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DESIGN OF PEARL MILLET CROP CUTTER USING SCOTCH YOKE MECHANISM

Prof. Sunil Shinde[1], Piyush Shingankar[2], Siddharth Shilimkar[3], Shrushti wakchaure[4], Geetesh Rajurkar[5], Nikita Surwase[6]

[1-2-3-4-5-6]Vishwakarma Institute of Technology, Department of Mechanical Engineering, Pune, India.

ABSTRACT

This Study presents the conceptual design of a pearl millet crop cutter utilizing the Scotch Yoke mechanism to achieve efficient and precise cutting action. The Scotch Yoke mechanism converts rotary motion into reciprocating motion, enabling smooth and consistent blade movement for slicing millet stalks. Key design aspects, including blade curvature, bevel angle, and material selection, are optimized to ensure effective cutting with minimal energy input. The design emphasizes simplicity, cost-effectiveness, and ergonomic usability, providing a practical solution for small-scale millet harvesting. This work aims to contribute to the mechanization of millet harvesting, enhancing efficiency and reducing manual labour.

Keywords: Millet Cutter, Scotch Yolk Mechanism

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I. INTRODUCTION

Bajra (Pennisetum glaucum), also known as Pearl Millet, is one of the most important crops grown in the arid and semi-arid regions of India and other parts of the world. This drought-tolerant grain is a staple food and fodder for millions of people, particularly in rural areas where it plays a crucial role in food security and economic stability. Bajra is primarily cultivated in regions such as Rajasthan, Maharashtra, Uttar Pradesh, and Gujarat, where it thrives in harsh climatic conditions. The crop is not only vital for human consumption but also serves as an important feed for livestock, making it a key player in both food and agricultural industries. Despite its importance, bajra harvesting presents several challenges, which has led to the exploration of more efficient and cost-effective methods for cutting the crop.

Traditional methods of bajra cutting largely involve manual labor, where workers use sickles to cut the mature plants by hand. This labour-intensive process, while effective, has become increasingly problematic due to rising labor costs, a shortage of farm workers, and the overall physical strain it places on those involved in the harvest. Bajra plants typically grow to a height of about 3 to 4 feet and have a bushy structure, which requires careful handling during the cutting process. Additionally, the plant's long, thick stems and tough leaves present mechanical challenges when using conventional cutting tools, often leading to inefficiencies and increased time spent per field. With labor costs on the rise, many small farmers find it difficult to afford enough workers to harvest their crops efficiently, which results in delays that could affect crop quality and yield.

In response to these growing challenges, mechanization has emerged as a potential solution. However, the existing machines available for crop harvesting, such as combine harvesters, are not designed for bajra, making them unsuitable for small-scale farmers. These machines are large, expensive, and often too powerful for the relatively short and bushy structure of the bajra plant. As a result, there is a need for a more accessible, affordable, and efficient cutting machine specifically designed for bajra crops, which is the primary focus of this paper. We propose the design and development of a bajra cutting machine powered by a Scotch Yoke mechanism, a mechanical system that converts rotary motion into linear motion, allowing for a more effective and controlled cutting motion. The goal is to create a machine that is affordable for small-scale farmers, reduces labor dependency, and increases overall harvesting efficiency. Traditionally, bajra is harvested by hand using sickles or other hand tools. This method is effective but highly labour-intensive, requiring a significant amount of manpower, especially during peak harvest season. The process starts with cutting the bajra plants close to the base, followed by bundling and stacking the harvested stalks. While this method has been in use for centuries, it presents numerous challenges that are becoming more pronounced as labor costs rise and the availability of agricultural workers decreases. One of the biggest challenges in bajra cutting is the timing of the harvest. Bajra must be cut at the right stage of maturity to ensure optimal grain quality. If harvesting is delayed, the grains may fall off the plant, leading to significant loss. Moreover, bajra's relatively short growing season means that multiple workers are needed for a short period of time to complete the harvest. Farmers often struggle to secure enough laborers during this crucial time, which can lead to further delays and crop loss. Another challenge is the physical nature of the work. Bajra harvesting requires bending, kneeling, and using sharp sickles, which can lead to physical exhaustion and injuries. For older farmers or those with limited manpower, the task becomes even more difficult. Fig 1 Showing A Laborer Cutting Bajra.

Fig A Laborer Cutting Bajra (Pennisetum glaucum) Crop Manually

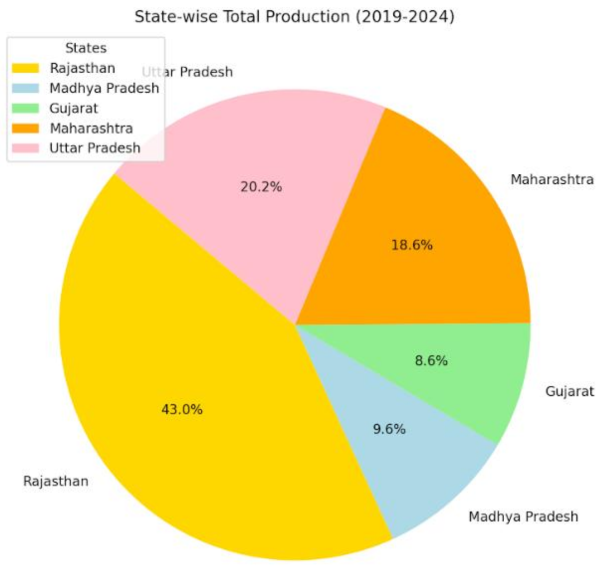

Fig 2. State-Wise Bajar Production in Last 5 Years (In Lakh Tons)

Additionally, with the growing labor shortage, hiring workers has become increasingly expensive. Small farmers often find that the money they spend on labor costs cuts into their overall profits, sometimes leaving them with minimal financial returns after the harvest. In light of these challenges, mechanization offers a potential solution to reduce labor dependence and increase efficiency.

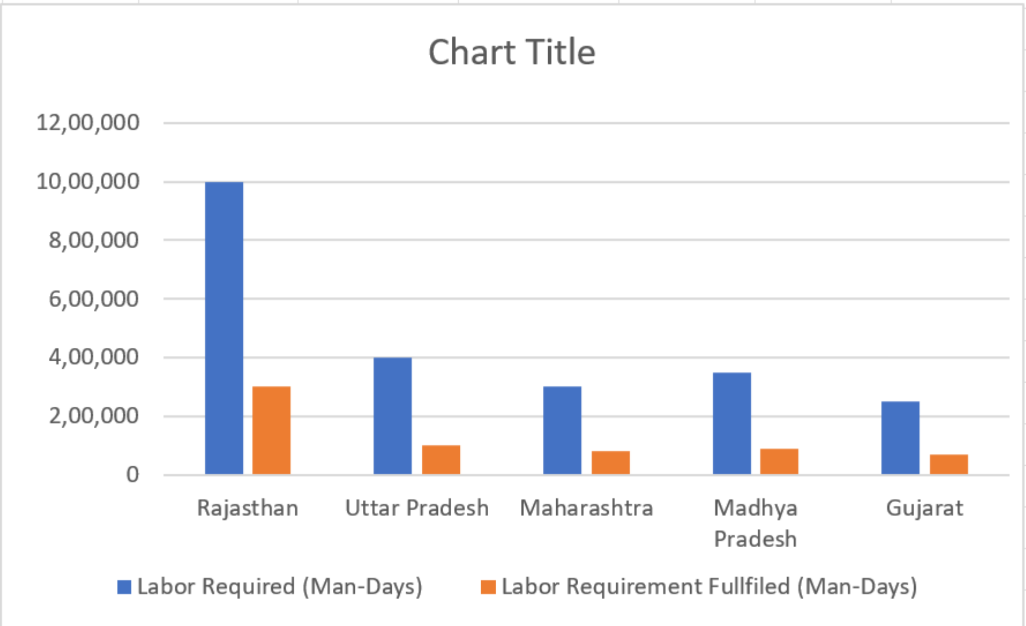

Fig 3. Labor Shortage State-wise In Last 5 Years

However, the high cost of large machinery is a barrier for many small-scale farmers. Therefore, there is a clear need for smaller, more affordable cutting machines that are specifically designed for bajra. By introducing a bajra cutting machine with a simple yet effective Scotch Yoke mechanism, farmers can reduce the labor required for harvesting and make the process quicker, safer, and more cost-effective. A survey was conducted among small-scale bajra farmers in key growing regions to better understand the challenges they face with the current harvesting methods. The results showed that nearly 70% of farmers cited labor shortages as their primary concern, with many struggling to find enough workers during peak harvest season. Additionally, high labor costs were a significant burden, with farmers reporting that a large portion of their crop income went toward paying workers. More than 50% of respondents indicated that after covering labor expenses and other costs, their profits were considerably lower than anticipated, making it difficult to sustain their livelihood from bajra farming. The survey also highlighted the inefficiencies in the traditional cutting methods, with farmers noting that manual harvesting was both physically exhausting and time-consuming. Over 60% of respondents expressed interest in adopting mechanized solutions if they were affordable and practical for small-scale operations. The cutting of bajra involves various mechanical forces that need to be considered to design an effective cutting machine. The force required to cut bajra stems depends on the material properties of the plant, such as the thickness and toughness of the stalk, as well as the height and growth pattern of the plant. The cutting force must be sufficient to break the stem of the bajra without damaging the plant's leaves or grains. The cutting operation generates two primary forces: shear force and normal force. The shear force is responsible for slicing through the bajra stalk, while the normal force acts perpendicular to the cutting surface and provides the necessary pressure to ensure that the blade engages with the plant effectively. The mechanical advantage of the machine's cutting mechanism, including factors such as blade sharpness, material strength, and the angle of attack, plays a significant role in optimizing these forces. The issues surrounding bajra harvesting—labor shortages, high costs, and inefficiencies—necessitate the development of an innovative solution. The proposed bajra cutting machine using a Scotch Yoke mechanism aims to address these challenges by offering a cost-effective and efficient alternative to traditional manual labor. By understanding the forces and power requirements involved in bajra cutting, and incorporating the feedback from local farmers, this machine has the potential to significantly improve the harvesting process for small farmers. The following sections of this paper will explore the detailed design and functionality of the proposed machine, its potential benefits, and how it can help reduce labor costs, increase efficiency, and improve the economic viability of bajra farming.

Table 1 State Wise Agriculture Labor Daily Wages- per day

State/Union Territory	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20
Andhra Pradesh	216.9	213.3	249.1	269.5	282.0	301.3
Assam	200.6	215.7	229.3	237.5	248.5	252.2
Bihar	198.9	207.1	212.7	223.0	240.3	257.3
Gujarat	160.0	177.6	184.0	187.9	199.3	208.4
Haryana	340.1	352.7	359.3	361.4	391.9	391.8
Himachal Pradesh	308.9	317.3	339.8	368.3	388.6	418.4
Jammu & Kashmir	367.7	394.5	409.8	436.0	443.6	452.9
Karnataka	205.1	228.3	251.9	267.3	288.7	291.8
Kerala	575.1	608.8	644.0	659.8	682.4	700.7
Madhya Pradesh	150.5	160.4	173.1	191.3	196.3	198.1
Maharashtra	196.7	195.9	196.8	207.4	213.7	230.7
Meghalaya	174.7	212.4	221.4	225.0	229.5	231.3
Odisha	180.0	191.3	208.7	222.6	227.4	232.1
Punjab	284.1	305.3	319.3	324.6	337.7	348.7
Rajasthan	269.9	285.2	285.5	287.1	292.9	297.6
Tamil Nadu	334.3	357.0	378.7	385.9	398.7	410.0
Tripura	209.4	209.6	225.0	270.0	270.0	270.0
Uttar Pradesh	191.9	199.6	211.8	229.8	247.1	257.7
West Bengal	216.0	220.2	237.6	255.9	263.1	267.2
All India	224.6	236.9	252.6	267.1	277.4	286.6

Source: Labour Bureau, Government of India.

II. RECENT INVESTIGATIONS IN AGRICULTURAL SECTOR

First, Agricultural mechanization has become a cornerstone of modern farming practices, significantly improving productivity, reducing labor costs, and enhancing the efficiency of crop harvesting. Among the various tools developed for mechanized farming, the reaper, reaper-binder, and multi-crop cutters have gained widespread application for their ability to efficiently handle large-scale harvests in diverse crop conditions. Over the years, various studies have contributed to the improvement of these machines, focusing on performance evaluation, design enhancements, and cost-effectiveness. Research by Jun et al. (2023) [1] and Halde et al. (2024) [7] has provided insights into the design and performance of reapers and reaper-binders, while other studies, such as those by Kumar et al. (2021) [9] and Tafa et al. (2021) [4], have emphasized the importance of machine modifications for improving operational efficiency and reducing costs. These efforts contribute to a more sustainable and efficient agricultural system, particularly in regions where mechanization can provide substantial benefits to smallholder farmers.

One significant area of research has been the design and development of reaper-binders, which combine the functions of both harvesting and binding crops in a single operation. Studies by Tafa et al. (2021) [4] and Kumar et al. (2021) [9] have evaluated the performance of reaper-binders for wheat harvesting, highlighting improvements in operational efficiency and cost-effectiveness. These studies also emphasize the reduction in labor requirements and the impact of mechanization on smallholder farmers in regions like Ethiopia and India. Tafa et al. (2021) [4] also explored the potential for expanding mechanized wheat harvesting in Ethiopia by assessing the economic viability and fuel consumption of reaper-binders.

Another important advancement in mechanized harvesting is the use of multi-crop cutters. Research by Halde et al. (2024) [7] and Pisal et al. (2023) [18] focused on designing and fabricating agricultural multi-crop cutters capable of working across different crop types such as wheat, rice, and millet. These studies underscore the flexibility of these machines in diverse agricultural settings, improving efficiency and reducing the need for multiple specialized tools. Similarly, Lammari et al. (2022) [16] explored the use of a four-bar mechanism for agricultural cutters, which provided insights into the optimal cutting angles and speed for increased harvesting efficiency.

Additionally, crop cutting efficiency and the overall mechanical performance of reaper-binders have been extensively analyzed. Kumar et al. (2021) [9] assessed the cutting efficiency of various reaper-binders and found that modifications to the cutting blades and feed mechanisms significantly influenced the overall performance. The evaluation considered factors such as cutting speed, fuel consumption, and residue management. Their findings indicated that small modifications could lead to substantial improvements in harvesting performance, especially in wheat and barley fields.

As agricultural production systems evolve, the role of crop residue management has become increasingly important. Zhang et al. (2021) [15] and McHugh et al. (2021) [15] reviewed global advancements in crop residue management machinery, emphasizing the growing need to address the by-products of mechanized harvesting. Their research shows that integrating residue management into reaper-binder machines not only enhances the harvesting process but also contributes to sustainable agricultural practices by minimizing field residue and improving soil health.

Furthermore, economic and environmental considerations play a significant role in the adoption of mechanized harvesters. The economic viability of mechanized harvesting systems has been studied extensively by Bhatia et al. (2020) [6] and Ghosh et al. (2019) [6], who analyzed the costs associated with the adoption of reaper-binders, fuel consumption, and labor savings. These studies demonstrate that the initial high cost of these machines can be offset over time through labor savings, increased productivity, and reduced post-harvest losses. For instance, Kumar et al. (2020) [9] reported that reaper-binders reduced harvesting time by 30% and labor costs by nearly 50%, making them economically viable for medium to large-scale farms.

The impact of nitrogen and cutting management on the growth and yield of crops like pearl millet and fodder bajra has also been a key focus of recent research. Studies by Kumawat et al. (2022) [8] and Anoohya et al. (2021) [19] explored the influence of various nitrogen levels and cutting techniques on crop yield and quality. These studies provide valuable insights into optimizing nitrogen use in fodder crops, which can have direct implications for enhancing the overall productivity of mechanized harvesting systems. By improving the quality and quantity of crops through better management practices, farmers can maximize the effectiveness of their machinery.

The development of portable reapers and multi-functional agricultural machinery also warrants attention. Research by Mohammadi Baneh et al. (2022) [2] on portable reapers, especially for rice harvesting, reveals advancements in cutting head design that have improved the efficiency and adaptability of these tools for smallholder farms. These improvements are essential in regions where labor shortages and land fragmentation are significant challenges.

Recent developments in agricultural machinery, particularly for crop harvesting, have led to significant improvements in efficiency and functionality. Advances have been made in enhancing the performance of reaper-binders, creating multi-crop cutters, and incorporating crop residue management systems. These innovations are instrumental in transforming agricultural practices, particularly in the Global South. Critical factors such as nitrogen management, cutting efficiency, and the pursuit of cost-effective designs are essential for optimizing machine performance. Ongoing advancements in these technologies are crucial for addressing modern agricultural challenges, such as labor shortages, the need for environmental sustainability, and the growing demand for mechanization in food production systems.

III. METHODOLOGY

1) Problem Statement

To design a crop cutter using a Scotch Yoke mechanism with the provided data, considering Factor of Safety (FoS) = 6 and following design failure criteria, we will calculate and dimension each component. Here's the step-by-step solution:

2) Material Selection

- **Material:** High-carbon steel grade EN9 (C45) with a carbon content of 0.8%.
- **Raw Material Form:** Steel sheets or bars are procured in the required thickness (2–5 mm for crop cutter blades).

High Carbon Steel EN9 is a viable material for the construction of blades used in bajra (pearl millet) crop cutting tools. This suitability is primarily attributed to several key properties of EN9 steel:

1. **Hardness:** EN9 exhibits a Rockwell hardness of 20-25 HRC, providing the wear resistance necessary for cutting applications. This hardness ensures that the blade maintains its sharpness and durability during prolonged use in field conditions.
2. **Tensile and Yield Strength:** The material demonstrates a high Ultimate Tensile Strength (UTS) of 600-850 MPa and Yield Strength (YS) of 370-570 MPa. These properties allow the blade to withstand significant mechanical stresses encountered during crop cutting, maintaining structural integrity and performance under demanding conditions.
3. **Toughness:** With good toughness, High Carbon Steel EN9 is capable of withstanding impact and shock forces, which are common during the cutting process. This resilience helps prevent the blade from cracking or breaking under pressure.
4. **Wear Resistance:** Due to its high carbon content, EN9 exhibits excellent wear resistance, making it well-suited to cutting through the tough stalks of bajra. The material's abrasion resistance ensures that the blade remains effective over an extended period.
5. **Edge Retention:** The ability of EN9 to maintain a sharp edge is a crucial characteristic for cutting tools, especially in agricultural settings. This property reduces the frequency of sharpening and improves the efficiency of crop harvesting.

To maximize the performance of EN9 steel in bajra cutting tools, appropriate heat treatment is necessary. Proper heat treatment enhances the steel's hardness and toughness, ensuring that the blade remains durable and effective throughout its service life.

In conclusion, High Carbon Steel EN9 is a suitable material for bajra crop cutting blades, owing to its combination of hardness, strength, toughness, wear resistance, and edge retention.

Table 2. High-carbon steel grade EN9 Property

Property	**Value**
Density	7.85 g/cm³
Ultimate Tensile Strength (UTS)	400-550 MPa
Yield Strength (YS)	250-270 MPa
Hardness (Rockwell C)	20-25 HRC
Modulus of Elasticity	210 GPa
Melting Point (MP)	1425-1500°C

3) Mechanism Selection

The Scotch yoke mechanism provides several distinct advantages when integrated into crop cutters, significantly enhancing their performance, efficiency, and durability. This mechanism is primarily valued for its ability to convert rotary motion into reciprocating motion, which is essential for the back-and-forth action required in cutting applications. By efficiently converting rotary motion from the engine or motor into the reciprocating motion needed to operate the cutting blades, the Scotch yoke ensures a smooth and consistent cutting action. This is critical for precision in crop harvesting, optimizing the cutting process and ensuring reliable operation throughout.

The reciprocating motion enabled by the Scotch yoke facilitates a steady, controlled back-and-forth movement of the cutting blades. This consistent cutting rhythm improves the efficiency of the crop cutting process, resulting in cleaner cuts and enhancing the overall precision of the harvest. Such a mechanism helps minimize crop damage, which is crucial for maximizing yield quality. Additionally, the Scotch yoke mechanism is designed to reduce vibration and shock, common challenges in mechanical cutting systems. By smoothly transitioning between rotary and reciprocating motions, it minimizes jerky movements that could damage the blades or other components of the machine. This reduction in vibration not only improves the cutting performance but also decreases wear on the machine, leading to a longer operational life.

The compactness and simplicity of the Scotch yoke mechanism make it an ideal addition to crop cutters. Its design allows it to occupy minimal space within the machine, which is especially important for maintaining the overall compact structure of agricultural machinery.

Furthermore, its simple design makes it easier to maintain and repair, which reduces maintenance costs and improves the overall usability of the equipment. The robust construction of the Scotch yoke also ensures that it can withstand high mechanical stresses, making it durable enough to handle tough conditions, such as cutting through thick or resistant plant stalks. This durability ensures that the mechanism remains effective and reliable over long periods of use.

In addition to its durability, the Scotch yoke mechanism operates with minimal friction, which results in greater energy efficiency. By converting rotary motion to reciprocating motion with minimal energy loss, it leads to better fuel or power utilization. This is particularly beneficial in agricultural settings, where machinery is often used for long hours, as it can significantly reduce operational costs. Moreover, due to its simple design and manufacturing process, the Scotch yoke mechanism is cost-effective. It is less expensive to produce than more complex motion conversion systems, making it an attractive option for farmers, particularly in regions where budget constraints are a consideration.

the Scotch yoke mechanism offers several important benefits when used in crop cutters, including efficient power transmission, improved cutting action, reduced vibration, enhanced durability, and energy efficiency. These advantages contribute to the overall performance, longevity, and cost-effectiveness of the crop cutter. The simplicity and affordability of the mechanism make it a valuable feature for agricultural machinery, especially in the context of crop harvesting, such as for bajra.

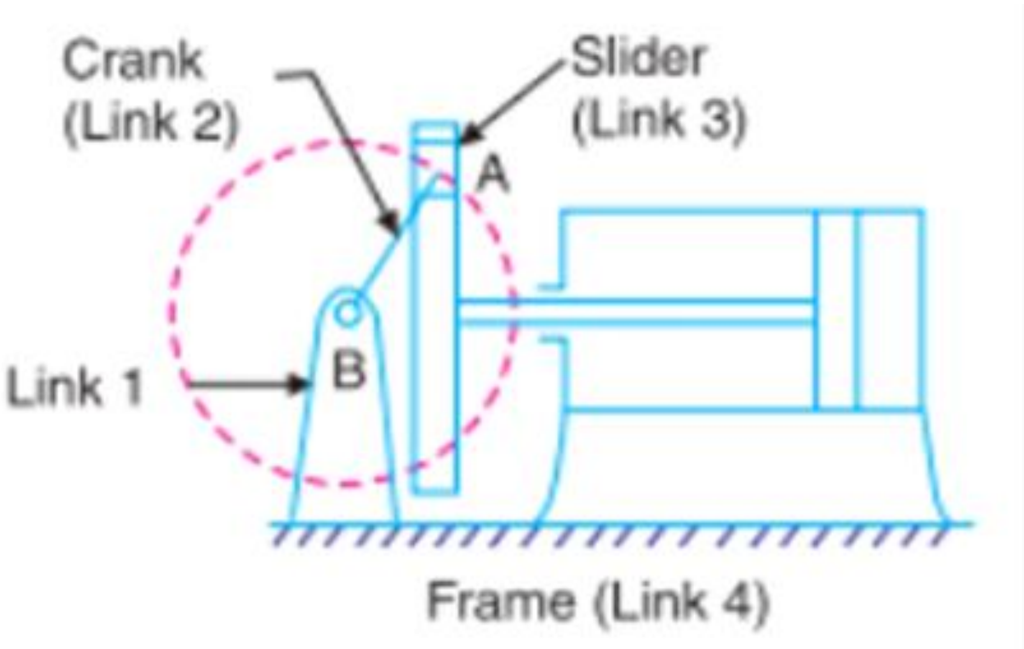

Fig.4 Schematic Scotch yoke mechanism

4) Calculations

Problem Data:

- Cutting Force (Fc) = 100 N
- Reciprocating Speed = 350 strokes/min
- Blade Angle (θb\theta_b) = 35°
- FoS = 6
- Material: High carbon Steel (σyield=250 MPa, σfatigue=125 MPa).
- Mechanism: Scotch Yoke

The mechanism includes:

1) Blade
2) Yoke
3) Crank and crank pin
4) Frame or support

- Procedure

Step 1: Stroke Length and Crank Radius

a) Stroke Length

The stroke length is twice the crank radius:

Stroke Length=2r.

Practical stroke length of 100 mm for bajra cutting.

$$r= = \frac{Stroke\ Length}{2} = \frac{100}{2} = 50\ mm$$

Step 2: Forces on Blade

The force acting on the blade (Fc) at an angle (θb) results in components:

1. **Normal Force (Fn):**

$$Fn = Fc \cdot co(\theta b) = 100 \cdot co(35 \circ) \approx 81.9\,N.$$

2. **Shear Force (Fs):**

$$Fs = Fc \cdot sin\ (\theta b) = 100 \cdot sin\ (35 \circ) \approx 57.4\,N$$

Step 3: Allowable Stress with FoS

The allowable stress is calculated as:

$$\sigma allow = \frac{\sigma yield}{FoS} = 2506 \approx 41.67\, MPa$$

Step 4: Blade Design

a) Stress Analysis

The blade is subjected to normal and shear forces. Using **Von Mises Criterion:**

$$\sigma vm = \sqrt{\sigma^2 + 3\tau^2}$$

where:

- $\sigma = \frac{Fn}{A}$(normal stress)
- $\tau = \frac{Fs}{A}$(shear stress)

Substituting:

$$\sigma vm = h\sqrt{(\frac{Fn}{A}) + 3\,.\frac{F_S}{A}}$$

Rearranging for the required area AA:

$$A = \sqrt{\frac{Fn^2 + 3Fs^2}{\sigma^2{}_{allow}}}$$

Substitute values:

$$A = \sqrt{\frac{81.9^2 + 3(57.4^2)}{41.67^2}}$$

$$A = \sqrt{\frac{6705.61 + 9892.68}{1736.19}}$$

$$A = \sqrt{9.56}$$

$$A = 3.09 mm^2$$

b) Blade Cross-Section

Blade thickness t=5 mm

$$b=\frac{A}{t}=3.095=0.618 \text{ mm}$$

Step 5: Yoke Design

The yoke is subjected to cyclic forces due to the crank pin. Use **shear stress failure theory** for the yoke slot and body.

a) Dimensions of the Yoke Slot

1. **Crank pin diameter** (d_{pin}) = 20 mm.
2. Adding clearance to avoid binding: Slot Width= $d_{pin} + Clearance$ = 20+2= 22 mm

b) Thickness of the Yoke

The yoke experiences a shear force F_n=81.9 N
Shear stress is:

$$\tau = \frac{F_n}{A_{yoke}}$$

$$Assume\ a\ yoke\ thickness\ of\ t_{yoke} = 10\,mm\ and\ width\ of\ 30mm$$
$$A_{yoke} = 30 \cdot 10 = 300\,mm^2$$
$$\tau = \frac{81.9}{300} \approx 0.273\,MPa$$

Compare with allowable stress:

$$\tau < \sigma_{allow}$$

The design is safe.

Step 6: Crank and Crank Pin Design

The crank pin transmits force F_n to the yoke.

a) Shear Stress in Crank Pin

Shear stress:

$$\tau_{pin} = \frac{F_n}{A_{pin}}$$
$$Crank\ pin\ diameter\ d_{pin} = 20\,mm$$
$$A_{pin} = \frac{\pi}{4} d^2{}_{pin} = \pi 4(20)^2 \approx 314.16\,mm^2$$
$$\tau_{pin} = \frac{81.9}{314.16} \approx \mathbf{0.261MPa}$$

Compare with allowable stress:

$$\tau_{pin} < \sigma_{allow}$$

The crank pin is safe.

b) Torque on Crank

The torque on the crank is:

$$T = F_n \, . r$$
$$Substitute\ F_n = 81.9\, N\ and\ r = 50\, mm$$
$$T = 81.9 \cdot 0.05 \approx 4.1\, N$$

Step 7: Power Requirement

Power is given by:

$$P = T \cdot \omega$$

Where:

- $T = 4.1\, Nm$
- $Angular\ velocity\ (\omega)$:
- $\omega = \frac{2\pi \cdot RPM}{60} = \frac{2\pi \cdot 350}{60} \approx 36.65\ \frac{rad}{s}$

$$P = 4.1 \cdot 36.65 \approx 150.3\, W$$

Thus, a **150 W motor** is sufficient.

- Final Dimensions
- **Blade:**

  Width = **0.618 mm** (increase for practical use)

  Thickness = **5 mm**
- **Yoke:**

  Slot Width = **22 mm**

  Thickness = **10 mm**

  Overall Length = **110 mm**
- **Crank Pin:**

  Diameter = **20 mm**

- **Crank:**

  Radius = **50 mm**

These dimensions ensure safety with a **FoS of 6**. And Material of blade High Carbon Steel EN9.

5. Design of Blades and Mechanism

For Blade Design a highly curved blade ensures an efficient slicing action, reducing the force required during cutting. For millet, a moderate curvature with a radius of 8–14 cm is ideal for maneuverability and effective cutting. Also, the bevel angle determines the sharpness of the blade it is the angle formed between a cut surface and a theoretical plane perpendicular to the surface of the material. For cutting millet, a **bevel angle of 22° to 30°** is recommended.

Fig. 5: Variations of Sickles with a Common Bevel Angle

Fig 6. Cutting Blade

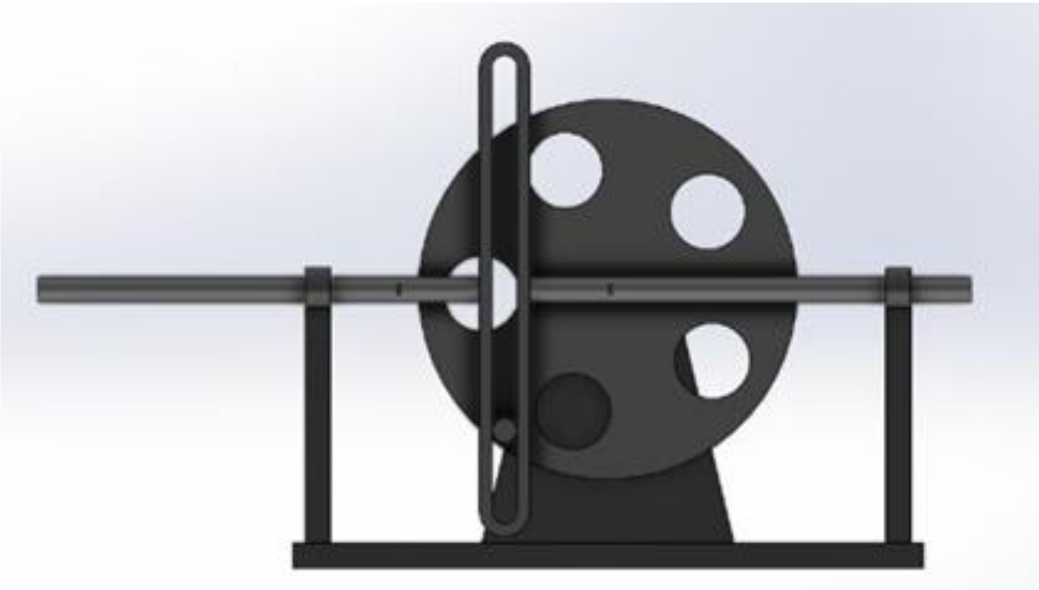

Fig 7. Scotch yoke mechanism

IV. RESULTS AND DISCUSSION

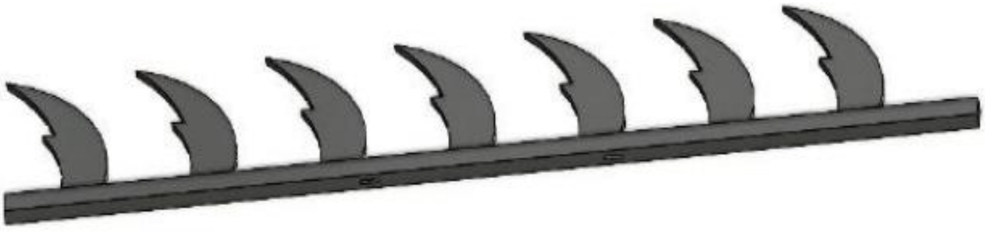

Fig 8 a. Complete Blade

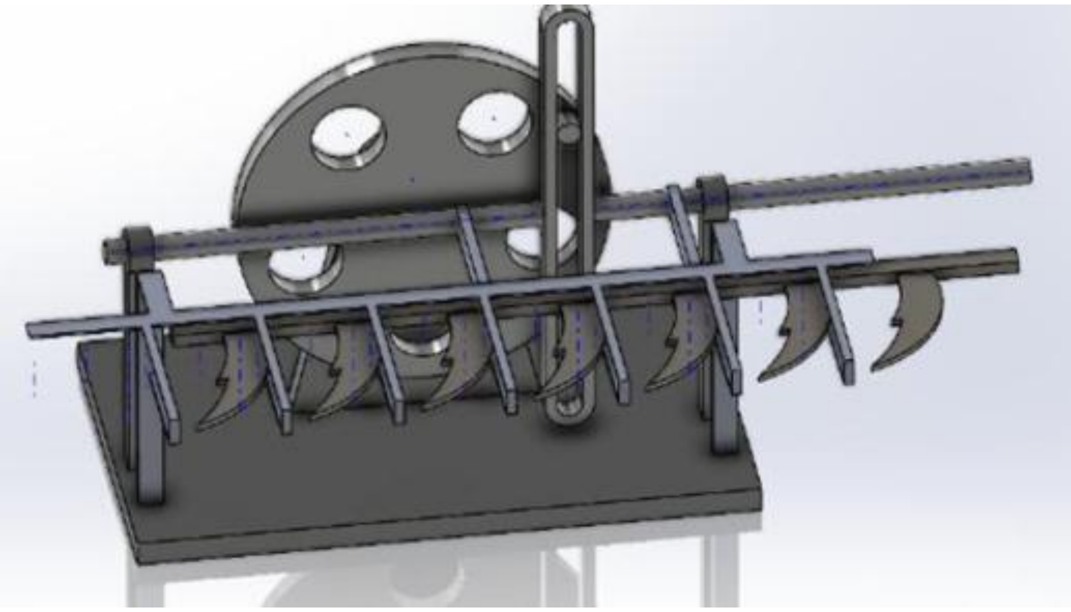

Fig 8 b. Complete Blade and Mechanism Assembly

Parameter	*Cutting done by mamal process*	Harvesting done by machine
Time required to 6 Day. Cutting bajram the I-acre farm	*6 Days*	*1 Day*
Labour Cost spend to harvesting	*Rs 1800*	*Rs 300*
Total cost spending	*Rs 1800*	*Rs 696*

Harvesting done by MANUAL process Amount paid to the labor for one day = Rs. 300 per labour Total number of labours required in general to harvest the 1-acre farm in a day = 6 Total amounts paid to the labour = 6 x 300 = Rs. 1800 per acre in one day Therefore, total expenditure in one day is = Rs. 1800

Harvesting done by Machine Quantity of petrol require for 0.25 to 0.3 acre = 1 litre Quantity of petrol require for 1 to 1.2 acre = 3 litre Cost of Petrol per litre Rs 112 Total cost of Petrol for 1 acre farm for a day = 3 x Rs 112- Rs. 336 Amount paid to the labour Rs. 300 per day Total expenditure = Total cost of Petrol + Amount paid to the labour + Maintenance 336+300 +60 Rs. 696 Amount saved by using the harvester 1800-696= Rs. 1104 per day per acre Saved

The comparison between manual and machine harvesting of pearl millet demonstrates substantial benefits when utilizing a machine, particularly one powered by the Scotch Yolk mechanism. Manual harvesting of 1 acre of pearl millet requires 6 days and involves a labor cost of Rs. 1800 per day for 6 laborers. In contrast, machine harvesting can complete the task in just 1 day. The total cost for machine harvesting, which includes petrol, labor, and maintenance, is Rs. 696 per acre. Of this, Rs. 336 accounts for the petrol cost, Rs. 300 for labor, and Rs. 60 for maintenance.

This leads to a significant cost saving of Rs. 1104 per acre per day when using the machine instead of the manual method. The time reduction is equally remarkable, with the machine cutting the time required for harvesting from 6 days to just 1 day. Furthermore, the labor cost is reduced by over 60%, making the machine-based method a much more cost-effective option.

The use of mechanical harvesters not only reduces time and labor expenses but also improves overall efficiency in terms of fuel consumption and operational speed. These advantages make the Scotch Yolk mechanism-driven harvester a highly promising solution for large-scale pearl millet farming, where maximizing productivity and minimizing costs are essential.

V. CONCLUSION

The bajra cutting machine powered by the Scotch Yoke mechanism effectively addresses challenges in traditional harvesting, such as labor shortages and high costs. Designed for small-scale farmers, it is affordable, durable, and easy to operate. The optimized blade design and use of mild steel ensure efficient cutting, significantly improving harvesting speed and reducing labor dependency.

This machine reduces labor costs by over 60% and cuts the harvesting time from six days to one, offering substantial savings. The total cost of machine harvesting, including fuel, labor, and maintenance, is much lower than manual methods, saving over Rs. 1100 per acre per day.

In addition to economic benefits, the machine supports sustainable farming practices, particularly in arid and semi-arid regions, by enhancing productivity and reducing operational costs, ensuring the long-term viability of farming in these areas.

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