Design of rice planting machine using ration of wheels rotation system

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Abstract— The Rice planting process by "Kelompok Tani" in the Tulungagung, East Java is done manually, Manual planting requires a lot of manpower and very costly because the Landowner need to pay to the laborers to plant their Rice Paddy yet requires a lot of time to do the work until done completely and drains a lot of works and efforts. From that, the Rice planter is designed to reduce the planting process. The design concept adopted the "Jajar Legowo" Rice Planting method, with the distance arrangement applied from the Gears comparison so as to produce equal and uniform distances. This manpowered machine is expected to help The Farmers to shorten the planting process without incurring additional costs for Fuel. From the results of the planning and calculation produced a machine with capability of planting rice 26.4m2/ hour using number 40 of chain, sprocket size 242.80mm and Ratio of each sprockets are 1: 4 to produce a uniform planting. Using a 400mm long shaft for the planter and 10mm diameter with ST37 material. On wheels use Bearing with 30mm Bore.

Keywords: Easy, Efficient, Rice Planting Machine.

1. INTRODUCTION

Rice (Oryza sativa L.) is the primary staple food for the majority of Indonesia's population, making its continuous availability crucial for national food security [1]. National rice productivity is strongly influenced by cultivation practices, particularly planting spacing, which significantly affects plant growth and yield performance [2]. To enhance productivity, the Indonesian government through the National Rice Production Enhancement Program (P2BN) has recommended the adoption of the jajar legowo planting system, which optimizes sunlight exposure and plant population arrangement [3]. Previous studies report that the jajar legowo system can increase rice yields by approximately 30% compared to conventional planting methods [4].

In practice, especially based on surveys conducted among farming communities in Tulungagung, East Java, traditional rice planting methods still require substantial labor and high operational costs. Farmers in this area typically pay around Rp60,000 per worker per ru, and completing one plot of rice field generally requires 3–4 workers working for an entire day. These conditions reduce farmers' profit margins despite relatively large land ownership.

Meanwhile, modern rice transplanters available on the market offer significantly improved efficiency, capable of planting one hectare of rice fields in approximately two hours with a service cost of around Rp150,000 per ru. However, the high purchase cost of such machines remains a major barrier for smallholder farmers, limiting their adoption of mechanized planting technology. This situation underscores the need for alternative technologies that are affordable, efficient, and easy to operate.

To address these challenges, the development of a rice planting machine that integrates the principles of the jajar legowo system while remaining manually operable presents a promising solution. One potential approach is the incorporation of a wheel rotation ratio mechanism, enabling automatic regulation of planting intervals to maintain consistent spacing without requiring specialized skills. Such an innovative, mechanically simple planting device is expected to improve productivity, reduce labor costs, accelerate planting operations, and allow farmers to manufacture or modify the tool independently at an affordable cost.

Ghosh explains that manual rice transplanters can improve planting efficiency and reduce labor use, especially for small farmers who cannot afford motorized transplanters. This study emphasizes the importance of simple mechanisms such as wheels and cranks in maintaining stable planting distances [9]

2. Previous Researches

Research on the development of rice planting machines has been conducted extensively in an effort to improve the efficiency of the planting process in paddy fields. Widodo et al. [5] designed a four-clump rice planting machine using a 5.5 HP gasoline engine that is capable of achieving planting accuracy of up to 80.125%, demonstrating that mechanization can improve planting distance accuracy and work capacity. Additionally, Kholik [6] developed a manual rice planting tool based on a wheel-chain transmission system that produces a planting distance of 20 cm × 30 cm through the utilization of wheel rotation ratios, making the tool an affordable alternative for small farmers. Both studies show that mechanical transmission systems, whether manual or motorized, can be used effectively to consistently regulate planting distances.

The development of planting mechanism designs was also studied through a kinematic and dynamic approach, as conducted by Silalahi and Wijianto [7], who increased the capacity of rice transplanters through mechanical motion synthesis, resulting in a constant planting distance of 25 cm with stable operating speed and optimal power consumption. Meanwhile, Saleh [8] designed a simple transplanter using a crank mechanism that facilitates planting two rows with low production costs and a construction suitable for Indonesian agricultural conditions. These studies emphasize the importance of designing precise, stable, and efficient motion mechanisms to produce uniform planting patterns.

Nguyen developed a low-cost transplanter with a simple mechanical system powered by human labor, similar to your design that prioritizes efficiency without fuel-powered machinery [13].

3. Method

This point will discuss in detail the planning and creation of tools. The overall process of creating and completing this Final Project is illustrated in the flow chart below.

3.1 Flow Chart Process Manufacturing Rice Transplanter Machine with Wheel Rotation Ratio System

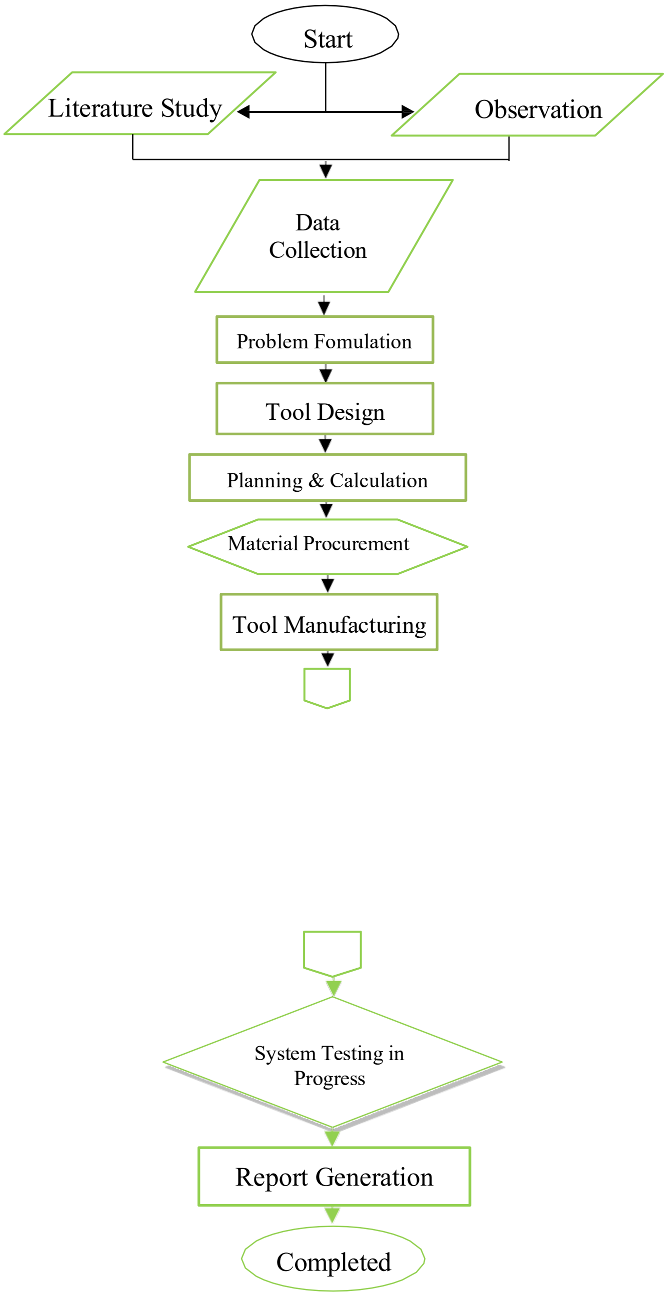

Figure 1 Machine Manufacturing Flowchart

3.2 Working Principle of the Rice Transplanter with Wheel Rotation Ratio System

This tool is used to continuously transplant rice at a constant distance according to the preset parameters. The working principle of this rice planting machine is to regulate a uniform and continuous planting distance between the right and left rice plants as well as the front and rear rice plants in accordance with the legowo planting system that has been applied to this machine. By placing the rice that is ready for planting (has been sown and is young) in the place provided on the rice planting machine, all that remains is to pull the rice planting machine using human power.

This machine is powered by human power, which produces an average power of 0.18 hp (appendix) to pull the rice transplanter. Therefore, this machine does not require high costs, diesel engine emissions, and is easy to maintain.

3.3 Machine Components

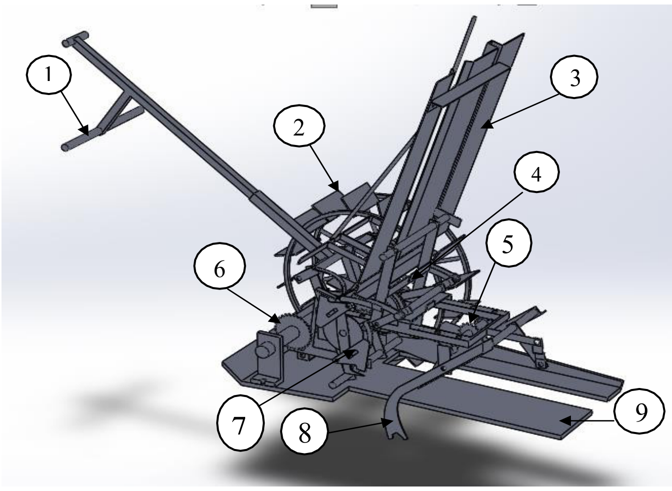

Figure 2 Sketch of Rice Transplanter with Wheel Rotation Ratio System

Pandey and Kumar the sprocket design for agricultural machines and showed that the diameter and number of teeth greatly affect the ratio and torque produced [17]. The performance of human-powered manual tools and found that the design must consider the operator's power limits, in line with the human power calculation [18].

Image description:

1. Handle for farmers
2. Rice planter wheel drive
3. Rice planting tray
4. Rice planting quantity regulator
5. Rice planter hand drive sprocket
6. System drive sprocket
7. Rice picking handle
8. Rice planter handle
9. Float

4. RESULT AND DISCUSSION

4.1. Power Analysis

From the attached document, it is assumed that the average age of the person operating this device is 35 years old. With this assumption, the power generated is:

$$HP = 0.35-0.09\log t$$

Where: t = working time performed by the person in minutes.

Note that if the user is around 20 years old, the power generated will be 15% higher, and if the user is around 60 years old, the power generated will be 20% lower. With this, the power generated in HP is:

$$\begin{aligned} HP &= 0.35-0.09\log t \\ &= 0.35 - 0.09\log 60 \\ &= 0.18 \text{ HP} \approx 134.226 \text{ Watts} \approx 0.1342 \text{ kW} \end{aligned}$$

4.2. Chain Calculation

Pradhan and Samantaray discuss the design of chain and sprocket mechanisms in agricultural equipment, emphasizing that the selection of pitch, number of teeth, and rotation ratio directly affects the consistency of mechanical motion output [10]. a chain transmission system to drive the planter mechanism, emphasizing that the sprocket–chain connection is capable of producing precise rhythmic movement [16].

4.2.1 Calculating Sprocket Diameter 1

Sprocket diameter is calculated using the formula:

$$D = \frac{p}{\sin(\frac{180}{Nt})}$$

Where:
p: Pitch
Nt: Number of Teeth

$$D_1 = \frac{p}{\sin(\frac{180}{Nt^1})}$$
$$= \frac{15{,}88}{\sin(\frac{180}{12})}$$
$$= 61{,}36mm$$
$$D_2 = \frac{p}{\sin(\frac{180}{Nt^2})}$$
$$= \frac{15{,}88}{\sin(\frac{180}{48})}$$
$$= 242{,}80mm$$

4.2.2 Calculating the speed during chain operation 1.
Calculate the chain speed during operation using the equation:

$$v = \frac{Ntxpxn}{12}$$

The chain speed when the machine is operating is:

$$v = \frac{Ntxpxn}{12}$$
$$= \frac{48x15{,}88x17{,}5}{12}$$
$$= 1111{,}6 ^{ft}/_{min}$$

4.2.3 Calculating Chain Length 1.
Chain length is calculated using the equation:

$$L = p\times\left(\frac{2\times C}{p} + \frac{Nt_1 + Nt_2}{2} + \frac{Nt_1 - Nt_2}{4\pi^2\times\frac{C}{p}}\right)$$

Where:
p = Pitch (mm)
C = Distance between sprocket shafts (mm) Nt= Number of drive sprocket teeth

From the above equation, the chain length from the wheel to the rice picker is:

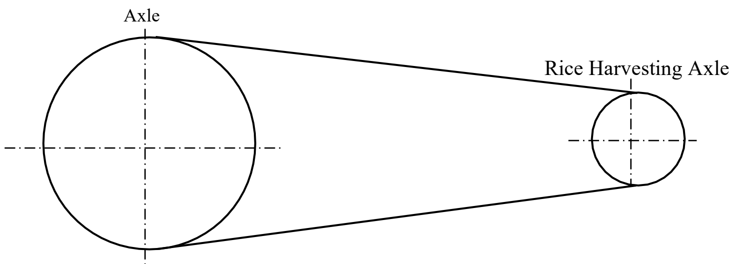

Figure 3 Wheel Shaft Sprocket to Rice Picker Sprocket

$$L = p \times \left(\frac{2 \times C}{p} + \frac{Nt_1 + Nt_2}{2} + \frac{Nt_1 - Nt_2}{4\pi^2 \times \frac{C}{p}} \right)$$

$$= 15{,}88 \times \left(\frac{2 \times 200}{15{,}88} + \frac{12 + 48}{2} + \frac{48 - 12}{4\pi^2 \times \frac{200}{15{,}88}} \right)$$

$$= 15{,}88 \times (25{,}189 + 30 + 0{,}072)$$

$$= 822{,}545\ mm$$

4.2.4 Calculating Sprocket Diameter 2

The Sprocket 2 data is as follows:

Small Sprocket (Nt1) = 12

Large Sprocket (Nt2) = 24

Tool Rotation (n) = 50 rpm

Pitch = 15.88 mm

The diameter of Sprocket 2 to be used by this tool is:

$$D_1 = \frac{p}{\sin(\frac{180}{Nt^1})}$$

$$= \frac{15{,}88}{\sin(\frac{180}{12})}$$

$$= 61{,}36mm$$

$$D_2 = \frac{p}{\sin(\frac{180}{Nt^2})}$$

$$= \frac{15{,}88}{\sin(\frac{180}{24})}$$

$$= 121{,}67mm$$

4.2.5 Calculating the speed during chain operation 2.

Calculate the chain speed during operation using the equation:

$$v = \frac{Ntxpxn}{12}$$

The chain speed when the machine is operating is:

$$v = \frac{Ntxpxn}{12}$$

$$= \frac{24x15{,}88x50}{12}$$

$$= 1588^{ft}/_{min}$$

4.2.6 Calculating Chain Length 2.

The length of the chain from the rice harvester to the rice planter is:

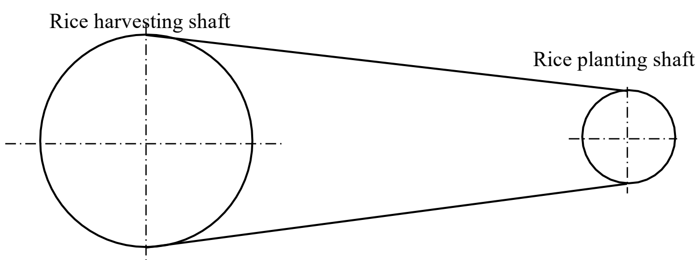

Figure 4 Pick-up Sprocket to Planting Sprocket

$$L = P\times\left(\frac{2\times C}{P}+\frac{Z_1+Z_2}{2}+\frac{Z_1-Z_2}{4\pi^2\times\frac{C}{P}}\right)$$

$$= 15{,}88\times\left(\frac{2\times 200}{15{,}88}+\frac{12+24}{2}+\frac{24-12}{4\pi^2\times\frac{200}{15{,}88}}\right)$$

$$= 15{,}88\times(25{,}189+18+0{,}024)$$

$$= 686{,}222\ mm$$

Optimized the planting system on the transplanter and found that the stability of the planting arm mechanism is greatly influenced by the alignment of wheel rotation and mechanical timing, in line with the concept of rotation ratio in your machine [11]. regulating the wheel rotation ratio plays a significant role in ensuring consistent planting distance [12].
Kim and Kang show that wheel-based planting systems can produce precision planting distances through a direct relationship between wheel movement and the planting output mechanism [14]. the stability of the wheel speed ratio to the planting mechanism is a determining factor in seedling position accuracy [15]

4.3. Shaft Planning
This rice planter has 3 shafts that drive 4 planting arms alternately and has 4 sprockets on the shaft. This calculation only discusses 1 shaft that drives 2 planting arms in the middle of the machine, because it has a lot of load and force on that shaft. Shaft planning calculations use the equation below:
The stress that occurs and safety requirements can be stated:

$$\tau_{max} = \sqrt{\left(\frac{16\times Mb}{\pi\times ds^3}\right)^2+\left(\frac{16\times Mt}{\pi\times ds^3}\right)^2} \le \frac{\sigma_{yps}}{sf}$$

$$\left(\frac{k_s\times S_{yp}}{sf}\right)^2 \ge \frac{16^2\times Mb^2+(16^2\times Mt^2)}{\pi^2\times ds^6}$$

$$ds \ge \sqrt[6]{\frac{(16^2\times Mb^2+16^2 Mt^2)}{\pi^2\left(\frac{k_s\times S_{yp}}{sf}\right)^2}}$$

Where:
ds = Shaft Diameter
Mb = Bending Moment
Mt = Torque Moment
ks = Correction Factor
sf = Safety Factor

4.3.1 Calculation Resultant Moment and Force Distribution 1.
Calculate and find the forces that occur and act on the planned shaft. The calculation is as follows
4.3.1.1 Tangential Force 1.
The tangential force that occurs is:

$$F_{ct} = \frac{Mt}{r}$$

$$= \frac{226{,}8^{lbf}/_{in}}{4{,}774\ in}$$

$$= 47{,}507 lbf$$

4.3.1.2 Normal Force 1

Due to contact, these tangential forces cause normal forces on the shaft (contact angle ϕ = 20°). The normal force that occurs can be calculated using the equation:

$$F_{CN} = F_{CT} \text{ x } \tan \phi$$

Then the Normal Force is obtained as follows:

$$F_{CN} = F_{CT} \text{ x } \tan 20°$$
$$= 47{,}507 lbf \text{ x } \tan 20°$$
$$= 17{,}291 lbf$$

4.3.1.3 Force Diagram 1

Design Power = 0.134 Kw

Driven Sprocket Rotation = 50rpm

Sprocket Force = $1.23\times10{-}2N$

Weight Force of Sprocket 1 = 100 grams = 0.98N

Weight Force of Sprocket 2 = 300 grams = 2.94N

Tangential Force = 95.65 lbf = 424.47N

Weight Force of Groove = 500 grams = 4.9N

Shaft Length = 650 mm

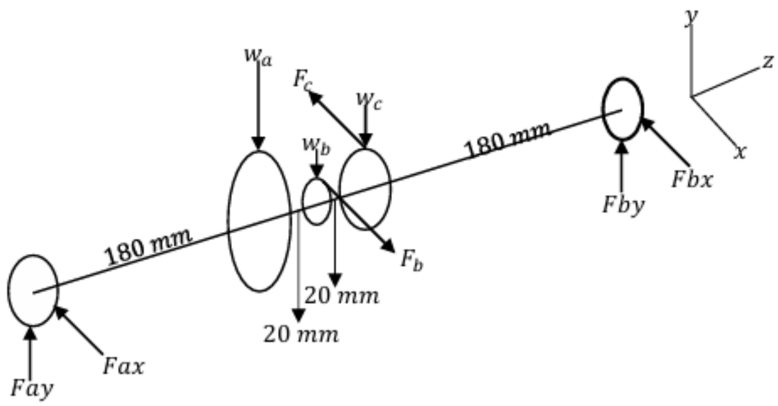

Figure 5 Force distribution on the drive shaft Arm

4.3.2 Calculation of Shaft Diameter

$$D \geq \sqrt[6]{\frac{\{16^2 \cdot M_B{}^2 + 16^2 \cdot M_t{}^2\} \cdot Sf^2}{\pi^2 \cdot ks^2 \cdot \sigma_{yp}{}^2}}$$

M_B = 811,8003N.mm

M_t = 11,57N.mm

sf/N = 1,5

ks = 0,7

σ_{yp} $Baja\ Karbon\ ST37$ = 25,9 $^{kgf}/_{mm^2}$

$$D \geq \sqrt[6]{\frac{\{16^2 \times 811{,}8003^2 + 16^{12} \times 11{,}57^2\}1{,}5^2}{\pi^2 \times 0{,}7^2 \times 25{,}9^2}}$$

$$D \geq \sqrt[6]{\frac{\{168709050{,}1 + 34269{,}41\}1{,}5^2}{3240{,}82}}$$

$$D \geq \sqrt[6]{\frac{\{168743319{,}5\}1{,}5^2}{3240{,}82}}$$

$$D \geq \sqrt[6]{117153{,}21}$$

$$D \geq 6{,}995mm \approx 7{,}00\ mm$$

4.3.3 Calculation of Resultant Moment and Force Distribution 2.

Calculate and find the forces that occur and act on the planned shaft.

The calculation is performed as follows:

4.3.3.1 Tangential Force 2.

The tangential force that occurs is:

$$F_{ct} = \frac{Mt}{r}$$

$$= \frac{648^{lbf}/_{in}}{68.897\ in}$$

$$= 9{,}405lbf$$

4.3.3.2 Normal Force 2

Due to contact, these tangential forces cause normal forces on the shaft (contact angle ϕ = 20°). The normal force that occurs can be calculated using the equation:

$$F_{CN} = F_{CT} \text{ x } \tan \phi$$

Then the Normal Force is obtained as follows:

$$F_{CN} = F_{CT} \text{ x } \tan 20°$$

$$= 9{,}405lbf \text{ x } \tan 20°$$

$$= 3{,}423lbf$$

4.3.3.3 Force Diagram 2.

Planned Power = 0.134 Kw

Driven Sprocket Rotation = 50rpm

Sprocket Force = $1.23\times10{-}2N$

Wheel Weight Force = 2500 grams = 24.53N

Sprocket Weight Force = 500 grams = 4.9N

Tangential Force = 95.65 lbf = 424.47N Shaft Length = 690 mm

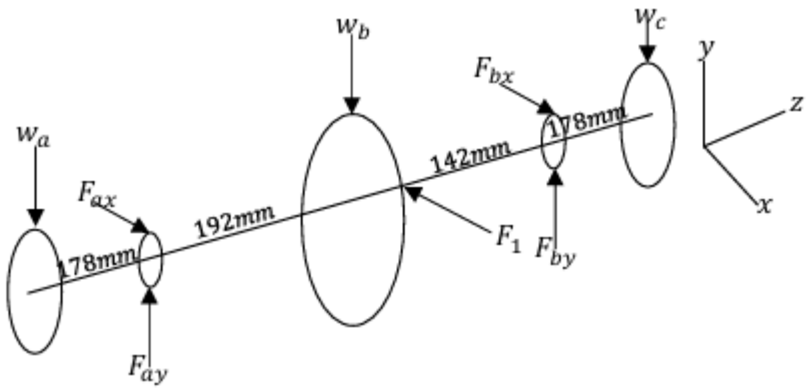

Figure 6 Distribution of force on the wheel axle

4.4. Bearing Design

The type of bearing used for the rice harvester's drive shaft is a rolling bearing (single row deep groove ball bearing).

Shaft Diameter = 10mm

Bearing force at point A = 1. $Fax = -0.433\times10-2N$

2. $Fay = 26.53N$

Bearing force at point B = 1. $Fbx = 1.663\times10-2N$

2. $Fby = 27.344N$

4.4.1 Radial Force on Bearings

The radial force occurring on the bearing can be calculated using the equation:

$$Fr = \sqrt{F_x{}^2 + F_y{}^2}$$

4.4.1.1 At point A

For the force occurring at point A:

$$Fr = \sqrt{Fa_x{}^2 + Fa_y{}^2}$$
$$Fr = \sqrt{(-0{,}433\times10^{-2})^2 + (26{,}53N)^2}$$
$$Fr = \sqrt{703{,}8410}$$
$$Fr = 26{,}53N$$

4.4.1.2 At point B

For the force occurring at point B:

$$Fr = \sqrt{Fb_x{}^2 + Fb_y{}^2}$$
$$Fr = \sqrt{(1{,}663\times10^{-2}N)^2 + (27{,}344N)^2}$$
$$Fr = \sqrt{747{,}69461255}$$
$$Fr = 27{,}344N$$

4.4.2 Equivalent Load on Bearings

The equivalent load on bearing A, which is a single bearing (single row ball bearing), can be calculated using the following equation:

$$P = XvF_r + yF_a$$

Given:

Co = 845 (Appendix 6 D bore 10mm) FrA = 26.53N

$v = 1$

$x = 0{,}56$

$y = 1$

With the bearing specifications above, it can be entered into the equation above as follows:

P = $v\times X\times F_r + y\times f_a$

P = 1×0,56×(26,53)

$P = 14{,}85N$

The equivalent load on bearing B with a Single Row Ball Bearing type is

$$P = XvFr + yFa$$

Given:

Co = 845 (Appendix 6) FrB = 27.344N

$v = 1$

$x = 0.56$

$y = 1$

With the bearing specifications above, we can substitute them into the equation above to get:
$P = 1 \times 0{,}56 \times 27{,}344$
$P = 15{,}312\ N$

4.4.3 Bearing Life Calculation

To predict the length of bearing life until the bearing fails, the following equation can be used:

$$L_{10h} = \frac{10^6}{60n}\left(\frac{C}{P}\right)^b$$

Where:
L10h = Bearing Life (Working Hours)
C = Dynamic Load
n = Shaft Rotation (rpm)
P = Equivalent Load
B = Constant (b=3)

4.4.3.1 For Bearing A

Using the above equation, the bearing life for part A is:

C = 1400N/ b=3 / np = 50 / P=14,85N

$$L_{10} = \frac{10^6}{60 \times 50}\left(\frac{1400N}{14{,}85}\right)^3$$

$$L_{10} = \frac{94{,}276 \times 10^6}{3000}$$

$$L_{10} = 31425{,}33\ Jam$$

4.4.3.2 For Bearing B

Using the same equation as for Bearing A, the life for Bearing B is obtained as:

C = 1400N / b = 3 / np = 50 / P = 15.312 *N*

$$L_{10} = \frac{10^6}{60 \times 50}\left(\frac{1400}{15{,}312}\right)^3$$

$$L_{10} = 30477{,}185\ Jam$$

4.5. Wheel Planning

Calculations to determine the diameter of the wheel to be made so that the ratio on the machine runs well. If the distance between the rice plants is 20 cm and one rotation must plant 4, then the circumference of the wheel must be 80 cm. Using the circumference formula, we get:
$Keliling = \pi D$
$80cm = \pi D$

$$D = \frac{80}{\pi} = 25{,}4647\,cm$$

4.6. Machine Test Result

From the results of the tests conducted by the author, the following data was obtained:

- Rice Distance (side) = 20cm
- Rice Distance (front to back) = 20cm
- Planting Duration = 1 minute
- Row Length = 2.2 m
- Number of Seeds Planted = ±20 Seeds Therefore, the Machine Capacity can be calculated as follows:

$$Capacity = \frac{A}{t}$$

Where:
A = Planting Area
t = Time required (Minutes)

$$Capacity = \frac{2{,}2m \times 0{,}2m}{1\ menit}$$

$$Capacity = 0{,}44^{m^2}/\text{menit}$$

In one hour, it can plant rice on an area of 26.4 m².

4.7. Comparison of Tools
The comparison between our tool and existing rice planting tools is as follows:

Table 1. The comparison between our tool and existing rice planting tools

	
Using a diesel engine	Using Human Power
Has planting 4 arms	Has planting 2 arms
Rice is sown in special containers	Rice is sown as usual
Planting arms can be adjusted	Planting arms are fixed
Working capacity 2-4 Ha/hour	Working capacity 0.0264Ha/hour

5. CONCLUSION

From the calculations and discussion in "Design of a Ratio Wheel Rotation System Rice Planting Machine," the following conclusions were reached:

5.1 The results of the machine element calculations are:
5.1.1 Chain and Sprocket
On the drive shaft, a sprocket numbered 40 with a diameter of 61.36 mm is installed, and the driven sprocket has a diameter of 242.80 mm. The gear ratio is 40:242.80 = 0.101.
A sprocket number 40 with a diameter of 61.36 mm is attached to the drive shaft, and the driven sprocket has a diameter of 242.80 mm with a ratio of 1:4. Both sprockets are connected by a chain.
5.1.2 Shaft
The shaft used has a diameter of 10 mm to meet the safe diameter in the shaft calculation and a length of 400 mm made of ST37 material.
5.1.3 Bearing
The type of bearing used on the shaft is a
single-row ball bearing with a bore diameter of 30 mm.

5.2 Experimental Results and Discussion

From the experiments conducted, the following capacities and specifications were obtained:

1. The effective planting speed is 0.51 meters per second.
2. The machine's field capacity is 26.4 m² per hour, or 0.0264 hectares per hour.
3. The force required for planting is 1.25 kgf or 14.91 N, as determined from the experiment.

6. CREDIT

Conceptualization, Methodology, Writing - original draft preparation, and Supervision: Ananda Trisukmo Utomo, Achmad Khuluqul Amin Formal analysis and investigation: Mahirul Mursid, Liza Rusdiyana, Dedy Zulhidayat Noor, Nurhusodo; Writing - review and editing: Ananda Trisukmo Utomo, Achmad Khuluqul Amin, Liza Rusdiyana; Funding acquisition: Liza Rusdiyana; Resources: Mahirul Mursid, Liza Rusdiyana, Dedy Zulhidayat Noor, Nurhusodo

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