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FINITE ELEMENT ANALYSIS (FEA) OF MULTI-PURPOSE CUTTING MACHINE FOR AGRICULTURE USES

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Abstract - FEM has high potential to be applied in other areas, such as in agricultural engineering. This paper aims to present a review of the FEM applications in these agricultural engineering areas. One of the main numerical methods used in modeling and simulations is the finite element method (FEM). This research is focused on agricultural mechanization, agricultural product processing, since these are agricultural engineering areas with highest number of publications using FEM. The 3D-dimensional model of Multi - purposed cutting machine was created in SolidWorks 2021 and then the stress analysis was carried out using Finite Element Analysis (FEA) to obtain optimum dimensions of different parts and to analyze the maximum stress and deformation in each component of the system. FEM enables to optimize and simulate the complex agricultural machinery 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.

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

1. INTRODUCTION

The Finite Element Method (FEM) is a numerical technique for finding approximate solutions to boundary value problems for partial differential equations. In simple terms, FEM is a method for dividing up a very complicated problem into small elements that can be solved in relation to each other. Useful for problems with complicated geometries, loadings, and material properties where analytical solutions cannot be obtained. FEA uses a complex system of points called nodes which make a grid called a mesh. This mesh is programmed to contain the material and structural properties which define how the structure will react to certain loading conditions. Nodes are assigned at a certain density throughout the material depending on the anticipated stress levels of a particular area. Regions which will receive large amounts of stress usually have a higher node density than those which experience little or no stress. Points of interest may consist of fracture point of previously tested material, fillets, corners, complex detail, and high stress areas. The mesh acts like a spider web in that from each node, there extends a mesh element to each of the adjacent nodes. This web of vectors is what carries the material properties to the object, creating many elements.

1.1 Literature Review -

1) 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 rapid multiplication of new sugarcane varieties: The problem of establishment and initial growth could be addressed by application appropriate plant growth regulators and essential nutrients. Construction of the sugar cane eye cutter is simple pedal operated machine is used in this sugar cane node cutter. Through the development of sugarcane node cutting machine, slicing the inter- node is made possible, sugarcane stalk can be utilized which is considered as wastage in traditional method.

2) 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 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 as wastage in traditional method. With the development of the sugarcane node cutting machine the workload on the labour is reduced and the 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

3) 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 reductio. It is used to chip out the node from sugarcane for sowing purpose. Most of the machines available are using flat cutters that separate the node completely. But in this project using two hemisphere chipping knifes which provides gentle cutting of node without extra loss of sugarcane during sowing. G 1 cutting Blades are using to cut the buds. 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 gear shaft in to a reciprocating motion of the cutter. The machine is powered by electric motor. Cutting speed can be calculated as per our motor and reduction gear boxes. Large number of buds can easily be chipped off in this way in a short period of time. They are using two cutters to double the capacity than that of single bud chipper machine. By this sugarcane bud chipper machine, we can separate 30 buds of piece within one minute time, away that it can handle various sugarcane sizes and diameter.

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

5) 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 businessman or for 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 manual process or any other processes. "GROUNDNUT SHELLER MACHINE" will save the tremendous time, energy manpower and save financial input of the project, reducing the cost and time considerably which is the backbone of the present world economy.

6) Arjun Vishwakarma et al [6] has designed and fabricated a machine whose production capacity is more & machine gets operated on 1 H.P. electric. The fresher and small farmer or business man can start business by investing less capital. groundnut decorticator consists of feed hopper with a flow rate control device, shelling unit, separating unit and power system.

7) Javeed Basha et.al [7] has fabrication and performance test of an ultraportable crop cutter. To increase the productivity and profit. How to cutting reduce the cost and how to solve the problem comes from workers. It is fabricated for cutting various crop varieties during the time cutting.

8) Atul R. Dange, S. K. Thakare, I. Bhaskarrao and Umar farooq momin.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 it has been attached to the lower end of the arm of 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 stem at 42.6 % (w b) moisture content. The cutting force I directly proportional to cross sectional area "stem cutter was design.

1.2 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 machine also discussed in previous section. Agriculture has been the backbone of Indian economy and culture and it will continue to remain as such for a long time in future. To farmer safety while using the agriculture machine, we need to analysis how much stresses, strain & deflection will be sustained while operating machine, so we need to simulate and analysis machine using 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

2. METHODOLOGY –

Sequence I: - Sugarcane Seed Cutting

When the single-phase motor is turned on, it starts running at 1400 rpm. Belt and pulley drive reduces speed. This speed is transmitted to the worm gearbox. A cam is connected to the gearbox which converts the rotary motion into reciprocating motion of the cutter.

Sequence II: Straw cutting

This part of 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

Sequence III: Groundnut Stripper

The power of motor is transmitted to the blades through shaft. The groundnut plant will be feed to blades with the help of safety hopper by manually. Then rotating blades will separate the groundnut from the plant. After that these separated groundnuts collected through slider.

3. Objectives –

The primary objectives of Finite Element Analysis (FEA) are as follows:

- Stress and Deformation Analysis: Determine how a structure or component responds to various loads and forces, calculating stresses and deformations at different machine components.
- Performance Evaluation: Assess the performance of a design or system under different conditions, such as static or dynamic loading
- Failure Prediction: Predict and understand the failure modes and failure mechanisms of structures or components, helping to prevent catastrophic failures. Determine the factors contributing to fatigue, fracture, or deformation failures.
- Cost Reduction: Reduce development costs by minimizing the need for physical prototypes and testing.

3.1 Construction & Working Principle –

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. Belt and pulley drive reduces 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 reciprocating motion of the cutter. As the cutter advances, it cuts the sugarcane which is manually fed. When the cutter moves backwards, 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 hollow cylinder with the rod welded on the 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 blades 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 connected to the motor through the belt drive. Rotating blades will be cut the straw into small pieces.

Construction:

Fig -1: Actual photo of multi-purposed cutting machine

3.2 Formulation of Research Problem –

Problem formulation for Finite Element Analysis (FEA) in a multi-purpose cutting machine for agriculture involve 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, 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 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 condition identified to 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.

14) 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 total stiffness matrix
- ✓ Formation of element loading matrix
- ✓ Formation of total loading matrix
- ✓ Formation of 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 equation are derived and the solution for the primary quantities is generated.

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

4. MODELING & ANALYSIS –

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

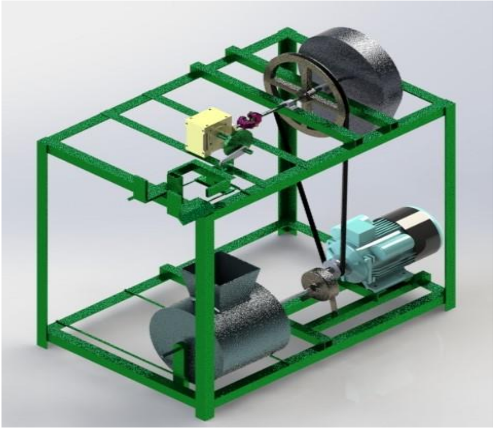

Fig -2: 3-D View of multi-purposed cutting machine

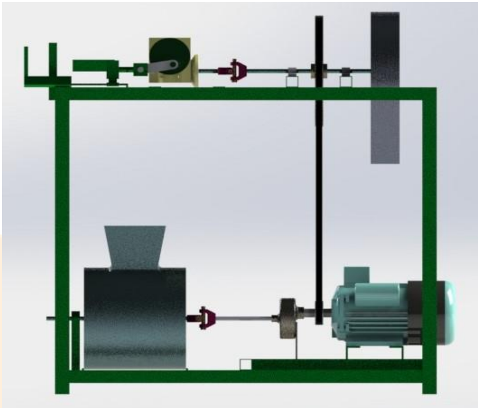

Fig -3: Front View of multi-purposed cutting machine

Fig -4: Top View of multi-purposed cutting machine

Analysis:

A. Mesh of Model:

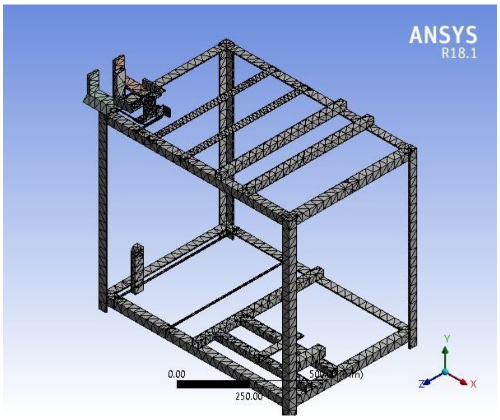

Fig -5: Model (A4) Mesh

Table 1. Nodes and Elements of Model

Statastics	
Nodes	22590
Elements	9882

B. Forces Exerted on Model:

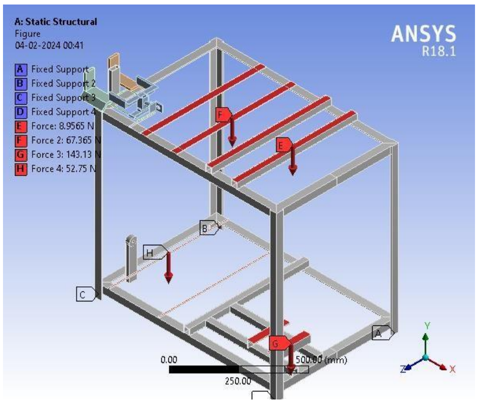

Fig -6: Forces on Model

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)

C. Total Deformation of Model:

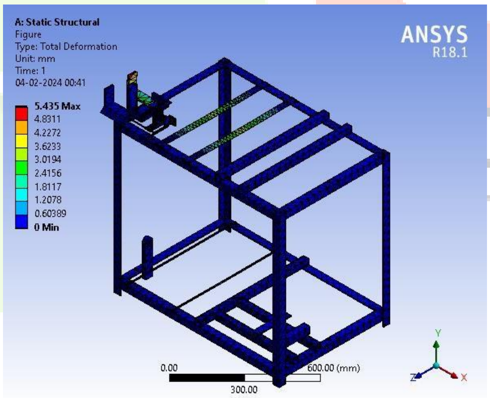

Fig -7: Total Deformation of Model

Table 3. Deformation of Model

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

D. Equivalent Stress of Model:

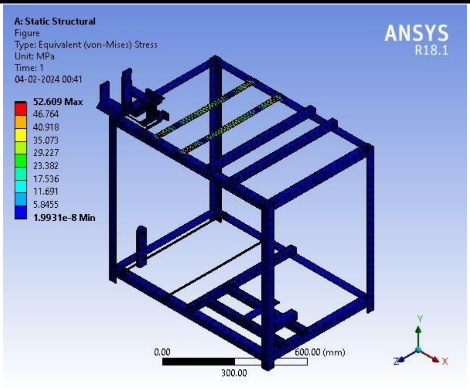

Fig 8: Equivalent Stress of Model

Table 4. Stress of Model

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

E. Equivalent Elastic Strain of Model:

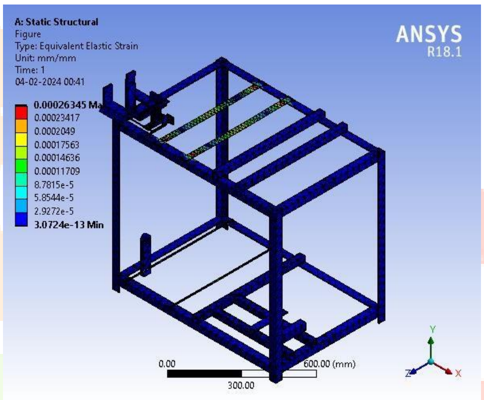

Fig 9: Equivalent Elastic Strain of Model

Table 5. Elastic Strain of Model

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

F. Safety Factor:

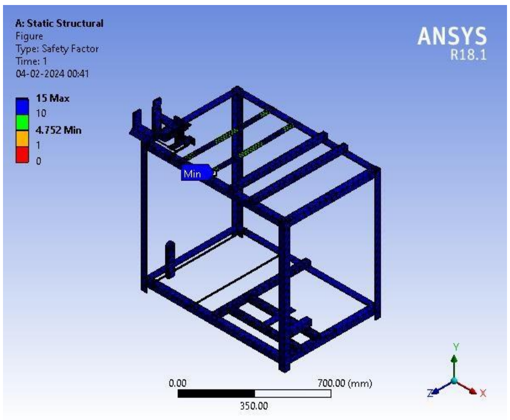

Fig 10: Safety Factor of Model

Table 6. Safety Factor value of Model

Time [s]	Minimum	Maximum
1.	4.752	15.

5. RESULT AND DISCUSSION -

1) Finite Element Simulation of Various Components: Developed three-dimensional model of implement was uploaded in ANSYS R18.1 software for doing static structural analysis on various components. Standard material properties like Young's Modulus, ultimate tensile strength, yield strength, Poissons's Ratio, density, etc. were provided to the software for further stress analysis. Proper connections between different components were established. Meshing method and size were selected to create mesh structure of different components. Theoretical calculations were done for various components taking shock and fatigue factors into consideration, and resulting values were used to apply force, moment and boundary constraints on the designed 3D model. The results of induced Von Mises stress and total deformation were analyzed, and necessary design changes were done accordingly in the 3D model to achieve optimum part dimensions for product development. Results of FE analysis are presented here in the form of coloured contours representing stress levels and deformation variation on the model.

2) Finite element analysis of the main frame: Applied forces and boundary conditions for FE analysis of the main frame are shown in Fig. 5. The results of finite element analysis are shown in Figs.6,7,8 and 9. The total deformation(5.435mm) of the model should have maximum equivalent stress induced (52.609 N mm^{-2}). The maximum equivalent Elastic Strain of Model has 2.6345e-004mm/mm. Therefore, Safety factor selected for main frame was maximum =15.

6. CONCLUSION -

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

1) The three-dimensional model of 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 to understand 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 implement.

3) FEM enables to optimize and simulate the complex agricultural machinery and to investigate the stresses, deformations and safety factor induced in the parts well before product development to avoid failure in the later phase of field evaluation

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