

Design and Fabrication of Soil Loosener Machine

Girish S Halli #1, Sunil Maradi #2, Mahantesh B Adnur #3

#1Department of Mechanical Engineering SKSVMACET Laxmeshwar

#2,3Department of Mechanical Engineering AGMRCET Varur

¹girishhalli018@gmail.com, ²sunil.agmme2022@gmail.com, ³mahantesh.agmme2023@gmail.com

Abstract— Soil preparation is a crucial step in agricultural practices, directly influencing crop growth and productivity. Traditional manual soil loosening methods require significant human effort and time, especially for small-scale farmers. In this work, a compact agricultural soil loosener machine was designed and fabricated to minimize manual labor and improve soil preparation efficiency. The developed system utilizes a petrol engine as the primary power source to drive rotary tiller blades through a gear reduction mechanism, ensuring adequate torque for effective soil penetration and loosening. The machine structure was designed to be lightweight, portable, and suitable for small farm operations. Field testing was carried out to evaluate the operational performance of the prototype. The experimental results demonstrated that the machine effectively loosens soil, improves soil aeration, and significantly reduces the time and labor required for land preparation compared to conventional manual methods. The developed system provides an economical and practical solution for small and medium-scale farmers.

Keywords— Soil Loosener, Agricultural Machinery, Rotary Tiller, Petrol Engine, Soil Preparation, Farm Mechanization

I. INTRODUCTION

Agriculture plays a vital role in the economic development of many countries, particularly in developing nations where a significant portion of the population depends on farming for their livelihood. One of the most important preliminary operations in agricultural practices is soil preparation. Proper soil preparation helps in creating favourable conditions for seed germination, root development, water infiltration, and nutrient absorption. Soil loosening or tilling is an essential step in this process, as it breaks up compact soil layers, improves aeration, and enhances the overall soil structure. Effective soil preparation ultimately contributes to higher crop yield and improved agricultural productivity.

Traditionally, soil loosening and tilling operations are carried out manually using hand tools such as hoes, spades, and pickaxes. While these tools are simple and inexpensive, the process requires significant human effort and time, especially when working on larger plots of land. Manual soil preparation can also lead to physical fatigue and reduced efficiency for farmers. In many rural regions, agricultural labour is becoming increasingly scarce and expensive, which further complicates the process of timely soil preparation. These challenges highlight the need for suitable mechanized solutions that can assist farmers in performing soil loosening operations more efficiently.

Large agricultural machinery such as tractors and power tillers are widely used in modern farming practices for soil preparation. However, these machines are often expensive and may not be economically feasible for small and marginal farmers. In addition, large machines are not always suitable

for small agricultural plots, gardens, or uneven terrains where manoeuvrability is limited. Therefore, there is a growing demand for compact, affordable, and easy-to-operate agricultural machines that can effectively perform soil loosening tasks in small-scale farming environments.

To address this problem, the development of compact soil loosening machines has gained attention in recent years. These machines are designed to reduce manual labor while maintaining operational efficiency. A compact soil loosener typically uses a small engine-driven mechanism to rotate tilling blades that penetrate and break the soil surface. The rotary tiller blades cut through the soil and create a loosened layer that facilitates better root growth and water movement. Such machines are especially beneficial for small farmers who require cost-effective mechanization solutions for land preparation.

II. LITRETURE REVIEW

Soil preparation is a fundamental agricultural operation that significantly influences crop productivity and soil health. Over the years, various researchers and engineers have worked on developing mechanized solutions to improve soil loosening and tillage operations. These studies mainly focus on reducing human labor, improving efficiency, and developing cost-effective agricultural machines suitable for small and medium-scale farmers.

Siddappa et al. have explored the development of rotary tillers powered by small internal combustion engines. Rotary tillers are widely used in agriculture because of their ability to break and mix soil effectively. The rotating blades cut into the soil and loosen compact layers, creating a suitable seedbed for planting. Researchers have shown that rotary tilling not only reduces soil compaction but also improves soil structure and enhances nutrient distribution. Small power tillers equipped with rotary blades have been found to significantly reduce labor requirements and improve field preparation time compared to manual methods.

Dibaba et al. developed a lightweight soil tilling machine powered by a small petrol engine. The machine consisted of a rotary shaft fitted with blades that penetrate and break the soil surface. Field testing results indicated that the machine was capable of covering a larger area in less time while requiring minimal human effort. The study concluded that compact machines could serve as an effective alternative to traditional manual tillage methods.

Hasanaj et al. focused on the design and fabrication of a portable mini tiller for garden and small farm applications. The machine used a small engine connected to a gearbox that reduced the rotational speed and increased torque. The gearbox transmitted power to rotary blades that performed the soil loosening operation. The results of the study demonstrated that the mini tiller improved soil pulverization and reduced the physical strain on farmers. The researchers



also emphasized the importance of ergonomic design and machine stability during operation.

Agbede and Okoh designed and tested a roto tiller for small-scale farmers to improve soil preparation and reduce manual labor. The machine features a compact frame, rotary blade mechanism, and adjustable depth control for efficient soil loosening. Performance evaluation showed that it provides uniform soil tillage and effective seedbed preparation. The study highlights that such machines reduce dependence on animal power and manual effort. It also emphasizes the importance of simple design, low cost, and ease of operation for small-scale farming applications.

Recent studies have also focused on improving the energy efficiency and operational performance of small agricultural machines. Researchers have analyzed different blade designs, rotational speeds, and power transmission mechanisms to optimize soil cutting performance. It has been observed that proper blade geometry and adequate torque are essential for effective soil penetration and loosening. Gear reduction systems are commonly used in such machines to convert the high-speed output of engines into lower speeds with higher torque suitable for soil tillage operations.

Based on the review of previous studies, it is evident that compact mechanized soil loosening machines can significantly improve agricultural productivity while reducing manual effort. However, there is still a need for simple, low-cost, and easy-to-maintain machines that can be effectively used in small farms and rural areas. The present work focuses on designing and fabricating a compact agricultural soil loosener machine powered by a petrol engine with a gear reduction mechanism. The developed machine aims to provide an economical and practical solution for soil preparation, particularly for small-scale farmers.

III. OBJECTIVES

The main objectives of this project are:

1. To design and fabricate a soil loosening machine.
2. To reduce human effort required for soil loosening operations.
3. To develop a compact and economical machine suitable for small and marginal farmers.

IV. METHODOLOGY

The methodology adopted for the design and fabrication of the compact agricultural soil loosener machine involved systematic steps including design planning, component selection, fabrication, assembly, and inspection. The primary objective was to develop a compact, portable, and efficient machine capable of reducing manual labor during soil preparation, especially for small-scale agricultural applications.

➤ Conceptual Design and Selection of Components.

The first stage involved **conceptual design and component selection**. Based on the functional requirements of soil loosening, the major components identified were a petrol engine, power transmission system, rotary tiller blade assembly, supporting frame, wheels, and handle mechanism. A small-capacity petrol engine was selected as the prime mover because it provides adequate power while maintaining



Fig. 1.

portability and independence from electrical supply. Petrol engines are widely used in small agricultural machines due to their reliability and ease of operation in rural environments.

➤ Transmission and Blade Design:

The second stage involved the **design of the power transmission system**. Since the engine operates at high rotational speeds, a gear reduction mechanism was incorporated to reduce the speed and increase torque. The transmission system, consisting of gears and shafts, transfers power from the engine to the rotary tiller blades. This arrangement ensures efficient power transfer and provides sufficient torque for the blades to penetrate and loosen compact soil layers.

➤ To facilitate mobility, wheels were incorporated into the design.

The wheels support the weight of the machine and allow easy movement across agricultural fields. Proper wheel positioning also helps maintain a consistent operating depth of the tiller blades and provides stability during operation.

- An **ergonomically designed handle mechanism** was attached to the frame to allow the operator to guide and control the machine during soil loosening. The handle enables the operator to push or maneuver the machine while maintaining the desired working depth.

➤ Fabrication of frame and components.

The **fabrication process** included cutting, welding, drilling, and assembling the mechanical components. The frame members were cut to the required dimensions and welded to form a rigid structure. The petrol engine was mounted on the frame using bolts and brackets. The transmission system was assembled and aligned with the rotary blade shaft, and the tiller blades were fixed onto the shaft with proper spacing to ensure balanced rotation.

➤ Assembly of Machine components:

The assembly of the soil loosener machine involves the systematic installation of all fabricated and purchased components onto the supporting frame to form a complete

working unit. Initially, the mild steel frame is positioned properly and checked for alignment and rigidity.

➤ **Inspection and Testing:**

After assembly, the machine was **inspected for alignment, stability, and smooth operation**. Necessary adjustments were made to ensure proper functioning of the transmission system and to minimize vibration and noise. The completed soil loosener machine was then prepared for **performance evaluation under field conditions** to verify its effectiveness in soil loosening and seedbed preparation.

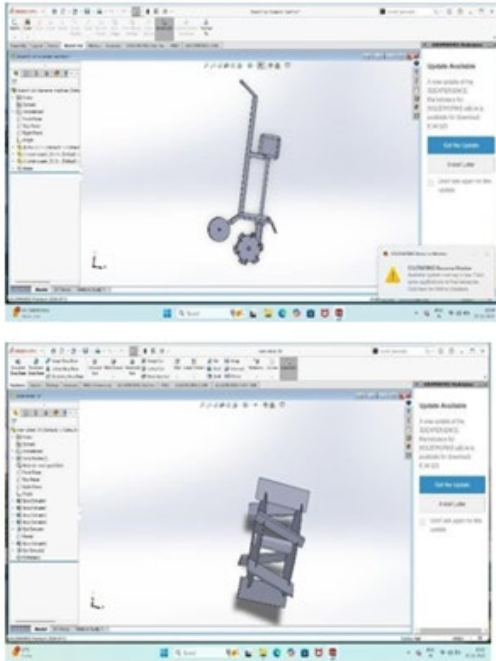


Fig. 2. Conceptual CAEd Model

A. DESIGN CALCULATION

The design calculations for the soil loosener machine were carried out to ensure that the selected components are capable of performing the required soil loosening operation effectively. The calculations mainly focus on determining the power requirement, torque transmitted to the rotary blades, rotational speed of the blade shaft, and the gear reduction ratio required for efficient operation.

1) Power Requirement

The power required for soil loosening depends on factors such as soil type, blade penetration depth, blade width, and operating speed. For small agricultural soil loosening machines, engines with power ratings between 3 HP and 5 HP are generally sufficient. In this design, a petrol engine of approximately **3.5 HP** was selected.

Power is given by the relation:

$$P = 2\pi NT / 60$$

Where:

P = Power transmitted (W)

N = Speed of shaft (rpm)

T = Torque transmitted (N·m)

Assuming the engine operates at **3000 rpm**, the power produced by a 3.5 HP engine can be calculated as:

$$1 \text{ HP} = 746 \text{ W}$$

$$P = 3.5 \times 746$$

$$P = 2611 \text{ W}$$

Thus, the engine produces approximately **2.6 kW** of mechanical power.

2) Torque Calculation

The torque transmitted by the shaft can be calculated using the power equation:

$$T = (P \times 60) / (2\pi N)$$

Substituting the values:

$$P = 2611 \text{ W}$$

$$N = 3000 \text{ rpm}$$

$$T = (2611 \times 60) / (2 \times 3.1416 \times 3000)$$

$$T \approx 8.3 \text{ N}\cdot\text{m}$$

Since soil cutting requires higher torque, a **gear reduction mechanism** is used to increase the torque at the rotary blade shaft.

3) Gear Reduction Ratio

To obtain sufficient torque for soil penetration, the rotational speed of the engine is reduced using gears. Assuming a gear reduction ratio of **1:10**, the output speed of the rotary shaft becomes:

$$\text{Output Speed} = \text{Engine Speed} / \text{Gear Ratio}$$

$$\text{Output Speed} = 3000 / 10$$

$$\text{Output Speed} = 300 \text{ rpm}$$

The torque at the rotary shaft increases proportionally with the reduction ratio.

$$\text{Output Torque} = \text{Input Torque} \times \text{Gear Ratio}$$

$$\text{Output Torque} = 8.3 \times 10$$

$$\text{Output Torque} \approx 83 \text{ N}\cdot\text{m}$$

This torque is sufficient to drive the tiller blades and penetrate the soil effectively.

4) Shaft Design

The shaft supporting the rotary blades must be capable of transmitting the required torque without failure. The shaft diameter can be determined using the torsion equation:

$$T = (\pi / 16) \times \tau \times d^3$$

Where:

T = Torque transmitted (N·m)

τ = Allowable shear stress (N/mm²)

d = Diameter of shaft (mm)

Assuming allowable shear stress for mild steel:

$$\tau = 40 \text{ N/mm}^2$$

Rearranging the equation:

$$d^3 = (16T) / (\pi\tau)$$

Substituting the torque value:

$$T = 83 \text{ N}\cdot\text{m} = 83000 \text{ N}\cdot\text{mm}$$

$$d^3 = (16 \times 83000) / (3.1416 \times 40)$$

$$d^3 \approx 10575$$

$$d \approx 22 \text{ mm}$$

Therefore, a **shaft diameter of approximately 25 mm** is selected to ensure safe operation with an adequate factor of safety.

5) Blade Speed

The effectiveness of soil loosening depends on the rotational speed of the blades. With the gear reduction system, the blade shaft rotates at approximately **300 rpm**, which is suitable for agricultural soil tilling operations. This speed provides sufficient cutting action while maintaining stability during operation.

6) Working Depth

The typical working depth for small soil loosening machines ranges between **80 mm and 120 mm**, depending on soil conditions. The designed machine is capable of achieving a working depth of approximately **100 mm**, which is suitable for seedbed preparation and soil aeration.

V. RESULTS AND DISCUSSION

After the design and fabrication of the compact agricultural soil loosener machine, experimental testing was carried out to evaluate its performance under practical field conditions. The objective of the testing process was to analyze the operational efficiency of the machine, its soil loosening capability, stability during operation, and the reduction in manual effort compared to traditional soil preparation methods.

The field tests were conducted on agricultural soil to observe the behavior of the machine during operation. The machine was operated using the petrol engine, which transmitted power to the rotary blade assembly through the gear reduction mechanism. As the rotary shaft rotated, the blades penetrated the soil and broke the compact soil layers. The testing focused on parameters such as working depth, area covered per unit time, soil pulverization, and ease of operation.

During operation, it was observed that the rotary blades effectively penetrated the soil surface and broke the compact layers into smaller soil particles. The soil loosening action improved the soil structure and created a suitable seedbed for agricultural activities. The machine maintained stable operation due to the rigid frame structure and proper alignment of components. The wheels provided smooth movement across the field, allowing the operator to guide the machine easily.

The working depth of the soil loosener was found to be approximately **90–100 mm**, which is sufficient for most soil preparation operations such as seedbed preparation and soil aeration. The blade rotation at around **300 rpm** provided adequate soil cutting action while maintaining stability and control. The gear reduction system successfully converted the high-speed rotation of the engine into lower speed with higher torque required for soil penetration.

The performance of the developed machine was also compared with traditional manual soil loosening methods. In manual methods, tools such as hoes or spades are used, which require considerable human effort and time. The developed soil loosener machine significantly reduced the

physical effort required from the operator. The machine also reduced the time needed to prepare the soil for planting.

VI. CONCLUSION

The present work focused on the design, fabrication, and performance evaluation of a compact agricultural soil loosener machine intended for small-scale farming applications. Soil preparation is a critical agricultural activity that directly influences crop growth, soil aeration, and water infiltration. Traditional soil loosening methods using manual tools require considerable time, effort, and physical labor. Therefore, the development of a compact mechanized solution was necessary to improve efficiency and reduce labor dependency.

In this study, a petrol engine-powered soil loosener machine was successfully designed and fabricated using simple and easily available mechanical components. The machine incorporates a rotary tiller blade mechanism driven through a gear reduction system, which converts the high-speed rotation of the engine into lower speed with higher torque required for soil penetration. The machine structure consists of a rigid supporting frame, rotary blade shaft, transmission system, wheels, and an operator handle for easy control during field operation.

The design calculations were performed to determine the power requirement, torque transmission, gear reduction ratio, and shaft dimensions necessary for effective soil loosening. Based on these calculations, a petrol engine of approximately 3.5 HP was selected to provide adequate power for the machine. The gear reduction system ensured sufficient torque at the blade shaft to penetrate compact soil layers. The fabricated machine was tested under field conditions to evaluate its operational performance.

Experimental testing demonstrated that the machine is capable of loosening soil effectively with a working depth of approximately 90–100 mm. The rotary blades were able to break compact soil layers and produce well-aerated soil suitable for planting operations. The machine significantly reduced the time and physical effort required for soil preparation compared to conventional manual methods. In addition, the compact size and portability of the machine make it suitable for small farms, gardens, and horticultural fields where large agricultural machinery cannot be easily used.

The results of this study confirm that the developed soil loosener machine provides an economical and efficient solution for small and marginal farmers. The machine helps reduce labor dependency, improves the efficiency of soil preparation, and contributes to better agricultural productivity. Furthermore, the simple design and ease of maintenance make it practical for rural agricultural applications.

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