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DESIGN CONSIDERATIONS AND STRESSES ANALYSIS OF LOCAL RICE TRANSPLANTING MACHINE

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Abstract

The research aimed to design, simulate, analyze stresses then manufacture a rice transplanting machine with local materials suitable for small rice holdings. The machine was designed and the stresses were simulated by Solidworks software to ensure the integrity of the design before manufacturing themachine. The transplanting machine consists of several parts, the most important of which are: Main frame, seedlings mat, and power transmission system. The main frame and the seedlings mat were designed and stresses affecting it were simulated in order to make sure that the design is suitable for the loads placed on them. The power transmission system is one of the most important parts in the rice transplanting machine. It contains important three unit of shafts namely: the intermediate reduction unit shaft, the transplanting unit shaft, and the wheel axle unit shaft. The sprockets and rotation speed of power transmission system were determined and synchronized to achieve the desired forward speed of 1.00, 1.25, 1.50, and 1.75 km h^{-1} and achieve the recommended hill spacing of 16, 18, 20, and 22 cm.Also, the diameters of the transmission shafts were calculated based on the torsional moments exposed to them and the stresses on shafts were analyzed and simulated. The design results concluded that the shafts diameters were 25, 20 and 40 mm and the maximum von Mises stress recorded 6.75e+001,4.34e+001and 5.39e+001 MPa for the intermediate reduction unit shaft, the transplanting unit shaft, and the wheel axle unit shaft, respectively. From simulation results, it was concluded that this parts will not fail under the given stresses and the parts will not carry out any significant deformations according to the applied loading conditions then the machine was manufactured based on these results.

Key words: *mechanical transplanting, design rice transplanter, mat,power transmission system, stress analysis*

INTRODUCTION

Machine design is the creation of new and better machines and improving the existing ones. A new or better machine is one which is more economical in the overall cost of production and operation. The process of design is a long and time consuming one. In designing a machine component, it is necessary to have a good knowledge of many subjects such as mathematics, mechanics engineering, materials strength, workshop processes and engineering drawing [5]. Mechanical transplanting refers to using a mechanical seedling picking mechanism instead of workers' hands to extract seedlingsfrom the tray holes and feed them by the plantingmechanism of the transplanting machine, and then the planting mechanism drives the transplanter totransplant the seedlings into the field. The whole operation needsto ensure that, the movements areaccurate and the connection is systematic [3]. Rice transplanting machine is a specialized machine equipped with a transplanting mechanism (usually having some form of reciprocating motion) driven by the power source from the axles, to transplant rice seedlings into rice fields [6]. Mechanical transplanting using a manual transplanter is a useful transplanting machine for small and marginal farmers due to its greater capacity compared with manual transplanting [8]. Karthik [4] designed and fabricatedof manual operated women friendly paddy transplanter and stated that the designed machine should be simple in design, it should have simple mechanism to transfer power from ground wheel to planting unit, the material used for various components should be of proper strength, durability and should perform intended functions with ease, It should be light in weight and easily portable, and the machine should be of modular structure with provision for easy assembly and dismantling. Ahmed and Imran [1] designed and fabricated of engine powered two rows rice transplanting machine, they carried out the solid modelling of their machine parts by ptc creo 2.0 software package then they analyzed the different stresses on machine parts before beginning manufacture the machine. They stated that choice of parts material relayed upon the strength required and material available.Fouda et al. [2] manufactured a rice transplanting machine with local materials suitable for small rice holdings, and achieve the technical recommendations of Egyptian conditions. Also, testing and evaluating the manufactured machine under different operation conditions. The manufactured machine consists of several parts such as main frame, transplanting unit, power source, power transmission system, guide rail, seedlings mat, floats, and drive wheels. The machine contains five rows, and the distance between each row is 20 cm. Patel et al. [7] fabricated a manual rice transplanting machine and mentioned that the operator should provide the first motion. The wooden plate boards are used to keep the constant spacing between the two following seedlings. The largest sprocket is installed on the same shaft with the drive wheels; thus, the sprocket will also rotate simultaneously. The largest sprocket is connected with the smaller sprocket by using a driven chain. When the power is transmitted to the smaller sprocket, it will rotate. The speed ratio between the driver and follower sprocket is 3:1. At the same shaft transplanting finger will be fixed at the four-bar linkage mechanism so as to it will swing at a certain angle. Since the operator delivers the drive, it will not have high speed, so through this sprocket arrangement, they have increased the transplanting finger speed. As the transplanting finger oscillates, it will pick up the rice seedlings from the mat and transplant them in soil. The transplanting finger is designed so that it is easy to pick rice seedlings during the mechanism motion and also, it must pick the seedlings during the downward motion only.Rajamanickam et al. [9] fabricated a manual rice transplanter machine; they manufactured and fabricated a special wheel type that can move in puddle soil. The wheels are installed ona shaft that rotates the wheel in the same direction. This shaft is installed on a base plate through the support of the shaft plate. The driver sprocket is installed at the shaft center. The mat is made in such a way that the transplanting mechanism can pick and transplant the rice seedlings in the wet soil. The mat is connected to theplate through the mat support. The support of the mat is welded to the base plate. The mat is inclined at an angle of 60 degrees. The follower sprocket is installed at the center of the shaft. Both sprockets are connected used to a chain. As the drive wheel rotates, the power is transmitted from the driver sprocket to the follower sprocket. The follower sprocket makes the transplanting arm pick the rice seedlings and transplant themin mud. The research problem in this study lies in not following the design considerations in the manufacture of agriculture machines, which leads to breakdowns and failure in the parts of the machines during operation.Rajput et al. [10] designed and developed a hand cranked rice transplanter. The machine aimed in eliminating the hand cranking efforts. Power from the wheels was using for operating the transplanting mechanism and in order to convert force of pulling into torque. The necessary tasks like design of chain drive, design of wheel shaft, bending of wheel spokes and selection of bearings were all accomplished using appropriate considerations. After the testing it was found that the chain drives transmitted the motion in required speed ratio. Seedling spacing of 15-16 cm was also achieved as per the standard required seedling spacing. Sisay et al. [11] developed manual rice transplanting machine. They mentioned that manual transplanter is consist of a main frame assembly made of MS tube which supports the seeding mat that made of metal sheet, lever for pushing indexing mechanism of the tray, transplanting arm assembly and pull arm. The developed manual transplanter is operated by one person in puddled soil with having no standing water by pull and push action. The operator has to do multiple task in operation of the transplanting machine, first the operator moves backward, pull the transplanting machine and then push the handle arm to pick the seedling and transplanting it in mud soil. Yuvraj [12] developed a power operated paddy transplanter and the transplanter driven with petrol engine. The power from engine was transmitted for transplanting operation through the gear box that reduced the engine power to the required gear ratio. The design features of the developed transplanter involved a wooden float in place of metal sheet float. Therefore, the objectives of the current study are todesign, simulate and analyze the stresses thenmanufacture a rice transplanting machine with local materials suitable for small rice holdings and achieve the technical recommendations of Egyptian conditions.

MATERIALS AND METHODS

The rice transplanting machine was designed and simulated at Agricultural Engineering Department, Faculty of Agriculture, Tanta University then manufactured and tested at the Rice Mechanization Center, Agricultural Engineering Research Institute, Egypt.

Solid modelling

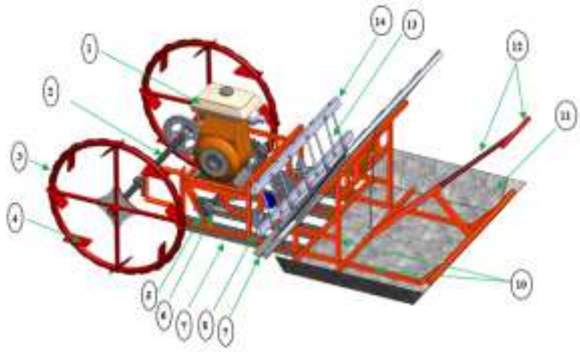
Solid modelling and stresses analysis simulation of the different machine parts carried out by Solidworks software package 2016. After the solid modelling and important calculation has been finalized, the machine was built and manufactured according to the simulation and analysis results.

Description of the manufacturing rice transplanting machine

The manufacturing rice transplanting machine consists of several major parts as shown in Fig. 1. The machine was designed and manufactured to transplant 5 rows, the distance between one row and the other is 20 cm.

Working theory

As the engine runs, the main sprocket rotates and operates the transmission system (intermediate reduction unit, transplanting unit, and wheel sprockets). The transplanting unit delivers its motion from the intermediate reduction unit using sprockets and chains, the crankshaft transfers the movement to the transplanting arm using four bar linkage mechanism and makes it rotate in an elliptical path.



No.	Item	No.	Item
1	Engine	8	Tine holder
2	Wheel axle shaft	9	Guide rail
3	Drive wheel	10	Main frame
4	Drive wheel lug	11	Main float
5	Intermediate reduction unit shaft	12	Handle arm
6	Bearing	13	Tension spring
7	Secondary float	14	Pushing rod holder

Fig. 1. Isometric of the rice transplanting machine
Source: Authors' drawing.

While, the transplanting arm is reached to its upper position, the planting tines pick up the seedlings from the seedling mat through the holes in the guide rail, and at the same time, the cams press on the levers which lift the seedling push holder with five pushing rods upwards until the planting tines can pick up the seedling. As the rotation continues, the transplanting arm is reached to its lower position and the planting tines carry the seedlings to the soil surface in a standing position at this moment the cams release the levers and the springs pull the seedling push holder downwards to push the seedlings into the soil in a specified depth by seedling push rods. Drive wheels delivered their motion from the intermediate reduction unit using sprockets and chains tomove the rice transplanter forward. The wheels are provided with fins so that they can travel easily in the mud. The drive wheels are used to maintain a constant distance between seedlings.

Main frame Design

The frame is the main component of the transplanting machine, which supports different parts such as the transplanting mechanism, transmission system mechanism, drive wheels' assembly, seedlings mat assembly and mat movement mechanism. Square mild steel hollow sections (20×20×1.25 mm, height, width, and thickness, respectively) was selected to manufacture the main frameof rice transplanting machinebecause it is high yield strength and is light in weight at the same time. The square mild steel hollow sections sticks were cut to several different lengths and welded together by 43 welding points to fit the machine parts, as shown in Fig. 2. The frame was designed and perform a stress analysis simulation on it by the Solidworks software and then it was implemented. The main frame dimensions were 1,500×950×500 mm, length, width, and height, respectively

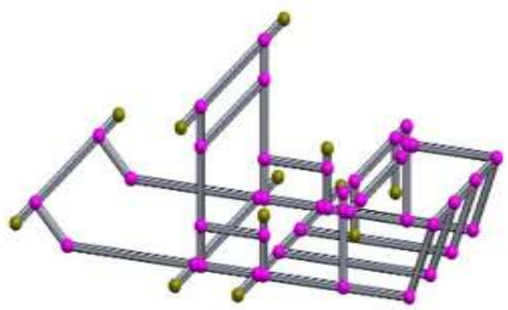


Fig. 2. Welding point of the rice transplanting machine main frame
Source: Authors' drawing.

Seedlings mat Design

The seedlings mat is the main component, which carries the seedlings to be transplanted. Basic factors (width, length, angle, speed of movement) are considered in designing the mat mechanism. Seedlings mat width depends on the number of rows to be transplanted. It should be adjusted to the required angle necessary for the continuous downward movement of seedlings. The inclination angle of the mat was determined by placing the seedlings on the mat, then raising the mat until the seedlings began to descend downward, then measuring the inclination angle of the mat, which was 55 degrees. The mat was designed on the Solidworks software, and all its measurements were set; then it was manufactured from galvanized steel sheet with dimensions of 1,045 × 740 mm, width and length, respectively, with a thickness of 0.7 mm to reduce the weight, and it was divided into 5 parts by a square mild steel hollow sections with a dimension of 15×15×1,000 mm height, width and length, respectively, and the width of every part was 191 mm, then supported from the rear side by a 20×20 mm square mild steel hollow sections frame as shown in Fig. 3.

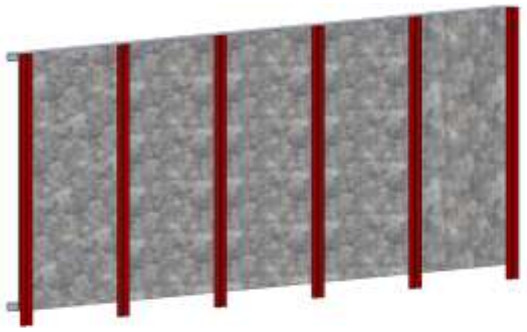


Fig. 3. The seedlings mat
Source: Authors' drawing.

Power transmission mechanism design

Engine

The maximum output power of the engine is 2.5 kW attached with internal gearbox give rotational speed (depending on the fuel throttle position) between 60-120 rpm and we fix the rotation speed at 85 rpm. The engine output shaft is supplied with four different sprockets with 20, 25, 30, and 35 teeth to change the machine's forward speed in the field.

Drive wheel

The diameter of the ground wheel D = 60 cm. The circumference of the ground wheel was calculated using the following equation:

Circumference of drive wheel = πD…....(1)

Circumference of the drive wheel = π (60) = 188.4 cm.

Power transmission system

Velocity of machine

The normal human walking speed is 1 m/s (3.6 km/h), butwalking speedsin the mud are lower,whichis taken as 0.5 m/s (1.8 km/h).

The angular speed of the wheel was determined according toKhurmi and Gupta [5] as following equations:

$$\omega = V/r \qquad (2)$$

$$N = 60\omega/2\pi \qquad (3)$$

where:
ω = Angular speed of the wheel, rad/seconds
v = Average walking speed of a man, m/s
r = Radius of the wheel, m
N = Revolution of the wheel in a minute
Adopted walking speed of a man v = 0.5 m/s
Radius of the ground wheel r = 0.3 m
ω =0.5/0.3=1.66 rad/sec
N = (60×1.66)/2π=15.93 rpm
So N of wheel is 15.93 rpm.

Velocity ratio

It is the ratio between the velocities of the driver and the follower or driven. It may be express, mathematically, determined according toKhurmi and Gupta [5] as following equations:

Let:
N1 = rotation speed of the driver (engine output sprocket), rpm
N2 = rotation speed of the follower (drive wheel sprocket), rpm
T1 = number of teeth of engine output sprocket. (Assumed 30 teeth)
T2 = number of teeth of drive wheel sprocket

$$\textit{Velocity ratio} = \frac{N1}{N2} = \frac{T2}{T1} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(4)$$

N2= (30×85)/15.93=160 teeth

Unfortunately, that sprocket is not available in stores, so the machine was provided with an intermediate reduction unit to obtain the required rotation speed with the available materials.

Intermediate reduction unit

The intermediate reduction unit contains three different sprockets, the first one delivers the motion from the main engine sprocket and it calls the main intermediate reduction unit sprocket. The second one transfers motion from the intermediate reduction unit to the transplanting unit and the third transfers the motion from the intermediate reduction unit to the drive wheel unit. There must be a synchronization between the rotation speed of the drive wheel and the rotation speed of the transplanting unit in order to obtain the required transplanting spacing.

To reduce the rotation speed, the follower sprocket must be larger than the drive sprocket; therefore, an available sprocket with 49 teeth was installed as a main intermediate reduction unit sprocket. Also, another sprocket of 49 teeth was installed on the wheel axle.

So, the velocity ratio of the machine was as presented below.

Let:
N1 = rotation speed of the driver (engine output sprocket), rpm
N2 = rotation speed of the follower (main intermediate reduction unit sprocket), rpm
N3 = rotation speed of the driver (wheel driver sprocket on intermediate reduction unit), rpm,
N4 = rotation speed of the follower (wheel follower sprocket on wheel axle), rpm,
N5 = rotation speed of the driver (transplanting unit driver sprocket on intermediate reduction unit), rpm,
N6 = rotation speed of the follower (transplanting unit follower sprocket), rpm,
T1 = number of teeth of engine output sprocket. (Assumed 30 teeth)
T2 = number of teeth of main intermediate reduction unit sprocket (Assumed 49 teeth)
T3 = number of teeth of wheel driver sprocket
T4 = number of teeth of wheel follower sprocket
T5 = number of teeth of transplanting unit driver sprocket
T6 = number of teeth of transplanting unit follower sprocket

$$\textit{Velocity ratio}\ (1) = \frac{N1}{N2} = \frac{T2}{T1} \qquad = \frac{85}{N2} = \frac{49}{30}$$

N2 = (30×85)/49=52 rpm

Rotation speed of main intermediate reduction unit sprocket = 52 rpm

So, N3 = N2 = 52 rpm, because they installed in the same shaft

$$\textit{Velocity ratio}\ (2) = \frac{N3}{N4} = \frac{T4}{T3} \quad = \quad \frac{52}{15.93} = \frac{49}{T3}$$

T3 = (49×15.93)/52= 15 teeth

Number of wheel drive sprocket teeth = 15 teeth

$$\textit{Velocity ratio}\ (3) = \frac{N5}{N6} = \frac{T6}{T5}$$

N5 = N6 = 52 rpm, because they were installed in the same shaft

As, the recommended intra-row hill spacing is 20 cm and it must be a synchronization between the rotation speed of the drive wheel and the rotation speed of the transplanting unit in order to obtain the required transplanting spacing.

$$\boldsymbol{Transplanting\ spacing} = \frac{\boldsymbol{\pi \times D \times N4}}{\boldsymbol{N6}} \ldots\ldots\ldots (\mathbf{4})$$

$$20 = \frac{\pi \times 60 \times 15.93}{N6}$$

N6 = 154 rpm, rotation speed of the transplanting unit follower sprocket.

A cassette sprocket with seven sprockets (speeds) starting from 12 to 28 teeth is used as a transplanting unit follower sprocket to obtain different intra-row hill spacing. Its purpose is to change the number of hits of the transplanting unit per unit distance). So,

$$\frac{52}{154} = \frac{(assumed)\ 16}{T5} \qquad = \frac{154 \times 16}{52} = 47.38\ teeth$$

So, number of teeth of transplanting unit drive sprocket = 48 teeth.

The forward speed and intra-row hill spacing changed in the field due to slippage, so the slip ratio, % was determined by using the following equation:

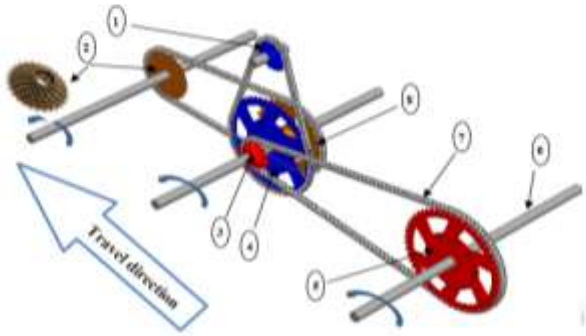
$$\boldsymbol{S} = \frac{\boldsymbol{L1 - L2}}{\boldsymbol{L1}} \times \mathbf{100} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (\mathbf{5})$$

where:
S = Slip ratio, %;
L1 = Advance per 10 revolutions of the wheel on asphalt, m;
L2 = Advance per 10 revolutions of the wheel on the tested surfaces, m;
S = (18.84-15.73)/18.84×100=16.50%.

Design of machine shafts

The material used for shafts should have the following properties:
1. It should have high strength.
2. It should have good machinability.
3.It should have high wear resistant properties

The transplanting machine contains three main shafts namely, intermediate reduction unit shaft, transplanting unit shaft and wheel axle shaft, as shown in Fig. 4. When the shaft is subjected to a twisting moment (or torque) only, then the diameter of the shaft may be obtained by using the torsion equations according to Khurmi and Gupta [5].



No.	Item	No.	Item
1	Main engine sprocket	5	Wheel follower sprocket
2	Transplanting unit follower sprocket (cassette sprocket)	6	Shaft
3	Wheel driver sprocket	7	Chain
4	Main reduction unit sprocket	8	Transplanting unit driver sprocket

Fig. 4. Schematic view of the power transmission system
Source: Authors' drawing.

Equivalent twisting moment (T_e)

$$\boldsymbol{T} = \frac{\boldsymbol{\pi}}{\mathbf{16}} \times \boldsymbol{\tau} \times \boldsymbol{d^3} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (\mathbf{6})$$

Torque transmitted by the shaft,

$$\boldsymbol{T} = \frac{\boldsymbol{P \times 60}}{\boldsymbol{2\pi \times N}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (\mathbf{7})$$

where:
T = Twisting moment acting up on the shaft, Nm
P = Power transmitted by the shaft, W
N = Rotation speed of shaft, rpm
τ = Torsional shear stress, N/m^2
d = Diameter of the shaft, m

The power generated by the engine based on fuel consumption will be P= 1,300 W.

Tangential force on the gear

$$\boldsymbol{Ft} = \frac{\boldsymbol{2T}}{\boldsymbol{D}} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (\mathbf{8})$$

where:
Ft = Tangential force on the gear, N
D = Diameter of sprocket

The normal load acting on the tooth of the sprocket

$$\boldsymbol{W} = \frac{\boldsymbol{Ft}}{\boldsymbol{cos \propto}} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (\mathbf{9})$$

where:

W = Normal load acting on the tooth of the sprocket, N
Ft = Tangential force on the gear, N
∝ = Pressure angle, deg
Since the sprocket is mounted in the middle of the shaft, therefore,

The maximum bending moment at the center of the gear

$$M = \frac{W \times L}{4} \quad \ldots \ldots \quad (10)$$

where:
M = Maximum bending moment at the center of the gear, Nm
W = Normal load acting on the tooth of the sprocket, N
L = Length of the shaft, m

Equivalent twisting and bending moment

$$T_e = \sqrt[2]{M^2 + T^2} \quad \ldots \ldots \quad (11)$$

Twisting stress

$$\tau = \frac{16\,T}{\pi d^3} \quad \ldots \ldots \quad (12)$$

where:
τ = Torsional shear stress, N/m^2
T = Twisting moment acting up on the shaft, N. m
d = Diameter of the shaft, m.

RESULTS AND DISCUSSIONS

The data obtained from the present study could be summarized under the following headings.

Static stress and displacement simulation analysis of the transplanting machine main frame.

The main frame of the transplanting machine was designed and the staticstress analysis simulation wasperformed on it by the Solidworks software to know if the design is safe ore not as shown in Fig. 5 and Fig. 6.The data in the Fig. 5 indicated that the maximum upper bound axial and bending stress was 1.755e+2 MPaand from the simulation results, it is concluded that this part will not fail under the given stresses as the maximum stress are much lower than the yield strength of the part. Also, the minimum and the maximum displacement occur on the main frame was very small and recorded 1.00e-030 and 4.159e+000 mm, respectively as shown in Fig. 6. From the simulation results, it is concluded that this part will not carry out any significant deformations according to loading conditions applied.

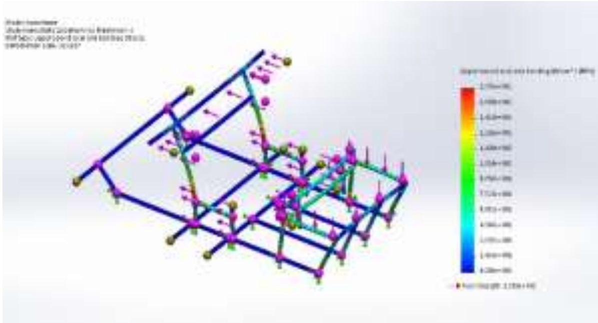


Fig. 5. Upper bound axial and bending stress simulation of the machine main frame.
Source: Authors' determination.

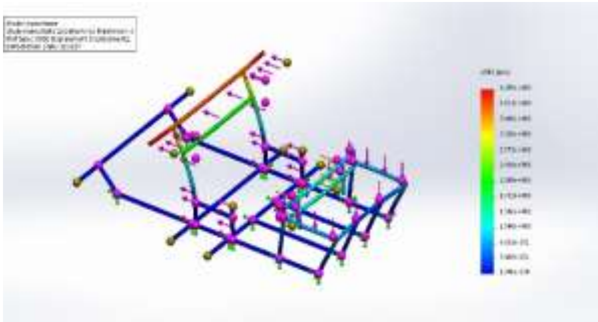


Fig. 6. Static displacement simulation of the machine main frame.
Source: Authors' determination.

Static stress and displacement simulation analysis of the transplanting machine seedling mat

The seedlings mat is the main component, which carries the rice seedlings trays to be transplanted.The loads affecting the seedling mat, which is the weight of the seedlings, were placed on the Solidworks software, and then the simulation was performed. The maximum static von Mises stress was too low compared with material yield strength, where it was recorded at 4.267e-002 MPa compared with 2.500e+002 MPa for the part material, as shown in Fig. 7. In addition to that, the data in Fig. 8 show very low deformation and the maximum static displacement recorded 5.903e-005 mm, and from this results, it is concluded that the design is safe.

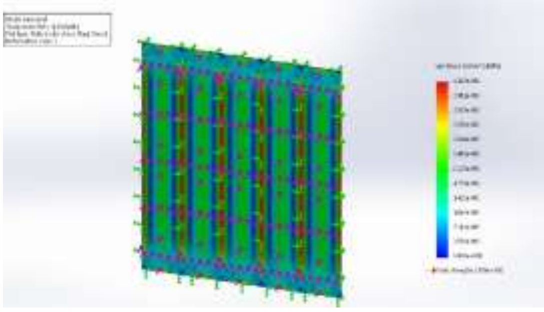


Fig. 7. Von Mises stress simulation of the machine seedlings mat.
Source: Authors' determination.

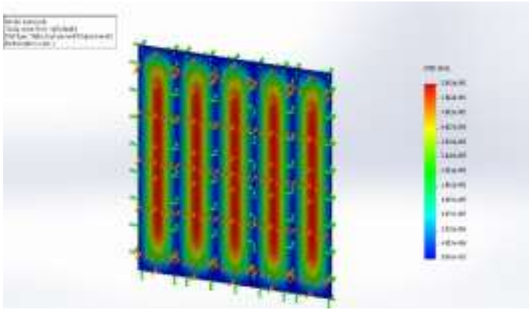


Fig. 8. Static displacement simulation of the machine seedlings mat.
Source: Authors' determination.

Transplanter velocities and hill spacing

It is very important to determine the required forward speeds for the transplanting machine and the desired and recommended hill spacing; even we can determine the shaft's rotational speeds and the sprocket teeth number, which achieve this desired aim. The data in Table 1 illustrate all of the shafts' rotational speeds as well as the sprockets that have been calculated in the design and installed in the machine to obtaindesired forward speeds of 1.00, 1.25, 1.50, and 1.75 km h^{-1}, as well as the rec ommendedintra-row hill spacing of 16, 18, 20, and 22 cm. It is also clear from the table that the synchronization between the rotation speeds of the drive wheel and the rotation speeds of the transplanting unit with the forward speeds of the machine was taken into account precisely so that the hill spacing is kept constant while changing the forward speeds of the machine.

Power transmission system design

Table 1. Specifications of sprockets, forward speeds and intra-row spacing of the transplanting machine

Main engine sprocket		Main intermediate unit sprocket		Wheel driver Sprocket		Wheel follower sprocket		Transplanting unit driver sprocket		Transplanting unit follower sprocket		Forward Speed, km/h		Intra-row hill spacing, cm	
teeth	**rpm**	**teeth**	**rpm**	**teeth**	**rpm**	**teeth**	**rpm**	**teeth**	**rpm**	**teeth**	**rpm**	**Out field**	**In field**	**Out field**	**In field**
20	85	49	34.69	15	34.69	49	10.62	48	34.69	16	104.08	1.20	1.00	19.24	16
										18	92.51			21.64	18
										20	83.26			24.05	20
										22	75.69			26.45	22
25	85	49	43.36	15	43.36	49	13.27	48	43.36	16	130.10	1.50	1.25	19.24	16
										18	115.64			21.64	18
										20	104.08			24.05	20
										22	94.61			26.45	22
30	85	49	52.04	15	52.04	49	15.93	48	52.04	16	156.12	1.80	1.5	19.24	16
										18	138.77			21.64	18
										20	124.89			24.05	20
										22	113.54			26.45	22
35	85	49	60.71	15	60.71	49	18.58	48	60.71	16	182.14	2.10	1.75	19.24	16
										18	161.90			21.64	18
										20	145.71			24.05	20
										22	132.46			26.45	22

Source: Authors' determination.

Dimensions analysis of machine shafts

It is very necessary to design the power transmission shafts in the machines to determine the required diameter of the shafts, as well as the type of material it is manufactured from, in order to avoid any collapses in the machine during operation. The diameter of the shafts is determined according to the aforementioned design equations by determining the engine powerand therotation speeds of shafts, then determining the torque transmitted by this shaft. The data in Table 2 shows the diameters of the transmission shafts for the different parts of the machine that were calculated with taking into consideration the of a safety coefficient in the calculation as well as all the moments, forces and stresses that effect on those shafts. The shaft diameters of the intermediate reduction unit, transplanting unit, and wheel axle unit were 25, 20, and 40 mm, respectively, and the calculated twisting stress for the three units were, 66.65, 43.38, and 53.16 MPa, respectively.

Table. 2. Dimensions analysis and the moments affecting onthe power transmissionshafts

Unit	Intermediate reduction unit shaft	Transplanting unit shaft	Wheel axle unit shaft
Engine power, Kw	1.30		
Shaft rotation speed, rpm	60.71	182.14	18.58
Torque, N.m	204.48	68.15	668.14
Diameter of sprocket, m	0.20	0.07	0.2
Tangential force on the gear (Ft), N	2,044.81	1,947.33	6,681.42
Normal load acting on the tooth of the sprocket (W), N	2,176.04	2,072.31	7,110.22
Length of the shaft, m	0.7	0.4	1.2
Bending moment at the center of the gear (M), N.m	380.80	207.23	2,133.06
Twisting moment (Te), N.mm	432,220	218,140	2,235,250
Shaft material yield strength, MPa	250	250	250
Shaft diameter, mm	20.64	16.44	35.70
Shaft diameter with 25% safety factor	25	20	40
Twisting stress (τ), MPa	66.65	43.38	53.16

Source: Authors' determination.

Stresses analysis simulation of the machine shafts

Intermediate reduction unit shaft

The diameter of the intermediate reduction unit shaft was calculated, which was 25 mm, and then the shaft was designed on the Solidworkssoftware in order to simulate the stresses on the shaft, as well as the deformation that occurred as a result of those stresses, in order to ensure the integrity of the design as shown in Fig. 9 and Fig. 10.

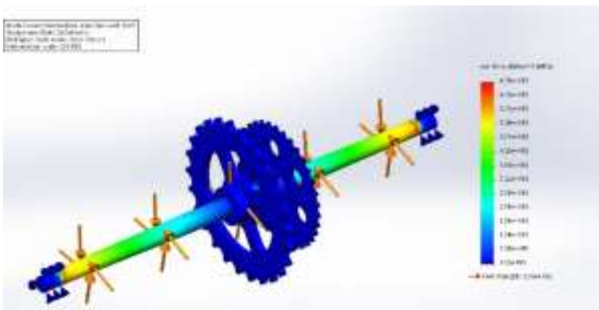


Fig. 9. Von Mises stress simulation of the intermediate reduction unit shaft
Source: Authors' determination.

The data in Fig 9 show the von Mises stresses of the shaft, which was much lower than the yield strength of the shaft material. The maximum von Mises stress was 6.75e+001 MPa and the minimum von Mises stress was 4.31e-006 MPa, while the yield strength of the shaft material was 2.50e+002MPa.

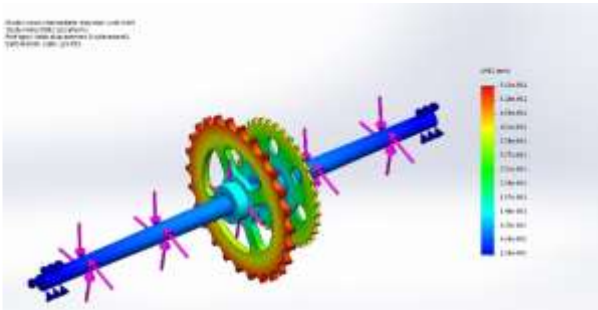


Fig. 10. Static displacement simulation of the intermediate reduction unit shaft
Source: Authors' determination.

Also, Fig. 10 shows the static displacement simulation of the shaft and from the figure, it is clear that the displacement occurred with a small amount in the sprockets installed on the shaft andthe maximum static displacement was 5.61e-001 mm.

Transplanting unit shaft

The transplanting unit shaft is one of the most important shafts in the machine because it transfers the movement to the transplanting arm. The transplanting unit shaft is designed and simulated by the Solidworks software, as shown in both Fig. 11 and Fig. 12. From the simulation results, it is concluded that this part will not fail under the given stresses as the maximum von Mises stress was 4.34e+001 MPa which are much lower than the yield strength of the part which was 2.50e+002 MPa as shown in Fig. 11. Also, from the simulation results shown in Fig. 12, it is concluded that this part will not carry out anysignificant deformations according to the loading conditions applied. In addition to that, the minimum and the maximum static displacement recorded, 6.47e-008 mm and 1.63e-001 mm respectively.

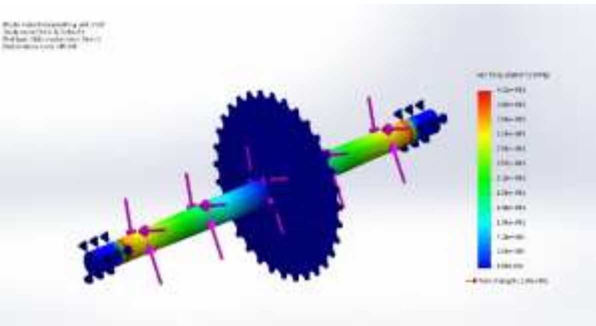


Fig. 11. Von Mises stress simulation of the transplanting unit shaft
Source: Authors' determination.

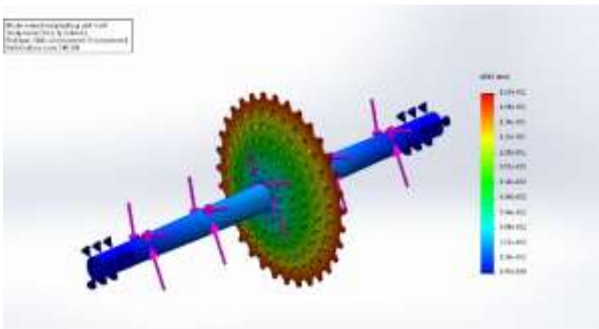


Fig. 12. Static displacement simulation of the transplanting unit shaft
Source: Authors' determination.

Wheels axle unit shaft

The diameter of the drive wheel shaft was calculated to be 40 mm, in order to withstand the torque applied to it, especially since the drive wheels of the transplanting machine are moving in the mud. The data of the axle shaft was placed in the Solidworks software, then the shaft was designed and a simulation of the stresses on it was performed. The von Mises stress simulation of the shaft is shown in Fig. 13 and the minimum von Mises stress recorded 1.49e-005 MPa and the maximum von Mises stress recorded, 5.39e+001 MPa, which was lower than the yield strength of the shaft material. Whereas, the maximum static displacement was 5.10e-001 mm, as shown in Fig. 14. From simulation results, it is concluded that this part will not fail under the given stresses as the maximum stress is much lower than the yield strength of the part and this part will not carry out anysignificant deformations according to the loading conditions applied.

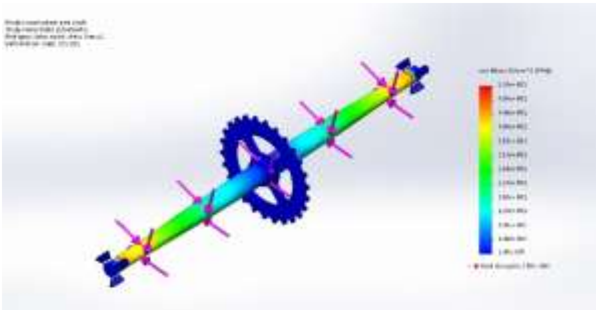


Fig. 13. Von Mises stress simulation of the wheel axle unit shaft
Source: Authors' determination.

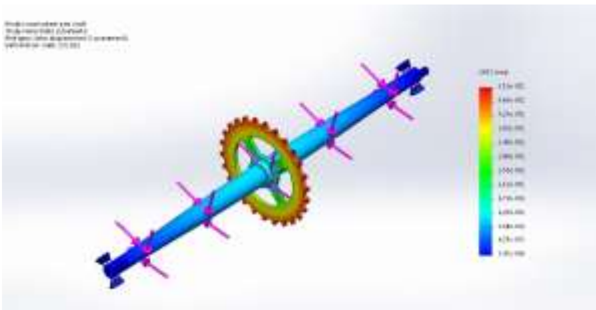


Fig. 14. Static displacement simulation of the wheel axle unit shaft
Source: Authors' determination.

CONCLUSIONS

The research aimed to design, analyze stresses and simulate then manufacture of a rice transplanting machine with local materials suitable for small rice holdings. The machine was designed and the stresses were simulated by Solidworks software to ensure the integrity of the design before manufacturing it. The power transmission system was designed to achieve the desired forward speed of 1.00, 1.25, 1.50, and 1.75 km h^{-1} and achieve the recommended intra-row hill spacing of 16, 18, 20, and 22 cm. Also, the main frame and the seedlings mat were designed and simulated. Finally, the diameter and the torsional moments of the different machine shafts were calculated then the static stresses and displacements on the shafts were simulated. From simulation results, it is concluded that this parts will not fail under the given stresses and the parts will not carry out any significant deformations according to the loading conditions applied.

REFERENCES

[1]Ahmed, A., Imran. S., 2014, Design and fabrication of engine powered two rows rice transplanting machine. B.Sc. Thesis, Department of Mechanical and Aerospace Engineering, Institute of Avionics and Aeronautics, Air University, Islamabad.
[2]Fouda, T., Abdrabo, A., Morgan, H., Didamony, M.I.E., Salah, S. 2022, Manufacturing and Testing of Local Rice Transplanting Machine. Scientific Papers. Series "Management, Economic Engineering in Agriculture and rural development". 22 (4), 251-262.
[3]Jin, X., Li, D. Y., Ma, H., Ji, J. T., Zhao, K. X., Pang, J., 2018, Development of single row automatic transplanting device for potted vegetable seedlings. Int J Agric & Biol Eng., 11(3): 67–75.
[4]Karthik, G., 2019, Development of manual operated women friendly paddy transplanter. M.Sc. Thesis, department of farm machinery and power engineering dr. N. T. R. College of agricultural. G. Ranga agricultural university Guntur, Andhra Pradesh, India.
[5]Khurmi, R. S., Gupta, J.K., 2005, A Textbook of Machin Design, Eurasia Publishing House (Pvt.) Ltd. Ram Nagar, New Delhi-110 055.
[6]Kumbhar, S., Khot., S., Mohite, S., Pandit, S.V., 2017, Design analysis and fabrication of manual rice transplanter. International Journal of Innovative Research in Science, Engineering and Technology. 6(3) 3699:3705
[7]Patel, H. B., Patel, M. R., Tandel, D. R., 2018, Design Analysis & Fabrication of Manual Rice Transplanting Machine. J. for Research, 4(1): 25-29.
[8]Pattar, P.S., Reddy, B.G.M., Kuchanur, P. H., 2001, Yield and yield parameters of rice (Oryza sativa L.) as influenced by date of planting and age of seedlings. Indian Journal of Agricultural Sciences, 71: 521-522.
[9]Rajamanickam, A. K., Uvaraja, V. C., Selvamuthukumaran, D., Surya, K., 2021, Fabrication of Paddy Transplanter Machine. IOP Conf. Series: Materials Science and Engineering 1059, 012064.
[10]Rajput, K. D., Bhide, A P., Kandan, G. R., Shukla, M. D., Bhaskar, R. V., 2017, Modification and Manufacturing of Hand Cranked Rice Transplanter. International Journal on Recent Technologies in Mechanical and Electrical Engineering (IJRMEE). 4(6): 1–6.
[11]Sisay, G., Bekele, K., Cheko, K., Tamru, M., Teklay, T., 2020, Design and Simulation of Manually Operating Rice Transplanting Machine. B.sc thesis, Department of Mechanical Design and Manufacturing Engineering, Adama Science and Technology University, Ethiopia.
[12]Yuvraj, M.R., 2018, Development and Performance Evaluation of Two Row Power Operated Paddy Transplanter for Root Washed Seedlings. M.Sc., Department of Farm Machinery and Power, College of Agricultural Engineering and Technology, India.