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Design of Crushing Machine for Agricultural Waste Crops

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Abstract **- Cutting, Crushing and then loading is a continuous process carried out in all agricultural fields. These processes are important so that the land become ready for the planting of new crops and can be completed by using latest mechanical machineries. In agricultural fields, it always seems that the residual part of crops such as stalks; roots etc. are removed with the help of hands. This paper discusses about the design and fabrication of crop cutter to crush various type of crops. A cutter is design and analyzes using analytical and finite element analysis. FE analysis has been carried out for single blade and for complete cutter which reveals that the blade may not fail for any type of crop. The experimentation has been perform for various type of crops for dry condition only which are crush up to 8cm to 15cm of short pieces.**

Index terms **–** Crop crusher, cutter, FEA, solid 186, Ansys.

I. INTRODUCTION

In times of feed shortages, livestock producer often consider using unusual plant material as stock feed. However, producers need to be aware that chemical residues may be present in these alternative stock feeds and may present a risk of unacceptable residues livestock, they produced. The cutter crush is available in two models. Powerful jaws and strong blade crush concrete and cut through round steel, re-bar, wire mesh, angle iron and i-beams. Whether mounted on a bobcat or excavator, this attachment provides incredible crusher power for hard-to-reach demolition jobs that require minimal noise and vibration.

Now there is requirement of a machine to reduce the human effort and cost of crushing and loading. In this project, fabrication of crusher will be done for the plants in the farm and to load it simultaneously in the trolley.

Nowadays cost reduction in every part of a production plant is a major key to surviving in global as well as in regional markets. Therefore, for quarries it is also necessary to review where money can be saved in order to increase profits and face challenging market prices. In this context, considerations regard-ing applications, case studies and the economic effects of fully mobile crushing and conveying systems are made.

The crop crusher is designed for effective utilization of agro straw resources; the successful development of it can not only avoid the waste of lots of bioman material but also protect the environment & develop the renewable energy. Solid fuel made of stow stalks & straw has the advantage of high calorific value, long burning time, energy storage & clean burning processing featured with reliable performance, simple & convenient operations widely usage range, the straw crushing machine can be used to crush corn stalks, straws, peanut shell, bean straws etc.

The crusher has specific scopewhich is going to be made with features of crushing all types of crops stalks after harvesting. This is not only reduces labour work but also complete the work in short time as fast as possible. It is nothing but the time consuming crusher which gives best effect and make land ready for the harvesting next crops.

II. WORKING MECHANISM

The mechanism of crusher consists of Drum, Blades, Pulley, and Conveyer belt and Motor. Two drums with 8 and 12 blades of rectangular shape are used for crushing which mesh together for cutting of crops between blades. The power is transmitted from the motor independently to each drum via V-belt drive which rotates at a speed of 837 rpm. The complete system will mounted on front face of heavy vehicle which pull the crops inside it due to rotation of cutter and transfer small pieces of crops on back side. The schematic of crusher is shown as below in figure 1.

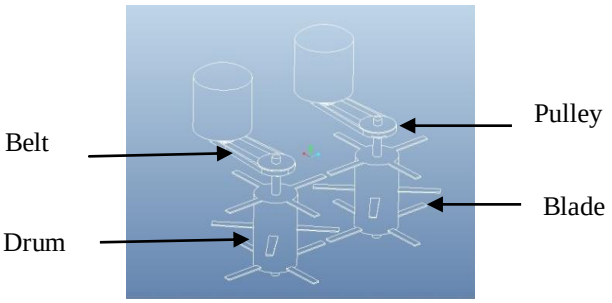

Figure 2. Mechanism of crushing machine

III. ANALYSIS OF CUTTER

An analysis of cutter having rectangular blade is carried out using analytical experimental and finite element analysis to define its strength by considering a steel material having 256MPa yield strength and 200GPa modulus of elasticity. The blade acquire sudden load along its area may fail for hard or larger diameter of crop. So the analysis defines the strength to crush the crops in number of pieces.

A. Analytical Analysis

The cutter is the important part of crusher. At first it is analyzed by considering a simple cantilever beam for point load and uniformly distributed load at various loading condition and find its bending strength and deformation. Approximately it is considered as the crops will strikes on every blade and sustains a maximum load of 200N. Hence the analysis has been carried out for forces of 40 N to 200 N which reveals the blades are safe up to loading condition of 200 N. A blade for point load is shown in figure 2 and

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for uniformly distributed load is shown in figure 3. The results for bending stresses and its deformation for point load are shown in table 1.

Figure 2. Blade with point load

The dimensions decided for the analysis are as follows which are used to found out section modulus, bending stress and deflection of blades by using following relations.
Length = 6.2 cm, width = 2.5 cm, Thickness = 4 mm

Sectional modulus, $Z = \frac{bh^2}{6}$

Bending stress (MPa), $\sigma_b = \frac{Pl}{Z}$

Deflection (mm) $\delta = \frac{Pl^3}{3EI}$

TABLE 1. ANALYTICAL ANALYSIS OF BLADE FOR POINT LOAD AT VARIOUS LOADING CONDITION

Load	40N	75N	100N	150N	200N
Z (mm^4)	6458.33	6458.33	6458.33	6458.33	6458.33
σ (MPa)	0.384	0.72	0.96	1.44	1.92
δ(mm)	0.19	0.369	0.492	0.738	0.984

The bending stress and deflection of blade for uniformly applied load is shown in table 2.

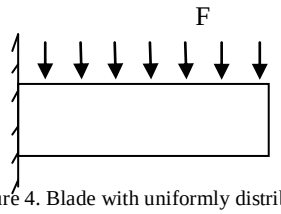

Figure 4. Blade with uniformly distributed load

By using following relations for blade, the section modulus, bending stress, deflection of beam for uniformly distributed load has been calculated.

Sectional modulus, $Z = \frac{bh^2}{6}$

Bending Stress (MPa), $\sigma_b = \frac{Wl^2}{2Z}$

Deflection (mm), $\delta = \frac{Wl^3}{8EI}$

TABLE 2. ANALYTICAL ANALYSIS OF BLADE FOR UNIFORMLY DISTRIBUTED LOAD AT VARIOUS LOADING CONDITION

Load	40 N	75 N	100N	150N	200N
Z (mm^4)	2562.66	2562.66	2562.66	2562.66	2562.66
σ (MPa)	11.90	22.32	29.76	44.76	59.52
δ (mm)	0.0738	0.138	0.184	0.276	0.369

B. Finite Element Analysis Of Blade and Cutter

In mathematics, the finite element analysis (FEA) method is a numerical technique for finding approximate solutions to boundary value problems for partial differential equations. It uses subdivision of a whole problems domain into simpler part, called finite elements, and variational methods from the calculus of variations to solve the problem by minimizing an associate error function.

For FE Analysis using ANSYS, an IGES file of blade is imported in environment of ANSYS. The imported model is mesh with hexahedral solid 186 element, having 3 degree of freedom in X, Y, and Z direction. The model is mesh with 304 elements and 1893 nodes. The general process of FEA by using software is divided into three main phases: preprocessing, solution, and post processing. For boundary condition a blade is fixed at one end and force is applied at front face. The results obtained are depicted in table 3. A solid model of individual blade with meshing and complete cutter is shown in figure 4 and results for single blade are shown in figure 5.

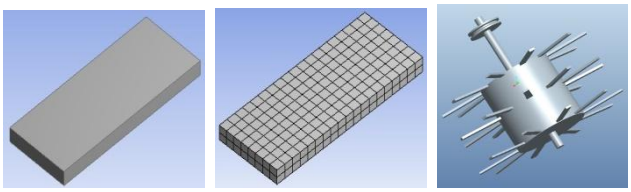

Figure 4. Solid model of blade and cutter with blades

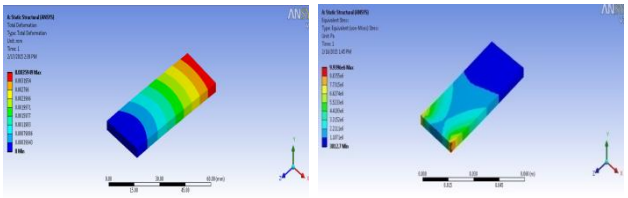

Figure 5. FE Analysis of blade of cutter.

TABLE3. RESULTS FOR FE ANALYSIS OF BLADE

LOAD	40N	75N	100N	150N	200N
Equivalent Stress (MPa)	10.89	22.033	27.078	41.046	58.987
Total Deformation (mm)	0.0176	0.1294	0.1798	0.2681	0.3978

It is necessary to find out strength of entire blade over the cutter for its working condition when crops strike over each blade with a maximum force of 200N. For FE analysis of cutter in ANSYS, geometry has been restricted on circular shaft and entire body is allowing for deformation. A force of 200N is applied on each blade and finds its equivalent stress and deformation which is within limit and design is safe under this load.

FE analysis has been carried out for both the cutters of 8 blades and 12 blades. The results obtained for 8 blade cutter with two circular rows are shown in figure 6 and table 4.

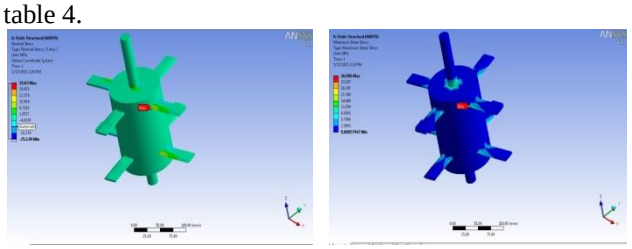

Figure 6. Maximum shear stress and normal stress of 8 blade cutter

TABLE 4. RESULTS FOR FE ANALYSIS OF 8 BLADE CUTTER

Stress	Maximum (MPa)	Minimum(MPa)
Maximum shear stress	26.096	0.00057947
Normal stress	35.83	-25.149

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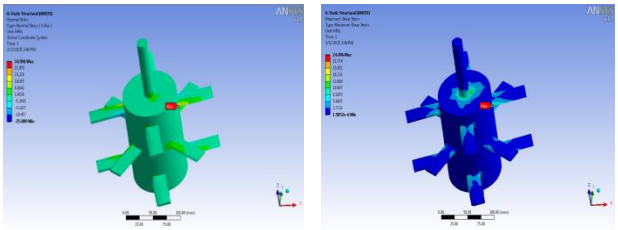

Figure 6. Maximum shear stress and normal stress of 12 blade cutter

TABLE 4. RESULTS FOR FE ANALYSIS OF 12 BLADE CUTTER

Stress	Maximum(MPa)	Minimum(MPa)
Maximum shear stress	34.586	-25.088
Normal stress	24.496	1.5052-6

From FE analysis of cutter, it is observed that the stresses are concentrated at joint of blade and drum and more on 12 blade cutter as it acquire more load than 8 blade cutter. But it is necessary to manufacture cutter with alternate blades for meshing of blades and crushing of crops.

C. Experimentation and Testing

A prototype model of crop crusher has been fabricated for testing and possible cutting of waste crops. At first, the speed of cutter has been measure by using tachometer to meet design criteria of crushing system and it is observed that the speed is obtained correct as per requirement and as per design for speed reduction. Then experimentation has been carried out for different waste crops with varying approximated diameter of crops and it is found that the machine can crush the dry wood up to 15 cm long piece but limited for larger diameter of crops of about 30mm. A running model of crushing machine and crush pieces of crops are shown in figure 7 and figure 8 and variation of crush piece length for different crops are shown in table 5. From experimental analysis it is found that the machine cannot crush a crop of about 30mm diameter bamboo wood but also blade can sustain its strength and cannot fail for its design.

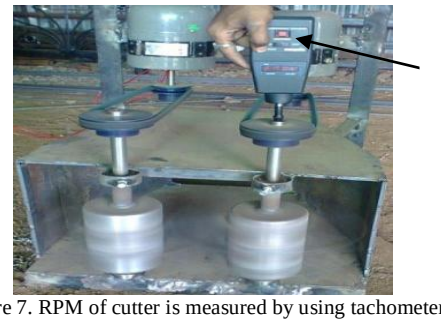

Figure 7. RPM of cutter is measured by using tachometer

Figure 8. Crush Pieces of waste crop

TABLE 5. VARIATION OF CRUSH PIECE LENGTH FOR DIFFERENT CROPS

Sr. no.	Type of woods	Approximate Diameter	Crush wood Length
1.	Babul wood	18 mm	15 cm
2.	Teak wood	12 mm	13 cm
3.	Pine wood	9 mm	8 cm
4.	Sal wood	8 mm	10 cm
5.	Mango wood	17 mm	12 cm
6.	Bamboo wood	30 mm	Not cut

IV. CONCLUSION

1. A crushing machine has been design and fabricated to crush the waste crops. The design reveals that cutter should rotate at high speed and in opposite direction to force crush pieces on backside of system.
2. Two motors of 1HP are mounted on driver shaft which rotates at 1440 rpm and it is reduces to about 840 rpm via belt drive. The reduced speed of cutter is validated by experimentation using tachometer.
3. The analysis is concentrate over safe design of cutter blade for two types of cutter viz. 8 blade cutter and 12 blade cutter.
4. An analytical analysis of blade reveals that the bending stress is limited to 59.52MPa for maximum loading up to 200N for uniformly distributed load.
5. FE analysis of blade reveals that the bending stress is limited to 59MPa for loading of 200N and FE analysis of cutter reveals that maximum shear stress is maximum for 12 blade cutter which is 34.5MPa and normal stress is maximum for 8 blade which is 35.8MPa.
6. The experimental analysis reveals that the machine can crush any type of crop with maximum approximate diameter up to 20mm and cut pieces up to 8cm minimum and 15cm maximum.

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