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# Development of Multipurpose Agricultural Equipment based on Lead user's Requirements

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**ABSTRACT:** Agriculture is one of the main contributors to the overall GDP of India. Presently, farmers who own small land use animals for the preparation of land. Improved hand tools will also facilitate farm work. Ploughs, riders, speeders, weeders cultivators are all some of the seasonal implements. The price of agricultural equipment has gone beyond the purchasing power of most small-scale farmers. Normally, cultivation of any crop involves various steps like the selection of seed, preparation of land, fertilizer application, sowing of seeds, irrigation, germination, thinning and filling, weed removal, vegetative stage, flowering stage, pesticide spraying, harvesting and threshing. Farmers use various agricultural tools and labor for performing these steps. Our purpose is to combine the individual tools mainly ploughing and leveling to provide farmers with multipurpose equipment which implements all the technical farming practices and specifications and suitable for the cultivation of crops with the least cost.

This paper is focused on the development of multipurpose equipment for ploughing and leveling process. The multipurpose agricultural equipment is cost-effective, compact and user friendly mainly aiming the small-scale farmers.

**KEYWORDS:** Agriculture, Ploughing, Rotary plough, Leveling, Small-scale farmer, Multipurpose, Lead user.

## I. INTRODUCTION

Indian Economy has agriculture as one of its vital sectors. In India, this sector contributes to 18 percent of India's gross domestic product (GDP) and 50% of the workforce gains employment from agriculture. Agriculture is one of the essential enterprises in the world. According to 2014 Food and Agriculture Organization (FAO) statistics, India is the world's largest producer of many fruits, vegetables and pulses. It ranks second in the world for the production of wheat and rice. India stands first in the world for the net cropped area under agriculture.

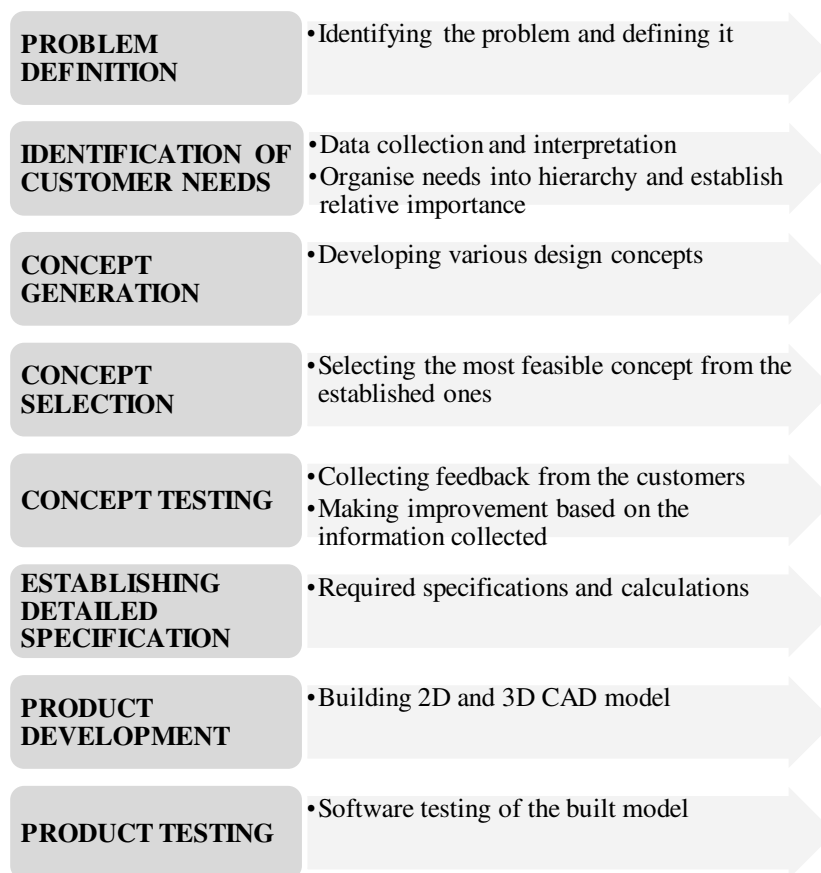
Over time deterioration is seen in production of some crops. There is an increase seen in farm inputs over years. Mechanization in farms helps increase land utilization, crop production etc.

The organization of the paper is as follows. Section II explains work related to the topic. Section III describes the methodology adopted in developing the equipment. Section IV presents the CAD model built and results obtained. Section V presents a conclusion followed by future scope and references.

## II. LITERATURE REVIEW

The idea of the rotary plough with the advantages associated with better soil breakup has been explained by Tharoon T et al [8]. The paper also aims at optimizing the parameters that affect the cutting action of the tool. This tool is designed such that both the blade tip and the length of the tiller blade can undertake to plough. S. Gebregziabhera et al [2] studied the considerations and design guidelines for improving tillage implements on a small-scale. The resultant vertical forces must be in equilibrium in case of stable operation and in the case of highly resistive soil, some force is required to be applied on the handle during the process of tilling to guide the plough. The design considered the effect of vibration of the plough perpendicular to the direction of the travel and lessen the draught requirement. Tejas P Phadnis et al [7] aimed at designing a ploughing tool at a low cost and in case of any failure in the tool body, the farmer

will have to replace only the tip of the tool and not the whole tool body. The sharpness of the tool will remain the same for a considerably long period. HSS is the material used for the tip of the tool. Hence the frequency of breakage of the tool is less. The tip that is designed can be used as a multipurpose tool for harvesting. Prof. V. N. Mujbaile et al [6] worked on semi-automating ploughing operation and thereby reducing manpower. Their work highlights the difficulty of the availability of electricity or components required for full automation in villages. Juan Quirós-Vargas et al [3] studied energy requirements in paddy cultivation. The implementation of Land levelling and Variable Slope had a good impact on the sustainability performance. The agricultural area which was levelled gave a higher yield when compared to the non-levelled area, hence it resulted in crop profitability and gain of energy efficiency. The case was analyzed by yield map, based on the information that was obtained by the yield monitoring system. Leveling provides sustainable performance and a higher yield.



### III. METHODOLOGY

We followed a methodology for carrying out this activity. It is depicted in figure 1.

**Problem definition:** Over the years small landholders (2-3 acres) use human labor, traditional tools and animals to cultivate their land. They find it difficult and expensive to use modern agricultural equipment. Therefore, the gap between this is identified and the equipment must be designed cost- effectively meeting their needs.

**Identification of customer needs:** The main objective of this paper is to cater to the needs of our end users. So, to conceptualize the design the method that we choose is to conduct a survey and interview our lead users. Data collection was carried out in three different places of Karnataka: Kangibettu, Udupi; Machohalli, Bangalore rural; D. Hosahalli, Tumkur. Totally 12 farmers were surveyed according to the survey questionnaire prepared.

Figure 1. Methodology used

The needs collected were interpreted as shown in table 1. These needs were later organized into the hierarchy in table 2 and their relative importance was established as in table 3.

Table 1. Needs matrix

Sl no	Customer statement	Interpreted needs
1	It should be affordable.	The equipment should be in the range of 10000 INR- 15000 INR.
2	Should be light and small.	It should be portable and easy to transport.
3	Can be used for more functions.	The modularity of functions.
4	Running costs should not be more.	Minimum operating cost.
5	Should not waste the produce.	Equipment must be effective.
6	Should not cause harm to crop.	Equipment must perform its operations without destroying the crops.
7	Can be used for different crops.	It should be able to plough and level soil for other crops.
8	Should not use more labours.	It should be handled with one or two persons.
9	Should last a lifetime.	The quality of equipment must be good.
10	Should be a useful investment.	It should perform as expected.
11	It should be used for a different land.	It should be able to plough various kinds of soil.
12	It should be easy to use at later times.	Easy to maintain.

Table 2. Hierarchical arrangements of needs

<b>Primary needs</b>
The equipment should be in the range of 10000 INR- 15000 INR.
The modularity of functions.
It should be portable and easy to transport.
It should be handled with one or two persons.
The quality of equipment must be good.
Equipment must be effective.
Equipment must perform its operations without destroying the crops.
Easy to maintain.
<b>Secondary needs</b>
It should be able to plough various kinds of soil.
It should perform as expected.
It should be able to plough and level soil for other crops.

Table 3. Importance of needs

Sl no.	Need	Importance
1	The equipment should be in the range of 10000 INR- 15000 INR.	5
2	It should be portable and easy to transport.	5
3	The modularity of functions.	4
4	Minimum operating cost.	2
5	Equipment must be effective.	3
6	Equipment must perform its operations without destroying the crops.	2
7	It should be able plough and level soil for another crop.	1
8	It should be handled with one or two persons.	3
9	The quality of equipment must be good.	3
10	It should perform as expected.	2
11	It should be able to plough various kinds of soil.	1
12	Easy to maintain.	3

**Concept generation:** During this phase, we followed a four-step process which is as follows: 1. Clarification about the problem. 2. External search for the related topics. 3. Internal search. 4. Reflection on the solution. From this, we came out with the functional diagram of our product as in figure 2.

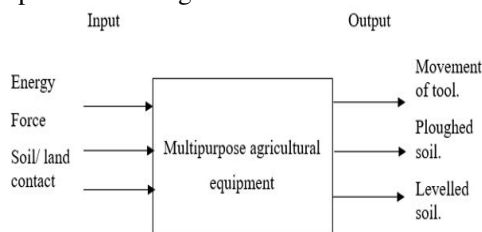


Figure 2. Functional diagram

**Concept selection:** Here we evaluated many various concepts and selected a rotary plough with bucket-shaped leveling tool using Pugh's method of evaluation. The selection criteria are shown below and the selection matrix in table 4 and 5.

For ploughing

- Does the equipment plough soil thoroughly as per the requirement?
- Does the equipment increase the quality of land ploughed?
- Is it easy to fabricate?
- Will fabrication be economical?
- Are the materials easily source-able?
- Ease of use.
- Does it meet the requirement?
- Is it portable?
- The safety aspect of mechanism.
- Does the concept have advantages?
- Does that maintain the fertility of ploughed land?
- Will there be a required depth of cut?
- It is suitable for wet or dry condition?

For levelling

- Does the equipment level the soil as needed?
- Ease of fabrication.
- Will fabrication be economical?
- Does the equipment increase the quality of levelled land?
- Are the materials easily source-able?
- Ease of use.
- Does it meet the requirement?
- The safety aspect of the equipment.
- Is it portable?
- Does the concept have advantages?
- Does it maintain the fertility of levelled land for the next operations?

Table 4. Pugh's selection matrix for ploughing tool

Selection criteria	Weight	Concepts for plough							
		Chisel		Disc		Rotary		Mould board	
		Rating	Score	Rating	Score	Rating	Score	Rating	
a	5	0	0	0	0	+	5	+	
b	4	0	0	-	-4	+	4	+	
c	5	0	0	+	5	-	-5	-	
d	4	+	4	+	4	-	-4	0	
e	4	0	0	+	4	0	0	-	
f	4	-	-4	-	-4	+	4	-	
g	3	-	-3	0	0	+	3	-	
h	3	0	0	-	-3	+	3	-	
i	2	0	0	0	0	0	0	0	
j	1	0	0	+	1	+	1	-	
k	4	0	0	+	4	+	4	-	
l	5	+	5	0	0	0	0	0	
m	3	0	0	+	3	+	3	-	
Sum + 's		2		6		8		2	
Sum 0's		9		4		3		3	
Sum - 's		2		3		2		8	
Net score		0	2	3	10	6	18	-6	
Rank		3	3	2	2	1	1	4	
Continue?		Yes		Yes		Yes	Yes	No	



Table 5. Pugh's selection matrix for leveling tool

Selection criteria	Weight	Concepts for leveling tool					
		Flat scraper	Bund former		Rod-shaped roller	Bucket shaped	
		Rating	Rating	Score	Rating	Rating	Score
a	5	-	+	5	0	+	5
b	4	0	-	-4	+	-	-4
c	4	+	0	0	-	0	0
d	5	-	0	0	-	+	5
e	3	+	0	0	-	0	0
f	4	0	-	-4	-	+	4
g	3	-	+	3	0	+	3
h	2	0	+	2	-	+	2
i	2	0	-	2	0	-	-2
j	1	-	+	1	0	+	1
k	2	0	+	2	0	+	2
Sum + 's		2	5		1	7	
Sum 0's		5	3		5	2	
Sum - 's		4	3		5	2	
Net score		-2	2	7	-4	5	16
Rank		3	2	2	4	1	1
Continue?		No	Yes		No	Yes	Yes

**Concept testing:** We selected the same farmers to collect their feedback about the product being developed. The questions that were raised to farmers are as follows:

- Will the product be able to fulfill your requirements?
- Will the plough tool and leveling tool be sufficient for your land?
- Can we go with this concept?
- Is the concept satisfying you?
- Will you buy if the product is developed?
- Would you be allowing us to test the prototype in your field once developed?
- How can we improve this according to your need?
- What do you think about this product?

The responses that we got from farmers are shown in table 6. We got many inputs from the farmers and we tried to inculcate them in our product.

Table 6. Farmer's response

Questions	Farmer responses											
	Farmer 1	Farmer 2	Farmer 3	Farmer 4	Farmer 5	Farmer 6	Farmer 7	Farmer 8	Farmer 9	Farmer 10	Farmer 11	Farmer 12
a	Yes	Yes	Yes	No	Yes	Yes	May be	No	Yes	Yes	Not sure	Yes
b	Not sure	Yes	Yes	Yes	No	Yes	Yes	Not sure	Yes	Yes	Yes	May be
c	Yes	No idea	No idea	Yes	Yes	Yes	Yes	Yes	No idea	Yes	Yes	Yes
d	Yes	Yes	Yes	Yes	Mostly	Yes	Yes	Yes	Mostly	Yes	Yes	Yes
e	Yes	May be	Yes	Yes	Yes	Yes	No	No	May be	Yes	Yes	Yes
f	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

#### Establishing detailed specification:

- Engine:** The engine is used to provide power to the equipment and is mounted on the chassis. The specification of the engine that we selected is shown below.

Technical specification	
Displacement	50cc
No of cylinder	1
Cold style	Air-cooled
Stroke	2 strokes
Max. Power	2hp@7000rpm
Fuel	Gas and oil mixture

**2. Shaft:** The shaft is used to supporting the two rotary plough wheels and has a sprocket mounted on it to receive motion from the engine through a chain. It is subjected to bending, torsion and axial load. Considering all these loads the design of the shaft is as follows.

The material chosen is carbon steel. The mechanical properties from DHB are:

- Yield strength-370 MPa
- Ultimate tensile strength- 440Mpa

Endurance limit modifying factors on the shaft is:

$$S_e = k_a k_b k_c k_d k_e k_f S'_e$$

I. Surface factor,  $k_a$

$$k_a = a S_{ut}^b$$

Where  $S_{ut}$  is the minimum tensile strength and a and b are taken from DBH.

For machine and cold drawn,  $a = 4.51$  and  $b = -0.265$ .

$$\text{Therefore, } k_a = 4.51 (370)^{-0.265} = 0.94$$

II. Size factor,  $k_b$

$$k_b = 1.51 d^{-0.157}$$

For axial loading, the size factor is 1.

III. Loading factor,  $k_c$

The shaft is subjected to rotating bending, axial and torsional loading. The average values for load factor are:

$$K_c = \begin{matrix} 1, & \text{bending} \\ 0.85, & \text{axial} \\ 0.59, & \text{torsion} \end{matrix}$$

IV. Temperature factor,  $k_d$

Any stress will induce creep at a higher temperature, so considering the temperature to be  $50^\circ \text{C}$ .

$$\text{Therefore, from DBH, } k_d = ST / S_{rt} = 1.0$$

V. Reliability factor,  $k_e$

Data presented by Haugen and Witching show standard deviations of endurance strengths of less than 8 percent.

Hence, the modification factor for reliability to justify this can be written as  $k_e = 1 - 0.08 Z_a$

Where the value for  $Z_a$  is obtained from DBH. Considering 95% reliability,  $k_e = 0.868$

VI. Stress concentration factor and notch sensitivity

$$\text{Notch sensitivity} = q = k_f - 1 / k_t - 1$$

For shear,  $k_t = 1.65$  and considering  $q = 0.85$

$$\text{Therefore, } k_f = 1 + 0.85(1.65 - 1) = 1.55$$

VII. Endurance limit,  $S'_e$

It is half of the ultimate tensile strength,  $S'_e = 0.5 * 440 = 220 \text{MPa}$

Therefore,

- The endurance limit for bending,  $S_e = 0.94 \times 1 \times 1 \times 1.0 \times 0.868 \times 1.55 \times 220 = 278.22 \text{MPa}$
- The endurance limit for torsion,  $S_e = 0.94 \times 1 \times 0.59 \times 1.0 \times 0.868 \times 1.55 \times 220 = 164.15 \text{MPa}$
- The endurance limit for axial load,  $S_e = 0.94 \times 1 \times 0.85 \times 1.0 \times 0.868 \times 1.55 \times 220 = 236.49 \text{MPa}$

Let A = clearance, B = wheel space, C = space between two rotary wheels

$$\text{Therefore, length of the shaft, } L = 2A + 2B + C = 2(30) + 2(30) + 590 = 710 \text{mm}$$

Considering the loss in transfer from engine to shaft,

$$\text{Power available for shaft: } 0.87 \times 2 = 1.74 \text{hp} = 1.3 \text{kW}$$

Considering the speed,  $v = 3 \text{km/h}$

$$U/V = 5, U = 5 * 3000/3600 = 4.17 \text{m/sec}$$

$$U = \frac{2 \pi N R}{60}, \text{ considering radius of the wheel, } R = 210 \text{mm, } N = 190 \text{rpm}$$

$$\text{Power transmitted by shaft, } P = \frac{2 \pi N T}{60}$$

$$\text{Therefore, } T = 65.34 \text{ Nm}$$

$$\text{Calculating bending moment, } M_b = Wl/4$$

$$\text{Considering, weight to be } 250 \text{N, } M_b = 250 * 0.710/4 = 44.375 \text{Nm}$$

Minimum diameter calculation,

For the design of shaft, there are combined shock and fatigue factors. From DBH, for rotating shaft with minor shock loads, we have  $K_b = 1.5$  and  $K_c = 1.0$

$\tau = \sigma / 3 = 370 / 3 = 123.33 \text{ Mpa}$ , taking FOS as 3.

Equivalent twisting moment is given by the formula,

$$T_E = \sqrt{(K_b M)^2 + (K_t T)^2} = \sqrt{(1.5 \times 44.375 \times 1000)^2 + (1 \times 65.34 \times 1000)^2}$$

$$T_E = 93273.16 \text{ Nmm}$$

Using the equation to calculate the diameter of the shaft,

$$d^3 = \frac{16}{\pi (1-K) \tau} \sqrt{(K_b M)^2 + (K_t T)^2}, K = 0 \text{ as there is no keyway}$$

$$d^3 = \frac{16}{\pi \times 1 \times 123.33} \times 93273.16 = 3689.57$$

$$d = 15.68 \text{ mm}$$

The minimum diameter is 15.68mm. Here we choose standard diameter  $d = 25 \text{ mm}$ , which is safe.

**3. Frame:** It is used to mount all the components and engine. It is made up of mild steel squares.

Specifications: Size: 40mm x 40mm; Thickness: 5mm

Dimensions: Length: 850mm; Breadth: 350mm

**4. Transmission system:** It involves a sprocket and chain to transmit motion from engine to shaft.

Sprocket: Dimensions of sprocket:

a) Larger sprocket	b) Smaller sprocket
No. of teeth: 18	No. of teeth: 42
Diameter: 75mm	Diameter: 180mm
Pitch: 11mm	Pitch: 11mm

Chain:

Driver sprocket,  $T = 18$

Therefore, driver diameter,  $D = \text{Pitch} / \sin(180/T)$

$$D = 11 / \sin(180/18) = 63.35 \text{ mm}$$

Therefore, design is safe.

Driven sprocket,  $t = 42$

$$d = \text{Pitch} / \sin(180/t) = 11 / \sin(180/42) = 147.2 \text{ mm}$$

Hence the design is safe.

Dimensions of chain:

Length of chain is given by the formula,  $L = Kp$

Where  $K = \text{no. of links}$

$$K = \left[ \frac{(T + t)}{2} + \frac{(2C)}{p} + \left\{ \frac{(p/c) ((t - T) / 2\pi)^2}{2} \right\} \right]$$

$$\text{Where } C = (D + d)/2 = 127.5$$

$$K = 54.44 = 54$$

Length of chain: 596mm

Pitch: 11mm

**5. Pillow block:** It is used to support the shaft with compatible bearings and other accessories.

1. Housing, Cast Iron,  $L = 140 \text{ mm}$
2. Outer ring, Inner ring, Cast Iron
3. Grease nipple
4. Ball and cage
5. Nut, bolt and washer, M12

**6. Rotary plough wheel:** The wheel has L-shaped blades to plough the soil. These blades are welded to the disc of the wheel. It has eight blades at an angle of  $45^\circ$  including both sides i.e four blades on one side.

Blade

Radius of the wheel = 210mm

Type of blade: L Shape

Working depth: 10-15 cm

Length of soil slices: 6-15cm

Therefore, from DBH,  $C_0 = 3$ ,  $\alpha = 500$ ,  $K_i = 0.21$

Specific work,  $A = A_O + A_B$

$$A_O = C_0 \times K_i = 3 \times 0.21 = 0.63 \text{ Kg/cm}^2$$



$$A_B = 0.001 \alpha \times v^2 = 0.5 \times 0.83^2 = 0.345 \text{ Kg/cm}^2$$

$$A = 0.97 \text{ Kg/cm}^2$$

$$\text{Bite length, } L = \frac{v \times 60}{N \times Z}, \text{ where } Z = 4 \text{ blades in a plane}$$

$$\text{Therefore, } L = (3 \times 0.28 \times 60) / (190 \times 4) = 0.066 \text{ m}$$

$$\text{Total no of discs faces} = 4$$

$$\text{Total no of blades} = 4 \times 4 = 16$$

$$\text{Assuming } 1/4 \text{ of blade will be striking soil, } K_0 = T / R = 311.14 \text{ N}$$

$$\text{Therefore, per blade } K_0 = 311.14 / 4 = 77.78 \text{ N per blade}$$

$$\text{Considering FOS} = 2$$

$$K_0 = 2 \times 77.78 = 155.57 \text{ N}$$

$$M = K_0 \times R = 155.57 \times 0.21 = 32.67 \text{ Nm}$$

$$\sigma = (M \times 36) / h^3 = 32.67 \times 36 / h^3$$

$$\text{Torsional stress, } \sigma_t = (2 \times K_0 \times S) / (2/9 \times b^2 \times h); b/h = 1/6$$

$$\text{Torsional stress} = 97965 / h^3$$

$$\text{Eq. stress} = \frac{1}{2} \sqrt{\sigma^2 + 4 \sigma_t^2}$$

$$\text{By substituting the values, we obtain Eq. stress of carbon steel} = 1080 \text{ Kg/cm}^2$$

$$\text{Therefore, from torsional stress equation we obtain, } h = 4.5 \text{ cm and } b = 0.75 \text{ cm}$$

$$\text{Thickness of the blade} = 7.5 \text{ mm and width of the blade} = 45 \text{ mm}$$

$$\text{The thickness that we have considered is 8 mm and width is 55 mm. Hence, the design of the blade is safe.}$$

## 7. Leveling tool

It is a tool that is used to level the soil after it is ploughed. Here bucket-shaped mild steel leveling tool is designed.

Dimension: 415mm \* 50mm \* 140mm with thickness as 10mm.

## IV. RESULTS

We developed the CAD model based on these calculations as shown in figure 3. The model was then analysed in ANSYS software and was shown to be a safe design. The stress, strain and deformation of the tools are shown in figure 4. A force of 300N was applied in the analysis. The maximum deformation was found to be 0.2.

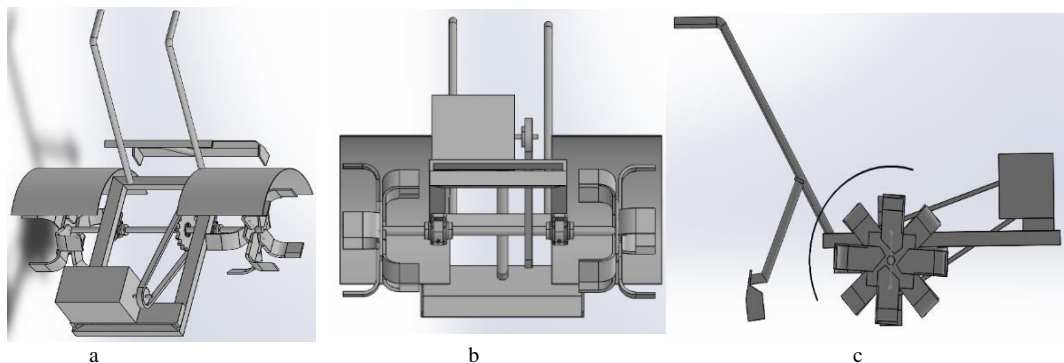


Figure 3. 3D CAD model of multipurpose agricultural equipment (a) Isometric view (b) Front view (c) Side view

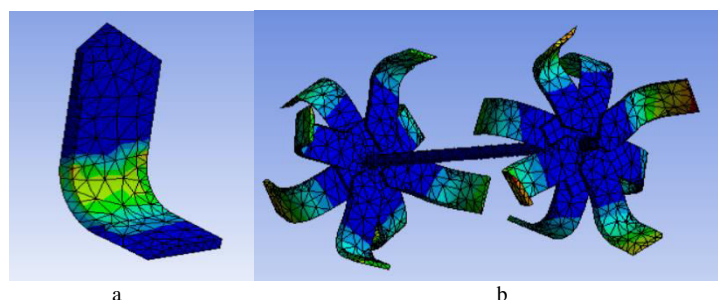


Figure 4. ANSYS analysis results (a) Stress analysis of plough blade (b) Deformation analysis of plough tool



## V. CONCLUSION

We have developed multipurpose agricultural equipment based on the needs of lead users. The equipment is capable of ploughing by using rotary blades of L shape and levels the soil after ploughing is done. It is semi-automated equipment which can be used easily by farmers holding small land area.

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