It consists of two blades which is mounted in a circular ring that is connected to the motor through the belt drive. Rotating blades will cut the straw into small pieces.

A hopper with a high-speed cutter, driven by a 10,000 RPM motor, will be incorporated into the machine. This addition will efficiently cut the stems of various crops, enhancing the machine's capability to handle different types of crops with ease and improving operational efficiency.

d. Grass stem Cutter

A grass stem cutter with a high-speed DC motor and self-sharpening blades offers efficient, precise cutting. Adjustable height, safety guard, and lightweight design enhance usability. DC power boosts mobility, making it ideal for trimming grass, weeds, branches, and residues.

A hopper with a high-speed cutter, driven by a 10,000 RPM motor, will be incorporated into the machine. This addition will efficiently cut the stems of various agricultural crops, enhancing the machine's capability to handle different types of crops with ease and improving operational efficiency.

D. Construction & Working Principle

Fig.2. Actual photo of multi-purposed cutting machine

Working Principle: Designed and built a machine, where it is possible to perform the following operations,
Sugarcane seeds cutting; Groundnut stripping; Straw cutting.
The different parts of this machine will be mounted on a sturdy frame. The wheels will be attached to this frame, so that it can move around the farm and it is a multipurpose cutter, to work in different conditions.

a. Sugarcane Seed Cutting

When the single-phase motor is turned on, it starts running at 1400 rpm. The belt and pulley drive reduce speed to 700 rpm. This speed is transmitted to the gearbox which contains the worm and the worm wheel which has a gear ratio of 1:30. The speed is now reduced to 23 rpm. A cam is connected to the gearbox which converts the rotary motion into the reciprocating motion of the cutter. As the cutter advances, it cuts the sugarcane which is manually fed. When the cutter moves backward, it releases sugarcane sprouts and these sprouts are collected in the collector. With this method, the rotational motion of the motor is converted and delivered as a reciprocating motion at the end of the cutter and, finally, the removal of the yolk is also achieved.

b. Groundnut Stripper

It consists of a hollow cylinder with the rod welded on its periphery. The electric motor which is connected to the external power supply transmitted to the shaft. The rotating shaft is mounted on the roller cylinder. Groundnuts are supplied in a rotating blade that will be separating the groundnut from the plants and shelling.

c. Straw Cutting

It consists of two blades which is mounted in a circular ring that is connected to the motor through the belt drive. Rotating blades will be cut the straw into small pieces.

d. Grass Stem Cutting

A grass stem cutter with a high-speed DC motor and sharp metal blades enhances cutting efficiency and precision. The motor ensures rapid operation, reducing manual effort. Adjustable blade height allows customization for different grass types, while self-sharpening blades ensure durability. A safety guard prevents accidental contact, improving user safety. Its lightweight and portable design makes it easy to handle. A battery-powered option increases mobility, allowing use in remote areas. The cutter can also be used for trimming weeds, small branches, and crop residues, making it a versatile agricultural tool for farmers and gardeners.

E. Formulation of Research Problem for FEA

Problem formulation for Finite Element Analysis (FEA) in a multi-purpose cutting machine for agriculture involves several steps:
Problem Formulation: -
1)Define the Objective: Start by clearly defining the objective. In this case, it could be improving the cutting performance, reducing wear and tear, enhancing safety, or any other specific goal.
2) Identify Key Components: Identify the key components of the cutting machine that are critical to its performance, such as blades, gears, motors, and structural elements.
3) Material Properties: Collect material properties data for the components. This includes information on the tensile strength, modulus of elasticity, and density of the materials used.
4) Load and Boundary Conditions: Determine the loads and boundary conditions the machine experiences during operation. For an agriculture cutting machine, this may include the forces exerted by the cutting process, vibrations, and external loads during transportation.
5) Geometry and CAD Modeling: Create a detailed CAD model of the cutting machine and its components. This model should accurately represent the machine's geometry.
6) Mesh Generation: Generate a finite element mesh for the model. The mesh divides the geometry into smaller elements, which are necessary for FEA calculations.
7) Define Analysis Type: Choose the type of FEA analysis to perform. This could be a static analysis, depending on the specific problem you are addressing.
8) Material Assignment: Assign material properties to the elements in the mesh based on the components' materials.
9) Apply Loads and Constraints: Apply the loads and boundary conditions identified to the FEA model.
10) Solve the Model: Use FEA software to solve the model and obtain results. These results may include stress distributions, deformation patterns, and other relevant data.

11) Evaluate Results: Analyze the results to determine if the machine meets the desired performance criteria or if any areas of concern are identified.

12) Documentation: Document the entire FEA process, including assumptions, inputs, and results, for future reference and potential regulatory compliance.

By following these steps, you can effectively identify and formulate FEA for a multi-purpose cutting machine in agriculture, helping to improve its performance, durability, and safety.

Basic Steps & Phases Involved in FEA:

Steps: -

- Discretization
- Selection of approximation of functions
- Formation of elemental stiffness matrix
- Formation of the total stiffness matrix
- Formation of element loading matrix
- Formation of total loading matrix
- Formation of the overall equilibrium equation
- Implementation of boundary condition
- Calculation of unknown nodal displacements
- Calculation of stresses and strains.

Phases :

Pre-Processing: Here a finite element mesh is developed to divide the given geometry into subdomains for mathematical analysis and the material properties are applied and the boundary Conditions.

Solution: In this phase governing matrix equations are derived and the solution for the primary quantities is generated.

Post-Processing: In the last phase, checking the validity of the solution generated, examinations of the values of primary quantities such as displacements and stresses, and errors involved are carried out.

5. MODELING & ANALYSIS

A. Software Modelling

The 3D isometric view of a multi-purpose cutting machine, including different operations by Solid Works CAD software.

Fig. 3: 3-D View of multi-purposed cutting machine

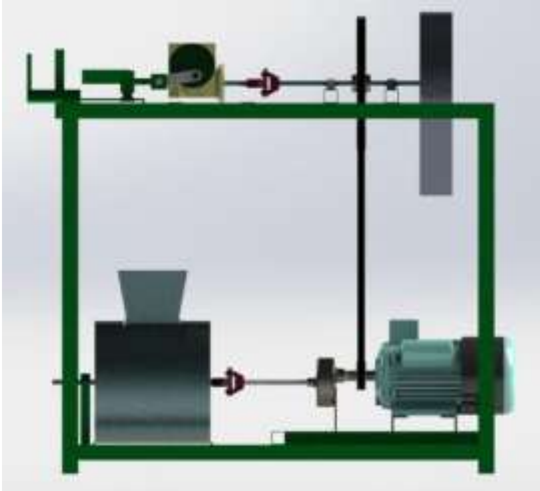

Fig. 4: Front View of multi-purposed cutting machine

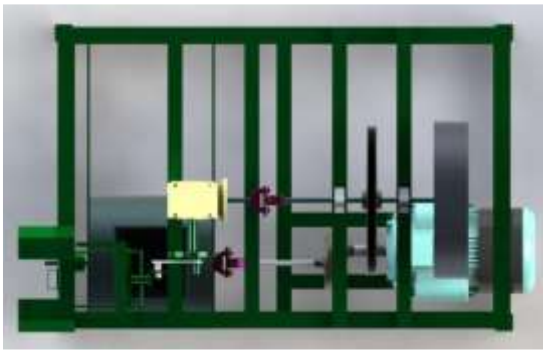

Fig. 5: Top View of multi-purposed cutting machine

B. Analysis using FEM

I. Mesh of Model:

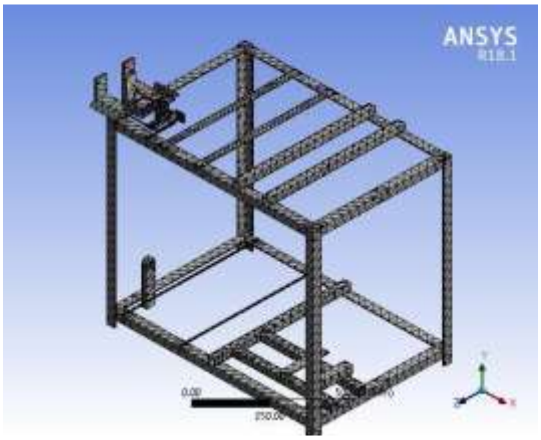

Fig. 6: Model (A4) Mesh

Table 1. Nodes and Elements of Model

Statistics	
Nodes	22590
Elements	9882

II. Forces Exerted on Model:

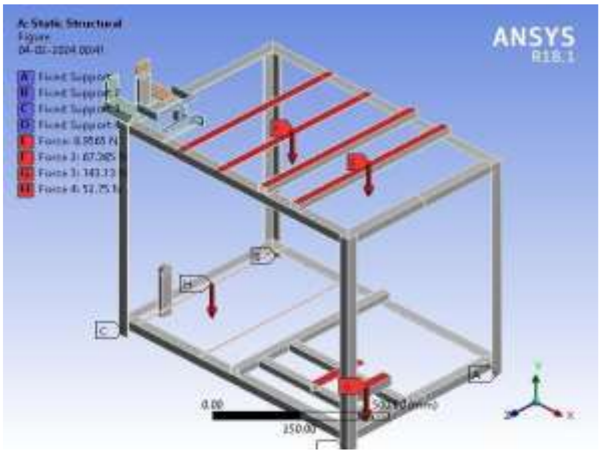

Fig. 7: Forces on Model

Table 2. Forces on Model

Object Name	Fixed Support	Fixed Support	Fixed Support	Fixed Support	Force 1	Force 2	Force 3	Force 4
Magnitude	A	B	C	D	E=8.9565N (ramped)	F=67.365N (ramped)	G=143.13N (ramped)	H=52.75 N (ramped)

III. Total Deformation of Model:

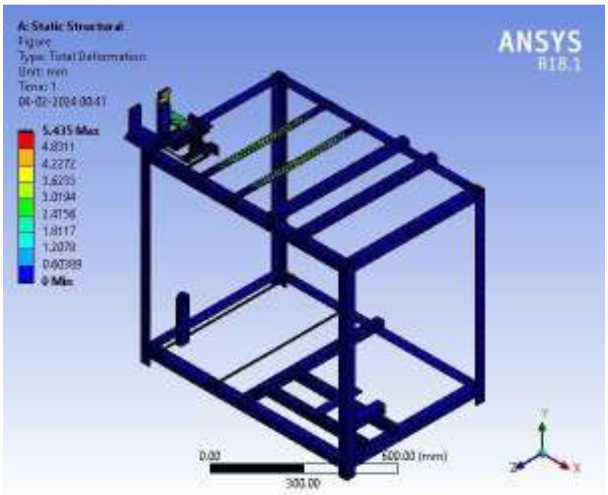

Fig. 8: Total Deformation of Model

Table 3. Deformation of Model

Time [s]	Minimum [mm]	Maximum [mm]
1.	0.	5.435

IV. Equivalent Stress of Model:

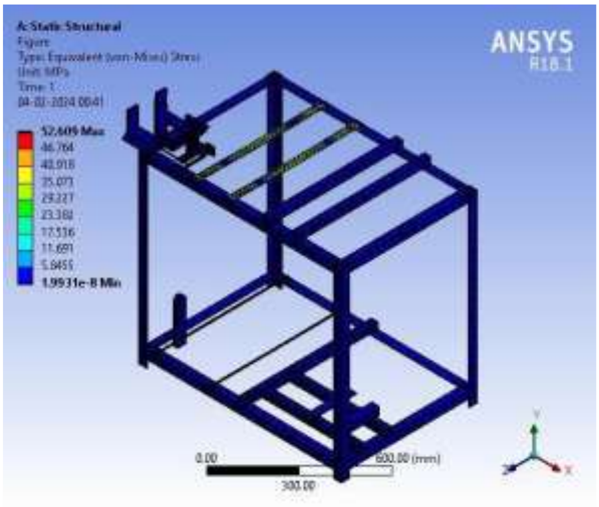

Fig 9: Equivalent Stress of Model

Table 4. Stress of Model

Time [s]	Minimum [MPa]	Maximum [MPa]
1.	1.9931e-008	52.609

V. Equivalent Elastic Strain of Model:

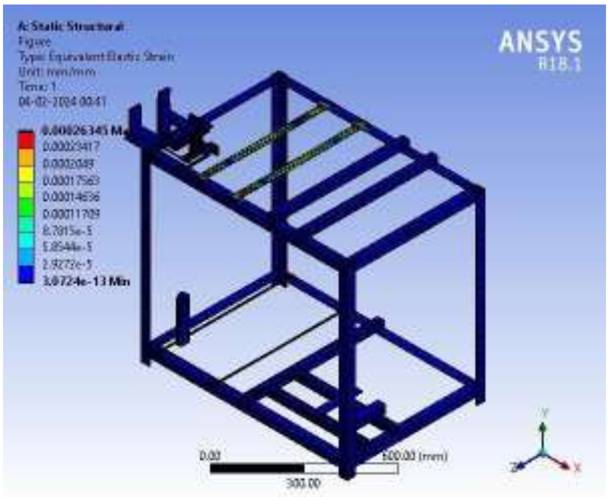

Fig.10: Equivalent Elastic Strain of Model

Table 5. Elastic Strain of Model

Time [s]	Minimum [mm/mm]	Maximum [mm/mm]
1.	3.0724e-013	2.6345e-004

VI. Safety Factor:

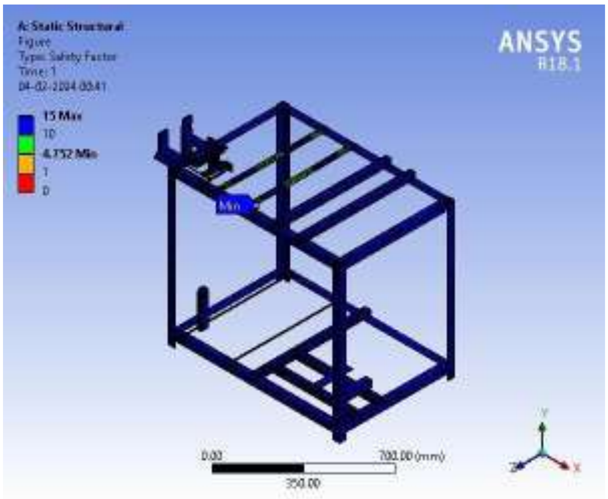

Fig. 11: Safety Factor of Model

Table 6. Safety Factor Value of Model

Time [s]	Minimum	Maximum
1.	4.752	15.

Finite Element Simulation (FEM) was conducted on various components of the implement using ANSYS R18.1 software to perform static structural analysis. A three-dimensional model was developed and uploaded into the software, where standard material properties such as Young's Modulus, ultimate tensile strength, yield strength, Poisson's Ratio, and density were assigned. Proper connections between different components were established, and an appropriate meshing method and size were selected to create the mesh structure. Theoretical calculations, considering shock and fatigue factors, were carried out to determine applied forces, moments, and boundary constraints. The resulting Von Mises stress and total deformation were analyzed, leading to design modifications for optimal part dimensions. The FE analysis results were represented using colored contour plots, showing stress levels and deformation variations.

For the mainframe, applied forces and boundary conditions were established, and the results showed a total deformation of 5.435 mm with a maximum equivalent stress of 52.609 N/mm². The maximum equivalent elastic strain of the model was calculated as 2.6345e-004 mm/mm. To ensure structural safety, a maximum safety factor of 15 was considered for the main frame. These analyses helped optimize the design, ensuring durability, efficiency, and reliability in real-world applications.

6. RESULTS AND DISCUSSION

The results obtained from the Finite Element Analysis (FEA) provide critical insights into the structural behavior of the implement. The total deformation observed in the main frame was 5.435 mm, which is within acceptable limits for safe operation. The maximum equivalent stress induced in the model was 52.609 N/mm², which is well below the yield strength of the material, ensuring structural integrity under applied loads. Additionally, the maximum equivalent elastic strain recorded was 2.6345e-004 mm/mm, indicating that the deformation is minimal and within the elastic range of the material.

The analysis of different components showed stress concentration areas that required optimization. Design modifications were implemented to reduce stress accumulation and improve overall durability. The results were presented in the form of colored contour plots, highlighting the variation in stress levels and deformation across different regions of the structure.

A safety factor of 15 was selected for the main frame, ensuring that the implement can withstand unexpected loading conditions without failure. The simulation results confirm that the designed model is structurally stable, efficient, and capable of performing under real-world agricultural conditions. These findings will contribute to the development of a more reliable and optimized agricultural implementation.

Table 7: Summary of FEA Results

Parameter	Value	Permissible Limit
Total Deformation	5.435 mm	<10 mm
Max. Equivalent Stress	52.609 N/mm²	Below Yield Strength
Max. Equivalent Strain	2.6345e-004 mm/mm	Elastic Range
Safety Factor	15	Standard Value

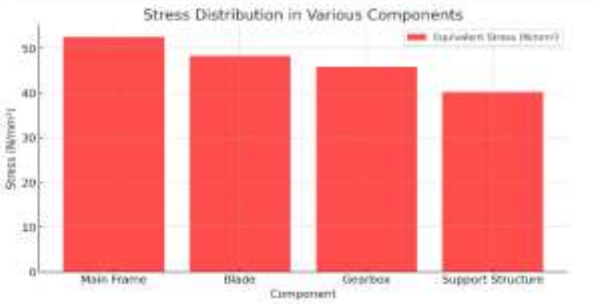

Fig. 12: The graphs represent the stress distribution in various components

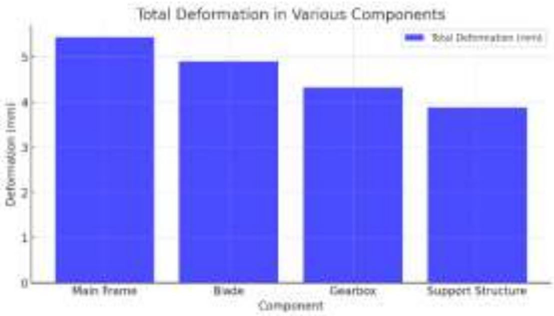

Fig. 13: The graphs represent the total deformation in various components

The obtained FEA results validate that the designed multipurpose cutting machine is structurally efficient and reliable. The observed deformations and stresses remain well within acceptable limits, preventing premature failure or excessive wear. By optimizing stress concentration areas, the implement's durability was improved. Additionally, the safety factor ensures robustness against unforeseen loads.

The use of FEA in agricultural machinery design allows for predictive performance assessment before field deployment, ultimately improving machine efficiency and longevity. Future work can focus on further material optimization to enhance cost-effectiveness without compromising strength.

The FEA analysis confirms the multipurpose agricultural cutting machine's stability and efficiency. With deformation and stress values within acceptable limits, the machine is safe for operation. Implementing design modifications based on stress analysis further improves performance, ensuring durability and reliability in agricultural applications.

7. ADVANTAGES, DISADVANTAGES, AND APPLICATION OF MACHINE

A. Advantages

1) Labour cost is reduced.
2) Wastage of sugarcane is reduced
3) Easy in construction.
4) Easy to maintain.
5) It reduces time.
6) It does not create air pollutants.

B. Disadvantage

1) The machine is heavyweight.
2) The machine creates more noise.

C. Application

1) It is used in the agriculture sector.
2) It helps institutions such as the agricultural university, the agricultural university, in School children to learn about the agricultural operation of farmers.

7. CONCLUSION

In the robust multi-purpose cutting machine, three individual operations are combined. Using this machine it is possible to reduce the problem of labor crises as it makes the process faster and the manpower required to operate the machine is also less. It performs more than one operation, so you can save processing time. In the sugarcane seed-cutting operation, the sugarcane waste can be controlled and the cut seeds are easy to sow. In the peanut shelling operation, instead of 10-20 jobs per acre, only two jobs can separate the peanuts from the plant using this machine. In the rice husking operation, while separating the rice from the grinding waste, more traditional methods will be used. Using this machine, the waste will be less, and instead of 5-6 jobs, only 2 jobs can perform the same operations in a minimum time. If this machine is used by the maximum number of farmers, surely the farmer can overcome the problem of job crises, thus reducing the number of jobs. Cost and process become faster and easier.

Based on the results obtained in this study, the following specific conclusions can be drawn:

1) The three-dimensional model of a multi-purposed cutting machine for agriculture was successfully created in SolidWorks 2021, and optimum part dimensions were achieved by doing FE analysis in ANSYS R18.1 workbench software. The simulation was very helpful in understanding the effect of different forces on the model.

2) The stress-induced and the deformation of each component were found to be less than the allowable stress and maximum deformation of the material selected which signifies the safe design of implementation.

3) FEM enables optimization and simulation of the complex agricultural machinery and investigates the stresses, deformations, and safety factors induced in the parts well before product development to avoid failure in the later phase of field evaluation.

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