Design and Analysis of Cutting Mechanism for Crop Harvester

Vishal Ullegaddi¹, Dr Chetan B²

¹PG Scholar, Department of Mechanical Engineering, Bangalore Institute of Technology, Bangalore-560004, Karnataka, India
²Asst. Professor, Department of Mechanical Engineering, Bangalore Institute of Technology, Bangalore-560004, Karnataka, India
Email: chetbk@gmail.com

Abstract
Harvesting is the main part in agricultural automation. The use of crop cutting technology in developing countries to reduce the merchandise cost which will be result in monetary development of agricultural production. This project tends to provide the design and development of cutting mechanism and crop collecting mechanism used for crop harvester machine. The current situation in our country the traditional use of harvesting mechanism is more tedious, time consuming and not able to develop the agricultural sector of the low farmers in economic. Developed cutting mechanism in this project has two sets of blade which cut the crop in a scissoring type of motion. A simple crank and slotted lever mechanism used to provide reciprocating action to cutting blades. The stalks are cut with the impact and shear forces at the linear velocity by cutting blades. This system has a crop collecting mechanism guiding the whole-stalk to one side of machine to stop being crushed under tires and for easy collection. Experimental and Finite element analysis showed that cutting blades had a significant effect on maximum cutting energy and cutting energy required to cut a crop. This demonstrates that Reciprocating blades have better cutting force and energy consumption reduction performance than ordinary rotary blades.

Keywords: Cutting blades, Cutting mechanism, Farm mechanization, Shear Strength.

INTRODUCTION
As our country has large amount of land used for cropping, a need of agricultural machines is increasing gradually. Whether it may be due to unavailability of labors or lack of usage of farm land, agriculture becomes modernization dramatically compared to last decade. Hence to prevent these problems, many agricultural equipment have been created. Since these all machines needed the power to work, consumption of energy in agricultural machines increasing. Blades in crop cutting machines are one of very important working parts. Cutting of crops requires huge amounts of power and cutting resistance of blades must be very small for proper cutting of crops. In this context cutting blades requires most of the energy. In present-days, majorly few types of cutting blades are used in crop cutting machines. One type is rotary blades and the type is reciprocating blades. As of present-day most of the blades used are rotary because of cost required to manufacture rotary blades is less and easy motion supply to rotary blades as it doesn’t required any special mechanism to operate. But a major disadvantage of rotary blades is it is used only for thin crops as ragi and paddy etc. Design aspects of these blades based on rotational sharp edges where center was around basic angles and movement parameters of edges. To overcome these problems usage of reciprocating blades started which are very effective for strong and thick crops. Designing of reciprocating blades mainly based upon arrangement of blades and shear stresses between two parallel blades.
PROBLEM STATEMENT
In present situation, especially in developing countries like India due to increase in population; there is much demand in agriculture due to meagreness of labours. As already discussed productivity of labours or manual methods very low and time taken by labours is high compare to mechanized products. Since machines like combines and reapers cannot be afford to buy because of high cost and limitation of farm area. Hence it is essential to make new machine which is required for small end farmers. Also need to develop cost effective cutting machine with proper cutting of stubble of crops.

METHODOLOGY

DETAILED DESIGN
DESIGN OF CUTTING BLADES:
Cutting blades are made of High carbon steel to withstand maximum shear stress required to cut stern of crops. Blade is designed in Triangular section with width of 50mm and height of 40mm. There are total 2 sets of cutting blades, first one is fixed blade with 12 sets of blades over length of 600mm. and second set blade with 9 sets of blades over length of 445mm which is reciprocates attached to lever of cutting mechanism. Force analysis is done of these blades using ANSYS 15.0 commercial software. Height of cutting blades from ground level is around 200mm to 250mm. a=50mm, b=70mm, d=30mm, and t=3mm.

DESIGN OF SPECIAL TYPE OF ELEMENT USED FOR PUSHING CROPS:
As dimensions shown are above it used for pushing crops which made to attach to chain drive of crop collecting mechanism with help of Bolt and nut of dia. 3mm.

DESIGN OF CRANK-SLOTTED LEVER MECHANISM:
Specification:
1. Stroke length, L= 260mm
2. No. of strokes/min, S= 30strokes/min
3. Quick return ratio= 5/3
4. Crank length=L1=50mm
Now, we know that,
Quick return ratio= \( \frac{360-\alpha}{\alpha} \)
\( \frac{360-\alpha}{\alpha} = 1.6 \)
\( \alpha = 140 \degree \)
Length of fixed link, \( L_2 = \frac{L_1}{\sin(90-\frac{\alpha}{2})} \)
\[ L_2 = \frac{50}{\sin \left(90^\circ - \frac{180^\circ}{2}\right)} \]

\[ L_2 = 145 \text{mm} \]

Length of slotted lever, \( L_3 = \frac{P \cdot L}{\sin \left(90^\circ - \frac{\alpha}{2}\right)} \)

\[ L_3 = 375 \text{mm} \]

Max. Force required to cut mulberry shoots = 85N

**POWER CALCULATION:**

Mean Cutting Velocity,

\[ V_{\text{mean}} = \frac{L \cdot S}{\alpha} \cdot 360 \]

\[ V_{\text{mean}} = \frac{260 \cdot 30}{140} \cdot 360 \]

\[ V_{\text{mean}} = 19.99 \text{m/s} \]

Cutting Power = \( \text{Force} \times V_{\text{mean}} \)

\[ = 85 \times 19.99 = 1.691 \text{kW} \]

**TORQUE CALCULATION:**

Max. Shear force required to cut shoots of 10 mm diameter

Shear stress = 1.2 N/mm²

Torque Required at Crank Pin:

\[ T_{\text{req}} = \frac{\pi \cdot D^3 \cdot F_s}{16} \]

\[ T_{\text{req}} = \frac{\pi \cdot 10^3 \cdot 1.2}{16} \]

\[ T_{\text{req}} = 0.235 \text{N-m} \]

Torque produced by Engine:

\[ P = \frac{2 \pi \cdot N \cdot T}{60} \]

\[ T_{\text{act}} = \frac{P \cdot 60}{2 \pi \cdot N} \]

As we used Std. Activa engine, According to Specification \( P = 5.2 \text{kW} @ 7000 \text{rpm} \)

\[ T_{\text{act}} = \frac{5.2 \cdot 60}{2 \pi \cdot 7000} \]

\[ T_{\text{act}} = 8.74 \text{N-m} \]

Since, \( T_{\text{req}} < T_{\text{act}} \)

Hence, design is safe.

**3D MODELLING**

**Fig.3: Fixed Blades**

**Fig.4: Moving Blades**

**Fig.5: Special element used for crop pushing**

**Fig.6: Geometry of Cutting Blade**

**Fig.7: Meshed Model of cutting Blade**

**Fig.8: Total Deformation of Cutting Blade**
Static analysis of cutting blade was done by commercially available software ANSYS 15.0. Total force applied on edge of blades is 85N and result of Max. Shear stress I 4.8761MPa as shown in Fig.6 and Max. Equivalent stress is 20.283MPa as shown in Fig. 7.

**RESULTS AND DISCUSSION:**

**SHEAR STRENGTH:**

**EXPERIMENTAL**

The test was conducted to know the sheer force necessity at various time of plant. Both harvesting and pruning tasks were carried utilizing UTM setup and results are organized as

<table>
<thead>
<tr>
<th>Age of mulberry plant (dia=10mm) in days</th>
<th>Shear strength (N/mm²)</th>
<th>Hardness (JHN)</th>
</tr>
</thead>
<tbody>
<tr>
<td>45</td>
<td>0.5</td>
<td>13</td>
</tr>
<tr>
<td>55-65</td>
<td>0.8</td>
<td>15</td>
</tr>
<tr>
<td>85-95</td>
<td>1.2</td>
<td>16</td>
</tr>
</tbody>
</table>

**THEORATICAL**

Cross- sectional area of shoots, d=10mm
Max. Force required cutting in worst condition =Fₛ = 85N …… (Young and Chow, 91)

\[
\text{Shear stress}= \frac{\text{Force}}{\text{cross sectional area of shoots}} \quad Fₛ \text{=} \frac{85}{\pi r^2} = \frac{85}{3.14 \times 5^2} = \frac{85}{78.5} = 1.08 \text{N/mm}^2
\]

**FEM RESULTS**

According Finite element analysis of cutting blades maximum shear stress required mulberry at worst condition is shown below. Max. Force required to cut stubble is 85N. Maximum shear stress is given as 4.8761MPa as shown in figure 7.

From above it is proved that Maximum shear force will satisfactorily withstand our designed Cutting blades. Hence design is safe.

**STRUCTURE OF CUT STUBBLE**

As shown in above figure rotary blade cut stubble has uneven compare to that of reciprocating blades. Also cutting resistance, force required to cut in rotary
Blades is very high compare to our designed blades and cut quality is very low in case of rotary blade. Our criteria for cutting surface quality are a smooth and clean cutting surface with no break on stalk fibers and vascular tissues. Hence designed Blade in our project has greater advantages than any other ordinary blades.

**CONCLUSION**

In this project, suitable cutting mechanism and crop collection mechanism for crop harvester was designed, analysed and fabricated. It can be concluded that, Cutting mechanism has a cutting blades with one fixed attached to frame and another moving connected to lever of mechanism which cut the whole-stalks by shear force. It was found that cutting mechanism was able to work under different farm conditions. Crop collecting mechanism was developed to push cut crop at one side of machine to stop being crushed under tires and for easy collection. Modelling of machine is done by commercially available software CATIA V5 and also critical elements like cutting blades and special element used for pushing of crop is analysed with help of ANSYS 15.0 Fabrication of designed elements was done properly according to design specification and found to be more useful.

**REFERENCES**

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