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Conceptual design of a swinging type brush cutter with ergonomic considerations for enhanced field efficiency

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Abstract

Agricultural mechanization is vital for enhancing productivity and decreasing reliance on labour, especially in small and marginal farming systems. Traditional brush cutters frequently lead to operator tiredness and restricted effectiveness in the field. To address these constraints, a conceptual design of an ergonomic swinging-type brush cutter was created. The system consists of a cutting unit, a swinging mechanism utilizing the Whitworth quick return mechanism, a wheeled chassis, and an easy-to-use operator interface. Field evaluation of prevalent grass species was carried out to identify factors affecting cutting efficiency. With a shear energy value of 3.9 mJ/mm², the necessary cutting power was calculated to be 41.32 W (0.055 hp), yielding force and torque values of 91.83 N and 11.47 Nm, respectively. The system delivers a cutting width of 90 cm at about 30 oscillations per minute, featuring a 2:1 quick-return ratio, enhancing operational efficiency. Ergonomic design grounded in BIS anthropometric data guarantees decreased operator fatigue. The suggested hybrid system (engine and battery) featuring interchangeable blades aims to improve field efficiency and minimize fatigue. Additional field assessment is advised to confirm effectiveness.

Keywords: Swinging type brush cutter, conceptual design, with-worth quick return mechanism, brush cutter, farm mechanization

Introduction

Agriculture plays a crucial role in the Indian economy, making a notable contribution to GDP and offering jobs to almost half of the population. Although it is a top worldwide producer of key crops, the sector encounters issues like low productivity, divided landholdings, and a shortage of labor. In India, the typical farm size is approximately 1.16 ha, with nearly 85% of farms categorized as small and marginal, which restricts the implementation of advanced technologies (Mehta *et al.*, 2016) ^[1]. Moreover, the decreasing role of human and animal labor has heightened dependence on machinery to guarantee prompt and effective agricultural activities. Nonetheless, the uptake of mechanization is still limited by expensive costs, restricted access to financing, and a deficiency in technical knowledge (Anonymous, 2020) ^[2]. This requires the creation of cost-effective and efficient agricultural equipment. Brush cutters are crucial for managing vegetation and preparing land, but traditional designs frequently lead to operator fatigue and have efficiency constraints. Thus, this research aims to create an advanced brush cutter system to boost efficiency, lessen user fatigue, and promote sustainable agricultural mechanization.

To address the limitations of conventional brush cutters, this study aims to design a swinging-type brush cutter that enhances field efficiency and reduces operator fatigue
Material and Methods

This section outlines the materials and methods used for the conceptual design of the swinging-type brush cutter. The design relies on analytical calculations, field data, and recognized engineering principles. It encompasses evaluating grass characteristics, creating design equations, and integrating ergonomic factors to improve operator comfort and effectiveness.

Grass parameters assessment

An evaluation in agricultural regions close to Akola was carried out to record essential physical

traits of prevalent grass and weed species affecting cutting machine design. Measurements were taken for five species, including plant height, stem diameter, stem characteristics, leaf dimensions, root type, biomass density, and cutting resistance: *Cynodon dactylon*, *Saccharum spontaneum*, *Imperata cylindrica*,

Pennisetum purpureum, and *Parthenium hysterophorus*. A design shear energy of 3.9 mJ/mm² (Nandish *et al.*, 2019) [3] was utilized for calculations of power and force, employing an average stem diameter of 3 mm as a typical reference for frequently found species such as Doob and Congress grass.

Table 1: Physiological characteristics of different grass

Parameter	Doob Grass (<i>Cynodon dactylon</i>)	Kans Grass (<i>Saccharum spontaneum</i>)	Cogon Grass (<i>Imperata cylindrica</i>)	Napier Grass (<i>Pennisetum purpureum</i>)	Congress Grass (<i>Parthenium hysterophorus</i>)
Plant Type	Creeping Perennial	Tall Perennial	Perennial Weed	Perennial Fodder Grass	Annual Invasive Weed
Plant Height	1-30 cm	1-3 m	0.2-3 m	2-7 m	0.5-1.5 m
Stem Diameter	~1 mm	3 -15 mm	2-8 mm	10-30 mm	3-10 mm
Stem Nature	Soft, Creeping	Hard, Erect	Firm	Thick, Fibrous	Soft to Medium
Leaf Length	2-15 cm	50-120 cm	12-80 cm	100-120 cm	5-20 cm
Leaf Width	1-6 mm	6-15 mm	10-20 mm	10-50 mm	20-80 mm
Root Type	Fibrous + Rhizome	Rhizomatous	Deep Rhizome	Fibrous	Tap Root
Cutting Resistance	Low	High	Medium-High	High	Low-Medium
Field Occurrence	Lawns, Fields	Riverbanks, Wastelands	Drylands, Wastelands	Cultivated Fodder Fields	Cropland, Roadsides
Reference Citation	Zhang <i>et al.</i> , 2024; ScientificLib, 2021	FAO, 2018; Wikipedia, 2024	CABI, 2023; USDA, 2022	Feedipedia (FAO), 2020	Adkins & Shabbir, 2014; CABI, 2023

Conceptual Design

The apparatus is made up of four primary components: (i) cutting section (Petro engine, Cutting shaft & blades), (ii) swinging system (DC motor with crank and slotted lever and pivot base), (iii) framework (mild steel structure, wheels,

adjustable caster), and (iv) user control (handle, throttle, switch). Its operation relies on the Whitworth quick return mechanism. When engaged, the crank generates oscillatory movement that moves the engine-blade unit side to side, spanning approximately 90 cm at close to 30 oscillations per minute.

Table 2: Components Specifications

Sr. No.	Components	Types	Specifications
1	Engine (GX 35)	Type / Displacement	4-Stroke Air-Cooled / 35 cc
		Rated Power / Max Speed	0.85 kW / 9000 RPM
		Fuel Tank / Oil Capacity	700 ml / 55 ml
2	Swing Motor	Type / Voltage	DC Planetary Gear Motor / 12 V
		RPM / Torque	30 RPM / 40 Nm
3	Battery	Voltage / Capacity	12 V / 12 Ah
4	Blades	Types Available	Nylon wire, Circular Blade, Two Teeth Blade
5	Drive Shaft	Inner / Outer	9-spline inner; 28 mm dia. outer
6	Frame	Material / Section	Mild Steel 25×25×3 mm angle
7	Crank	Diameter / Pin offset	-
8	Slider	Dimensions	-
9	Main Tyres	Size / Type	3.50 - 15 Rubber Pneumatic
10	Caster Wheel	Size / Load capacity	2.50-4 / 80-150 kg per wheel
11	Cutting Swath	Width (swing stroke)	90 cm
12	Switch	Type	Toggle 12 V (swinging / non-swinging)

Design Calculations

The cutting power requirement as estimate d using the shear energy approach: (Nandish *et al.*, 2019) [3]

$$A = \frac{\pi}{4} d^2, \quad P = E \times n_s$$

where d = 3 mm. The calculated power requirement was 41.32 W (0.055 hp). The corresponding cutting force and torque were obtained as:

$$F = \frac{E}{d}, \quad T = F \times r$$

yielding 91.83 N and 11.47 Nm, respectively. The shaft was designed based on combined bending and torsion using: (Budynas, B., *et al.*, 2019) [4]

$$T_s = \sqrt{M^2 + T^2}, \quad d = \left(\frac{16T_s}{\pi\tau} \right)^{\frac{1}{3}}$$

resulting in a shaft diameter of 19 mm.

The swinging mechanism was designed using Whitworth quick return mechanism with a quick return ratio:

$$QRR = \frac{\beta}{\alpha}$$

ensuring efficient cutting operation.

The crank pin and slider were designed using standard strength equations: (Bansal, R. K., 2005)

$$d = \left(\frac{16T_s}{\pi\tau} \right)^{\frac{1}{3}}, \quad t = \sqrt{\frac{6M}{b\sigma}}$$

resulting in 10 mm crank pin diameter and 5 mm slider thickness. The frame was selected based on section modulus criteria $Z = M/\sigma$, ensuring adequate strength.

Ergonomic consideration for the handle

The handle acts as the main user interface, and poor design may

elevate musculoskeletal strain (Bo Li and Shusen Li, 2016; Jadhav *et al.*, 2025) ^[5, 6]. Consequently, the ergonomic handle was developed utilizing anthropometric information from BIS IS 9621:1980, which encompasses the 5th to 95th percentile of Indian agricultural labourers.

Table 3: Anthropometric parameters for the handle design

Anthropometric Parameter	Range (5 th -95 th %ile)	Design Decision
Standing Elbow Height	920-1100 mm	Handle height: 1000 mm (adj. 950-1050 mm)
Shoulder Bi-deltoid Width	360-500 mm	Handle spread: 430 mm
Hand Breadth	75-95 mm	Grip diameter: $d = 0.2 \times 85 = 17$ mm (selected 35 mm OD hollow tube)
Hand Length	165-195 mm	Grip length per hand: ≥ 120 mm
Recommended Grip Diameter	30-40 mm	Adopted: 35 mm OD / 31 mm ID steel pipe

The handle underwent structural verification for a steering moment of 20 Nm, leading to a required force of 100 N. For a hollow steel pipe (OD 35 mm, ID 31 mm), the bending stress was determined to be 3.24 MPa, significantly under the yield strength of mild steel, providing a strong safety margin. The handle height can be adjusted between 950 and 1050 mm to suit various users (BIS, 1980) ^[8].

The design reduces operator vibrations by isolating engine vibrations via the wheeled chassis, with further damping from rubber mounts at the engine base, enhancing operator comfort (Bo Li and Shusen Li, 2016; Jadhav *et al.*, 2025) ^[5, 6]

Key Design Features and Advantages

The suggested swinging-style brush cutter will offer a 90 cm cutting width with each swing, removing the need for manual side-to-side movement and enhancing field coverage. The Whitworth quick return mechanism (2:1 ratio) will improve cutting efficiency, while the cart-mounted design will lessen operator fatigue by shifting the machine's weight to the wheels. The system will feature dual-mode functionality (swinging and conventional) along with replaceable blades for various types of vegetation. The combination of engine and battery in the hybrid setup will guarantee uninterrupted function, while the height adjustment feature will allow for accurate cutting regulation.

Design Limitations

The suggested machine will exhibit greater weight and mechanical intricacy than standard brush cutters, potentially impacting portability and necessitating frequent upkeep. Its capability might be restricted on steep or irregular surfaces. The initial production expense is projected to be greater; nevertheless, it is expected that operational efficiency will offset this. The battery will offer restricted support for the swinging mechanism, requiring occasional charging or replacement.

Conclusion

The conceptual design of the swinging-type brush cutter will focus on enhancing operational efficiency, ergonomics, and area coverage. The design aims to meet a cutting power requirement of around 41.32 W, with suitable dimensions for the shaft, crank, and structural elements to guarantee safe operation. The system will employ a 2:1 quick-return mechanism for effective cutting across a 90 cm width.

Additional research will be necessary to confirm the machine's performance via field assessments, encompassing factors like field capacity, cutting efficiency, energy usage, and ergonomic functionality.

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