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FEA OF COMPACT PADDY TRANSPLANTER EQUIPPING FERTILIZER DISCHARGE

Manoj Jagdale[1], Atul Kulkarni[2], Amol Dhumal[3], Naren Kate[4], Leena Deshpande[5]

[1] Dept. of Mechanical Engineering, Vishwakarma Institute of Information Technology, Pune, India. **Email:** manoj.jagdale@viit.ac.in

[2] Dept. of Mechanical Engineering, Vishwakarma Institute of Information Technology, Pune, India. **Email:** atul.kulkarni@viit.ac.in

[3] Dept. of Mechanical Engineering, Vishwakarma Institute of Information Technology, Pune, India. **Email:** amol.dhumal@viit.ac.in

[4] Dept. of Mechanical Engineering, Vishwakarma Institute of Information Technology, Pune, India. **Email:** naren.kate@viit.ac.in

[5] Dept. of Computer Engineering, Vishwakarma Institute of Information Technology, Pune, India. **Email:** Leena.deshpande@viit.ac.in

Abstract

In this paper a paddy transplanter is introduced which is very compact and efficient working. Performance with the proper mechanism is emphasized during the development. A 2-row transplanter is made with motor which can be easily operated by farmers easily adding fertilizer simultaneously with less efforts. Low-cost apparatus which is suitable to buy for Indian farmers. Soil moisture content, system of raising seedlings in nursery, planting claw size are the key points influencing the performance. In this paper we have discussed the working principle of two row transplanter. We have made the provision for the sprinkling of fertilizers simultaneously while transplanting the paddy seedlings. The paddy transplanter is automized order to increase the feasibility and its working efficiency. The paper includes the general part including detailed information of Paddy transplanter and its analysis. A cad model is made and analyzed with Ansys considering various force and deformation parameters. Finite element analysis is carried out using structural analysis on the meshed CAD model. The analysis is carried out in Ansys with applying various boundary conditions. The final analysis is made and inferences are taken.

Keywords: transplanting, working, efficiency, farmers, seedling, analysis, fea, mesh, nodes, data analysis, elements.

Introduction

Rice is the staple food of our country. More than three fourth of the country consumes rice as their daily basic diet. From the rich to the poor every person needs rice. Hence there is growing demand as consumers are more than producers. It becomes a difficult task for our Indian farmers to cultivate rice/paddy and yield more volume as per the requirement. A lot of effort from its land ploughing to sowing, adding fertilizer and up to final harvest, a farmer has to dedicate his whole life. Beyond these natural calamities may occur, like water shortage that totally affects the crop resulting in failure.

A farmer’s dedication to his work and this responsibility makes him to work more and more. A lot of human effort is required. But in today’s world lot of machineries are there to automate the cultivation easily. Many of the farmers are adapted to the latest techniques. Some of them can afford but some may not. Apart from these there are still regions people are not in contact with the emerging world still use human effort.

The state of art of agricultural machineries had already reached up to a level where humans just need to just on the button, the machine will carry out the whole process. Machineries like ploughing tractors, mini tractors, spraying machines, harvesters, rotavators, tillers, reapers are already in the market. These are used by most framers having high capital. Using these machineries, it is capable to produce double the volume of production compared to manual transplanting. But the poor remains like poor.

Growing rice is a difficult and time-consuming task that requires large number of daily labours. Sometime while transplanting, there is a shortage labour. Such problems may lead to the delay in the time. It is also not easy to guide their properly throughout and giving the daily wages. Therefore, sometimes proper implanting cannot be maintained properly hired labours. A newly developed transplanters are loaded with a tractor creates some problems in the field. It is difficult to control the heavy tractor in wet land. Meanwhile transplanting requires less speed for the proper implanting. So, it is not guarantee that tractor type implanters ensured this. Apart from these maintenance and working cost is high[1].

Therefore, the need for a small, inexpensive, labour-intensive machine is evident in paddy cultivation areas of India.

Fig 1. Manual Transplanting

Fig 2. Two Row Transplanter

Literature Survey

By referring some case studies and research papers we could infer that, first: design the apparatus with compatibility gives more performance. Second: four bar mechanism can efficiently work for 2,3 6 rows transplanting no matter what the soil texture is.

A study was taken in which field research was conducted using a hand-made transplanter. It was from the International Rice Research Institute (IRRI). Some tests were performed. It has been found that the manual hand transplanters can carry work up to a certain limit only. Since level of land is even, it was difficult to drag in the wet land. Such problems were in top hill sides and areas having uneven spreading with less water[2].

Along with this paper it came to know that compactness of transplanter could positively vary the performance. The transplanting part also requires certain specific parameters to improve planting by allotting it with the proper rotating radius and direction angle.

One study reported that the functional characteristics of mechanical replacement methods were compared. This comparison is made with a view to finance, power and mechanization. Various factors of transplanters like specifications, efficiency other parameters had pointly studied are surveyed. Inferences had taken from the existing transplanters of their usage and working. Limitations, defectiveness and problems were drawn.

To overcome the problems a developed transplanter is introduced that is unavailable in various parts of state and also working had improvised based on the researched soil, climate and land conditions.

To improvise the manual hand transplanter value by understanding its necessity, an engineering planning structure of various parameters of transplanter was introduced to form a four-row paddy transplanter by applying the mechanics and mechanism. An economical test done on this resulting in to the inference that hand transplanter is good to implant in two and three rows. But if it is about more rows such manual transplanters go out of use. Researchers concluded the power requirement for the machine is 41.3 W which was well below the average power of a man which is 76 W, designed planting rate being 777 plants in a minute at a mean forward speed of 1.4 m/s.

All the prefeasibility literature survey study was about the planting mechanism and its parameters. But considering the state of art only transplanters reached up to higher row transplanting. However, there were no such researches on the innovation and its provision of additional features. This paper is about a transplanter that has a dedicated fertilizer discharge provision mounted over it to add fertilizer while transplanting simultaneously. Therefore, we tried to implement the same in this research paper.

Prefeasibility study

Rice is a stapple food of India. Paddy production in India was 172.58 Mt in area of about 44.50 million ha with average productivity of 3.87 tonnes. ha-1 in the year 2018-19). India ranks second in production of paddy, after China, and first in area under paddy production. The process of transplanting can be carried out manually or by machines. Manual process involves more energy and labour involved activity. Farmers prefer mostly transplanting methods due to high yield and less man power.

In India, during summers, there is a huge scarcity of water, so farmers usually prefer to grow those crops which consume less amount of water. Moreover, Indian farmers tend to use conventional methods to cultivate paddy. So they are technologically lagging in fact.

In the prefeasibility, procedures were not considered.

a) life span of seedlings
b) space (density of plants per matrix and per unit area meter)
c) water management habits
d) aerobic conditions using rotary weeder
e) natural fertilizers were not introduced and tested.

Mechanical transplanting is pursued by a large number of research institutions as the labour availability has been critical during the peak agricultural season. Use of mechanical transplanters in India is currently limited. Non- availability of mechanical transplanter suitable for Indian conditions may be one main reason for this situation. With the help of transplanter about 90% of labour saving can be obtained which is helpful during the peak period of transplanting.

Methodology

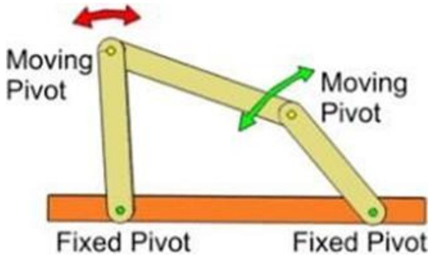

Fig 3. Four Bar Mechanism

This methodology has four parts or links. They are the frame, input and output link and coupler link. These connected part forms a kinematics series of four rotating pair having a single degree of freedom [3].

A four-bar crank-rocker method has been selected required to invest trajectory and efficiency.

In the four-bar crank rocker linkage, shortest link rotates fully while the other link pivoted to the fixed link oscillates. But in case of Grashoff linkage, it is the sum of the lengths of the shortest link and the largest link which is less than sum of the lengths of the other two links.

The following operations are to be fulfilled during the mechanism

a) transplanting arm tip are required to pass through two mentioned points that is the selection point and the planting area.
b) Fingers should not dig down after planting the seedlings.
c) Low speed should be maintained in the area of picking and planting the seedlings[4].
d) Speed of machine planting should be higher than the planter forward speed, so that the plants that are fixed by arms are not pulled from the wet land upwards by arm reciprocating movement.

A. Features

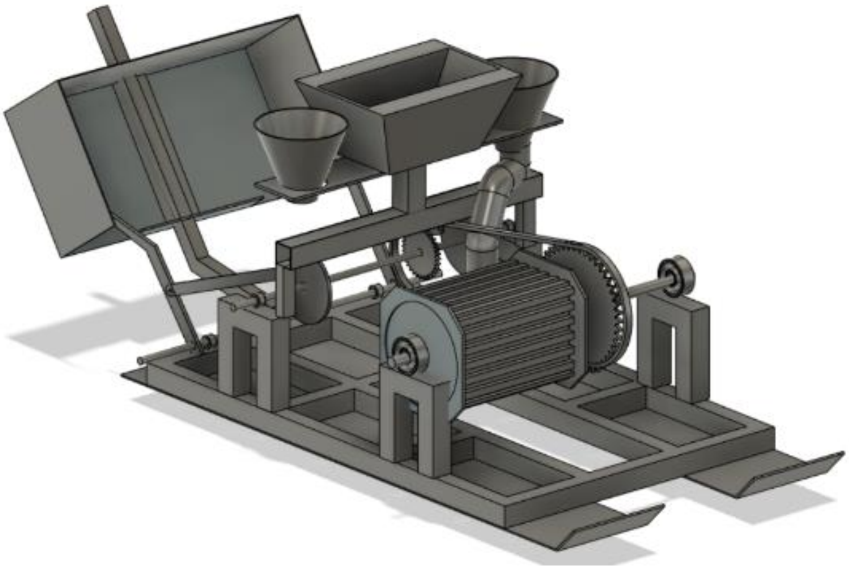

Fig 4. Paddy Transplanter

a) This transplanter helps to transplant paddy in 2 rows.
b) It is easily operated.
c) Efficient stepper motor is used for maintaining the speed limit in the wet land.
d) A provision to add fertilizer is given to do simultaneously along transplanting.
e) Less maintenance cost.
f) Compact apparatus which is user friendly for farmers.

B. Parts and constructions

- Sprocket: Two sprockets are used in the apparatus i.e., small and big. One is for the front shaft on which mechanism performing parts like disc and connector are attached. Other sprocket is connected with motor to translate the energy to smaller sprocket.
- Chain: connects the small and big sprocket for translating the torque and drive the mechanism.
- Disc with connector: - These two are the main part of four bar mechanism. The torque from the motor is transferred from big sprocket to small sprocket shaft in which these arts on attached. When the disc rotates, connector attached with arm reciprocates up and down.
- Seedling Tray: -It is the storage cabin for the paddy seedling. During transplanting the seedlings are picked up from this.
- Arm/sprong: - The main part used in transplanting. It has teeth like design at its tip. This is for the picking up of paddy seedlings. As mechanism starts it takes seedling from cabin and try to fix in the wet mud upright.
- Stepper motor: The stepper motor can be used to provide specific angular rotation, as an alternative to constant rpm. We know that in any rotor, the rotation angle is 180 degrees. However, in a step-by-step mode, the complete rotation angle can be divided into a multiple of 10 degrees. The constant rpm is low compared to normal rpm as it needs to be replanted in the same way with one or two seedlings in the area.
- Fertilizer cabin: This apparatus is attached in the uppermost part of the transplanter. It is the storage for the fertilizer. During transplanting the farmer can take some amount of

fertilizer and add some as per amount required. This becomes a part of innovation. As adding fertilizer is the next step after transplanting. Here this transplanter comes with this provision to add fertilizer while transplanter simultaneously thereby minimizing the human effort.

- Frame and base: The lower most part of apparatus on which the other parts are mounted. It provides structural strength to transplanter. Lower most part in contact with wet land on which this apparatus is dragged manually maintaining the sustainability
- Bearing: The shaft which is aligned in the center of sprocket are attached in between the bearings to rotate properly. It is kept on the side stand of frame.

Working

This apparatus is based on four bar mechanism and motor driving mechanism. This mechanism consists of 4 nodes in which one is kept stationary and the other three performs a combined motion. This mechanism is implanted in this apparatus and working is attained by the involved parts. The base plate has a frame and side stand mounted on it. The working parts are the sprocket, arms, connectors, motor, shafts etc. The one shaft is attached to small sprocket on which the crucial parts like the arms, disc is mounted. The other shaft is connected to motor with the big sprocket. The main part of the apparatus is the arms or sprong that plays the role of implanting the seedlings. When the circular disc rotates which is on the small sprocket shaft the connected part of the arms starts oscillating due to which the arms also start reciprocating up and down thereby taking the seedlings and implanting in the wet land. The circular disc acts as the moving node or link and the lower part of arm is fixed to the plate on the rod which acts as the stationary part relatively as in four bar mechanism. In order to drive the sprockets efficiently a stepper motor is used whose rpm can be controlled which is fixed at low rpm to maintain the seedling implanting properly [5]. The chain is connected between the wo sprockets which is driven by the motor to drive the mechanism. Hence the two-mechanism work hand in hand for the transplanting. Finally, we can add fertilizer simultaneously from the cabin simultaneously while transplanting which is the key point of this apparatus [6-7].

Technical Aspects

Table 1. Specifications and Measurement

Parameters	**Specs.**
Dimensions	750 mm x 450 mm
Weight (Approximate)	36.220 kg
Planting Mechanism	Fixed fishing hook type fingers actuated
Number of rows	Two
persons required	Two (operator and bring seedlings)

Table 2. Weight Estimation of Apparatus

Sr No.	Part	Weight in Kg
1.	Base	17.89
2.	Motor Stand	2.9
3.	Fertilizer Stand	4.81
4.	Arms	0.34
5.	Base Plate	1.71
6.	Seedling Box	2.5
7.	Fertilizer Box	3.38
8.	Seedling Stand	1.5
9.	Gear	1.19

Table 2 includes the total weight estimation of each part. The overall calculates and estimated cost is based on the weight.

Table 3. Cost Estimation

Approximate Weight	40-41 kg
Material Cost	40000 Rs. (approx. including manufacturing, paint, tax)
Material Used	Mild Steel, Aluminium, Stainless Steel

Table 3 includes the cost of overall material from the estimate weight summarized in table 2.

Table 4. Comparison

FUNCTIONS	IDEAL	OUR DESIGN
BRAND	STALLON	VIIT
MODEL	HRP-2	1
TRANSPLANTIN G ROWS	2	2
ROAD TRAVELLING SPEED	NO	NO
TYPE	WALKING TYPE AND RIDING TYPE	WALKING TYPE
WORKING EFFICIENCY	VERRY GOOD	VERRY GOOD
PRICE	35,000/-	40,000/-
WEIGHT	26 kg	SOLID WEIGHT- =40-42 Kg LIQUID WEIGHT=6 -9 Kg

ROW SPACE	210 mm	260mm
DEEPEST PLANTING DEPT	65mm	60mm
BEST RICE SEEDLLING HEIGHT	15-35 cm	15- 30 cm
THICKNESS	2-5mm	2-5 mm
OUTSIZE	75*46 cm	700*450 mm
OPRATABLE	MANUALL Y	MOTOR AND MANUALL Y
FERTILIZER SYSTEMS	NOT- AVAILABLE	AVAILABLE

The table 4 is a comparison table for the transplanter already in market and the transplanter designed by us. It is clear from table that how the feature differ from other and highlighting the features [8-9].

Analysis

The Finite Element Analysis (FEA) is the simulation of any given model using the numerical method known as Finite Element Method (FEM). FEA is used to reduce the number of physical prototypes and experiments and optimize components in their design phase to develop better products, faster by saving the expenses.

It is necessary to use maths that quantify any physical phenomena such as structural behaviour. The processes are initiated using Partial Differential Equations. However for a computer to solve these PDEs, numerical techniques have been developed over the last few decades and one of the convenient ones, is the Finite Element Analysis[16].The analysis is carried in 4 steps:

A. Developing a cad model

For the Finite Element Analysis, firstly, solid model of the Paddy Transplanter needs to be created in CAD software, and also a FE model. In the present work, static analysis has been carried out for the transplanter considering sudden load effects.

Fig 5. shows Autodesk fusion 360 is used for modelling. The model has a solid hollow handle of square cross-sectional area of 20mmX20mm – 7mmX7mm, machined at both ends.

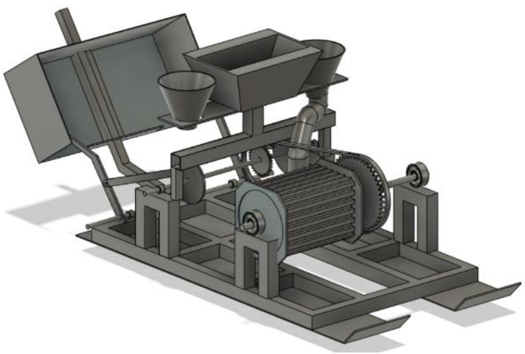

Fig 5. CAD model

B. Discretisation

Using analysis software, the model is discretized using Hex- Dominant method [17] for meshing with 7474 elements & 29351 nodes.Hex or hex-dominant mesh generated, or a highly controlled hex meshes provide optimal solution efficiency and accuracy.

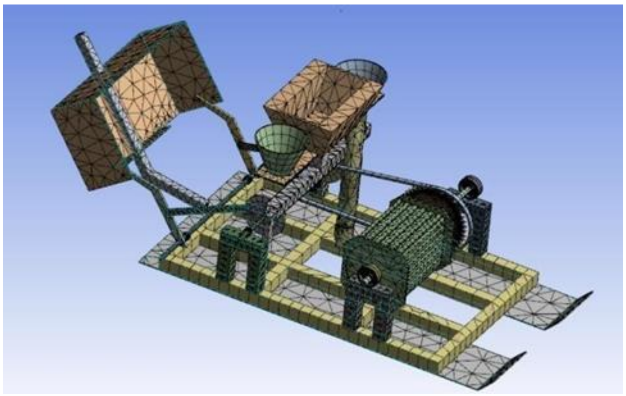

Fig 6. Meshed Model

In actual case the load acting is only the handle or seedling container rod. Hence the other parts are eliminated from the meshed and boundary

Conditions were given to the load part only.

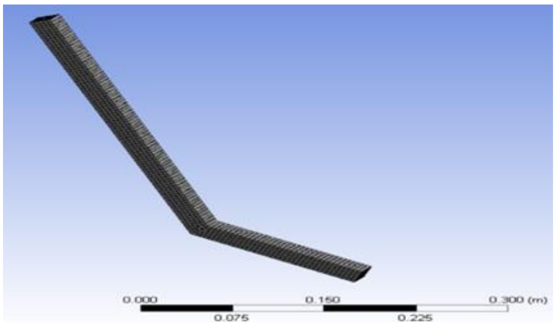

Fig 7. Meshed Load Part

Table 5. Material Properties

Element type	**Hex-dominant(fine)**
Number of elements	7474
Number of nodes	29351
Element size	4×10^(-3)m
Youngs modulus	2×10^11 pa
Poissons ratio	0.3

Table 5. displays mechanical properties of Structural Steel which was used to make the handle arm of the transplanter.

Boundary conditions were provided: First the base is fixed, secondly a load of 15 N will be concentrated upon the seedling container rod, as it is the main backbone of apparatus that carries whole weight and load under a certain dragging frictional force in a wet land.

It will be exerted in the horizontal direction parallel to the base. Base of the transplanter, being fixed, load will be zero in all the three directions [18].

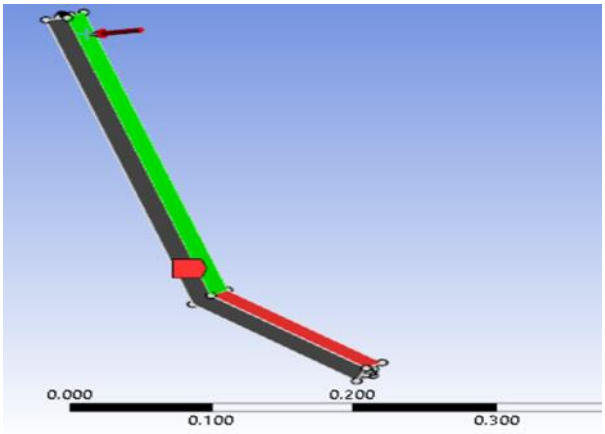

Fig 8. Force Direction

After all pre-processing procedures and definitions, the FEA simulation was run, and the results were recorded.

The deformation at the arm, is caused by the tensile strength of the body while dragging the transplanter. The deformation occurred at the junction of the part, over which the seedling tray is mounted, and the part of it which connects to the base.

C. Post- Processing

After giving the boundary conditions the analysis is carried out.

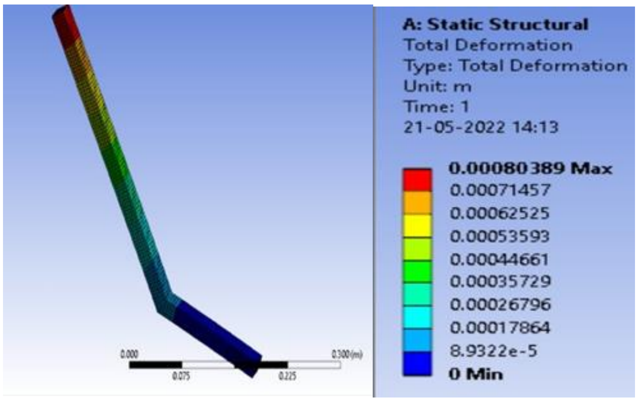

Fig 9. Total Deformation

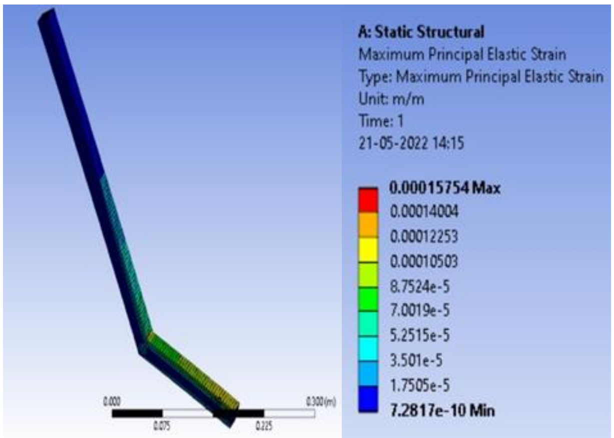

Fig 10. Maximum Principal Elastic Stress

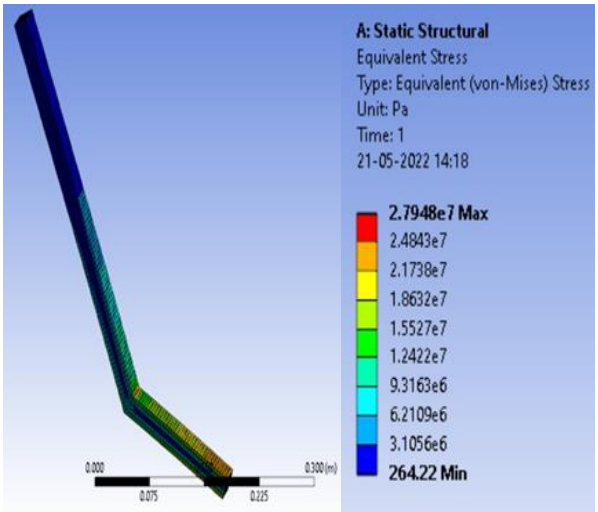

Fig 11. Equivalent Stress (Von-Mises)

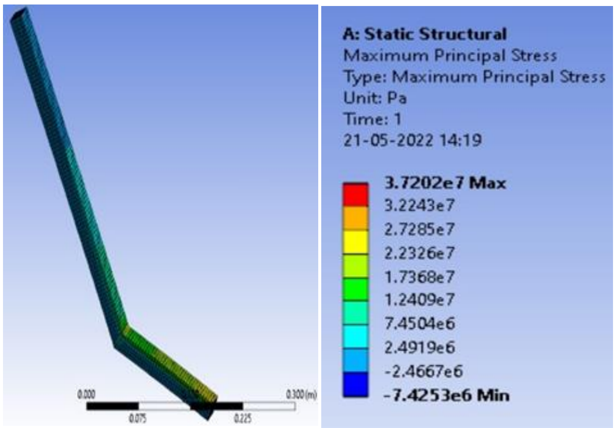

Fig 12. Maximum Principal Stress

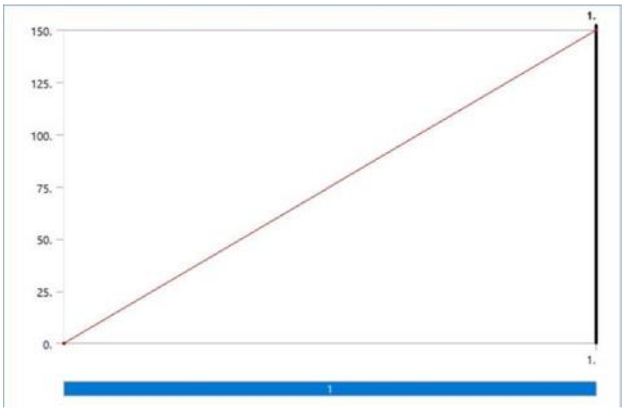

Fig 13. Graph for Analysis

D. Results and discussions

Stress distributions in the junction and locations of the critical regions and the premature fatigue failure, based on Von-Mises theory are shown in Fig 11. The greatest amount of stress is occurred at the junction. The highest stress was equal to 3.7×10^7N/m2.

These results showed that most stress in the arm occurs at the connection of the part of it having the seedling tray and part of it connected to the base, and therefore, it is worst likely to break.

After analysis result, we further identified ways to extend its sustaining capacity by withstanding the force experienced by rod.

a. The rod inner diameter is reduced to ¾ so that it become rigid to uphold the force.
b. Weight is a factor for this, so the material used for cabin and base plate is changed to aluminium and stainless steel instead of using mild steel. Herby the apparatus can uphold the extra weight for seedlings.
c. A welded triangular fillet is joined at the edge of the road and frame to make it rigid and bear more force

Calculations

Maximum principal stress is acting at the joint of rod and base plate.

There are two types of stresses acting on it

1. Direct tensile stress

2. Bending stress acting at the joint.

The calculations are as follows,

$$\sigma = P/A + (M/I)y \quad (1)$$

where,

P/A = Direct Stress acting at the joint.

(M/I)y = bending stress acting at the joint.

P = force = 150 N

A = Area of cross section = (202 - 72) mm2 = 351 mm^2

M =Bending Moment=150×350/√2 =37123.1060 N-mm

I = Area moment of inertia about neutral axis

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I = (204 – 74) / 12 = 13133.25 mm^2

y = Distance of the surface from neutral axis =10 mm

On putting all the values in the above eqn (1), we get,

σ = (150)/(351) + ((37123.1060)/(13133.25))10 σ = 2.86938 × 107 Pa ----------- Calculated value

Ansys value is;

σ = 2.7948 × 107 Pa ----- Calculated via software.

Error involved is around 2.59 %

Hence the design is validated.

Table 8. Result

Parameter	**Maximum**	**Minimum**
Total Deformation	8.0389e-004 m	0. m
Equivalent Stress	2.7948e+007 Pa	264.22 Pa
Principal Elastic Strain	1.5754e-004 m/m	7.2817e-010 m/m

Conclusion

A paddy field should be made levelized and watery to enhance good soil texture so that transplanter works efficiently [13-14]. Cost and sophisticated mechanical design are a major factor in this implant. It was difficult to do service and other repairs at a regular store. Since the design is simple, no work required and no operating costs required, easy maintenance by farmers, less effort required for handling, much cheap compared to high end transplanter models. These necessitates the requirement of compact paddy transplanter to avoid health issues with much less work

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