DEVELOPMENT AND EVALUATION OF POWER TILLER OPERATED RIDGE PLASTERING ATTACHMENT

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PROJECT REPORT

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2024

DECLARATION

We hereby declare that this project report entitled **"DEVELOPMENT AND EVALUATION OF POWER TILLER OPERATED RIDGE PLASTERING ATTACHMENT"** is a bonafide record of project work done by us during the course and that this report has not previously formed on the basis for the award to us of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

Place: Tavanur

Date: 04 /06/2024

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CERTIFICATE

Certified that this project report entitled **"DEVELOPMENT AND EVALUATION OF POWER TILLER OPERATED RIDGE PLASTERING ATTACHMENT"** is a record of project work done jointly by **Ms. Meherban Shah U M, Ms. Abhaya C Anil, Mr. Aditya Tiwari, Mr. Shubham Sonu** under our guidance and supervision and that it has not previously formed the basis for any degree, diploma, fellowship or associateship or other similar title of another University or Society.

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DEDICATED TO

OUR PROFESSION

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SYMBOLS AND ABBREVIATIONS

Symbols	Abbreviation
±	Plus or minus
×	Multiplication
°	degree
°C	Degree centigrade
cm	Centimeter
Rs	Rupees
SI No	Serial number
et al	And others
KCAET	Kelappaji College of Agricultural Engineering and Technology
MJ	Mega Joule
km/h	Kilometer per hour
hp	Horse power
mm	Millimeter
m	Meter
Rs/h	Rupees per hour
g/cc	Gram per cubic Centimetre

FIM	Farm Implements and Machinery
db	Dry basis
g	Gram
°F	Degree Fahrenheit
cm^2	Square Centimetre
kN	Kilo Newton
N	Newton
l/h	Liter per hour
m/s^2	Meter per square second
kPa	Kilo pascal
m^2	Square meter
Nm	Newton meter
kgf	Kilo gram force
SAE	Society of automotive engineers
rpm	Revolutions per minute
KAMCO	Kerala Agro Machinery Cooperation
Fig.	Figure
IS	Indian Standard
kg/m^3	Kilogram per cubic meter

%	percentage
kN/m^2	Kilo newton per square meter
m/s^2	Meter per square seconds
kg	kilogram
kW	Kilo Watt
mm^2	Square millimeter
W	Watt
MPa	Mega Pascal
N-mm	Newton millimeter
ha	hectare

INTRODUCTION

CHAPTER I

INTRODUCTION

Agriculture is a critical component of India economy, forming the foundation of the nation's economic structure. It is the primary source of livelihood for nearly 55% of India's population (Behera and Singh, 2016). India has the largest area planted for wheat, rice, and cotton, and is the largest producer of milk, pulses, and spices in the world. Thus, farmers become an integral part of the sector to provide us with a means of sustenance.

Food grain production in India touched 330.5 million metric tonnes in 2022-2023 (PIB, 2023). In Indian agriculture, food grain production accounts for the majority of the planted land (65%). India is the world's second-biggest producer of wheat, rice, and pulses and the world's largest producer of millet. The success of Indian agriculture has received worldwide appreciation as food grain yield has increased to 2325 kg / ha in 2019-20, and the total food grain production comprised of 135.755 million tonnes of rice, 107.742 million tonnes of wheat, 33.730 million tonnes of maize (Indiastat, 2023). The contribution of grains other than rice and wheat in rural India was 1 kilogram per person per month, whereas in urban India it was 0.8 kg per person per month in 2011–12. It is predicted that by 2050, the average monthly consumption of all food grains per person in rural regions will drop from 15.3 kg in 2000 to 13.8 kg, while in urban areas it will only marginally fall from 11.8 kg to 12.6 kg (Khatkar *et al.*,2016).

Rice accounts for a significant contribution to the total food grain production in India around 1355.42 Lakh Tonnes (PIB, 2023). Rice continues to hold the key component for sustainable food production in the country. The demand for rice in India is projected at 128 million tonnes by the year 2012 and will require a yield level of 3.0 t/ha. Moreover, the supplementary report of Better Crops International opined that rice production followed the ups and downs in India. India's yields are too low (4.2 t paddy/ha) even under irrigated condition compared to other countries (6.1 and 9.3 t/ha for China and Egypt, respectively). Again, only 51% of the total rice area is under irrigation (Mandal *et al.,* 2019). This low level of productivity in India is due to degraded and less fertile soils, pests and diseases, low input use, faulty cropping systems, a low adoption rate of improved technologies and less farm mechanisation due to a greater number of small and marginal farmers. Thus, the yield gap (difference between achievable yield under on-station experimental condition and average farmer's field) in India is in the range of 35 to 75%, with the exceptions of Tamil Nadu (15%) and Punjab (22%) (Rao *et al.,* 2015)

The pre-planting step of paddy cultivation starts with the selection of rice varieties, good quality seeds, developing the cropping calendar and land preparation. Land preparation is one of the most important tasks which help in control of weeds, adding nutrients to soil and provide soft soil bed for transplanting (Haque *et al.,* 2016). It is usually done by puddling. Rice is typically grown in bunded fields with water which makes the ridge preparation and planting important. Then the rice crops are directly seeded or transplanted to the soil. Fertilizers, pesticides, insecticides are added and weeds are controlled in the growth stage of paddy cultivation. Paddy harvesting activities include reaping, stacking, handling, threshing, cleaning, and hauling. These can be done individually or a combine harvester can be used to perform the operations simultaneously. Then the rice is dried, stored, milled and processed.

Adoption of mechanization ensures timeliness of agricultural operations, reduces cost of production as well as reduces drudgery in carrying out various farm operations. At present, the tractors and power tillers are easily available for the farmers to carry out almost all the tillage operations like ploughing, puddling, levelling as well as transportation. But sowing, transplanting, harvesting, threshing, winnowing is still done manually with traditional equipment which are insufficient. The ridge preparation is one among field operation in which bunds or ridges are simply embankment like structures, constructed across the land slope to retain water in low land transplanted rice system. Ridges are required to hold water in between them and prevent breaching of water from field to field. The method of planting on raised ridges is best used when poor soil drainage is a problem, where flood type irrigation is used, or where heavy rains occur.

Ridge plastering, an operation where field bunds are trimmed and thereafter plastered and compacted using the earth excavated. In traditional method, bunds are usually done in two steps at the beginning of each crop season and was being done manually. First, the bund should be cleared from weeds and grass before initial ploughing. Then the bund should be plastered with a layer of mud after the second plough. The shape of bund formed in pulverised/cultivated field with bund former is triangular. After manually packing/firming of formed bund, it becomes trapezium shaped. Good bunds help to limit water losses by seepage and under bund flows. Bunds should be well compacted and any rat holes should be plastered with mud.

The aim of a ridge plastering machine is to automate the process of ridge plastering in rice fields. The primary objectives of using ridge plastering machines include increased efficiency, cost reduction, labour reduction, precision and consistency. Ridge plastering machines are designed to create uniform bunds or ridges with consistent dimensions, ensuring optimal water management in the rice field. This precision helps improve crop yield and reduces water wastage. Ridge plastering helps in efficient water management, prevention of soil erosion, weed control, increased crop yield. Ridge plastering helps farmers to adapt to the climate change by providing a more controlled environment for crop growth, especially in areas prone to drought or heavy rainfall. By promoting efficient water use, soil conservation, and reduced reliance on manual labour, ridge plastering contributes to sustainable farming practices that minimize environmental impact and promote long-term agricultural viability. thus plays a vital role in ensuring the sustainability and productivity of agricultural systems in a changing environment.

At present, tractor attached ridge plastering machines are only available as mechanisation package to perform the plastering operation. This creates problems such as sinkage of machine in puddled field due to combined weight of tractor and ridge plastering attachment, not suitable for small land preparations where the use of tractors in small fields are not efficient, tractors may have difficulty in accessing certain terrains, such as steep or uneven slopes, rocky areas, or areas with dense vegetation, tractors can cause soil compaction which negatively impact soil health and fertility and acquiring a tractor-operated ridge plastering machine involves a significant initial investment. This can be a barrier for small-scale farmers or those with limited financial resources. Thus, as an effective solution, a power tiller operated ridge plastering machine is need to develop for the small and marginal farmers.

OBJECTIVES:

1. To develop a ridge plastering attachment to power tiller.
2. To evaluate the ridge plastering attachment to power tiller.
3. To determine the cost economics of the developed unit.

REVIEW OF LITERATURE

CHAPTER II

REVIEW OF LITERATURE

The development and refinement of machinery for agricultural practices are essential to improving productivity and efficiency in farming operations. Agricultural fields mostly consist of ridges and therefore the mechanization is crucial. Given the large number of marginal farmers in India, the power tiller attached to the ridge plastering equipment is quite relevant. This chapter, which is summarized under the following sections, includes the research projects completed that are pertinent to the current study.

2.1 EVOLUTION OF BUND FORMING AND MAINTENANCE EQUIPMENT

Chenhuang *et al*. (2003) analysed the percolation and seepage in paddy bunds. Field experiments were carried out in Hsin-Pu, Hsin-Chu County, Taiwan, to assess soil water content across different bund types. Results showed unsaturation along the sloped surface of the terrace, with no seepage face development even after heavy rainfall lasting two days. Employing a three-dimensional model, FEMWATER, percolation and lateral seepage were simulated under various bund conditions. Percolation for the bund without plow sole measured 0.85 cm, primarily infiltrating vertically downward in the central terraced paddy area, while lateral flow prevailed near the bund, indicating a high hydraulic gradient. After 85 days of rice cultivation, simulated infiltration flux into the bund (1.47 cm) surpassed that of the central area (0.54 cm) by a factor of 2.72. Final percolation flux from the bund (1.24 cm) also exceeded that from the plow sole (0.68 cm) by a factor of 1.82. Lateral seepage fluxes through the bund, downward and upward along the slope surface, were 2.01 cm and 22.12 cm, respectively. Both experimental and simulation results elucidate water movement mechanisms in terraced paddies, revealing the presence of an unsaturated seepage face along the sloping surface of the terraced field.

Pathirana *et al*. (2010) researched sustainable farming through mechanization by development of a bund making machine. For bund clearing, a simple cutter with a height adjusting mechanism and rotary blade arrangement had been developed and tested for two-wheel tractor. When the moisture content increases, the bund formation was not successful. The drum should rotate at a high speed to form a well compacted bund. There was another attachment only for bund clearing built by a Sri Lankan farmer for two-wheel tractors. A plastering technique was suggested which include a channel to convey mud when it moves forward with the tractor and direct mud towards the bund. This was fabricated using steel sheets and cost of fabrication approximates Rs. 6000.

2.2 ADVANCEMENTS IN BUND MAINTENANCE TECHNOLOGY

Fakruddin (2018) developed bund trimming and plastering equipment for rice fields. In the study, the rotation of the cutter was utilized to resize the bund, while the plastered soil resulting from cutting was employed to strengthen the bund with the assistance of a pressing roller. Through experimentation, the optimal forward operating speed was determined to be 1.6 km/h, where the machine achieved a maximum bund trim efficiency of 80.17% and a degree of compaction of 90.11%, while consuming 2.53 Liters of fuel during operation. The energy requirement varied, reaching a peak of 160.33 MJ at a speed of 3.0 km/h and a minimum of 98.76 MJ at a speed of 1.6 km/h. The study revealed that the effective bund trim capacity and volume of soil handled by the bund trimmer increased with higher tractor speeds, albeit at the expense of reduced bund trim efficiency and degree of compaction. On average, the cost of operation amounted to Rs. 484 per hectare.

Reddy *et al*. (2020) developed and evaluated mini tractor operated ridge plastering machine. A mini tractor operated ridge plastering machine was developed at FIM, Scheme, Rajendranagar, Hyderabad, Telangana and evaluated in sandy loam soil with a moisture content of 31%. The machine can be operated with 18-25 hp range mini tractors. This attachment weighs about 390 kg with overall dimensions of 1,620 mm length, 1,660 mm width and 1,130 mm height. The roller attached to the rotating disc compresses the soil. During the field study, it was observed that, the field capacity of the machine was 833 m per hour with an average speed of 1.0 km/h. Overall dimensions of bund was 178 mm height and 288 mm width respectively. The angle between ground and the side wall of the bund is 120º. The fuel consumption of the machine was 3.42 l/h. The cost of operation of the machine was Rs. 700-800/ h.

Singh *et al*. (2016) developed tractor operated bund former-cum-packer for increasing resource productivity. A rectangular tool-bar frame of differential height was designed for bund forming and bund packing operations. The width of the frame was carefully adjusted to ensure that the conical disc of the bund packer would begin compacting the bund immediately after soil deposition by the bund former. This design maintained a distance of approximately 450 mm between the disc of the bund former and the bund packer. When the tractor's forward speed was increased from 2nd low to 3rd low gear, it was noted that less compaction occurred both from the sides and the top. Consequently, the bund former-cum-packer was operated in pulverized fields at a speed ranging from 2.85 to 2.93 km/h (2nd low gear), while only the bund former was operated at a speed of 3.95 km/h. Soil moisture content varied between 6.95% and 10.37%. The manually packed bunds, formed by the bund former, exhibited the highest bulk density (1.286 g/cc), indicating effective compaction from the top. However, the bunds formed by the bund former-cum-packer showed slightly lower bulk density (1.256 g/cc) after a day. No seepage or spillage was observed during the operation. The fabrication cost of the equipment was estimated to be Rs. 50,870. The field capacity achieved with the equipment was 1.4 ha/h at a tractor speed of 2.93 km/h in 2nd low gear. Overall, the utilization of this equipment holds significant potential for enhancing resource productivity by up to 38%.

Sood *et al*. (2023) designed and developed tractor operated bund former for mulched field. A tractor operated bund former was conceptualized, designed and CAD models were developed using Pro-E software before the actual development/fabrication. The machine was developed with integrating mainly three units such as mulcher, rotavator and bund forming unit based on design calculations. These respective units perform three operations, namely, mulch removing, soil pulverizing and bund forming on desired path simultaneously in one pass. This machine is found to be an excellent and convenient option over existing bund forming technologies to be operated in the mulched field. Straw mulch was retained over the bund which played a role in conserving moisture and forming a protective cover for bund. There could be reduction in seepage of water through bunds due to decreased porosity of soil. Therefore, use of mulcher, rotavator and bund former combined proved to be a better option over the conventional bund making methods. The mulcher, rotavator and bund former was designed based on the amount of soil required to prepare the bund. Removing of paddy straw from in front intended operational area of bund former using mulcher and pulverizing the same soil surface by rotavator. During the forward travel of the machine, mulcher picks the straw, rotavator pulverizes the straw free soil and bund former makes the bund. The picked straw by mulcher was thrown in rear side on the prepared bund.

2.3 STUDIES IN EVALUATION OF RIDGE PLASTER MACHINE

Rahul *et al*. (2018) evaluated the performance of tractor operated ridge plastering machine in the field conditions at FIM scheme, Rajendranagar, Hyderabad with sandy loam soil of 13.87% (db) moisture content. The ridge plastering machine was attached to 55 HP John Deere tractor and was operated at a specific speed in the field and the bunds were formed by rotavator and leveller. The rotating blades pulverise the soil and the rotating disc trimmed the bund and plastered. The speeds were observed as 1.152 km/hr and 1.94 km/hr for black and sandy soils respectively. The trench width, depth of the bund, slant height and width of the bund were observed as30.16cm, 25cm, 28.3cm and 21. 8cm.The RPM of the rotating disc and rototiller were found to be 227 and 238.6 respectively. The field performance of the ridge plastering machine was found to be 1000 m/hour. The trimming and plastering with the machine costs Rs.0.9-1.0 per meter. The attachment weighs about 390 kg with 1.62 m length, 1.66 m width and 1.13 m height. The ridge plastering machine costs Rs.3.0 lakh.

Jadav et.al (2020) evaluated the performance of a manually operated bund former. The forward speed and actual field capacity were found to be 0.472 m/s and 0.044 ha/h, respectively. The mean effective operation time for the hand operated bund former on a 1 ha field of a sandy loam soil at 13.42 % moisture content was found 22.64h. The average field efficiency with the equipment was 74.05 % at tractor speed of 1.7 km/h.

Ashish et al. (2022) assessed the performance of tractor-operated bund former for mulched field to observe the effects of rotor speed ratios (3:1, 4:1, 5:1), opening width of bund forming plates (270, 340, 410 mm), and straw loads (4.0-4.5, 6.0-6.5 $t.ha^{-1}$) on the pulverization index (mm), height of bund (mm), width of bund (mm), fuel consumption (l/h) and field capacity (ha/h) of the machine. The effects of rotor speed ratio, opening width of bund forming plates, and straw load were significant ($p < 0.05$) on pulverization index, bund height, bund width, and fuel consumption. Best performances were obtained at rotor speed ratio of 4:1 and bund forming plates opening width of 340 mm under both straw loads. This combination gave the optimum height of bund (277.6 mm), bund width (720 mm), pulverization index (12.76 mm), and fuel consumption (7.05 l/h) under both straw loads. The effective field capacity of the tractor-operated bund former was 1.17 hah-1 at forward travel speed of 1.5 km/h. The operational cost of the bund former was Rs.792.36 /ha.

MATERIALS AND METHODS

CHAPTER III

MATERIALS AND METHODS

The materials and techniques taken into account during the creation and assessment of the power tiller with ridge plastering machine are included in this chapter. The mechanical and physical properties of soil, the modifications and approaches done, evaluation and simulation are included in the current chapter. The development and evaluation of the power tiller attached with ridge plastering machine was carried out at research workshop of, Department of FMPE, KCAET, Tavanur.

3.1 PHYSICAL AND MECHANICAL PROPERTIES OF SOIL

3.1.1 Moisture content

The soil moisture content (θ_m) is the ratio of the mass of water in a sample to the dry soil mass, expressed as either a decimal fraction or as percentage. It is often referred to as 'gravimetric water content'. The moisture content of soil is inversely related to the shear strength of the soil. The shear strength of the soil decreases with increase in moisture content. Wet soil can increase the resistance faced by the tiller and the plastering unit, requiring more power. The soil moisture content may be expressed by weight as the ratio of the mass of water present to the dry weight of the soil sample, or by volume as ratio of volume of water to the total volume of the soil sample (Adeniran and Babatunde, 2010).

The mass water content is found by the following equation described in IS 2720 (P2) 1973.

$$\theta_m \text{ (db)} = \frac{M_w}{M_s} \qquad \text{....(3.1)}$$

θ_m = soil moisture content, percent (db)

M_w = mass net weight of the soil

M_w = initial weight of the wet soil − final weight of the dry soil

M_S = final weight of dry soil sample

Procedure:

- Preparation of the soil sample: Collect a representative soil sample from the field or project site after the puddled condition. Remove any organic material, rocks, or debris present in the sample.
- Weighing the container: Clean and dry the moisture cans or containers. Take three containers. Weigh each container (without the lid) using the analytical balance and record its mass (M_1).
- Soil sample preparation: Fill the container with the soil sample approximate 20g. Break down any soil clumps or lumps using the spatula or spoon, and ensure the sample is evenly distributed within the container.
- Weighing the soil sample: Place the containers and weigh the container with the soil sample using the analytical balance. Record this mass (M_2).
- Drying the soil sample: Place the container (without the lid) containing the soil sample in the drying oven. Set the oven temperature to 110 ± 5°C (230 ± 9°F) and dry the sample for 24 hours, or until it reaches a constant mass.
- Cooling and weighing the dry soil sample: After drying, remove the container from the oven using tongs or heat-resistant gloves and place it in the desiccator to cool down to room temperature. Once cooled, weigh the container with the dry soil sample using the analytical balance and record the mass (M_3).

Plate 3.1 Oven drying method

Calculating the moisture content by,

$$w = [(M_2 - M_3) / (M_3 - M_1)] \times 100 \quad \text{…. (3.2)}$$

3.1.2 Bulk density

It is the density of the undisturbed (bulk) soil sample which is the ratio of mass of the soil to its total volume. It is measure of compactness of the soil influencing the soil engaging tool parameters.

Bulk density was determined using the following equation (Heuscher *et al.,* 2005).

$$\rho_b \text{ (db)} = \frac{Ms}{V} \quad \text{…. (3.3)}$$

Test Procedure:

- Measure the inside dimensions of the core cutter accurate to 0.25 mm and calculate its volume. Weigh the core cutter accurate to 1 g.
- Expose the small area, about 30 cm^2 to be tested and level it. Put the dolly on top of the core cutter and drive the assembly into the soil with the help of rammer until the top of the dolly protrudes about 15 mm above the surface.
- Dig the container from the surrounding soil, and allow some soil to project from the lower end of the cutter. With the help of the straight edge, trim flat the bottom end of the cutter. Take out the dolly and also trim flat the top end of the cutter.
- Weigh the cutter full of soil.
- Keep some representative specimen of soil (from the middle of the cylindrical soil sample) for water content determination.
- Repeat the test at two or three locations nearby and get the average dry density.

Plate 3.2 Core cutter Method

3.1.3 Cone index

Cone index is the average force per unit base area required to force a cone-shaped probe into soil at a steady rate. Cone index is used as the measure of soil strength in the traction equations.

The Proving Ring Penetrometer is a cone type penetrometer which can be used as a rapid means for determining the penetration resistance of soils in shallow exploration work. The reading obtained in this method maybe correlated to standard or modified compaction data for compaction control in the field. The instrument consists of a T-handle, one 50 cm penetration rod graduated every 2.5 cm above the cone base, one proving ring of 1 kN capacity with dial indicator and a removable cone point. The cone point has a base diameter of 3 cm and cone angle of 22.5°.

Cone index is determined by the following equation:

$$CI = 0.025Y + 0.099 \quad \text{...(Kumar and singh, 2012)}$$

Where ,

CI =Cone Index (N/mm^2)

Y = Gauge deflection (divisions)

Procedure:

- Be certain that the dial indicator has been set to zero position. Zeroing the dial indicator may be done by one of two methods. One method is with the bearing point of the dial indicator stem making contact with the head of the knurled screw, any adjustment of the screw will allow zeroing to be accomplished. A second method for zeroing the dial indicator is by adjustment of the dial face itself. This is done by releasing the knurled screw located on the upper left side of the dial housing. After rotation of the dial face to the zero position, be certain to tighten the knurled screw so as to maintain this position.

- Select the site to be tested and clear the test location so that a flat and clean surface is available for testing.
- Hold the assembly vertically on the test location. Grasping the handle firmly, push the cone point down into the soil at a steady uniform rate until the top of the cone goes just below the surface.
- Record the dial indicator reading. Using the proving ring calibration chart, determine the maximum penetration. Refer to the conversion chart to read the penetration resistance value.
- In order to measure the penetration resistance at different depths, push the cone point down into the soil until the corresponding graduation marks on the rod just flush with the ground surface and record the dial indicator reading.
- Withdraw the penetrometer, wipe it clean and repeat the procedure at different locations, at least 50-60 cm apart from each other to minimize the errors due to soil disturbance.

Plate 3.3 Cone penetrometer measurement

3.2 SELECTION OF PRIME MOVER

The prime mover is an initial source of motive power. Power tillers typically have engine capacities ranging from 8 HP (horsepower) to 18 HP. The selection of engine power depends on the work requirements and the size of the field. The prime mover is selected based on the energy required to perform the propulsion of the machine, ditching and plastering of the soil.

3.2.1 Power requirement for power tiller attached with ridge plastering unit

The power requirement for a power tiller attached with a ridge plastering unit depends on several factors, including the type of power tiller, the design of the ridge plastering unit, and the working conditions (soil type, field size, moisture content, etc.). The power required for the power tiller attached with ridge plastering unit is the sum of power required for propulsion, ditching and plastering unit.

Total power requirement = power required for the propulsion + power required for ditching unit + power required for the plastering unit

3.2.1.1 Power requirement for propulsion of power tiller

One of the primary factors contributing to a machine's power consumption is its own propulsion system. The propulsion force includes inertial force, aerodynamic resistance, motion resistance, drawbar pull and gradient resistance. The propulsion force is thus determined for the effective forward motion of the machine.

The tractive effort or the propelling force (F) is calculated by the following equation,

$$F = F_i + R_a + R_v - F_d + R_g \qquad \text{.... (3.4)}$$

Where,

F_i – inertial force,

R_a –aerodynamic resistance,

R_v – motion resistance,

F_d – drawbar pull,

R_g- gradient resistance

Inertial force refers to the force needed to overcome the mass of the tiller when accelerating from a standstill or changing speeds.

Inertial force is given by,

$$F_i(N) = \frac{Wa}{g} \quad \text{.... (3.5)}$$

Where,

W= weight of the machine (N);

g = acceleration due to gravity (m/s^2),

a =acceleration of the machine (m/s^2).

$$a = \frac{\text{velocity}}{\text{time}}$$

Aerodynamic resistance is the force required to overcome air resistance when the tiller is moving forward. Aerodynamic resistance, R_a can be neglected due to very slow speed.

Motion resistance encompasses forces like rolling resistance from the tires and internal mechanical resistance.

Motion resistance,

$$R_v = \mu_c \times W \quad \text{.... (3.6)}$$

Using Wismer – Luth equation,

$$\mu_c = 0.04 + \frac{1.2}{C_n} \quad \text{.... (3.7)}$$

$$\text{Wheel numeric}, \; C_n = \frac{CI\,bd}{W} \quad \text{.... (3.8)}$$

Where,

CI=cone index (kPa),

b=width of the wheel (m)

d= diameter of the wheel (m)

s = permissible slippage which is assumed as 15%.

Drawbar pull is the force needed to pull implements attached to the tiller, such as a ridge plastering unit. It depends on the soil type, tilling depth, and the design of the implement.

Drawbar pull,

$$F_d = \text{Weight} \times \text{coefficient of friction} \quad \text{.... (3.9)}$$

Gradient resistance is the force needed to overcome gravity when moving uphill.

Gradient resistance,

$$R_g = W \times \text{Sin}\ \theta \qquad \text{.... (3.10)}$$

Maximum force required for propulsion (eqn. 3.4),

$$F = F_i + R_a + R_v - F_d + R_g$$

Therefore the power required for the propulsion is calculated by the equation,

$$\text{Power required(kW)} = \text{Force(N)} \times \text{Forward speed} \qquad \text{.... (3.11)}$$

3.2.1.2 Power requirement for ditching unit

The ditching unit is used to cut the soil and throw it to the plastering unit. Blades are the ditching unit's primary component. Thus, it is necessary to ascertain the amount of power needed to cut the soil.

Theoretical power required for operating blade is determined by the formula,

$$P_t = SR \times V_f \times A \qquad \text{.... (3.12)}$$

Where,

SR is specific soil resistance

V_f is the speed of operation,

$$V_f = \frac{(3.14 \text{ x d x N })}{60} \qquad \text{.... (3.13)}$$

A is the area of blade in m^2

3.2.1.3 Power requirement for plastering unit

The soil thrown by the ditching unit is plastered by the plastering unit and compacts the soil in the ridges. The plastering unit mainly comprises of the plastering disc. The ridge plastering unit is typically used to smooth and compact soil ridges, which helps in water management and crop growth. The forces acting on the disc are weight of the disc assembly and the maximum vertical force a operator can exert.

Total force acting on the disc,

$$F\ (N) = (W_1 + W_2) \times 9.81 \qquad \text{.... (3.14)}$$

W_1 = Weight of the disc assembly acting downward

W_2 = Maximum force the operator can act downward

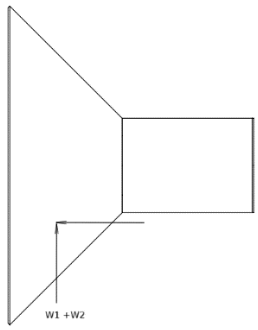


Fig. 3.1 Forces acting on the plastering disc

Frictional forces encompass the resistance that needs to be overcome to move the unit across the soil surface effectively.

$$\text{Frictional force, } F_f = \mu F \qquad \text{.... (3.15)}$$

Where,

μ is the coefficent of friction ,

$$\mu = \tan\theta \qquad \text{.... (3.16)}$$

F is the total force acting

$$\text{Torque (Nm)} = F_f \times d$$

Where, d is the mean diameter of disc

$$d = \frac{d1+d2}{2} \qquad \text{.... (3.17)}$$

where d_1= outer diameter of disc

d_2= inner diameter of disc

$$\text{Power (kW)} = \frac{2\pi NT}{60} \qquad \text{.... (3.18)}$$

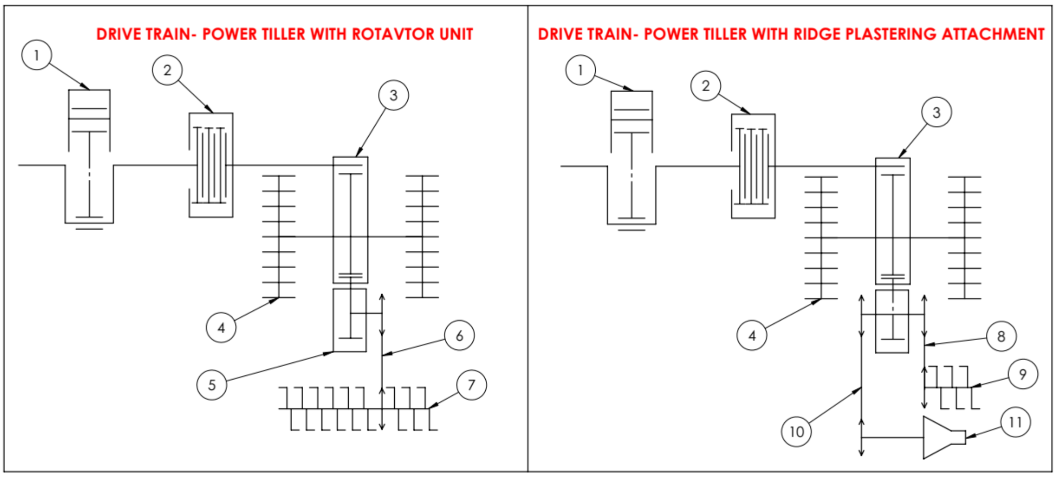
N is the rotational speed in rpm

3.2.1.4 Total power requirement

Power is necessary to move the unit, compact the soil, and overcome frictional and drag forces, ensuring efficient and effective operation. Therefore, the total power can be calculated by the following formula,

Total power requirement = Power requirement for propulsion of power tiller + Power requirement for plastering unit + Power requirement for ditching unit

3.3 EXISTING AND MODIFIED POWER TRAIN



1- Engine
2- Clutch
3- Main gearbox
4- Cage wheel/ Pneumatic wheel
5- Auxiliary gearbox
6- Chain drive for rotor
7- Rotovator unit
8- Chain drive for ditching unit
9- Ditching unit
10- Chain drive for plastering disc
11- Plastering disc

Fig. 3.2 Power train of the existing (left) and modified (right)

In the existing power train, power from the engine is transmitted to the clutch with the help of belt, which is then transferred to the gear box and the wheels. The gear box adjusts the speed and torque, transmits the power through the transmission system to rotavator tynes through chain.

In the modified power train, the power from the engine is transmitted to the clutch with the help of belt and is transmitted to the wheel and auxiliary gear box. From the auxiliary gear box, the power is transmitted to the ditching and plastering unit via two different chain drives. The ditching unit helps in the cutting of soil and sliced portion of soil is thrown to the plastering unit, which plasters and finishes the top portion of the bund.

3.4 MODIFICATION OF POWER TILLER AUXILLARY GEARBOX SYSTEM

KAMCO KMB 200 type model consists of sliding mesh type gearbox with oil grade is SAE 90. The main gear box assembly has 6 forward and 2 reverse speeds (high and low). At the end of main gearbox drive is transferred to auxiliary gearbox where the drive is transferred to the rotary unit. The auxiliary gear box consists of two shafts, four bearings and a pair of spur gear sets, which meshes with each other in vertical position.

Fig. 3.3 KAMCO KMB 200 - 9 hp power tiller

Engine is having a rated rpm from which the transmission takes place from gearbox output shaft to rotary shaft. Two combinations are 29-26 and 34-21 gear teeth for 315 rpm and 215 rpm respectively. The number of teeth on drive sprocket is 15 and on driven sprocket is 12. Thus, the speed reduction ratio is 1.25:1. Design considers the 215 rpm. The gear has a module value of 3 mm and a pitch circle diameter of 102 mm. Single drive shaft gets splitted for the design. There is dog clutch for engaging purpose.

3.4.1 Auxiliary gearbox

The auxiliary gearbox is used for transferring the power from main gearbox to rotary shaft. The auxiliary gearbox of KAMCO KMB 200 power tiller consists of the following components:

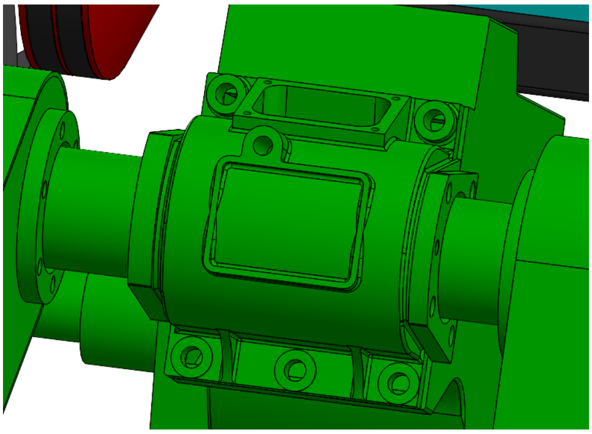


Fig. 3.4 Auxiliary gearbox

1. Rotary driving shaft
2. 29 teeth gear with pawl
3. 34 teeth gear with pawl
4. Collar for 29 teeth gear
5. 34 teeth gear bush
6. Dog clutch
7. 29 teeth gear bush
8. Collar 24 mm diameter
9. Collar 32 mm diameter
10. Ball bearing 6304
11. Ball bearing 6207
12. Oil seal 35 x 62 x 6
13. Stopper ring 32 mm diameter

3.4.2 Modifications on the auxiliary gearbox

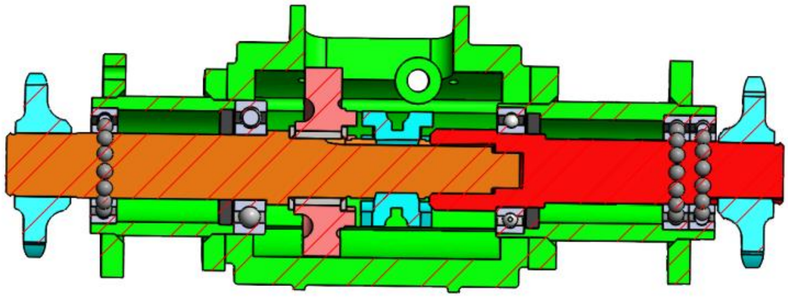


Fig. 3.5 Modifications on the auxiliary gearbox

- The 29 teeth gear (315 rpm) in the auxiliary gearbox was removed and the drive for operating the ridge plastering unit was taken from the remaining 34 teeth gear (215 rpm).
- Rotavator driving shaft running through the auxiliary gearbox was modified.
- Suitable length from its splined end was removed and it was replaced by another shaft.

3.5 DESIGN OF COMPONENTS

The power tiller operated ridge plastering attachment has mainly three units, the modified auxiliary gear box, the ditching and plastering unit. And all these units consist of shafts, bearings, oil seals and many flanges. Chains are also present for the transmission of power from the gearbox to the ditching and plastering units.

3.5.1 Design of gearbox box splined shaft

A splined shaft is one that (usually) has equally spaced teeth around the circumference, which are most often parallel to the shaft's axis of rotation to prevent the relative motion between the drive transmission components. Splined shafts are selected in the auxiliary gear box assembly to transfer power rather than the tapered shafts because of the ease of machinability and cost economics.

The design of splined shaft includes adjustment for the operating conditions by including a service factor K_s. This factor is based on a design factor K_d, an application factor K_a, a load distribution factor K_m, a fatigue life factor K_f, and a wear life factor K_w.

Based on compressive strength, resulting Compressive stress in spline, σ_c (N/m^2)

$$\sigma_c = \frac{T.K_s}{n.d.Le.r} \quad \text{.... (3.19)}$$

Where,

r = Mean radius of spline (m)

n = Number of splines

Le = Effective Length of spline = Straight Length (m)

d = Depth of Spline (m)

T = Applied Torque (N.m)

K_s = Service factor

For a fixed /Guided spline,

$$K_s = \frac{K_a.K_d}{K_f} \quad \text{.... (3.20)}$$

K_s= Service factor

K_a= application factor

K_d = Design factor

K_f=fatigue life factor

τ = Resulting Shear stress in spline (N/m^2)

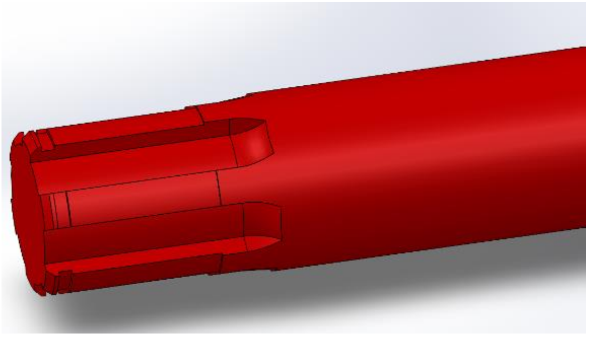


Fig. 3.6 Splined shaft

Shear stress in the reduced shaft diameter,

$$\tau = \frac{16.T.K_s}{\pi.D_i^3} \quad .... (3.21)$$

3.5.2 Design of shaft for plastering and ditching unit

The shaft is a rotating machine element, usually circular in cross section, which is used to transmit power from one part to another, or from a machine which produces power to a machine which absorbs power. The shafts in ditching and plastering unit helps in transmitting power from the auxiliary gearbox to the blades and disc in ditching and plastering unit respectively.

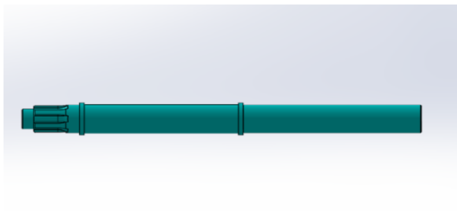


Fig. 3.7 Shaft for plastering unit (left) and ditching unit (right)

For the design, it is assumed that the shaft is subjected to twisting moment only and neglecting bending moment.

$$T = \frac{60P}{2N\pi} \quad .... (3.22)$$

Where,

P is the engine power

T is the Torque,

Select the shaft material and its Yield strength

Yield shear strength = Yield strength x k

Assume the Factor of safety, FOS

Allowable shear stress,

$$f_s = \frac{\text{Yield shear strength}}{\text{Factor of safety}} \quad .... (3.23)$$

Torque is determined by the following equation (PSG Design Data book)

$$\text{Torque} = \frac{\pi}{16} f_s \, d^3 \quad .... (3.24)$$

d is the Diameter of shaft in mm

$$d^3 = \frac{16T}{\pi f_s} \qquad \text{.... (3.25)}$$

Select bearing based on dynamic loading capacity.

3.5.3 Design of chain drive

Chain drive is used to transmit the power from the auxiliary gear box to the ditching and plastering units.

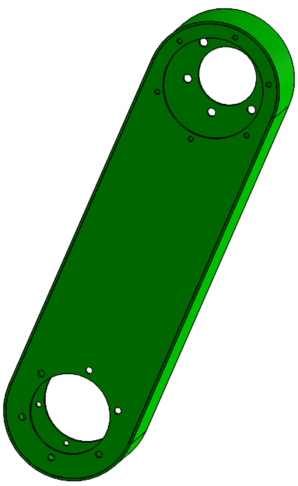


Fig. 3.8 Chain drive cases

P = Power

N = Rotary speed of drive sprocket

n = Rotary speed of driven sprocket

a = Inter shaft distance

$$\text{Transmission ratio, } i = \frac{\text{rotary speed of driven sprocket}}{\text{rotary speed of drive sprocket}} \qquad \text{.... (3.26)}$$

For transmission ratio, take minimum number of teeth on sprocket.

z =No of teeth on smaller sprocket

Z = No of teeth on larger sprocket

$$Z = i \times n \qquad \text{.... (3.27)}$$

p =Pitch,

a = Centre distance

Service factor is determined by the following equation (PSG Design data book),

$$K_s = K_1 \text{ x } K_2 \text{ x } K_3 \text{ x } K_4 \text{ x } K_5 \text{ x } K_6 \quad .... (3.28)$$

K_1 =Load factor

K_2 =Factor of distance regulation

K_3 =Factor for centre distance of sprockets

K_4 =Factor for the position of sprockets

K_5 = Lubrication factor

K_6=Rating factor

Chain velocity,

$$V(m/s) = \frac{z \text{ x } N \text{ x } p}{60 \text{ x } 1000} \quad .... (3.29)$$

Take factor of safety, F_S

Breaking load,

$$Q\ (kgf) = \frac{75 \text{ x } P \text{ x } F_S \text{ x } K_S}{v} \quad .... (3.30)$$

According to pitch and breaking load, chain is selected.

$$\text{Actual factor of safety} = \frac{Q}{\sum P} \quad ...(3.31)$$

Tangential force due to power transmission,

$$P_t = \frac{75 \times P}{v} \quad .... (3.32)$$

Centrifugal tension,

$$P_c = \frac{wv^2}{g} \text{ in kgf} \quad .... (3.33)$$

where,

w =weight of chain per m length

g= acceleration due to gravity (9.8m /s^2)

Tension due to sagging of chain,

$$P_s = K_{sag} \times w \times a \quad .... (3.34)$$

where,

K_{sag} = coefficient for sag

$$\sum P = P_t + P_c + P_s \quad \text{.... (3.35)}$$

If actual factor of safety is greater than assumed factor of safety, the design is safe.

Approximate centre distance in multiples of pitches,

$$a_p = \frac{a}{p} \text{ in mm} \quad \text{.... (3.36)}$$

Length of continuous chain in multiples of pitches (approximate number of links),

$$l_p = 2\, a_p + \frac{z+Z}{2} + \frac{(\frac{Z-z}{2\pi})^2}{a_p} \quad \text{.... (3.37)}$$

Length of chain,

$$l = l_p \times p \text{ in mm} \quad \text{.... (3.38)}$$

Diameter of small sprocket,

$$d_1 = \frac{p}{\sin(\frac{180}{n})} \quad \text{.... (3.39)}$$

Diameter of larger sprocket,

$$d_2 = \frac{p}{\sin(\frac{180}{N})} \quad \text{.... (3.40)}$$

3.6 FABRICATION OF POWER TILLER OPERATED RIDGE PLASTERING MACHINE

Power tiller operated ridge plastering machine mainly consist of four units: the modified gearbox assembly system, ditching unit, plastering unit and chain cases. These units were fabricated and assembled separately, finally attached to the 9 hp power tiller.

3.6.1 Modified Gearbox Assembly System

The modified gearbox assembly system comprises several critical components, each meticulously fabricated and assembled to ensure optimal performance and longevity. The key elements of this system include two 15-teeth sprockets, a 34-teeth gear, a collar, a splined shaft, a coupler shaft, a variety of ball bearings

(6007(3),6207,6008), flanges, pipes, an oil seal, and gaskets. Each of these components undergoes a series of precise manufacturing processes, starting from material selection to final assembly, to create a robust and reliable gearbox.

3.6.1.1 Shaft Fabrication and Joining

The process begins with the fabrication of the splined and coupler shafts, which are integral to the gearbox's functionality. These shafts are typically made from high-strength steel, selected for its durability and resistance to wear. The raw steel stock is first cut to the required length, and then the splines are milled using a horizontal milling machine. This milling process involves cutting multiple grooves along the length of the shaft to create the splines, which are essential for transmitting torque and aligning the shaft with other components. After milling, the shafts undergo heat treatment, a crucial step that enhances their mechanical properties. Heat treatment involves heating the shafts to a specific temperature and then cooling them rapidly to increase hardness and strength, making them capable of withstanding high loads and stresses during operation.

Plate 3.4 Shaft fabrication

3.6.1.2 Gear and Sprocket Integration

The gearbox also includes two 15-teeth sprockets and a 34-teeth gear, which are responsible for torque modulation and speed adjustment. These components are typically fabricated from hardened steel to ensure durability. These gears and sprockets are then assembled onto the shafts, ensuring proper alignment and secure fit to facilitate efficient power transmission.

Plate 3.5 Sprocket

3.6.1.3 Bearings and Collar Installation

Bearings play a critical role in reducing friction and supporting rotational motion within the gearbox. The modified gearbox system uses a combination of 6007, 6207, and 6008 ball bearings, each selected for their specific load-carrying capacities and dimensions. These bearings are installed on the shafts and within the gearbox casing, providing smooth and stable rotational support for the gears and sprockets. The collar, which is typically a cylindrical component that fits over the shaft, is also installed to maintain the position of other elements along the shaft.

Plate 3.6 Bearing

3.6.1.4 Flanges and Pipe Fabrication

The left and right side flanges and pipes are crucial for mounting and stabilizing the gearbox components. These flanges are fabricated using laser cutting technology, which offers high precision and the ability to create complex shapes and hole patterns as per the design specifications. Once the flanges are cut, holes are drilled at designated locations to accommodate bolts and other fastening elements. The flanges are then welded to the pipes, creating a strong and secure connection. These flange-pipe assemblies are subsequently attached to the gearbox casing, providing a stable framework for the gearbox components.

Plate 3.7 Circular flange

3.6.1.5 Sealing and Gasket Application

Plate 3.8 Gaskets

To prevent lubricant leakage and contamination, the gearbox system is sealed with an oil seal and gaskets. The oil seal, with dimensions 35x62x7, is installed at strategic locations to prevent oil from leaking out of the gearbox while allowing the shafts to rotate freely. Gaskets are cut to size and placed between mating surfaces to create a tight seal. These gaskets prevent the ingress of dust and debris and ensure that the gearbox operates smoothly and efficiently.

3.6.1.6 Final Assembly

The final assembly of the modified gearbox involves the careful integration of all components. The shafts, gears, sprockets, bearings, flanges, and seals are all assembled within the gearbox casing, with each part fitting securely into its designated position. Once assembled, the gearbox is tested to verify its functionality, ensuring that it meets the required performance standards.

(a) With casing

(b) without casing

Plate 3.9 Modified Gearbox Assembly System

3.6.2 Chain drive cases

3.6.2.1 Fabrication of Chain Drive Cases for Power Transmission

The fabrication of chain drive cases ensures the efficient and secure transmission of power from the gearbox to the corresponding units, such as the ditching and plastering units. These enclosures, designed to house sprocket and chain assemblies, play a vital role in shielding the internal components from external contaminants and facilitating smooth, uninterrupted operation. The construction of these cases involves a combination of advanced fabrication techniques, including laser cutting, welding, and meticulous assembly processes, using high-quality steel materials to achieve precision and durability.

3.6.2.2 Material Selection and Preparation

The chain drive cases are constructed from a variety of steel plates, which include side plates, straight plates, and curved plates. The fabrication process begins with the careful selection of these steel plates, ensuring they meet the required specifications for thickness, strength, and durability. These materials are chosen for their ability to withstand the operational stresses and environmental conditions to which the chain drive cases will be exposed. The number of links and length of the chain are selected according to the distance between the shafts. These chains connect and transmit the power from the auxiliary gearbox to the ditching and plastering units.

Plate 3.10 Chains

3.6.2.3 Laser Cutting of Plates

The initial step in fabricating the chain drive cases involves the use of laser cutting to prepare the steel plates. Laser cutting is favoured for its high precision and efficiency in producing clean, accurate cuts, even for complex shapes and patterns. A high-powered laser beam is focused on the steel plate, melting or vaporizing the material along a pre-defined path to achieve the desired shape and dimensions. The straight plates measure 600mm x 75mm are cut to form the main structural elements of the chain drive case. Then a part of the straight plate is bended to form the curved plates and all these are joined to form the structural component of the chain case.

Plate 3.11 Curved plates

3.6.2.4 Welding and Assembly of Structural Components

Plate 3.12 Welding of the chain case

Following the laser cutting process, the steel plates are assembled and welded to form the primary structure of the chain drive case. Welding is a critical step that involves joining the metal plates by heating them to a high temperature and fusing them together to create a strong, durable bond. The straight plates are first welded together to construct the basic framework of the enclosure, ensuring that the joints are secure and capable of withstanding operational vibrations and stresses. The curved plates, which have a radius of 83mm, are designed to fit around the sprockets and chains, providing a protective cover that conforms to the contours of the moving parts. The welding of the curved plates requires careful alignment and control to ensure a snug fit around the sprockets and chains, eliminating any gaps or misalignments that could compromise the integrity of the enclosure.

3.6.2.5 Installation of Shafts and Supporting Components

Once the primary structure of the chain drive case is assembled, the next step involves the installation of shafts according to the design specifications. These shafts are crucial for supporting the sprockets and facilitating smooth rotational motion. The insertion process demands precise alignment to ensure that the shafts are firmly secured in place, often using bearings and other supporting components to minimize friction and wear.

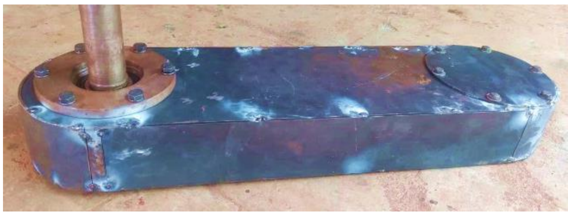


Plate 3.13 Chain drive case

3.6.3 Ditching unit

The ditching unit is a critical component designed to perform efficient and effective ditching operations. Its fabrication involves the precise assembly of various parts, including the blade shaft, case pipe, hub, flanges, pipe holder units, sprocket, bearings (6205,6207(2)), oil seals (35×62×7), and blade holders. The process requires careful attention to detail to ensure that each component functions correctly and integrates seamlessly into the overall system.

3.6.3.1 Fabrication of blade shaft and Case Pipe

The blade shaft is the central element of the ditching unit, responsible for holding and driving the blades that perform the cutting action. Fabrication of the blade shaft begins with selecting high-quality steel, which is then machined on a lathe to achieve the desired dimensions and surface finish. The lathe machining process involves rotating the workpiece while cutting tools are applied to shape it accurately. This ensures that the shaft has the correct diameter, length, and surface properties to fit within the unit and support the blades.

The case pipe serves as the protective housing for the blade shaft and other internal components. It is fabricated by cutting a steel pipe to the required length and ensuring its ends are precisely squared off. The case pipe provides structural integrity and protects the internal components from external debris and damage during operation.

3.6.3.2 Machining Hubs and Flanges

Hubs and flanges are essential for connecting various parts and facilitating rotational motion. These components are typically produced through a combination of machining and drilling processes. The hubs are machined to fit snugly onto the blade shaft, providing a secure connection point for the flanges and other components. The flanges are drilled with holes to accommodate bolts and fasteners, ensuring they can be securely attached to the hubs and other parts.

3.6.3.3 Welding the Pipe Holder Units

The pipe holder units, which consist of three holders, are fabricated through welding. The holders are cut and shaped using laser cutting and then welded together to form a single unit. This assembly is designed to hold the case pipe securely in place, providing stability and alignment for the ditching unit. The welded pipe holder unit is then bolted to another pipe holder unit, ensuring a robust and stable connection.

Plate 3.14 Pipe holder

3.6.3.4 Sprockets and Bearings Installation

The 12-teeth sprocket is used to drive the blade shaft. Bearings, including the 6205 and two 6207 bearings, are selected for their ability to support rotational motion and reduce friction. These bearings are pressed into place within the hubs and flanges, ensuring they are securely seated and aligned. Oil seals (35x62x7) are critical for preventing lubricant leakage and protecting the bearings from contaminants. These seals are carefully installed to ensure a tight fit and effective sealing.

3.6.3.5 Blade Fabrication

The blades are made from high-carbon steel. The flat blades are sharpened using the grinding machine and holes are drilled for the proper placement and tightening of blade holders. Then they are pre heated and is twisted to 45° inclination for the efficient cutting and throwing of soil.

Plate 3.15 Blade holder unit(left) and flat blade (right)

3.6.3.6 Final assembly of ditching unit

All the components of the ditching unit are installed and assembled carefully for the efficient ditching operation. Then the entire ditching unit is connected by the chain case and power is transmitted from the engine to ditching unit via the chain.

Plate 3.16 Ditching unit

3.6.4 Plastering unit

The plastering unit is a specialized component designed to facilitate efficient plastering operations, involving the precise construction and assembly of various parts, including the disc, roller, case pipe, plastering disc holder pipe, holder rib, holder plate, plastering disc cover, pipe holder units, drive shaft, sprocket, bearings (6205,6207,6008(2)), oil seal (40×55×10), oil seal seat, bearing seats, side plates, outer plates, and cover.

3.6.4.1 Fabrication of Plastering Disc Holder Components

The plastering disc holder pipe, holder rib, and holder plate are fabricated through a combination of cutting, machining, and welding processes. The holder rib and holder plate are cut using laser cutting techniques for precision and then welded to the holder pipe, creating a robust and stable assembly that can withstand the operational stresses of plastering. Pipe holder units are fabricated through welding, with each unit consisting of three holders that are cut and shaped using laser cutting. These holders are then welded together to form a single unit that can securely hold the case pipe in place. The pipe holder units are essential for maintaining the alignment and stability of the plastering unit, ensuring that the case pipe remains securely in place during operation. The case pipe serves as the main housing for the plastering unit, protecting the internal components and providing structural integrity.

Plate 3.17 Plastering disc **Plate 3.18 Holder rib**

3.6.4.2 Drive Shaft Fabrication and Bearing Installation

The drive shaft, which transmits power to the plastering disc and roller, is fabricated using precision machining techniques. The shaft is machined to the required diameter and length to ensure the secure connection of other components. The drive shaft is supported by bearings, including the 6205, 6207, and two 6008 bearings, which are selected for their ability to support rotational motion and reduce friction. These bearings are pressed into place within the bearing seats, ensuring they are securely seated and aligned. The oil seal (40x55x10) and its corresponding oil seal seat are critical for preventing lubricant leakage and protecting the bearings from contaminants. The bearing seats are also machined to precise dimensions, ensuring they can securely hold the bearings in place and provide support for the drive shaft.

Plate 3.19 drive shaft

3.6.4.3 Final Assembly and Alignment of the Plastering Unit

The final assembly of the plastering unit involves carefully aligning and fastening all the components together. The plastering disc, roller, and drive shaft are installed and secured, ensuring they are correctly aligned and can operate smoothly. The case pipe, holder units, and other components are assembled and fastened together, ensuring that the unit is stable.

Plate 3.20 Plastering unit

3.7 COST ANALYSIS

3.7.1 Calculation of cost of operation

Cost of plastering operation was calculated based on the initial investment and fabrication charges of the machinery and rental wages of operator and labours. The cost of operation of spading machine is divided as fixed cost and variable cost, where fixed cost is independent of operational use, while variable cost differs proportionally with the quantity of use (IS:9164-1979).

The fixed cost includes depreciation, interest, housing, insurance and taxes. The variable cost includes, cost of fuel and lubricants, repair and maintenances cost, wages of operator.

3.7.1.1 *Fixed cost*

The fixed cost includes depreciation, interest, taxes and housing (IS:9164-1979).

- **Depreciation**

It was the measure of quantity by which worth of the machine decreased with the path of the time. The yearly depreciation was calculated as follows (IS:9164-1979):

$$D=\frac{C-S}{L\times H} \quad \text{.... (3.41)}$$

Where,

D = Depreciation per hour

C = Initial price (Rs)

S=Salvage value, 10 per cent of initial price (Rs)

L = Life of machine in years.

H = No. of hours per year

- **Interest**

Interest is calculated on the machine's average investment, considering the machine's worth in the first and last years. Typically, they are calculated on a yearly basis (IS:9164-1979). The yearly interest rate on the initial purchase price may be computed as follows.

$$I=\frac{C+S}{2}\times\frac{i}{H} \quad \text{.... (3.42)}$$

where,

I = Interest per hour

i = 12 per cent per year

H = No. of working hours per year

C = Initial price

- **Taxes and insurance**

Insurance charges were taken based on the actual payment to the insurance; it may be taken as 2 per cent of the initial cost of the machine per year (IS:9164-1979).

- **Housing**

Housing cost is calculated based on the prevailing rates of the locality, but roughly, the housing cost may be taken as 1 per cent of the initial cost of the machine per year (IS:9164-1979).

3.7.1.2 ***Variable cost***

The variable cost involves repair and maintenance cost, fuel and lubrication charges and wages of operator.

- **Repair and maintenance cost**

The repair and maintenance cost are the product of machine's cost price and repair and maintenance percentage factor.

RM = 5 per cent × Initial price of implement

- **Fuel cost**

Fuel cost was calculated based on actual fuel consumption for the operation.

- **Lubricant cost**

It can be determined depending upon the maintenance cost or depending upon the lubricating oil consumption. Average lubrication cost was taken as 3 per cent of the fuel price (IS:9164-1979).

- **Wages of operator**

Wages of operator was calculated based on the actual wages of worker in local area.

3.7.1.3 ***Total cost of operation***

The total price of ploughing per hour of the developed spading machine can be calculated by summation of total fixed and variable cost per hour.

Total cost = fixed cost + variable cost

3.7.2 Break Even Point

The break-even point is at which neither profit nor loss is incurred. The break-even point is equal to the annual fixed cost divided by difference between the custom hiring charge per hour and the operating cost per hour. The break-even point was calculated using the following equation:

$$\text{BEP} = \frac{\text{AFC}}{\text{CF} - \text{V}} \qquad \text{.... (3.43)}$$

where,

BEP = Break-even point (h year-1)

AFC = Annual fixed cost for the machine (Rs. year-1)

CF = Custom fee (Rs. h-1)

3.7.3 Payback Period

It is the number of years it would take for an investment to payback its original cost through the annual cash revenue it generates, if the net cash revenue remains constant each year. The payback period is calculated as follows:

$$\text{Payback period} = \frac{\text{Initial investment}}{\text{Average net annual benefit}} \qquad \text{.... (3.44)}$$

3.7.4 Benefit-cost (B:C) ratio

It is the ratio of annual benefit to annual cost. The B.C ratio must be unity or more for a project investment to be considered worthwhile. This technique also ranks the project investments for selection. The ratio of unity indicates the coverage of costs without any surplus benefits. But usually the ratio has to be more than unity in order to provide some additional return over the costs for clear decision.

$$\text{B:C ratio} = \frac{\text{Benefit cost}}{\text{Cost of machine operation}} \quad \text{.... (3.45)}$$

3.7.8 Cost per meter length

The operational cost per meter length of bund using the power tiller machine was found to be just Rs. 0.588, while the conventional method costs is Rs. 7 per meter. This substantial difference highlights the significant cost savings achieved by using the power tiller-operated machine.

3.9 SIMULATION- STRUCTURAL ANALYSIS

SOLIDWORKS Simulation offers a powerful suite of tools for structural analysis, allowing engineers and designers to virtually test their CAD models and predict their real-world physical behaviour using Finite Element Analysis (FEA). This helps optimize designs, identify potential problems early in the development process, and ensure product safety and functionality. Finite element analysis (FEA) is a powerful computational tool used to analyse the behaviour of complex structures and systems under various loading conditions. It works by dividing the object into smaller, simpler pieces called "finite elements." The governing equations of each element are then solved, and the results are assembled to predict the overall behaviour of the entire structure.

The portfolio provides a range of capabilities, including:

- Linear static analysis: This assesses the behaviour of a structure under static loads, calculating stress, strain, and deformation to identify critical areas and optimize material usage.
- Non-linear static analysis: This analyses the behaviour of structures that exhibit non-linearity, such as large deformations or contact interactions, providing a more comprehensive understanding of complex scenarios.
- Dynamic analysis: This evaluates the dynamic response of structures to time-varying loads, such as vibrations and fatigue, helping to ensure product durability and functionality.

3.9.1 Simulation Software and Methodology

The plastering disc was modelled and simulated in SOLIDWORKS, a powerful CAD (Computer-Aided Design) and CAE (Computer-Aided Engineering) software. The simulation involved finite element analysis (FEA) to predict the response of the disc under various loading conditions, which are representative of actual field operations.

The simulation identified the stress distribution across the disc. It revealed that the weakest point on the disc had a significantly lower yield strength. Identifying these weak points is crucial for improving the design and material selection to enhance the overall durability and longevity of the disc.

Similar to the plastering disc, the ditching blades were simulated using SOLIDWORKS. The FEA method was employed to analyse the stress distribution and identify potential failure points under operational loads. The simulation helps in understanding how the blades perform under practical conditions, including the impact of soil resistance and mechanical forces.

3.9.2 Methodology of Simulation

To simulate the blade and plastering disc using SolidWorks, the process begins with modelling each component and setting up the simulation environment. Switching to the `Simulation` tab, a new study is created, selecting `Static` to analyse the static stress on the blade. Fixtures are applied to fix the blade in place where it would attach to the holder or shaft, simulating the constraints. External loads, representing forces along the blade edge or pressure loads simulating contact with soil, are applied using the `External Loads` feature. The model is then meshed, with a finer mesh applied to critical areas for more accurate results. The simulation is run by clicking `Run`, which calculates the stresses and deformations based on the applied loads and constraints. Results are viewed through `Results`, showing stress distribution, displacement, and factor of safety. Areas with high stress or significant deformations are analysed to determine if the blade or disc can withstand the applied loads without failure. Based on the results, the blade and disc design might be optimized, such as changing the material, thickness, or adding reinforcement, and additional simulations with different load conditions or constraints are run to validate the blade's robustness.

By simulation and analyzation, it is to ensured that the blade and disc meet the required performance criteria, allowing for any necessary design optimizations to be made before production. This comprehensive approach ensures that the components will function effectively in their intended applications, providing reliable and efficient operation.

RESULT AND DISCUSSION

CHAPTER IV

RESULT AND DISCUSSION

This chapter contains the results and discussions of the development and evaluation of power tiller operated ridge plaster. This deals with the fabrication, selection of prime mover, design of components cost analysis, evaluation of physical and mechanical properties of soil and simulation of structural analysis using SOLIDWORKS.

4.1PHYSICAL AND MECHANICAL PROPERTIES OF SOIL

4.1.1 MOISTURE CONTENT

The average weight of the collected samples before drying was 20 g, and after drying, the soil samples weighed 16 g. The soil moisture of the sample was calculated as 25 % on dry basis. The moisture content of the soil has a significant effect on the compactness and shear strength of the soil. As the wettability of soil increases, the shear strength and compactness decreases.

4.1.2 BULK DENSITY

The soil bulk density was measured by conducting core cutter method. The bulk density of soil increases with increase in soil moisture content and it plays an important role in determining the water holding capacity and indicates compactness of the soil. The obtained bulk density was 1342 kg/m^3.

4.1.3 CONE INDEX

The cone index of soil is an important consideration in the design of power requirement of machine. It is a widely used mechanical property of soil that measures its strength, compaction, and resistance to deformation. The cone index of soil was determined by conducting cone penetrometer test. As the depth increased from surface, penetration resistance also increased. Cone index is obtained as 271.65 kN/m^2.

4.2 SELECTION OF PRIME MOVER

Power tiller was selected rather than the tractors as India have more marginal farmers and small land holdings. The power tiller has engine capacities varying from 8 to 18 hp. Therefore, a suitable prime mover was selected based on the calculated total power requirement for the operation of power tiller operated ridge plastering attachment. The total power required was sum of power required for propulsion, ditching and plastering units.

4.2.1 Power requirement for propulsion of power tiller

The power requirement for propulsion refers to the power needed to move the ridge plastering unit attached to a power tiller forward and involves overcoming various resistive forces such as rolling resistance, drag, and gradient forces. The inertial force required to overcome the mass of power tiller is found to be 104.38 kg. Aerodynamic resistance was neglected due to very slow speed. Motion resistance was found to be 306.833kg. Drawbar pull has a negative draft of 204.8kg. The gradient resistance was calculated as 512 kg. Therefore, the maximum force required for propulsion is 719.21kg. The power required for the propulsion of the power tiller operated ridge plastering machine is 1.46 kW.

4.2.2 Power requirement for ditching unit

The ditching unit, which relies on blades as its primary component to cut and transfer soil to the plastering unit, requires careful determination of the power needed for efficient soil cutting. Ditching unit helps in the cutting of soil with the help of blades. To determine the power requirement for the ditching unit of a power tiller attached to a ridge plastering unit, several factors must be considered. The maximum unit draft of the soil is given as 0.103×10^6 N/m^2. The forward speed of the power tiller is 0.75 km/h, which converts to 0.2083 m/s, while the rotor operates at a speed of 200 rpm. According to SolidWorks drawings, the area of the blade is 5658.0356 mm^2. The engine of the power tiller delivers a power of 6.7 kW (equivalent to 9 hp) at a rated engine speed of 2000 rpm. The theoretical power required to operate the blade of the ditching unit is calculated to be 1.94 kW.

4.2.3 Power requirement for plastering unit

Plastering disc is responsible for receiving soil from the ditching unit and subsequently smoothing and compacting it into ridges. The plastering disc ensures that the soil is evenly distributed and adequately compacted. In the operation of the disc assembly, several factors affect its performance and power requirement. The downward force exerted by the disc assembly is calculated as 50 kg, augmented by the operator's additional force of 20 kg, totalling 70 kg or 686 N. Considering sandy loam soil conditions with a friction coefficient of 0.4, the frictional force is determined as 274.4 N. The torque was found as 48.02 Nm. With a rotational speed of 215 rpm, the power required for the operation is determined to be 1.08 kW.

4.2.4 Total power requirement

Total power requirement for the power tiller operated ridging plastering attachment is the sum of power requirement for propulsion of power tiller, power requirement for ditching unit and plastering unit. The power required for the propulsion was found to be 1.46 kW. Power required for the ditching and plastering unit are 1.94 kW and 1.08 kW respectively. The total power requirement for the power tiller operated ridge plastering attachment is 4.48 kW i.e, 6.01 hp. Hence, considering all the losses, 9 hp power tiller is selected. Thus, KAMCO KMB 200 9 hp power tiller is chosen.

4.2 DESIGN OF COMPONENTS

4.3.1 Design of gearbox splined shaft

Splined shafts in the auxiliary gear box assembly help in transferring power. It is rather preferred than the tapered shafts because of the ease of machinability and cost economics. The design of splined shaft includes adjustment for the operating conditions by including a service factor K_s. A standard straight sided spline of medium series spline of size 6 × 28 × 34 is selected. (IS -2327:1993). The material selected for the shaft is EN-24 with case hardened with the tensile strength, shear strength and compressive strength as 1100 MPa, 634 MPa and 324 MPa respectively. Outer most diameter and reduced diameter of the shaft are 34 mm and 28 mm respectively. Six splines of width 7 mm and length of 36mm is given. Mean radius of the spline is 15.5mm. Resulting effective depth of the teeth is 3 mm. The shear stress in the reduced shaft diameter is determined as 157.875 MPa. Factor of safety is 4.0. The compressive stress in the spline and the shaft is 135.43 MPa and the factor of safety is 2.24. Therefore, the design is safe.

4.3.2 Design of shaft for plastering and ditching unit

The shafts in ditching and plastering unit helps in transmitting power from the auxiliary gearbox to the blades and disc in ditching and plastering unit respectively. For the design, it was assumed that the shaft is subjected to twisting moment only and neglecting bending moment. EN 24 is the shaft material which has yield strength of 1100 MPa and yield shear strength of 660 MPa. Allowable shear stress was found to be 82.5 MPa. As the torque value is 298200 Nmm, the diameter of the shaft was found to be 26.40mm. After bending moment considerations, the diameter of shaft is taken as 35mm and 6207 bearing is selected. The dynamic loading capacity of bearing 6207 is 27 kN.

The chain drive is connected to plastering unit through another shaft. Plastering discs and a forming roller make up the plastering unit. The speed at the end of the plastering unit shaft increases when the gear tooth reduction goes from 15 to 12. The torque decreases as the speed rises. As a result, the shaft can have the diameter of 35 mm. Safety factor is taken into account to ensure proper design without failure. A factor of safety, also known as safety factor, expresses how much stronger a system is than it needs to be for an intended load.

4.3.3 Design of chain drive

Chain drive is used to transmit the power from the auxiliary gearbox to the ditching and plastering units. To transmit power from a 9-horsepower (6.714 kW) power tiller, with a rotary speed of 215 rpm at high gear and 172 rpm at low gear, a chain drive is designed using a transmission ratio of 1.25. The limited spacing necessitates a minimum sprocket tooth count of 7. Here, the smaller sprocket has 12 teeth and the larger one has 15 teeth, calculated as the product of the transmission ratio and the smaller sprocket's teeth. The chain pitch of 19.05 mm and a centre distance of 450 mm is taken.

The chain velocity is calculated as 0.819 m/s, based on the formula involving the sprocket teeth, rotary speed, and chain pitch. Assuming a factor of safety of 3.125, the breaking load is determined to be approximately 3200 kgf. This calculation led to the selection of an R-60 chain. The actual factor of safety is calculated as 3.876, confirming the design's safety as it exceeds the assumed factor of safety. The approximate centre distance in multiples of pitches is calculated to be 23.62, leading to an approximate number of chain links (length of continuous chain in multiples of pitches) of about 60.754, which translates to a chain length of 1157.38 mm. The diameters of the smaller and larger sprockets are calculated to be 73.6 mm and 91.625 mm, respectively. This detailed design ensures the efficient and safe transmission of power in the power tiller’s chain drive system.

4.4 MODIFICATION OF POWER TILLER AUXILLARY GEARBOX SYSTEM

4.4.1 Modifications on the auxiliary gearbox

The KAMCO KMB 200 power tiller is equipped with a sliding mesh type gearbox running on SAE 90 oil grade, featuring 6 forward and 2 reverse speeds, including high and low ranges. Drive from the main gearbox is transmitted to the auxiliary gearbox, which then powers the rotary unit. This auxiliary gearbox consists of two shafts, four bearings, and a pair of spur gear sets meshing vertically, ensuring effective power transfer. The gear setup includes a 15-teeth drive sprocket and a 12-teeth driven sprocket, yielding a speed reduction ratio of 1.25:1. The design prioritizes the 215-rpm setting for optimal performance.

Critical components of the auxiliary gearbox include the rotary driving shaft, gears with pawls (29 and 34 teeth), collars, bearings (6304 and 6207), oil seals, and stopper rings. These components work in harmony to ensure smooth and reliable power transmission from the main gearbox to the rotary unit, enhancing the tiller's operational efficiency.

Modifications on the auxiliary gearbox involve removing the 29-teeth gear, originally set for 315 rpm, and utilizing the remaining 34-teeth gear (operating at

215 rpm) to drive the ridge plastering unit. Rotavator driving shaft running through the auxiliary gearbox was modified. Suitable length from its splined end was removed and it was replaced by another shaft. This adjustment ensures the tiller is optimized for plastering tasks while maintaining ideal speed and performance levels.

4.5 FABRICATION OF POWER TILLER OPERATED RIDGE PLASTERING MACHINE

The power tiller-operated ridge plastering machine integrates four main units: the modified gearbox assembly system, chain drive cases, ditching unit, and plastering unit, designed to enhance agricultural efficiency when attached to a 9 hp power tiller. The modified gearbox assembly system transmits power from the engine to the ditching and plastering units through components like sprockets, gears, and shafts, with fabrication involving milling, heat treating, and welding of flanges and pipes, followed by assembly and gasket sealing for effective power transfer.

Plate 4.1 Fabricated power tiller operated ridge plastering machine

Chain drive cases, constructed from welded and precision-cut plates, enclose the sprocket and chain assembly to facilitate power transmission and ensure durability and smooth operation. The ditching unit, which creates ditches, includes a blade shaft, hub, flanges, and high-carbon steel blade holders, fabricated through laser cutting, drilling, and welding to ensure robust and precise functionality. The plastering unit, responsible for applying plaster to ridges, features a disc, roller, and various holder components within an enclosed chain and sprocket assembly, secured with welded plates and assembled through drilling and machining to ensure controlled and high-quality plaster application. The ridge plastering attachment was fabricated in the farm machinery finally attached to the KAMCO KMB 200 9 hp power tiller.

4.6 COST ECONOMICS OF POWER TILLER OPERATED RIDGE PLASTERING MACHINE

The cost economics of the developed machine should be economical for its adaptability along with its better performance. The cost of operation of the ridge plaster was calculated taking into consideration of both tractor operated ridge plaster machine and was compared with the conventional method of bund former.

For estimating the operational cost of a power tiller-operated ridge plastering machine, the straight-line depreciation method was applied, as detailed in Appendix IV. The initial cost of the machine was Rs. 62,000, leading to an hourly operational cost of Rs. 353. When assessing the cost per hectare, it was calculated to be Rs. 6,537.04. In comparison, the traditional method of plastering, which relies heavily on manual labour, incurs a significantly higher cost of Rs. 17,500 per hectare. Analysing the cost efficiency on a more granular level, the operational cost per meter length of bund using the power tiller machine was found to be just Rs. 0.588 meter, while with the tractor operated machine and the conventional manual method costs was Rs. 0.77 per meter and Rs. 5 per meter respectively. Using power tiller operated ridge plaster machine saves 62.64 % operational costs compared to traditional method and 23 % as compared to tractor operated machine. This substantial difference highlights the significant cost savings achieved by using the power tiller-operated machine. Specifically, the savings amount to Rs. 12,962.96 per hectare, representing a 62.64% reduction in costs compared to the traditional plastering method.

These savings not only make the power tiller-operated ridge plastering machine economically viable but also highly advantageous in terms of cost-efficiency. The financial metrics further underscore its viability: the break-even point for the machine is 142.24 hours of operation annually. This indicates that after this point, the machine starts to generate net savings. The payback period for the initial investment in the machine is calculated to be 3.164 years, meaning the machine will effectively pay for itself through the savings it generates in just over three years. The benefit-cost ratio of the machine was 2:1. This ratio indicates that for every rupee invested in the machine, there is a return of two rupees in terms of cost savings and operational efficiency. This makes the investment in the power tiller-operated ridge plaster machine not just a cost-saving measure but also a profitable one in the long term.

4.7 SIMULATION

4.7.1 Simulation of plastering disc

The plastering disc, a critical component in agricultural machinery, was subjected to a comprehensive simulation using SOLIDWORKS to evaluate its structural integrity and performance under operational loads. The disc, essential for even plastering and soil preparation, was analysed for its yield strength and stress distribution to ensure it meets the demands of practical applications.

4.7.1.1 Material Properties and Yield Strength

The material used for the disc was assumed to have a yield strength of 3.516 x 10^8 N/m^2. Yield strength is a critical parameter as it indicates the maximum stress that the material can withstand without undergoing permanent deformation. The yield strength ensures that the disc can handle the forces encountered during operation without failing.

4.7.1.2 Stress Distribution and Weak Points

The simulation identified the stress distribution across the disc. It revealed that the weakest point on the disc had a significantly lower yield strength of 1.1 x10^8. This discrepancy highlights areas where the disc is more likely to experience stress concentrations and potential failure. Identifying these weak points is crucial for improving the design and material selection to enhance the overall durability and longevity of the disc.

4.7.1.3 Interpretation of simulation results of plastering disc

The results from the SOLIDWORKS simulation show that the plastering disc is generally robust. However, the presence of weaker points necessitates design optimizations. Reinforcing these areas can lead to a more uniform stress distribution, thereby increasing the operational lifespan and reliability of the disc in the field.

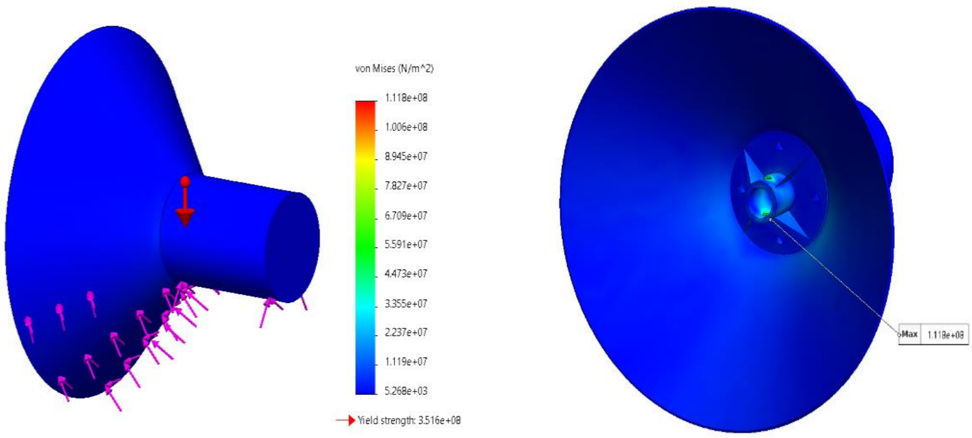


Fig 4.1 Simulation results of plastering disc

4.7.2 Simulation of blades

Ditching blades are integral to the functionality of machinery used for creating ditches and preparing agricultural land. These blades must endure significant forces and resist wear and tear over time. The simulation of ditching blades using SOLIDWORKS provides insights into their structural performance and helps in refining the design for better efficiency and durability.

4.7.2.1 Material Properties and Yield Strength

For the ditching blades, the material was specified with a higher yield strength of 5.300×108 N/m^2. This higher yield strength is crucial for withstanding the intense mechanical forces exerted during ditching operations. The maximum stress value observed in the simulation was 7.944×10^7 N/m^2, indicating the maximum load the blades can endure without permanent deformation.

4.7.2.3 Factor of Safety

The factor of safety (FoS) is a crucial parameter in engineering design that indicates how much stronger a system is than it needs to be for an intended load. For the ditching blades, the maximum and minimum values of the factor of safety were found to be 10 and 6.67, respectively. A higher factor of safety indicates a more robust design, providing a significant margin for error and unexpected loading conditions.

4.7.2.4 Interpretation of simulation results of ditching blades

The simulation results, depicted in Figure 4.2, show that the ditching blades possess a high factor of safety, reflecting their capability to withstand the operational stresses comfortably. The higher yield strength and favourable factor of safety suggest that the blades are well-designed for durability and effective performance in the field. However, further optimizations can be made to ensure even better stress distribution and longevity, especially focusing on areas that might experience higher stress concentrations.

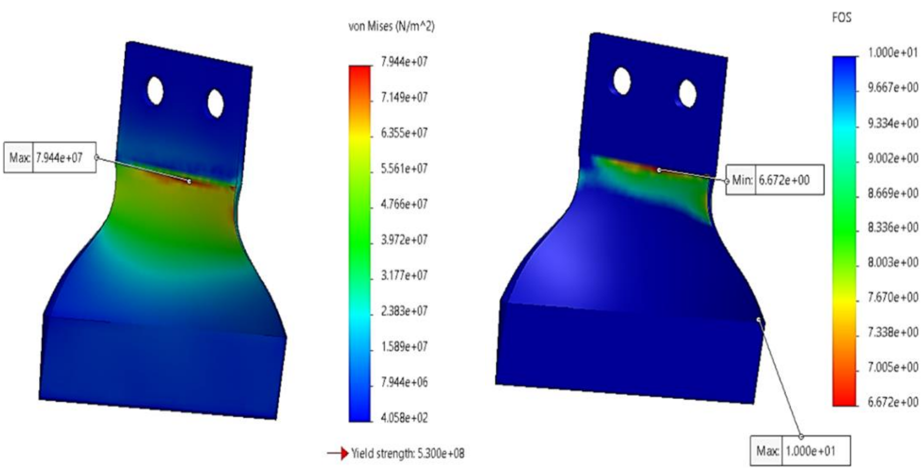


Fig 4.2 Simulation results of ditching blades

SUMMARY AND CONCLUSION

CHAPTER V

SUMMARY AND CONCLUSION

Small landholders often face challenges in adopting modern agricultural techniques and equipment. The high cost of tractors and specialized machinery can be a significant barrier, putting them out of reach for many farmers with limited financial resources. Additionally, a lack of knowledge and training on the benefits and proper use of modern techniques can hinder their adoption. Furthermore, for small landholdings, the investment in large equipment may not be economical, as the land size may not justify the expense. Despite these challenges, scientific farming methods offer significant benefits for small landholders. Practices like using improved seed varieties, proper nutrient management, and efficient irrigation can significantly increase crop yields and improve overall farm productivity. These methods can also help optimize resource use, leading to reduced costs for fertilizers, water, and labour. Moreover, scientific farming can lead to better quality crops, fetching higher market prices and improving the farmer's income.

Mechanizing the bund-making process is crucial for sustainable paddy cultivation. The fabricated power tiller operated ridge plastering machine offers a significant advantage over traditional methods as well as tractor operated ridge plaster machine. By effectively trimming, plastering, and compacting the bunds, it not only improves water management but also helps control rodent damage. This shift from tractor-based equipment to a power tiller operated one makes the technology simpler, more effective, locally adaptable, and cost-effective. This innovation allows the machine to be used in both dry and wet field conditions, further enhancing its versatility and potential impact on paddy farming.

The project focused on optimizing the transmission system for efficient operation. The auxiliary gearbox underwent modifications, with the 29-teeth gear (315 rpm) being removed. The drive for the ridge plastering unit was then sourced from the remaining 34-teeth gear (215 rpm). Additionally, the rotavator driving shaft passing through the auxiliary gearbox was adjusted. A specific length was removed from its splined end and replaced with another shaft, ensuring compatibility with the 6-12 hp range of power tillers. The power from the gearbox is transmitted to two shafts in left and right side, which transfer the power to ditching and plastering unit through different chain drive assemblies. The ditching unit helps in the cutting of soil and sliced portion of soil is thrown to the plastering unit, which plasters and finishes the top portion of the bund. This innovative design allows for simultaneous ridge making and plastering, significantly improving the efficiency of the process.

The design and development of the power tiller operated ridge plastering machine involved a comprehensive process. Utilizing SOLIDWORKS software, the team meticulously designed and simulated the machine's functionality, providing valuable insights into its performance. This knowledge was then translated into a physical prototype through fabrication. To assess the machine's effectiveness in real-world conditions, field evaluations were conducted. These evaluations involved measuring soil properties and analysing the machine's performance in terms of bund dimensions. The data gathered from these tests allowed for a thorough evaluation of the machine's capabilities. Finally, a cost analysis was performed to determine the economic feasibility of the machine for farmers. This analysis considered the production costs, potential savings in labour and time, and overall return on investment. The total power requirement for the power tiller operated ridge plastering attachment is 4.48 kw, hence KAMCO KMB 200 9 hp power tiller is chosen as prime mover. Also, for the safe design of the components, the gearbox splined shaft, shaft for ditching unit, shaft for plastering unit and chain drive were calculated.

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APPENDICES

APPENDIX -I

Soil parameters

SI No.	Soil parameters	Unit	Values
1	Soil type	-	Sandy loam
2	Soil moisture content	%	36%
3	Bulk density	kg /m^3	1342
4	Cone index	kN/m^2	271.65

APPENDIX -II

Power requirement for power tiller attached with ridge plastering unit

A. Power requirement for propulsion of power tiller

The maximum velocity is 4m/s which is to be attained in 2 s.

$$a = \frac{v}{t} = \frac{4}{2} = 2\ m/s^2$$

$$\text{Inertial force, } F_i = \frac{Wa}{g} = \frac{512 \times 2}{9.81} = 104.38\ \text{kg}$$

Aerodynamic resistance, R_a is neglected due to very slow speed.

Motion resistance $R_v = \mu_c \times W$

From Wismer Luth equation, $\mu_c = 0.04 + \frac{1.2}{C_n}$

$$\text{Wheel Numeric, } C_n = \frac{214 \times 0.57 \times 0.08835}{5022.72} = 2.1456$$

Slip is 15%

$$\text{Coefficient of rolling resistance, } \mu_c = \left(0.04 + \frac{1.2}{C_n}\right) = 0.599$$

Motion resistance $R_v = \mu_c \times W$ =306.833 kg

Drawbar pull, F_d = Weight of the tiller × coefficient of friction

=512 x 0.4 = 204.8 kg

Gradient resistance, R_g = W ×Sin θ= 512 N, considering the ridge crossing θ is taken as 90^0.

Maximum force required for propulsion=306.833+0+104.38-204.8+512= 719.21 kg

$$\text{Power required} = \text{Force} \times \text{Forward speed} = \frac{719.21 \times 0.75 \text{ x } 9.8}{1000 \times 3.6} = 1.46kW$$

B. Power requirement for ditching unit

Assume maximum unit draft of the soil (SR) = 0.103 x 10^6 N/m^2

Forward speed of power tiller = 0.75 km/h =0.2083 m/s

Rotor speed = 200 rpm

From Solid work drawing, Area of blade = 5658.0356 mm^2

Engine power = 6.7 kW (9 hp power tiller is taken)

Rated engine speed = 2000 rpm

Theoretical power required for operating blade

P_t =SR x V_f x A

Where, SR is specific soil resistance

V_f is the speed of operation, $V_f = (3.14\ x\ d\ x\ N\ )\ /\ 60$

A is the area of blade in m^2

$P_t = 0.103 \times 10^6 \times 3.14 \times 20 \times \frac{200}{60} \times 5658.0356 \times 10^{-6}$

= 1942.59 W

= 1.94 kW

C. Power requirement for plastering unit

Weight of the disc assembly acting downward=50kg

Max force the operator can act downward= 20kg

Total force acting=50+20=70kg=70x9.8=686 N

Frictional force $F_f = \mu F$

Assume for sandy loam soil, θ = 21.8°

$\tan \theta = 0.4$

$\mu = 0.4$

F_f =0.4x686=274.4 N

Force acting at a distance $\frac{R1+R2}{2} = \frac{270+80}{2}$=175mm

Torque= 274.4 N x 0.175= 48.02 Nm

Rotational speed=215 rpm

Power= $\frac{2 \times 3.14 \times 48.02}{1000} \times \frac{215}{60}$ = 1.08 kW

D. Total power requirement

Total power requirement = Power requirement for propulsion of power tiller + Power requirement for plastering unit + Power requirement for ditching unit

Total power requirement = 1.46 kW +1.94 kW +1.08 kW

= 4.48 kW

= 6.008 hp

APPENDIX-III

Design of components

A. Design of gearbox splined shaft

A standard straight sided spline of medium series spline of size 6 × 28 × 34 is selected. (IS -2327:1993)

The material selected for the shaft is EN-24 with case hardened with the following specifications:

Tensile strength =1100 MPa

Shear strength, S_S= 634 MPa

Compressive strength, S_C = 324 MPa

Outer most diameter = 34 mm

Reduced diameter, D_i = 28 mm

Width of the spline, B=7 mm

No. of Spline, N= 6

Length of spline selected, L_e: = 36 mm

Mean radius of the spline, r= (28+34)/4 = 15.5mm

Resulting effective depth of the teeth (y) = (D- D_i)/2 = (34-28)/2 =3 mm

K_a= 2.4 (Medium shock for internal combustion engine)

K_d = 1 (Closed fit loaded)

K_f=1.0 (No. of start/ stop cycles= 10000)

For a fixed /Guided spline,

$$K_s = \frac{K_a.K_d}{K_f}$$

$$K_s = \frac{2.4\ x\ 1}{1.0} = 2.4$$

The shear stress in the reduced shaft diameter (D_i),

$$\tau = \frac{16.T.K_s}{\pi.D_i^3}$$

$$\tau = \frac{16 \times 283.39 \times 4.8}{\pi\ \times\ 28^3}$$

$= 157.875$ MPa

Factor of Safety = $\frac{S_s}{\tau} = \frac{634}{157.875} \sim 4.0$

The compressive stress in the spline and the shaft,

$$\sigma_c = \frac{\mathrm{T.K_s}}{\mathrm{Le.n.r.y}}$$

$$\sigma_c = \frac{283.39 \times 4.8}{36 \times 6 \times 15.5 \times 3}$$

$$= 135.43 \text{ MPa}$$

Factor of Safety = $\frac{S_c}{\sigma_c} = \frac{324}{135.43} = 2.239$

So, the design is safe.

B. Design of shaft for plastering and ditching unit

Assuming the shaft is subjected to twisting moment only and neglecting bending moment.

EN 24 is the shaft material

Yield strength = 1100 MPa

Yield shear strength = Yield strength x k

= 1100 x 0.6

= 660 MPa

Assume FOS = 8

Allowable shear stress,

$$f_s = \frac{660}{8}$$

$$= 82.5 \text{ MPa}$$

$$\text{Power, P} = \frac{2\pi NT}{60}$$

$$9 \text{ hp x } 746 = \frac{2\pi \, x \;\; 215 \, x \, T}{60}$$

Torque, T = 298.20Nm

= 298200Nmm

Torque

$$T = \frac{\pi}{16} f_s d^3$$

$$298200 = \frac{\pi}{16} \text{ x } 82.5 \text{ x } d^3$$

$$d^3 = 18408.72$$

$$d = 26.40mm$$

After bending moment considerations, the diameter of shaft is taken as 35mm.

So, bearing selected = 6207

The dynamic loading capacity of bearing 6207 is 27 kN.

C. Design of chain drive

Power transmission from a 9 hp power tiller, P=6.714 kW

Rotary speed of high, N= 215 rpm

Rotary speed of low, n= 172 rpm

Inter shaft distance, a =450mm

Transmission ratio, $i = \frac{rotary\ speed\ of\ high}{rotary\ speed\ of\ low} = \frac{215}{172} = 1.25$

For transmission ratio of 1.25, since spacing is limited, minimum number of teeth on sprocket = 7

No of teeth on smaller sprocket, z =12

No of teeth on larger sprocket, Z = i x n =1.25 x 12 =15

Pitch, p =19.05

Centre distance, a = 450mm

Service factor, $K_s = K_1 \times K_2 \times K_3 \times K_4 \times K_5 \times K_6$

Load factor, K_1 =1.25

Factor of distance regulation, K_2 =1.25

Factor for centre distance of sprockets, K_3 =1

Factor for the position of sprockets, K_4 =1

Lubrication factor, K_5 = 0.8

Rating factor, K_6=1

Service factor, K_s=1.25 x 1.25 x 1 x 1 x 0.8 x 1 =1.25

Chain velocity, $v = \frac{z \times N \times p}{60 \times 1000} = \frac{12 \times 215 \times 19.05}{60 \times 1000} = 0.819$ m/s

Let the assumed factor of safety F_S =3.125

Breaking load, $Q = \frac{75 \times P \times F_S \times K_S}{v} = \frac{75 \times 9 \times 3.125 \times 1.25}{0.819} = 3217.47 \approx 3200$ kgf

According to pitch and breaking load, R-60 chain is selected.

Actual factor of safety= $\frac{Q}{\sum P}$

Tangential force due to power transmission, $P_t = \frac{75 \times P}{v} = \frac{75 \times 9}{0.819} = 824.17$ kgf

Centrifugal tension, $P_c = \frac{wv^2}{g} = \frac{1.45 \times 0.819^2}{9.8} = 0.099$ kgf

where, w =weight of chain per m length

g= acceleration due to gravity (9.8m /s^2)

Tension due to sagging of chain, $P_s = K_{sag} \times w \times a$ =2 x 1.45 x 0.45 = 1.305 kgf

where, K_{sag} = coefficient for sag

$\sum P = P_t + P_c + P_s$ = 824.17 + 0.099 + 1.305 =825.574 kgf

Actual factor of safety = $\frac{3200}{825.574} = 3.876$

Since actual factor of safety is greater than assumed factor of safety, the design is safe.

Approximate centre distance in multiples of pitches, $a_p = \frac{a}{p} = \frac{450}{19.05} = 23.62$ mm

Length of continuous chain in multiples of pitches (approximate number of links), l_p

$$= 2\,a_p + \frac{z+Z}{2} + \frac{(\frac{Z-z}{2\pi})^2}{a_p} = 2 \times 23.62 + \frac{12+15}{2} + \frac{(\frac{15-12}{2\pi})^2}{23.62} = 60.754 \text{ mm}$$

Length of chain, $l = l_p \times p$ =60.754 x 19.05 =1157.38 mm

Diameter of small sprocket, $d_1 = \frac{p}{\sin(\frac{180}{n})} == \frac{19.05}{\sin(\frac{180}{12})} = 73.6$ mm

Diameter of larger sprocket, $d_2 = \frac{p}{\sin(\frac{180}{N})} == \frac{19.05}{\sin(\frac{180}{15})} = 91.625$ mm

APPENDIX -IV

Economic evaluation of developed power tiller operated ridge plastering machine

The cost economics of machine was worked out based on the following assumptions

1. Capital cost of power tiller = Rs. 2,00,000
2. Capital cost of plastering machine = Rs.6200
3. Annual usage of power tiller = 500 h
4. Daily usage of power tiller = 8 h /day
5. Annual usage of machine = 250 h
6. Life of power tiller = 10 years
7. Life of machine = 8 years
8. Salvage value of power tiller (10 per cent of capital cost) = 20000
9. Salvage value of machine (10 per cent of capital cost) = 6200
10. Rate of interest (i = 12 per cent of capital cost per annum)
11. Insurance and Taxes cost = 2 per cent of capital cost of machine
12. Fuel (diesel) cost = Rs. 95.26 per litre
13. Housing cost = 1 per cent of capital cost of machine
14. Average fuel consumption of machine = 1.23 1/h
15. Repair and maintenance cost = 5 per cent of capital cost of machine
16. Lubrication cost = 3 per cent of fuel cost
17. Wages of driver @ Rs. 750 per day for 8 h day^{1} = Rs. 93.75 h^{1}

A. Fixed cost of power tiller operated ridge plaster machine

S No	Annual fixed cost	Power tiller	Plastering machine
		Per hour	Per hour
1.	Depreciation, Rs	36	27.9
2.	Interest, Rs	22	13.64
3.	Insurance and taxes @2% of capital cost	8	4.96
4.	Housing @ 1 % of initial cost	4	-

5.	Fixed cost Rs.h-1	70	46.5
6.	Total fixed cost	70+46.5	
7.	Total amount of fixed cost	116.5	

B. Variable cost of machine

1. Repair and maintenance of power tiller charges @ 5% of capital cost, Rs. h^{-1} = 20
2. Operator wages @ Rs. 700 per day, Rs. h^{-1} = 93.75
3. Fuel cost @ Rs. 95.26 L^{-1} (1.23 $L \cdot h^{-1}$), Rs. h^{-1} = 117.16
4. Lubrication charges @ 3% of fuel cost, Rs. h^{-1} = 3.155
5. Repair and maintenance of machine charges @ 1% of capital cost, Rs. h^{-1} = 2.48
6. Total variable cost, Rs. h^{-1} = 236.5

C. Total cost of operation of machine

Total cost of operation of machine = Total Fixed cost + Total variable cost

=116.5+236.5= Rs. 353 per hour

D. Total cost of operation of machine per hectare

Actual field capacity = 0.054 ha /h

Therefore, total cost of operation of machine = 353/0.054= Rs. 6537.037

E. Total cost of plastering operation by conventional method

Total labour per hectare for manual ridge making operation = 25 labour /ha

Total cost of operation by conventional method = 25× Rs. 700 /day

= Rs. 17500 /ha

F. Saving in cost

Total cost of operation by conventional method = Rs. 17500 /ha

Total cost of operation of machine = Rs.6537.03 /ha

Saving in cost = Rs. 12962.96 /ha

Saving of cost = 62.64 per cent

G. Break Even Points

$$\text{BEP} = \frac{\text{AFC}}{\text{CF} - \text{V}}$$

where,

BEP = Break-even point, h $year^{-1}$

AFC = Annual fixed cost for the machine, Rs. $year^{-1}$

CF = Custom fee, Rs. h^{-1}

Total annual fixed cost in Rs = 116.5 x 250 29125 $year^{-1}$

Custom fee (CF) = (Cost of operation h^{-1} + (25 per cent profit over new cost))

$$= (353 + (353 \times 0.25))$$

$$= Rs.\ 441.25/h$$

Variable cost of machine (V) = Rs. 236.5 h^{-1}

BEP (h year-1) = $\frac{29125}{441.25-236.5}$ = 142.24

Annual utility = Effective field capacity × Annual utility period

$$= 0.06675 \times 250$$

$$= 16.6875\ ha$$

Thus, BEP can be obtained at (142.24 ×100) / 250 = 56.89 per cent of the annual utility of 250 hours of the developed power tiller operated ridge plaster machine.

H. Payback Period

Payback period = Initial investment / average net annual benefit

Average net annual benefit = (CF-V) × Annual usage of the machine

$$= (441.25-236.5) \times 250$$

$$= Rs.\ 51187.5$$

Initial Investment = Initial cost of power tiller for 250 + Initial cost of machine

$$= \frac{200000 \times 250}{500.} +62000$$

$$= Rs.\ 162000$$

Therefore, Payback period = 162000/51187.5

= 3.164 years

I. Benefit-cost (B:C) ratio

B:C ratio = $\frac{\text{Benefit cost}}{\text{Cost of machine operation}}$

Benefit cost = Cost of manual operation - Cost of machine operation

= 17500 – 6537.03

= Rs. 10962.97 ha-1

Therefore, B:C ratio = $\frac{10962.97}{5288.38}$ = 2.073

DEVELOPMENT AND EVALUATION OF RIDGE PLASTERING ATTACHMENT FOR POWER TILLER

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ABSTRACT

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ABSTRACT

Mechanization indeed presents a promising solution to address the challenges faced in agriculture, particularly in regions where labour shortages are prevalent. The decreasing rural population is becoming increasingly responsible for feeding the growing urban population, increase in productivity of agriculture has become an essential feature in stepping towards sustainability. Replacing manual processes with mechanized ones not only enhances efficiency but also makes agriculture more attractive to the younger generation who are often deterred by the labour-intensive nature of traditional farming methods. Mechanization provides advantages such as increased efficiency, reduced labour requirements and improved profitability. The traditional manual ridge making and plastering process is one of the perfect examples of a task that can benefit greatly from mechanization. By introducing mechanized equipment to prepare untilled soil near ridges and corners of fields, farmers can significantly save the time and energy required for these tasks. This not only boosts productivity but also improves the overall profitability of paddy cultivation by reducing labour costs and increasing output. Moreover, mechanization brings about improvements in the quality and strength of the bunds, thereby enhancing their effectiveness in water management and soil conservation. This is crucial for sustainable agriculture, especially in the context of climate change and increasing pressure on agricultural resources. Furthermore, investing in research and development to innovate and improve mechanized farming technologies will be key in ensuring its widespread adoption and long-term sustainability in agriculture.

Farm mechanization should prioritize the development of technologies tailored to local conditions, ensuring compatibility with socioeconomic and field realities. Many farming operations, such as field preparation, transplanting, weeding, and harvesting, have already undergone complete mechanization. Ridge plastering, a crucial step involving trimming and compacting field bunds, has also seen mechanization advancements. Commercially available tractor-drawn

machines, ranging from 35-45 hp, effectively handle ridge plastering tasks by utilizing the tractor's full power take-off (PTO) capacity. Additionally, to cater to the needs of small and marginal farmers, power tillers have gained prominence in India. Power tiller operated ridge plastering machines has more advantages than the tractor operated as it is more suitable to the small and medium land holding farmers and reduces the risk of sinkage. Addressing this need, a power tiller-operated ridge plastering machine was developed and evaluated at the Department of Farm Machinery and Power Engineering, Kelappaji College of Agricultural Engineering and Technology, Tavanur, Malappuram, Kerala. This innovative unit, compatible with power tillers ranging from 9-12 hp, features with two sets of twisted blades on its blade holders cut, pulverize and throw the soil against the cover. The plastering disc with conical shape trims and plasters the existing or the new ridges and the roller at the end of the conical disc compact the soil from the top. The roller attached to the rotating disc compresses the soil, ensuring the ridge reaches a height of 200 mm efficiently. The cost analysis of the power tiller-operated ridge plaster machine reveals significant savings, with a 62.64% reduction in operational costs compared to traditional manual methods and 23% savings over tractor-operated machines, underscoring its economic viability and efficiency. The financial assessment shows that the machine pays for itself in just over three years, with a benefit-cost ratio of 2:1, highlighting its long-term profitability.