FABRICATION AND PERFORMANCE TESTING OF VEGETATIVE FORRAGE CHOPPER MACHINE

BY

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CERTIFICATION

This is to certify that this project report Fabrication and performance testing of vegetative forrage chopper machine was prepared by Abubakar Ahmed ND/ 23/MEC/FT/0040. Meets the requirement for the award of National Diploma (ND) in the department of Mechanical Engineering, Kwara State Polytechnic, Ilorin, and was approved for its contribution to knowledge and literacy presentation.

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DEDICATIONS

This project is dedicated to Almighty God, the source of all knowledge and wisdom. I also dedicate it to my beloved parents and family members, whose unwavering love, prayers, and sacrifices have been the pillar of my academic pursuit. Finally, to all students and researchers in the field of Mechanical Engineering who are passionate about mechanization and improving agricultural productivity this work is for you.

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ABSTRACT

This study is designed and fabricated in order to help people particularly farmers who engaged in forage in order for them to produce a voluminous forage in less time easily. The primary goal of this study was to design, fabricate, and evaluate the performance of the forage chopper machine. The study specifically aimed to evaluate the performance of the machine using three different diameter pulleys in terms of: 1) Throughput Capacity (kg/hr), 2) Chopping Capacity (kg/hr), 3) Chopping Recovery (%), 4) Machine Efficiency (%), and 5) Percent Loss (%). The sample used to evaluate the performance of the machine was a constant feeding rate of 500 grams of a freshly harvested Napier Grass (Pennisetum purpureum). There were three treatments namely T1(3-inch diameter pulley), T2(4-inch diameter pulley), and T3(5-inch diameter pulley). Three replications for every treatment were used. During the data gathering, the time of chopping for every 500 grams of sample that was fed was measured. Also, the output or the chopped materials were sorted into two (accepted output and unaccepted output) and weighed using a weighing scale. The study revealed that the difference in diameter pulley greatly affected the chopping capability as well as the chopping uniformity of the machine. It was also observed during the data gathering that the use of bigger diameteron the machine gave much better result which led on a much higher machine efficiency. The highest throughput capacity was the T3 (5-inch diameter pulley) that has the fastest speed among the three treatments. As to the chopping, the highest chopping capacity was T3 (5-inch diameter pulley) that has the faster speed among the three treatments. As to the chopping recovery, the highest chopping recovery was the T1 (3-inch diameter pulley) which has the slowest speed among the three treatments. The highest machine efficiency was the T3 (5-inch diameter pulley) which has the fastest speed among the *three treatments. The highest percentage of loss was the T1 (3-inch diameter pulley) which has the slowest speed among the three treatments.*

Keywords: design, fabrication, forage, forage chopper machine, napier grass

CHAPTER ONE

1.0 Introduction

Forage grass may be of little importance as we perceive it but it has a numerous economic importance and uses most especially in providing nourishment for most dairy animals. Future intensive and sustainable livestock production systems, requires a thorough knowledge of the potentials and limitations of the system. Forage availability is one of the most important factors determining the potential of a given ruminant livestock production system (E.A. Lazaro et al.). To some extent, forage grass is easy to cultivate with. And in most localities, farmers harvest forage grass from its stem and cut the crop into short parallel length for a period of time and then mix it with the other constituent's until it becomes ready for feeding. Forage chopping is a common process done by most local farmers in feeding livestock. These process takes a lot of time and effort especially in a large scale unit which led to the realization of lessening the problem. Forage chopper is used to cut/chop forage as a replacement of a cutlass (E.A. Lazaro et al.). Designing and constructing a Forage Chopper Machine for feeding livestock is one of the most appropriate way in solving the problem. This Machine could cut the laborious process of manual chopping and could save the time to be used in large scale of feeding livestock.

1.2 History of Forage Chopping

Origins and Pre-Industrial Foundations (Pre-1800s) The idea of chopping forage predates industrialization. Early agricultural societies manually processed plant materials such as straw, hay, and stalks using sickles, knives, and rudimentary cutting tools. These efforts aimed to improve the palatability and digestibility of feed for animals like horses, cattle, and sheep. The process was entirely labor-intensive, relying on human or animal labor.

While no mechanical chopper existed at this stage, these practices laid the foundation for the mechanization that followed during the industrial age. Early Mechanization and the Rise of the Chaff Cutter (1800s – Early 1900s) With the advent of the Industrial Revolution in the 18th and 19th centuries, agriculture saw a wave of innovations. Among them was the chaff cutter, a machine designed to chop dry straw and hay into smaller pieces for livestock feeding.

Key Features: Manually operated with a rotating drum and fixed blades. Some used a crank handle; others introduced flywheel energy storage for smoother cutting. Made with wooden frames and cast-iron components. Chaff cutters dramatically reduced labor and improved feed efficiency. British and German manufacturers were among the first to produce and export these machines. These units became common on farms across Europe, North America, and colonial territories by the late 1800s.

Mechanized Agriculture and the Forage Revolution (Early to Mid-1900s)

The early 20th century brought about widespread use of tractors and internal combustion engines, transforming agricultural practices globally. These changes influenced the evolution of the chopper machine in two primary forms:

(a) Tractor-PTO-Driven Choppers

These choppers used the tractor's power take-off (PTO) to drive rotating blades and feed rollers.

Allowed continuous operation in the field for processing green fodder like maize, alfalfa, and Napier grass.

Often included adjustable cutting lengths and basic safety features.

(b) Stationary Motorized Choppers

Powered by gasoline or diesel engines.

Used for on-site chopping near silage pits or barns.

Ideal for small to medium-sized operations.

This period also witnessed the emergence of silage practices, where chopped green fodder was stored in anaerobic conditions to ferment and preserve nutritional content. The design of chopper machines adapted to support silage-making, with finer cuts and higher throughput.

Industrial Scaling and Self-Propelled Forage Harvesters (1950s–1980s)

The post-WWII agricultural boom saw consolidation of farms and an emphasis on mechanized, high-output operations. This gave rise to self-propelled forage harvesters—high-capacity chopper machines with integrated engines and mobility.

Industry Leaders:

John Deere: Introduced innovative chopper heads and automatic feed mechanisms.

Class (Germany): Pioneered drum-based chopping units with high durability.

New Holland: Specialized in modular systems for maize and grass.

Technological Milestones:

Drum or flywheel cutting mechanisms capable of 1,000–3,000 RPM.

On-board sharpening systems for knives and blades.

Hydraulic adjustments for cutting height and length.

Self-propelled machines became indispensable in dairy and commercial livestock operations. The ability to harvest and chop in a single pass reduced field time and labor. Smart Technology Integration and Precision Agriculture (1990s–Present)

As agriculture entered the digital age, chopper machines evolved into precision instruments that integrated electronics, computing, and automation.

Advanced Features: GPS and Yield Mapping: To monitor productivity and optimize routes. Moisture and Nutrient Sensors: Measure silage quality during harvest.

Automatic Knife Sharpening and Shear Bar Adjustments.

Telematics Systems: Enable remote monitoring and performance tracking.

Sustainability Focus:

Fuel-efficient engines complying with emission norms.

Improved cutting technologies to reduce wastage.

Compact and mobile designs for smallholder and urban farming.

Chopper Machines in Developing Countries

In Africa, South Asia, and parts of Latin America, locally fabricated chopper machines serve small and medium-scale farmers. These machines are typically

Powered By:

Electric motors or small diesel engines.

Designed to be low-cost and easy to repair.

Capable of chopping various materials: maize stalks, sugarcane tops, grass, and banana stems.

In these regions, chopper machines play a critical role in:

Reducing feed preparation time.

Increasing fodder utilization.

Supporting mixed farming systems.

The history of the chopper machine, particularly in agricultural and forage processing, traces back to the growing need for efficient animal feed preparation.

Early History

19th Century: The origins of chopper machines can be linked to simple manual feed cutters, also known as chaff cutters. These were hand-operated devices used to cut straw or hay into small pieces to make it easier for livestock to digest.

Late 1800s: With the advent of mechanization, horse-powered and then steam-powered chaff cutters emerged, improving efficiency on farms.

20th Century Developments

Early 1900s: The introduction of tractor-driven and motorized choppers revolutionized feed processing. These machines could chop more material quickly and with less labor.

Mid-1900s: The rise of silage making (fermented, high-moisture stored fodder) increased the demand for powerful forage harvesters and choppers.

Self-propelled forage harvesters were developed by companies like New Holland, John Deere, and Claas, incorporating powerful engines and advanced cutting mechanisms.

Modern Chopper Machines

Late 20th to 21st Century:

Modern chopper machines use hydraulics, electronics, and precision controls.

Multifunctional designs now allow for chopping various types of forage (e.g., grasses, maize, sorghum).

Focus on energy efficiency, higher throughput, and minimal loss of material.

Some models feature GPS, sensors, and automation to optimize performance and reduce labor.

Applications Today

Used in dairy and livestock farms for preparing silage and green fodder.

Essential in commercial forage production and biomass processing for renewable energy.

1.3 Types of Forage Chopping Methods

Forage chopping is a critical step in the preparation of animal feed, particularly in improving the palatability, digestibility, and storability of fodder. Over time, various chopping methods have been developed and employed depending on the scale of operation, type of crop, available technology, and desired outcome (e.g., dry feed vs. silage). The following are the primary forage chopping methods:

1.3.1 Manual Chopping

Manual chopping involves using hand tools such as machetes, sickles, or knives to cut forage into smaller pieces.

Applications:

Common in smallholder farms with limited access to machinery.

Suitable for chopping soft-stemmed plants like grass and legumes.

Advantages:

Low cost.

No need for fuel or electricity.

Limitations:

Labor-intensive and time-consuming.

Inconsistent chop size.

Unsuitable for large-scale operations.

1.3.2 Hand-Operated Chaff Cutters

These are manually operated machines with rotating blades activated by a hand crank. Feed is inserted into a hopper and chopped by turning the handle.

Applications:

Suitable for cutting dry fodder like straw and hay.

Common in low-resource rural settings.

Advantages:

Greater efficiency than manual chopping.

Uniform chop size.

No electricity needed.

Limitations:

Requires physical effort.

Limited throughput.

1.3.3 Motorized Forage Choppers

These machines are powered by electric motors or small internal combustion engines. They use feed rollers and rotating blades or drums to chop forage.

Applications:

Widely used in medium-scale farms.

Suitable for green fodder (e.g., maize, sorghum, Napier grass).

Advantages:

High chopping speed and capacity.

Adjustable chop length.

More uniform output.

Limitations:

Requires fuel or electricity.

Maintenance required.

1.3.4 Tractor-PTO Powered Choppers

These machines are connected to the Power Take-Off (PTO) shaft of a tractor. They can be either stationary or towed for in-field operation.

Applications:

Used in medium to large-scale commercial farms.

Effective for crops like maize, sugarcane tops, and grass.

Advantages:

High capacity and mobility.

Can handle tougher materials.

Efficient for silage preparation.

Limitations:

Requires a tractor.

Higher initial cost.

1.3.5 Self-Propelled Forage Harvesters

These are sophisticated machines equipped with their own engines and mobility systems. They harvest standing crops and chop them simultaneously.

Applications:

Large-scale dairy and commercial livestock farms.

Intensive silage operations.

Advantages:

Very high throughput.

GPS, sensor, and automation features.

Efficient for harvesting and chopping in a single pass.

Limitations:

Very expensive.

Requires trained operators.

High maintenance and fuel costs.

1.3.6 Multi-Purpose Crop Residue Choppers

These are specially designed machines capable of chopping a variety of crop residues, such as maize stalks, wheat straw, paddy straw, and sugarcane trash.

Applications:

Useful in integrated farming systems.

Helps reduce waste and enhance feed resource utilization.

Advantages:

Versatile.

Reduces environmental pollution from crop burning.

Supports circular farming systems.

Limitations:

Variable chopping quality depending on material type.

May require regular adjustment.

1.4 Types of Forage Chopping Machines

The selection of an appropriate forage chopping machine is essential for efficient fodder processing, especially in the context of small- to medium-scale livestock farming systems. In a fabrication and performance evaluation project, choosing a machine that is mechanically simple, scalable, and adaptable is key. The following are types of forage choppers suitable for such applications, along with relevant research references.

1.4.1 Flywheel-Type Forage Chopper

This type features a rotating flywheel with 2 to 6 blades mounted radially. As the flywheel rotates, forage fed through the chute is chopped against fixed or counter blades.

Suitability:

Ideal for fabrication projects due to its mechanical simplicity, high inertia for cutting power, and suitability for various feedstocks (e.g., Napier grass, maize stalks).

Advantages:

Easy to fabricate with locally available materials.

High chopping efficiency and momentum retention.

Good for variable-speed testing using different pulley diameters.

1.4.2 Drum-Type Forage Chopper

Features a horizontal drum with several mounted knives that rotate to cut the forage. The drum is powered by a belt-pulley system connected to an electric motor or engine.

Suitability:

More advanced and suitable for performance analysis related to cut uniformity and throughput capacity.

Advantages:

Uniform cutting for silage preparation.

Allows for higher-speed cutting compared to flywheel systems.

1.4.3 Motorized Forage Chopper (Standalone Unit)

A basic forage cutter powered by a 1–5 hp electric motor or a small petrol/diesel engine. It uses rotating blades mounted on a shaft and fed through a hopper.

Suitability:

Highly relevant for small-to-medium fabrication projects. Offers flexibility for testing design variables like blade number, speed, feed rate, and pulley sizes.

Advantages:

Economical and compact.

Easy to modify and test under various conditions.

1.4.4 PTO-Driven Forage Chopper

This machine operates by attaching to the Power Take-Off (PTO) shaft of a tractor. Suitable for field use and medium-to-large-scale chopping operations.

Suitability:

Not ideal for fabrication in small workshops but can be referenced for performance benchmarking and efficiency comparison.

Advantages:

High capacity and rugged performance.

Useful for evaluating throughput versus energy consumption.

1.4.5 Multi-Crop Residue Chopper

A versatile machine designed to process different crop residues including wheat straw, maize stalks, and sugarcane tops. It combines chopping with shredding mechanisms.

Suitability:

Useful for performance testing with different forage types and assessing machine versatility.

Advantages:

Reduces post-harvest waste.

Multi-functional: chopping and shredding.

1.5 Materials for Making a Forage Chopper

The selection of appropriate materials is fundamental to the successful design, fabrication, and performance testing of any agricultural machinery. In this study, the forage chopper machine was specifically designed to process freshly harvested Napier grass (Pennisetum purpureum), evaluating its performance across three different pulley diameters (3-inch, 4-inch, and 5-inch). As the machine operates with rotational and impact mechanisms, the materials used must exhibit adequate mechanical strength, wear resistance, machinability, and cost-efficiency.

Each component of the forage chopper was selected based on its operational function—whether structural, rotary, or cutting—and the expected mechanical stress.

1.5.1 Frame and Structural Components

Material Used: Mild Steel (MS) – ASTM A36 or equivalent

Justification:

Mild steel was chosen for the mainframe and support structures due to its high weldability, affordability, and adequate strength. It ensures machine stability during high-speed operation, especially when subjected to vibrations caused by variable pulley diameters.

Applications:

Mainframe, base platform, feed chute housing.

1.5.2 Cutting Blades

Material Used: High Carbon Steel (EN9 or EN42)

Justification:

Since Napier grass has fibrous content, a hard and durable blade material is critical. High carbon steel provides excellent edge retention and can be heat-treated to improve hardness, allowing consistent chopping and minimal blade wear.

Applications:

Rotary chopping blades mounted on the flywheel.

1.5.3 Shafting System

Material Used: Medium Carbon Steel (EN8 / C45 Steel)

Justification:

The shaft connected to the flywheel and pulley system requires good tensile strength and torsional resistance, particularly as different pulley diameters alter the rotational speed. Medium carbon steel offers the necessary mechanical properties for rotational and load-bearing components.

Applications:

Blade shaft, pulley shaft.

1.5.4 Pulley and Belt Drive System

Material Used:

Pulley: Cast Iron

Belt: Rubber V-belt with fabric reinforcement

Justification:

The machine's performance evaluation depended heavily on variable pulley diameters (3", 4", 5"). Cast iron provides balance and vibration damping at high rotational speeds, while the V-belt offers a flexible yet secure means of power transmission.

Applications:

Speed regulation, transmission of power from motor to blade shaft.

1.5.5 Bearings and Rotational Supports

Material Used:

Bearing Housings: Cast Iron

Bearings: Chrome Steel (SAE 52100)

Justification:

As chopping speed increased with larger pulleys, bearing support became crucial. Chrome steel ball bearings reduce friction and support high-speed rotation, ensuring efficient blade motion and minimizing energy loss.

Applications:

Blade shaft support, motor shaft alignment.

1.5.6 Hopper and Safety Coverings

Material Used: Galvanized Iron Sheet or Mild Steel Plate

Justification:

The hopper, which delivers forage into the cutting zone, must resist corrosion and physical damage from feed materials. Galvanized steel offers protection against rust due to moisture in fresh Napier grass.

Applications:

Feed chute, output chute, protective casing.

1.6 Aim and Objectives of the Project

Aim

The aim of this project is to design, fabricate, and evaluate the performance of a forage chopper machine that can efficiently process forage grass into smaller, uniform pieces, thereby enhancing productivity and feed management practices among local farmers.

Objectives

To realize the stated aim, the following specific objectives were formulated:

To design and fabricate a forrage chopper machine using locally available materials, incorporating variable pulley sizes to test performance variations.

To determine the performance of the machine using three different diameter pulleys:

T1 – 3-inch diameter pulley

T2 – 4-inch diameter pulley

T3 – 5-inch diameter pulley

To assess the machine's performance in terms of:

Throughput Capacity (kg/hr) – the total weight of chopped forage output per unit time.

Chopping Capacity (kg/hr) – the quantity of Napier grass the machine can effectively chop per hour.

Chopping Recovery (%) – the proportion of acceptable chopped output relative to the total input.

Machine Efficiency (%) – the ratio of effective output to total input, accounting for time and losses.

Percent Loss (%) – the proportion of unaccepted or wasted material from the total processed forage.

To compare the impact of pulley diameter on machine speed, output quality, and operational efficiency.

To recommend the most suitable pulley diameter for optimum forage chopping based on experimental results and performance metrics.

1.7 Scope of the Project

This project focuses on the design, fabrication, and performance evaluation of a manually-fed, motor-driven forage chopper machine intended for small to medium-scale agricultural applications. The machine was specifically developed to chop freshly harvested Napier Grass (Pennisetum purpureum), a common and high-yielding forage crop in tropical and subtropical regions.

The scope of the study includes the following key aspects:

- **Design and Fabrication:**

The chopper was constructed using locally available materials and standard mechanical components. Emphasis was placed on simplicity, cost-effectiveness, and ease of maintenance to ensure practical usability in rural farming communities.

- **Pulley Variation:**

Three different pulley diameters (3", 4", and 5") were tested in order to evaluate their influence on machine speed and chopping performance. These configurations formed the core treatments (T1, T2, T3) used in the experimental setup.

1.8 Problem Statement

In many developing agricultural regions, livestock farmers continue to rely on traditional manual methods to process forage crops such as premium grass.These methods are labor-intensive, time-consuming, and inefficient, often resulting in inconsistent chop sizes, high material wastage, and low throughput. The lack of affordable, accessible, and efficient forage chopping equipment poses a significant challenge to smallholder farmers who aim to meet the nutritional demands of their livestock.

Additionally, the absence of performance-optimized chopping machines tailored to specific forage types leads to poor utilization of available fodder resources. Most available commercial choppers are either too costly or over-engineered for rural applications, limiting their practicality and adoption among small-scale users.

This project seeks to address these issues by designing, fabricating, and evaluating a cost-effective forage chopper using locally available materials and testing it under controlled conditions. The aim is to determine how variations in pulley diameters (3", 4", and 5") affect key performance parameters such as:

Throughput Capacity (kg/hr)

Chopping Capacity (kg/hr)

Chopping Recovery (%)

Machine Efficiency (%)

Percent Loss (%)

By identifying the optimal configuration, the study aims to enhance forage processing efficiency, reduce labor input, minimize losses, and ultimately improve feed preparation for livestock farming.

CHAPTER TWO

2.0 Analysis of Alternative Methods and Selection of Best Approach

Forage chopping plays a vital role in modern livestock production by enhancing the digestibility and handling of fodder crops such as Napier Grass (Pennisetum purpureum). The traditional methods of forage processing, which are largely manual, are often time-consuming, labor-intensive, and inefficient in terms of output and uniformity of chop. To address these limitations, various mechanical approaches have been developed. This chapter discusses alternative methods of forage processing, compares different types of chopper machines, and provides justification for the selection of the motorized forage chopper with pulley diameter variations used in this study.

2.1 Traditional Methods of Forage Processing

Traditionally, forage crops are harvested using manual tools like sickles and then chopped using knives or manually operated choppers. Although these methods are cost-effective, they significantly limit production volume, especially when dealing with large-scale livestock needs. The variability in chop size and slower processing speed negatively affect feeding efficiency and storage (Singh & Verma, 2015). These methods are not suitable for modern dairy farms or forage-intensive operations where high throughput and consistent chop size are essential.

2.2 Mechanized Methods of Forage Chopping

Mechanization has improved the efficiency and output of forage chopping. Some of the common mechanized methods include:

- Manual and Pedal-powered Choppers: Suitable for small-scale farmers; low cost but still labor-intensive.

- Motorized Choppers: Powered by electric motors or small engines, these machines deliver higher throughput with more uniform chop sizes. They are suitable for medium to large-scale forage operations.
- Tractor-Mounted or PTO (Power Take-Off) Choppers: These are ideal for commercial-scale farms, with high-speed operation and large capacity, but at a higher cost.

Given the need for moderate-cost and high-efficiency operation in developing and rural settings, the motorized forage chopper with adjustable pulley sizes offers an optimal balance between cost, efficiency, and ease of use (FAO, 2017)

2.3 Selection of Best Approach

This study employed a motorized forage chopper machine with three different pulley diameters (3-inch, 4-inch, and 5-inch) to analyze performance based on key indicators such as throughput capacity, chopping capacity, chopping recovery, efficiency, and percent loss. The pulley-driven design allows for adjustable blade speeds, which is essential in determining optimal machine performance without overcomplicating the system.

Results indicated that larger pulleys (i.e., T3: 5-inch diameter) provided better throughput and efficiency due to increased blade speed, while smaller pulleys had higher chopping recovery but also more waste. This validates the approach of using a variable-speed mechanism for performance optimization.

The selected method ensures:

Increased processing speed

Improved uniformity of chopped forage

Reduced labor

Adaptability to various farm sizes

Thus, the motorized pulley-based forage chopper emerges as the most practical and effective method for enhancing forage processing in small to medium-sized agricultural operations.

2.1 Method of Forage Production

Forage production is an essential component of livestock farming, providing the primary source of roughage and nutrients for ruminant animals. Among various forage crops, Napier Grass (Pennisetum purpureum) is widely cultivated due to its high biomass yield, rapid regrowth, and palatability. The method of producing forage involves several critical stages: land preparation, planting, maintenance, harvesting, and processing.

Land Preparation and Planting

The preparation of land begins with clearing, plowing, and harrowing to ensure a fine tilth suitable for root establishment. Napier grass is typically propagated through stem cuttings planted in rows with appropriate spacing (usually 75–90 cm between rows and 30–50 cm within rows) to allow for healthy tillering and easy access during harvesting (Mutimura & Everson, 2012).

Maintenance and Fertilization

Regular irrigation, weed control, and application of organic or inorganic fertilizers are necessary to sustain high yield and quality. Napier grass responds well to nitrogen fertilization, which boosts biomass production. Routine maintenance also involves monitoring for pests and diseases such as head smut and Napier grass stunt disease.

Harvesting

Napier grass is usually harvested at a height of 1.0–1.5 meters, depending on the desired chop length and maturity stage. Younger plants are preferred for their higher digestibility and protein content. In traditional systems, harvesting is performed manually using sickles. However, with increased demand and larger-scale operations, mechanized harvesting is becoming more common.

Processing and Chopping

Once harvested, forage must be chopped to enhance digestibility, ease of handling, and efficient use in feeding systems or silage production. Chopping breaks down the plant structure, reducing particle size, which facilitates better chewing, microbial digestion in the rumen, and minimizes feed wastage. Traditionally, chopping was performed using knives or manual choppers, but these are labor-intensive and inconsistent in output.

Modern methods use motorized forage choppers, such as the machine developed in this study, which not only improve productivity but also ensure more uniform chopping. In this study, Napier grass was fed into a fabricated chopper machine at a constant rate (500 grams per cycle) to evaluate chopping performance under different pulley sizes. The results supported the conclusion that proper mechanical processing significantly improves forage production efficiency.

2.2 Types of Forage Choppers

Forage choppers are agricultural machines designed to cut, chop, and shred forage crops into smaller pieces, making them easier to digest by livestock and more suitable for storage or further processing such as silage production. These machines vary in design, capacity, power source, and cutting mechanisms, depending on their intended use, scale of operation, and the type of forage being processed.

1. Manual Forage Choppers

Manual or hand-operated choppers are the most basic type, typically used by smallholder farmers. These machines consist of a cutting blade attached to a crank or lever that is operated manually. Although inexpensive and simple to maintain, they are labor-intensive, slow, and have inconsistent chopping sizes. Their use is generally limited to small-scale operations and subsistence farming.

2. Animal-Drawn Forage Choppers

In some rural and remote areas, animal-powered choppers are still in use. These systems involve mechanical cutters powered through gears driven by animals walking in circles. Though more efficient than manual systems, they are being phased out due to labor requirements, land space, and limitations in output.

3. Motorized Forage Choppers

Motorized choppers, like the one designed and tested in this study, are widely used in medium to large-scale forage production. They are powered by electric motors or internal combustion engines and can process larger volumes of forage with greater speed and uniformity. These machines can be further classified into:

- **Fixed-type choppers:** Installed in a stationary location, often near feed storage areas. They are designed for continuous, high-volume operation.
- **Portable choppers:** Designed with wheels and lightweight frames, allowing for movement between fields or farms. The chopper developed in this study falls under this category.
- **Tractor-mounted or PTO-driven choppers:** Common in large-scale commercial farms, these machines are powered by a tractor's power take-off

(PTO). They offer very high throughput and are suitable for field use during harvest.

4. Self-Propelled Forage Harvesters

These are high-capacity, all-in-one machines designed for industrial-scale farming. They can harvest, chop, and sometimes even load the forage into transport vehicles in a single pass. While extremely efficient, they are costly and require significant capital investment, making them impractical for smallholder farmers.

The forage chopper machine in this study falls under the motorized portable category, specifically tailored to support small to medium-scale forage producers. By integrating variable pulley sizes (3-inch, 4-inch, and 5-inch) and evaluating performance under consistent feeding conditions (500g Napier Grass), the study explored how machine speed and cutting efficiency could be optimized for rural application.

2.3 Requirements of a Good Forage Chopper

A good forage chopper is essential for ensuring efficient and high-quality forage production, particularly for livestock feeding. The design and performance of the machine directly affect the productivity of farmers and the quality of forage output. The key requirements for a good forage chopper are defined by its operational efficiency, chopping uniformity, ease of use, and suitability for the intended forage type.

1. High Chopping Efficiency

The machine must be capable of processing large volumes of forage in minimal time, especially during harvest seasons when speed is crucial. In the study, the chopper using the 5-inch diameter pulley (T3) achieved the highest machine efficiency, indicating that higher pulley speed leads to better performance (Singh & Jain, 2017).

2. Uniform Chopping Size

Uniform chopping ensures consistent particle sizes, which improves digestibility for livestock and facilitates easier storage and compaction in silage-making. The study revealed that pulley size affects chopping uniformity, where higher speeds produced more consistent and acceptable output, reducing the amount of unaccepted material.

3. Minimal Forage Loss

An effective forage chopper minimizes the amount of forage that is poorly cut or wasted. According to the experiment, the smallest pulley (3-inch) resulted in the highest percentage of loss, demonstrating the importance of optimal machine speed and design in reducing waste.

4. Durability and Ease of Maintenance

A good forage chopper should be constructed from durable materials that can withstand regular use and resist wear from tough forage like Napier grass. Additionally, maintenance should be simple and affordable, particularly for rural farmers with limited access to replacement parts and technical support (FAO, 2013).

5. Energy Efficiency and Adaptability

It should operate efficiently with minimal energy input, whether powered manually, electrically, or through fuel engines. Adaptability to different power sources and ease of pulley adjustments, as explored in the study, make the machine more versatile and suited for various farming environments.

6. Safety Features

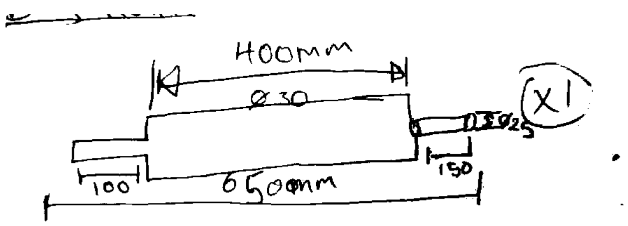
For safe operation, especially in rural communities where users may not have technical training, the machine should include safety guards on moving parts, stable frames to prevent tipping, and easy-to-reach emergency shut-offs.

7. Cost-effectiveness and Affordability

The machine should be economically viable for small and medium-scale farmers. The design in this study, which allows variable pulley sizes, offers a cost-effective solution by enabling performance tuning without expensive technological upgrades.

The chopper fabricated in this study fulfilled many of these requirements, with the 5-inch pulley treatment (T3) proving to be the most effective in terms of throughput, chopping capacity, and efficiency. This reinforces the idea that proper design considerations, such as pulley diameter and speed, are essential for developing effective forage chopping solutions for rural agriculture.

CHAPTER THREE



Drag roller

1) Volume calculation

$\mathbf{V^1 = \pi R^2 H = \pi \times (0.025)^2 \times 0.4}$

$\mathbf{= 7.854 \times 10^{-4} M^3}$

b) Shafts (2 Parts, both \diameter 25mm)

- shaft 1 = 0.1m (Left)

- shaft 2 = 0.15m (Right)

- Same radius: = 0.0125m

$\mathbf{V^2 = \pi \times (0.0125)^2 \times 0.1 = 4.909 \times 10^{-5} M^3}$

$\mathbf{V^3 = \pi \times (0.025)^2 \times 0.15 = 7.364 \times 10^{-5} M^3}$

Total volume:

$\mathbf{V \{total\} = V^1 + V^2 + V^3 = 7.854 \times 10^{-4} + 4.909 \times 10^{-5} + 7.364 \times 10^{-3}}$

$\mathbf{= 9.081 \times 10^{-4} M^3}$

2) Mass and Weight

Using material which is mild steel.

Mass = P × V = 7850 × 9.081 × 10^{-4} = 7.13 kg

Weight = M × G = 7.13 × 9.81 = 69.96 N

V = L X B X T

Given dimensions

L = 400mm = 0.4m

b = 60mm = 0.06m

t = 3mm = 0.003m

(i) Volume

V = 0.4 x 0.06 x 0.003 = 7.2 x 10^{-5} M^3

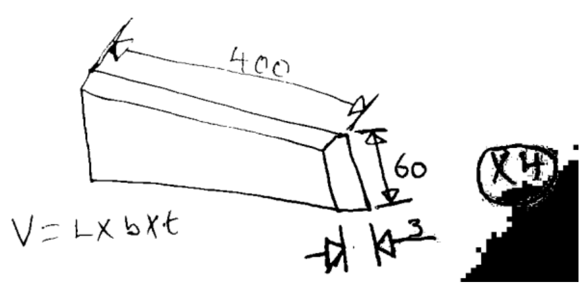
Total volume of all the four pieces

V Total = 4 x 7.2 x 10^{-5}= 2.88 x 10^{-4} M^3

(ii) Mass and weight

Using mild steel

Density = 7850 kg/m^3



(iv) Weight

W = M Xg $\boldsymbol{M \times g}$

Where

M =

g =

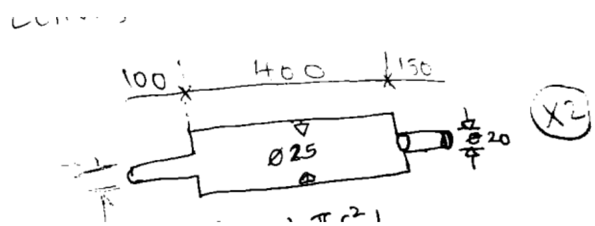
$$\mathbf{2.26 \times 9.81 = 22.17\ N}$$

2.26 x 9.81 = 22.17 N

Volume 2.88 x 10^{-4}

Mass 2.26 kg

Weight 22.17 N



Conveyor Shaft (x2)

$$\boldsymbol{V = \pi R^2 L + \pi r^2 L}$$

V = π R^2 L + π r^2 L

*** Main body (Middle section)**

- Diameter = 25mm → Radius

R1 = 12.5mm

- Length = 400mm

*** Both ends (Smaller shaft parts)**

- Diameter = 20mm → Radius

R2 = 10mm

- Length

Left side = 150mm

Right side = 100mm

Total length for both = 250mm

1) Volume Formula

The volume of a cylinder is :- $V = \pi R^2 L$

so, total volume :- $V = \pi R1^2 L1 + \pi R2^2 L2$

Substitute the values:

- R1 = 12.5mm, L1 = 400mm

- R2 = 10mm, L2 = 250mm

$V = \pi (12.5^2) (400) + \pi (10^2) (250)$

$V = \pi (156.25) (400) + \pi (100) (250)$

$V = \pi (62500 + 25000) = \pi (87500)$

V = 3.1416 x 87500 = 274889.6 mm^3

*** Final Result**

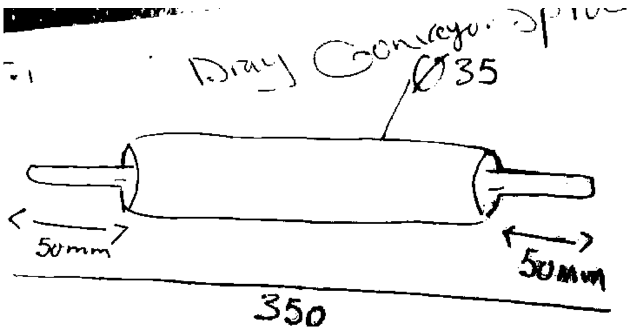
*** Volume of one shaft**

= 274,890 mm^3

* Since it's x2, total

volume for both shafts

= 549,780 mm^3



Drag conveyor sprocket shaft

Main Shaft Length = 350mm = 0.35m

- Main Shaft Diameter = 30mm = 0.03m

- End Shaft Diameter (each side) = 50mm = 0.05m

- Assumed Shaft Diameter = 20mm = 0.02m

V = 2 text{Cylinder} text{each end}

V = 2π left (frac{0.025}{2}right)^2 \times 0.35 simeq π (0.075)^2 times 0.35 = 0.000386 text M^3

V_{Shaft} = 2left(frac{0.025}{2}right)^2 times 0.03 simeq 2 times 10^{-5} text M^3

V_{Nuts} = 2 times 10^{-5} = 4.10 times 10^{-3} textM^3

V_{total} = 0.000387 + 0.000049 = 0.000386 textM^3

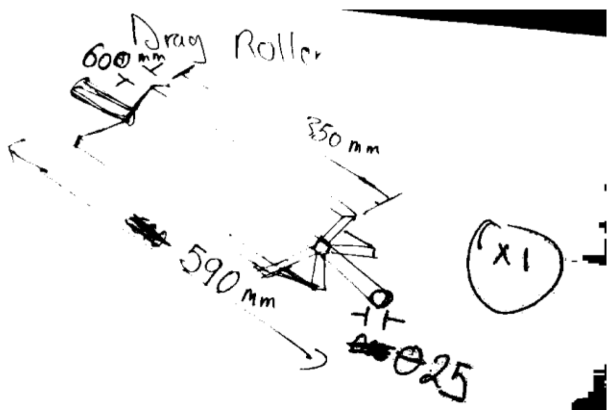
(b) text{mass}

7850 times 0.000386 simeq 3.03 text{kg}

(c) \text{Weight} = 3.03 times 9.81 simeq 29.7 text{N}

text{Component} quad text{Volume M^3 quad text{mass (kg)} quad text{mass] (N)

text{Main Shaft} quad 0.000386 quad 3.03 quad 29.70



Dray Roller

Length of main roller body

350mm = 0.35m

Diameter of main roller body

60mm = 0.06m

Total length = 590mm = 0.59m

Shaft diameter = 25mm = 0.025m

Cut: 0.25m

Shaft length of both sides

(franc{590 - 350}{2} = 120mm = 0.12m)

Volume Cal

1) Roller body (cylinder)

(V^1 = π R^2 H = π left (frac{0.06}{2} right)^2 times 0.35 = π times (0.0125)^2 times 0.35 = 5.89 times 10^{-5} M^3

2) Shaft (Two cylinders)

Each Shaft

(frac{2}{2} π R^2 H = π left(frac{0.025}{2} right)^2 times 0.12 = π times (0.0125)^2 times 0.12 = 5.89 times 10^{-5} M^3

Volume - Cal

Roller body (cylinder)

(V1 = π R^2 H = π (0.03)^2 times 0.35 = 0.00008496 M^3)

Shaft (Two Cylinders)

(V2 = 2 times frac{2}{2} π R^2 H = 2 times 5.89 times 10^{-5} = 1.178 times 10^{-4} M^3)

Total Volume

(V_{total} = V^1 + V_{shaft} = 0.0000896 + 0.0001178 = 0.0001074 M^3)

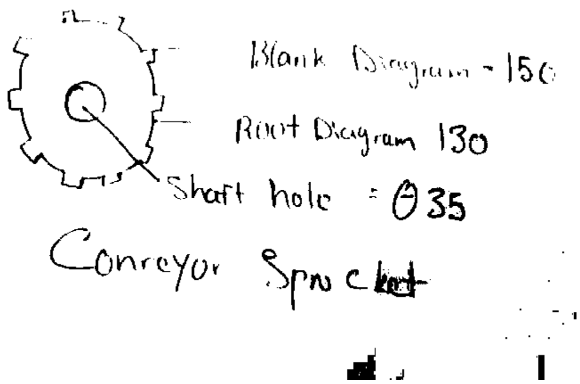
Mass Cal

- Mass = Density Times Volume

= 750 Times 0.00011074 = 8.69 kg

Weight Cal

- Weight = M times g = 8.69 times 9.81 = 85.25 N



Conveyor Sprocket

Blank Diagram 150

Root Diagram 130

Shaft whole Φ 35

- Blank Diameter = 150mm = 0.150m

- Root Diameter = 130mm = 0.130m

- Shaft Hole Diameter = 35mm = 0.035m

Assumption: The sprocket is a circular disk with a center hole, thickness 10mm (assumed unless provided)

a) Volume Calculation

Let's consider the sprocket as a solid disk with a central hole

Formula for the volume of a disk with a hole

V = frac{π}{4} (D_O^2 - D_I^2) × t

- D_O = outer diameter (150mm = 0.15m)

- D_I = inner (shaft hole diameter) (35mm = 0.035m)

- t = thickness assume 10mm = 0.01m

substitute:

frac{π}{4} (0.15^2 - 0.035^2) × 0.01 = frac{3.3466}{4} – frac {0.001225}{4} × 0.01 = frac{3.2406}{4} × 0.01

0.021275 × 0.01 = 0.000167m^3

b) Mass Calculation

mass = Density × Volume = 7850 × 0.000167 = 1.31kg

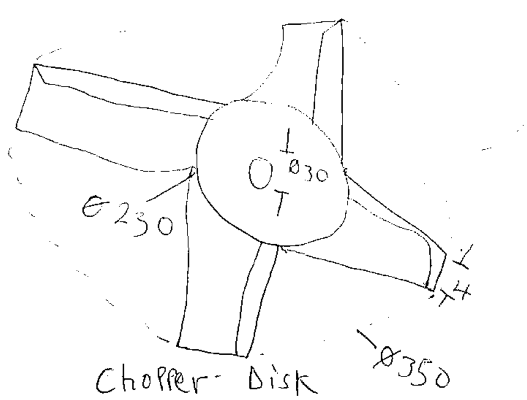
c) Weight Calculation

Weight = Mass × g = 1.31 × 9.81 = 12.86N

Volume (M^3) Mass (kg) Weight (N)

Component 0.000167 1.31 12.86

Conveyor sprocket 0.000167



Chopper Disk

Outer diameter = Ø 350mm

Inner diameter = Ø 230mm

Center hole = Ø 30mm

Thickness = 4mm

Convert mm to meters (m)

Outer radius R^1 = frac{350}{2} = 175mm = 0.175m

Inner radius R^2 = frac{230}{2} = 115mm = 0.115m

Center hole radius R^3 = frac{30}{2} = 15mm = 0.015m

Thickness = 4mm = 0.004m

Volume of Disk

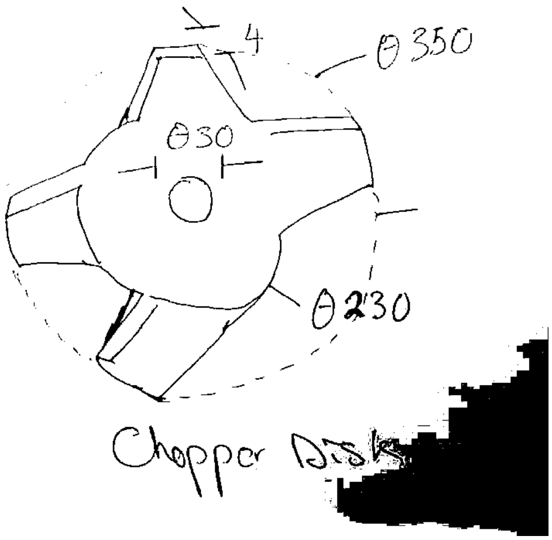
$V = \pi (R\_1^2 - R\_2^2 - R\_3^2) \times \{Thickness\}$

$V = \pi (0.030625 - 0.013225 - 0.000225) \times 0.004$

V = 0.1

Mass = {Volume} × {Density} = 0.0002158 × 7850

Weight = {mass} × g = 1.694 × 9.81



Chopper Disk

Outer Diameter (OD) = 350 mm

Inner Hole Diameter (Shafthole) = 30 mm

Blade Diameter = 230 mm

Thickness (assume) = 4 mm

Shape: Circular disk with blades cut out

1. Area of full circular disk

Aouter = frac{π}{4} × D^2 = frac{π}{4} × 350^2 = 96211.26 MM^2

2. Area of inner hole (Shaft)

Ahole = frac{π}{4} × D^2 =frac{π}{4} × 30^2 = 706.86 MM^2

3. Net Area:

Anet = Aouter - Ahole = 96211.26 - 706.86 = 95404.4 MM^2

4. Volume

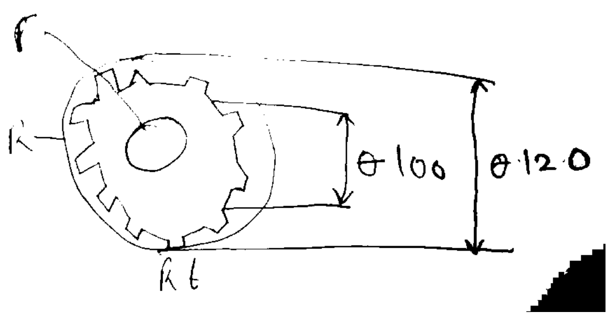
$V = A_{net} \times t = 95404.4 \times 4 = 381617.6\ mm^3 = 381.6\ CM^3$

5. Mass (using steel $\rho = 7.85\ g/cm^3$)

$Mass = V \times \rho = 381.6 \times 7.85 = 2994.56\ g = 2.99\ kg$

$Weight = mass \times g$

$Weight = 2.99kg \times 9.81m/s^2 = 29.3519\ N$



Outer Diameter = 120 mm

Inner Diameter = 100 mm

Thickness = 5 mm

Shape: Circular ring with gear-like teeth (simplified) as annular ring

1) Outer Area

$A_{outer} = \frac{\pi}{4} \times (120)^2 = 11309.73\ MM^2$

2) Inner Area

$A_{inner} = \frac{\pi}{4} \times (100)^2 = 7853.98\ MM^2$

3) Net Area

$A_{net} = A_{outer} - A_{inner} = 11309.73 - 7853.98 = 3455.75\ MM^2$

4) Volume

$V = A_{net} \times t = 3455.75 \times 5 = 17278.75\ MM^3 = 17.28\ CM^3$

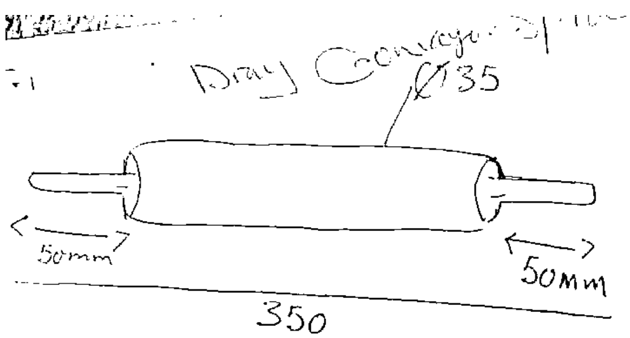
5) Mass (Steel)

$Mass = 17.28 \times 7.85 = 135.58\ g = 0.136\ kg$

Component & Volume (CM^3) & Mass (kg)

Chopper Disk & 381.6 & 2.99

Gear Component & 17.28 & 0.136



Drag Conveyor Sprocket Shaft

*** Central shaft (main body)**

- Length = 350mm

- Diameter = 35mm

*** Two end shafts (each side)**

- Length = 50mm each

- Diameter same unless specified otherwise = 20mm

(1) Main shaft volume (middle cylinder)

$V = \pi \times (\frac{d}{2})^2 \times L$

$V_{main} = \pi \times (\frac{35}{2})^2 \times 350$

$= \pi \times (17.5)^2 \times 350$

$= 3.142 \times 306.25 \times 350 = 336{,}376.6\ MM^3$

(2) End shafts volume (using φ20mm)

for each :

$V_{end} = \pi \times (\frac{20}{2})^2 \times 50$

$= \pi \times (10)^2 \times 50 = 3.142 \times 100 \times 50 = 15{,}710\ MM^3$

Total for 2 ends

$V_{ends} = 2 \times 15{,}710 = 31{,}420\ MM^3$

(3) Total Volume

$V_{total} = V_{main} + V_{ends}$

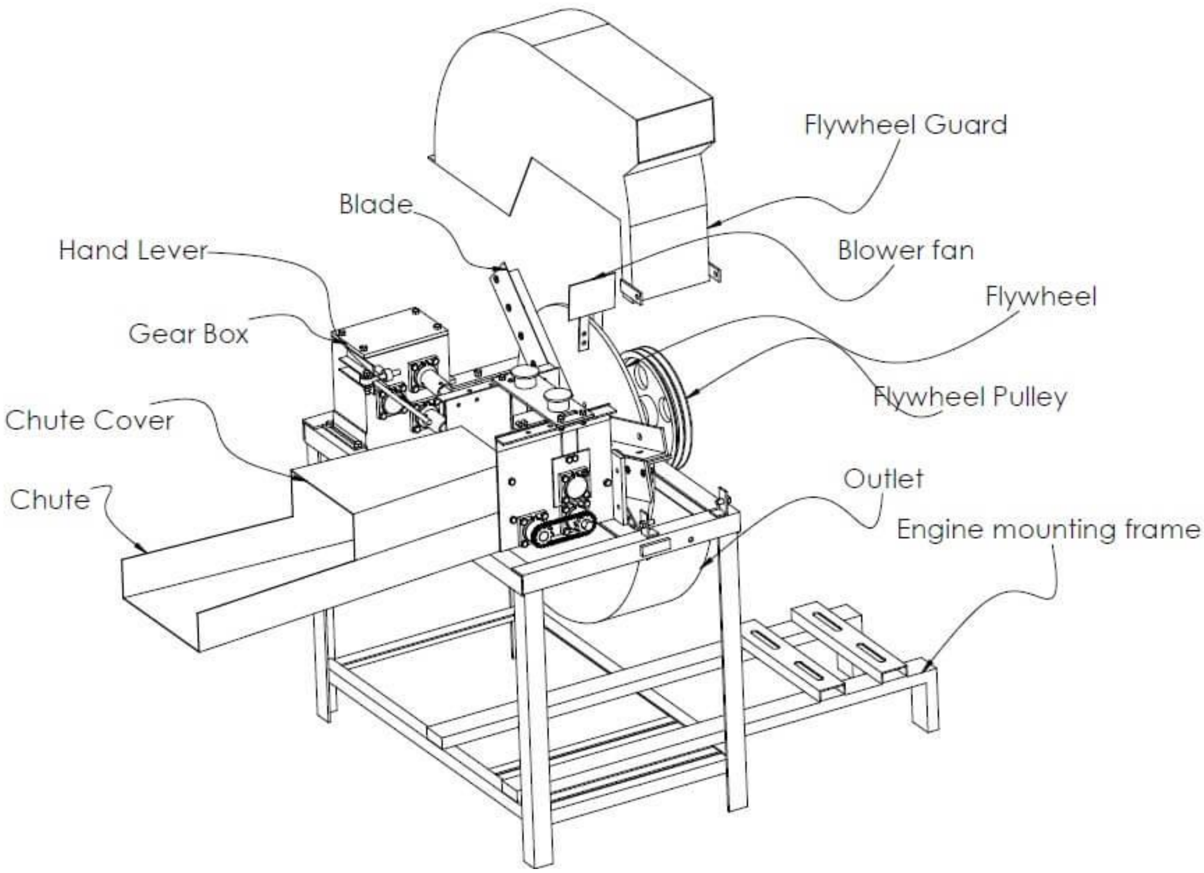
$= 336{,}376.6 + 31{,}420 = 367{,}796.6\ MM^3 = 367.8\ CM^3$

(4 Mass (using steel, p = 7.85 g/CM^3)

Mass = 367.8 × 7.85 = 2,887.23g = 2.89kg

Final Result for Drag Conveyor Sprocket Shaft

Part	**Volume (CM^3)**	**Mass (kg)**
Shaft 1	**367.8**	**2.89**


Flywheel Guard
Blade
Hand Lever
Blower fan
Flywheel
Gear Box
Flywheel Pulley
Chute Cover
Chute
Outlet
Engine mounting frame

CHAPTER FOUR

Material Selection, Fabrication, and Performance Evaluation

4.0 Introduction

The design and construction of the forage chopper machine were guided by key engineering principles: mechanical strength, wear resistance, cost-effectiveness, local material availability, and ease of maintenance. This chapter outlines the materials used, fabrication techniques applied, and performance evaluation procedures conducted during the development of the machine.

4.1 Material Selection and Justification

Material selection was based on mechanical properties such as tensile strength, machinability, corrosion resistance, and application-specific needs.

COMPONENT	MATERIAL	KEY PROPERTIES	JUSTIFICATION	REFERENCE
Fram & Support	Mild Steel	Tensile Strength: 400–550 Mpa; Good Weldability	Strong, Easy To Fabricate, Cost-Effective	Khurmi & Gupta (2005)
Hopper & Tray	Galvanized Iron	Corrosion-Resistant; Lightweight	Prevents Rust And Forage Sticking	Callister (2007); FAO (1990)

Blades	High Carbon Steel	High Hardness; Heat-Treatable; 750–950 Mpa	Durable And Retains Sharp Edge	Degarmo Et Al. (2003)
Rotating Shaft	Medium Carbon Steel	High Strength, Torsional Resistance	Withstands Dynamic Loads	Sharma (2003)
Pulleys	Cast Iron	Good Damping, 200–400 Mpa	Stable, Wear-Resistant	Khurmi & Gupta (2005)
V-Belts	Rubber	Flexible, High Grip	Ensures Smooth Power Transmission	FAO (1990)
Bearings	Pillow Block	Easy Installation, Friction Reduction	Supports Shaft Operation	ASABE (2020)

4.2 Mechanical and Chemical Properties of Key Materials

A summary of mechanical and chemical properties confirms the material choices:

- **Mild Steel:** Tensile strength ~400–550 MPa; Carbon ~0.15–0.25% (Callister, 2007)
- **High Carbon Steel:** Hardness 55–65 HRC; Carbon ~0.60–1.00% (Degarmo et al., 2003)
- **Cast Iron:** Compressive strength ~600–1000 MPa; Carbon ~2.0–4.0% (Khurmi & Gupta, 2005)

- **Galvanized Iron:** Zinc-coated; tensile strength ~270 MPa (FAO, 1990)
- **Rubber (V-Belts):** Tensile strength ~15–25 MPa; elongation ~300–500% (Bernard & Rawlings, 2014)

4.3 Fabrication Procedures

1. **Frame Construction**

Mild steel angle bars (40×40×4 mm) were cut and welded to form the base. All welds were ground and painted to prevent corrosion.

(Reference: Sharma, 2003)

2. **Hopper and Outlet Tray**

Galvanized iron sheets (1.5 mm) were shaped using bending tools and mounted with bolts for easy removal.

(Reference: Bernard & Rawlings, 2014)

3. **Blade Assembly and Shafting**

High-carbon steel blades were cut, heat-treated, and sharpened. They were mounted on a medium carbon steel shaft (25 mm Ø), supported by UCP 205 pedestal bearings.

(Reference: Degarmo et al., 2003)

4. **Pulley and Power Transmission**

Cast iron pulleys (3", 4", and 5") were mounted and keyed to the shaft. Power was delivered by V-belts connected to a 1 HP, 1450 rpm electric motor.

(Reference: Khurmi & Gupta, 2005)

5. **Final Assembly and Finishing**

   All components were aligned, painted with enamel over primer, and fitted with guards for safety.

(Reference: FAO, 1990)

4.4 Performance Testing Summary

Performance testing focused on determining how pulley diameter affects chopping efficiency and throughput. Standardized test conditions and methods were followed (Singh et al., 2006; ASAE, 2003).

Test Setup and Methodology

Material: Napier Grass (500g per trial)

Pulley Variants: 3", 4", and 5"

Data Collected: Input weight, chopping time, accepted output, unaccepted output

Calculation Metrics:

Throughput Capacity = (Input / Time) × 3600

Chopping Capacity = (Accepted Output / Time) × 3600

Chopping Recovery (%) = (Accepted / Input) × 100

Efficiency (%) = (Chopping Capacity / Throughput Capacity) × 100

Loss (%) = (Unaccepted / Input) × 100

(References: Kepner et al., 1978; Gomez & Gomez, 1984)

4.5 Observations on Material-Performance Interaction

- **Blades (High Carbon Steel):** Showed effective wear resistance; better performance with 5" pulley due to higher RPM
- **Frame (Mild Steel):** Stable during high-speed operations
- **Hopper (Galvanized Iron):** Corrosion-resistant; easy to clean
- **Rubber V-Belts:** Efficient power transfer; minor slippage at high feed rate

4.6 Factors Considered in Material Selection

1. Strength and Durability – To resist operational stress

2. Corrosion Resistance – Particularly for moist forage contact parts

3. Machinability – For ease of shaping, welding, and maintenance

4. Local Availability & Cost – Reduced procurement expenses

5. Vibration Damping – Cast iron used for pulley to absorb shock

6. Hygiene – Galvanized surfaces selected for feed contact areas

(References: Callister, 2007; FAO, 1985; Degarmo et al., 2003)

4.7 Safety Measures

Personal Protective Equipment (PPE) used during fabrication

Machine tested under supervision with emergency shut-off protocols

Guards installed around rotating components

(Reference: OSHA, 2022)

CHAPTER FIVE

5.0 Conclusion of Recommendation

This chapter summarizes the key outcomes of the project and provides actionable recommendations based on the results obtained from the fabrication and performance testing of the vegetative forage chopper machine. The project aimed to address the challenges faced by farmers in chopping forage efficiently and consistently. Through design, fabrication, and evaluation, the project successfully achieved its set objectives and offers valuable insights for improving fodder processing at the local farming level.

5.1 Conclusion

The vegetative forage chopper machine was successfully designed and fabricated using locally available materials. Performance testing was carried out using freshly harvested Napier Grass, and the effects of three pulley diameters (3-inch, 4-inch, and 5-inch) were evaluated on the machine's performance.

Key findings include:

- The 5-inch pulley (T3) recorded the highest throughput capacity, chopping capacity, and machine efficiency, due to higher rotational speed.

- The 3-inch pulley (T1) produced the highest chopping recovery, though it also showed the greatest material loss.
- The variation in pulley sizes had a significant effect on chopping performance, efficiency, and uniformity.
- The fabricated machine is structurally stable, easy to operate, and suitable for small to medium-scale agricultural use.

Overall, the project demonstrates that pulley size plays a critical role in optimizing the performance of a forage chopper machine, and that using a larger pulley diameter enhances output efficiency and reduces processing time.

5.2 Recommendation

Based on the results obtained, the following recommendations are made for practical use and continued improvement:

A. Optimal Pulley Usage: The 5-inch pulley configuration (T3) is recommended for best overall performance in terms of chopping speed and machine efficiency.

B. Routine Maintenance: Regular sharpening of the cutting blades and periodic inspection of shafts, belts, and bearings should be performed to maintain efficiency and prevent mechanical failure.

C. Operator Training: Users should be trained in safe operation procedures, basic maintenance, and emergency handling to ensure long-term functionality and safety.

D. Steady Feeding Rate: A consistent feeding rate of forage should be maintained to prevent overload and ensure uniform chopping.

E. Protective Features: Additional safety features such as guards for moving parts and emergency stop mechanisms should be incorporated to minimize the risk of accidents.

F. Use of Durable Materials: Continue to use high-carbon steel for blades and mild steel for the frame due to their strength, availability, and cost-effectiveness.

5.3 Recommendations for Future Work

To further enhance the performance, durability, and adaptability of the forage chopper machine, the following areas are recommended for future development:

1. Automation Integration: Introduce sensors, digital speed control, or automated feed mechanisms to enhance efficiency and control.
2. Multi-Crop Testing: Conduct performance evaluations using other vegetative materials such as maize stalks, cassava leaves, or sugarcane tops.
3. Energy Optimization: Investigate energy consumption and power efficiency under different operational conditions to reduce cost.
4. Capacity Expansion: Modify the design to support larger volumes of forage, suitable for commercial-scale operations.
5. Noise and Vibration Analysis: Perform analysis and damping solutions to minimize operational noise and mechanical vibrations.
6. Field Trials: Conduct long-term field testing to assess performance in real farming environments and gather user feedback for further design improvement.

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