Design and Development of New Mulching Machine for Agriculture

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Abstract – This paper establishes the design and development of agricultural mulch transplanter apparatus used for covering the soil/ground to make more favourable conditions for plant growth, moisture conservation, weed control, development and efficient crop production rate. Major topics discussed are (1). History of mulching machine and plastic mulch, (2). Basic model of mulching machine, mechanism and its limitations, (3). Selection of materials, development of new mulching machine and its design, and (4). Fabrication and assembly of new mulching machine. The invention of spreading of mulching paper machine for covering the soil is chosen on the basis of technical and economic parameters, way of utilization and external economic conditions of the agricultural enterprise. This paper presents a new modified design model solution to the choice of a suitable basic model mulching machine set for spreading of polyethylene black mulch paper on soil. It has been found and developed a new mulching machine of optimum cost sturdy construction, fine finish, easy to operate for the unskilled farmer can do and poor farmer can purchase with the invention comprises novel constructions, combinations, and arrangements of components.

Keywords— Plastic Mulch; Mulching Machine; 3D Model; Fabrication.

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1. INTRODUCTION

Advancements in development of mulching on growth and yield of annual and perennial crops have long been identified [1, 2, and 3].

Specifically, mulching with organic or inorganic materials aims to cover the soils and forms a physical barrier to limit the evaporation of water from the soil, automatic control of weeds, preserve a good soil structure, and protecting the crops from soil contamination. Naturally available mulches are those derived from animal and plant materials, if they are used accurately; they can proffer all the advantages and profits of other types of mulches available. Natural mulches help in maintaining soil organic matter and tilth and provide food and shelter for earthworms and other desirable soil biota [4, 5]. However, natural mulching materials are not available in sufficient amounts, their quality is inconsistent, and they require more labour for spreading. Natural mulches do not always provide sufficient weed control; they may also carry weed seeds and repeatedly slow down the soil warming in spring season and such condition can delay the growth and ripening in warm season vegetables [6, 7]. The straw mulches often contaminate the soil with weed seeds and deplete the seedbed nitrogen because of their high carbon-to-nitrogen (C/N) ratio. Organic materials that have a high C/N ratio such as grain straw may temporarily immobilize soil nitrogen as they decompose, although humified organic matter accumulated from long-term straw mulching sometimes results in net mineralization of N [8, 9]. Natural mulch harbors pests such as termites, slugs, snails, earwigs, etc. Natural mulches are reported to reduce soil temperature and evaporation, but do not invariably cause higher yields [10, 11]. Therefore, natural mulches could not be used efficiently in crop production during all the seasons. To overcome some of the problems outlined above, paper and plastic mulches have been developed and are most suitable in agriculture.

Paper mulches were used regularly, had attracted and drawn a good deal of attention in the early 1920s. The paper mulches were not employed for commercial vegetable productions due to their short life, as well as the cost of material accessible and labour, which was not still mechanized [12]. Thus, the trend has been set towards the use of synthetic mulches such as films made of formulations of paper, which includes combinations of paper and polyethylene films, foils and waxes. Petroleum and resin mulches were also developed for arid climates at the same time. Nowadays, synthetic mulches including thin sheets of plastics, papers, and petroleum materials present more advantages over natural mulches available. Of these mulches, only those made of polyethylene are still widely used today in the agricultural industry as shown in Figure 1. Plastic film used as mulch has revolutionized the age-old technique of mulching.

Fig.1. Fresh market tomato production using raised beds covered with polyethylene mulch

Waggoner et al. described microclimatic changes caused by various mulches such as polyethylene film, straw, paper, and aluminium films and concluded that polyethylene film mulch was the most effective method of mulching [13].

Methods of mulching

- Orchard/Fruit/Established trees
- It is desired that mulching area should possibly be equivalent to the canopy of the plant.
- Required size of mulch film is cut from the main roll.
- The required area must be cleaned by removing stones, nuggets, pebbles, weeds etc.
- Till the soil well and apply a little quantity of water before mulching [14].
- To facilitate anchoring of the mulch film, the small trench could be made around the periphery of the mulching area.
- The entire area around the tree must be covered from the mulch film and the end should be buried in the soil ground.
- In order to assist the water movement easily, semi circular holes could be made at four corners of the film.
- The position of the slit/opening should be as much as possible parallel to the direction of wind.
- Cover the corners of the film with 4-6 inches of soil on all sides to keep the mulch film in position accurately.
- In hard soil, make a trench of 1'x1'x2' depth on four corners of the mulching area and fill it up with gravel or stones, wrap the trenches with the mulch film and permit the water to pass through the mulch to the trenches through semi circular holes on the much film.

Mulch Laying Techniques [14]

1. Mulch should be laid on a non-windy condition
2. The mulch material should be held tight without any crease and laid on the bed.
3. The borders (10 cm) should be anchored inside the soil in about 7-10 cm deep in small furrows at an angle of 45°.

The main objective of this research paper is design and development of mulching machine for spreading of mulch paper for covering of soil in order to provide a barrier to soil pathogens, to limit the water losses and conserves moisture, to maintain a warm temperature even during night time which enables seeds to germinate quickly and for young plants to rapidly establish a strong root growth system with the aim to assess and determine minimum justified annual utilization of mulching machines of various manufacturers from the economy point of view.

2. BASIC MODEL AND MECHANISM

Figure 2 shows the front and profile views of basic drafting mechanism, which consists of a punch which forces the much paper outside, plough and wheel insists for further movement, a lever is a rigid body capable of rotating on a point on itself, a handle is a part of, or attachment to, an object that can be moved or used by hand. Figure 3 shows the modelling of mulching mechanism in different positions.

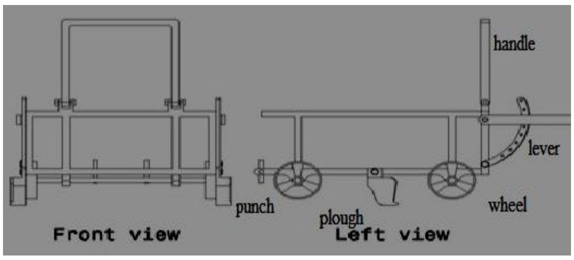

Fig. 2. Drafting of Mechanism

Limitations of Basic Model

- Width is fixed so it is not useful for all types of beds

- Width adjustment is complicated because of throughout shaft

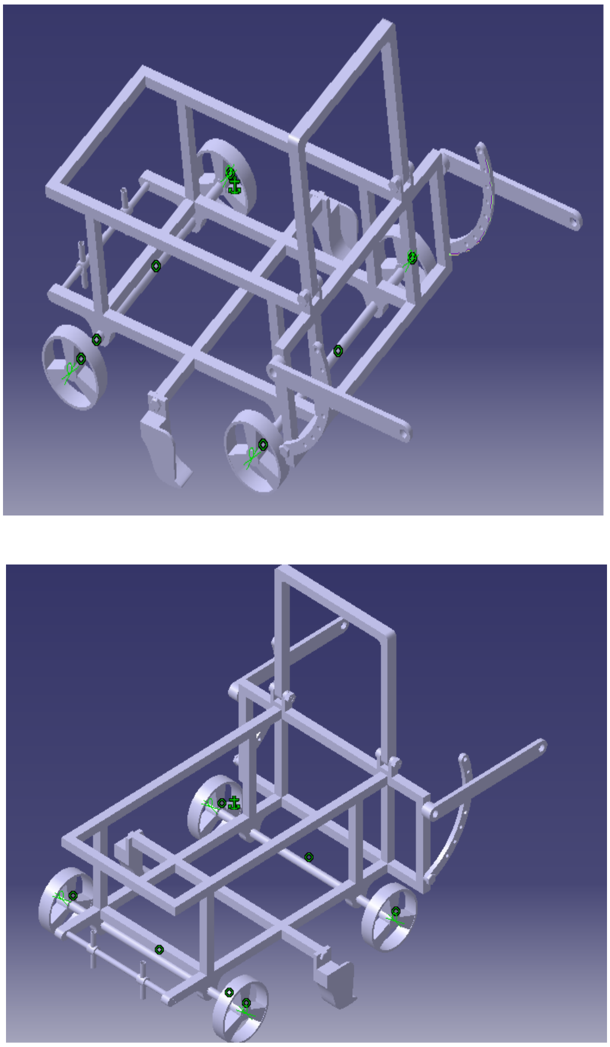

Fig. 3: 3D modelling of Mechanism

3. RESULTS AND DISCUSSIONS

3.1. Developed Model

In order to overcome the limitations observed in the basic model, authors made specific desired and sophisticated technical modifications in design and developed new model. Figure 4 predicts the front, top and profile views of developed model of drafting mechanism which is practically applied for spreading of mulch paper to cover the soil. Similarly Figure 5 shows the developed 3D model of the same.

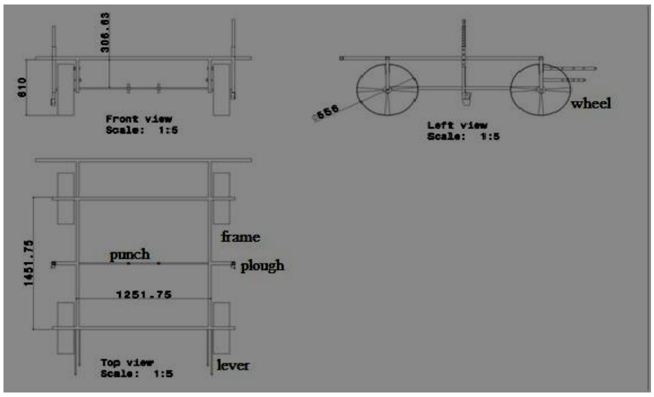

Fig. 4: Drafting of Developed Model

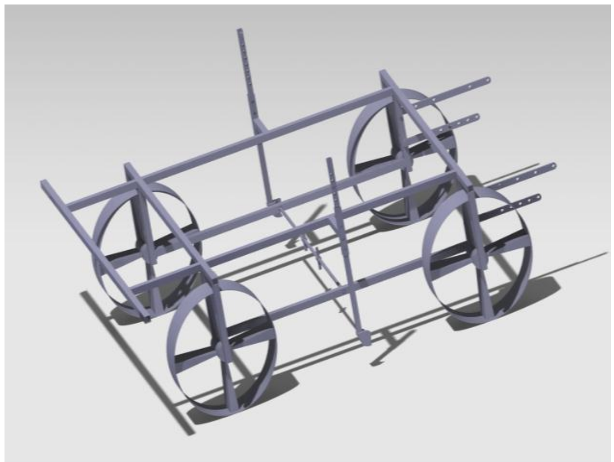

Fig. 5: Developed Model in 3D

Advantages of Developed Model

- Shaft is eliminated so width adjustment is easily possible
- Useful for various sizes of bed width
- Can be used as trolley

3.2. Design Considerations

Selection of materials

Material is selected from the Product Range Available - Tata Structure Square Hollow Sections and Market survey by considering the availability of material in the market. Table 1 and 2 show the properties of selected material of square hollow section (SHS) and product range: Square Hollow Sections (SHS) respectively.

Table No. 1: Properties of Square Hollow Sections (SHS)

Properties of Tata Structura (Square Hollow Sections) — YST 310 Grade

SHS B x B mm	Thickness mm	Sec Area A cm^2	Unit W Kg/m	Moment of Inertia I_{xx} cm^4	Moment of Inertia I_{yy} cm^4	Radius of Gyration r_{xx} cm	Radius of Gyration r_{yy} cm	Elastic Modulus Z_{xx} cm^3	Elastic Modulus Z_{yy} cm^3	Torsional Constants J cm^4	Torsional Constants B cm^3	Outer Surface Area per m m^2
25x25	2.00	1.74	1.36	1.48	1.48	0.92	0.92	1.19	1.19	2.29	1.68	0.090
	2.60	2.16	1.69	1.72	1.72	0.89	0.89	1.38	1.38	2.68	1.92	0.087
	3.20	2.53	1.98	1.89	1.89	0.86	0.86	1.51	1.51	2.96	2.07	0.084
32x32	2.00	2.30	1.80	3.36	3.36	1.21	1.21	2.10	2.10	5.30	3.05	0.118
	2.60	2.88	2.26	4.02	4.02	1.18	1.18	2.51	2.51	6.45	3.63	0.115
	3.20	3.42	2.69	4.54	4.54	1.15	1.15	2.84	2.84	7.41	4.07	0.112
38x38	2.60	3.51	2.75	7.14	7.14	1.43	1.43	3.76	3.76	11.51	5.49	0.139
	3.20	4.19	3.29	8.18	8.18	1.40	1.40	4.30	4.30	13.45	6.28	0.136
	4.00	5.03	3.95	9.26	9.26	1.36	1.36	4.87	4.87	15.67	7.12	0.131
40x40	2.60	3.72	2.92	8.45	8.45	1.51	1.51	4.22	4.22	13.63	6.20	0.147
	3.20	4.45	3.49	9.72	9.72	1.48	1.48	4.86	4.86	16.00	7.12	0.144
	4.00	5.35	4.20	11.07	11.07	1.44	1.44	5.54	5.54	18.75	8.12	0.139
50x50	2.60	4.76	3.74	17.47	17.47	1.92	1.92	6.99	6.99	28.53	10.37	0.187
	2.90	5.25	4.12	18.99	18.99	1.90	1.90	7.60	7.60	31.15	11.23	0.185
	3.60	6.35	4.98	22.15	22.15	1.87	1.87	8.86	8.86	36.58	12.98	0.181
	4.50	7.67	6.02	25.50	25.50	1.82	1.82	10.20	10.20	41.99	14.68	0.177

Table No. 2: Product Range: Square Hollow Sections (SHS)

Section Size: Tube Dimension (mm) B	B	Wall Thickness (mm) = t: 2.0	2.6	2.9	3.2	3.6	4.0	4.5	4.8	5.0	5.4	6.0	8.0
25	25	■	■		■								
32	32	■	■		■								
38	38		■		■		■						
40	40		■		■		■						
50	50		■	■		■		■					
60	60		■		■		■		■				
72	72				■		■		■				
80	80				■		■		■				
91.5	91.5					■		■			■		
100	100						■			■		■	
113.5	113.5								■		■		
132	132								■		■		
150	150						■			■		■	■
180	180						■			■		■	■
220	220									■		■	■
250	250											■	■

Orange box sizes are for large diamete

3.3. Design of Body

Material selected for Body is YST 310 Grade, Square hollow pipe

Size of section: 25×25 mm

Thickness of Section: 2 mm

Total Weight of act on body = 60 kg

$= 60 \times 9.81$ N

$= 588.6$ N

The weight on one hallow square bar = 30 kg **=** $30 \times 9.81 = 294.3$ N

Data is taken from Table No. 2.

$x = y = 12.5$ mm

Area = $174\ mm^2$

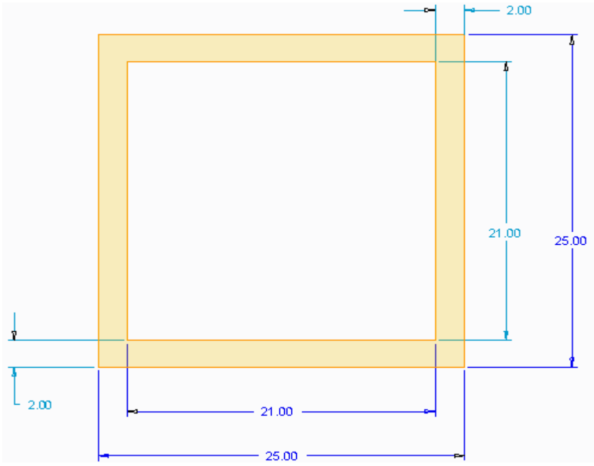

Fig. 6. The design of design of the body

The design and safe considerations of support plate is analysed and calculated below.

Moment of Inertal in x − x direction, I_{xx} = **14800 mm**^{4}

Distace of neutral axis, $y = 12.5\ mm$

Maximum bending moment of the square pipe is given by

$$m_b = \frac{wl^2}{12} = \frac{294.3 \times 1^2}{12} = 24.525\ Nm = 24525\ Nmm \qquad (1)$$

$$\frac{m_b}{I} = \frac{\sigma_b}{y}$$

$$\sigma_b = \frac{24525 \times 12.5}{14800} = 20.71\ N/mm^2 \qquad (2)$$

Now, theoretical bending stress is given by eqn.

$$\sigma_{b(th)} = \frac{Syt}{f.s} = \frac{310}{1} = 310\ N/mm^2 \qquad (3)$$

As $\sigma_b < \sigma_{b(th)}$,

hence the design is safe.

3.4. Buckling of column,

Material for Column is YST 310 Grade,

Slenderness ratio,

$$\frac{l}{k} = \frac{330}{9.2} = 35.86 \quad (4)$$

According to boundary line between Johnson's and Euler's equation is given by,

$$\frac{S_{yt}}{2} = \frac{n \times \pi^2 \times E}{\left(\frac{l}{k}\right)^2}$$

$$\left(\frac{l}{k}\right)^2 = \frac{n \times \pi^2 \times E \times 2}{S_{yt}}$$

$$\left(\frac{l}{k}\right)^2 = \frac{4 \times \pi^2 \times 210 \times 10^3 \times 2}{310} = 53486.88$$

$$\frac{l}{k} = 231.27 \quad (5)$$

Since, the slenderness ratio of the sq. pipe is (35.86) is less than (231.27), the bar is treated as a short column and Johnson's equation is applicable.

$$P_{cr} = Syt \times A \times \left[1 - \frac{Syt}{4 \times n \times \pi^2 \times E} \times \left(\frac{l}{k}\right)^2\right]$$

$$= 310 \times 174 \left[1 - \frac{310}{4 \times 4 \times \pi^2 \times 210 \times 10^3} \times (35.86)^2\right]$$

$$= 53291.58\ N$$

Safe compressive force is given by,

$$P = \frac{P_{cr}}{F.s} = \frac{53229.58}{1} = 53291.85\ N$$

3.5. Design of support plate

Figure 7 shows the design of support plate.

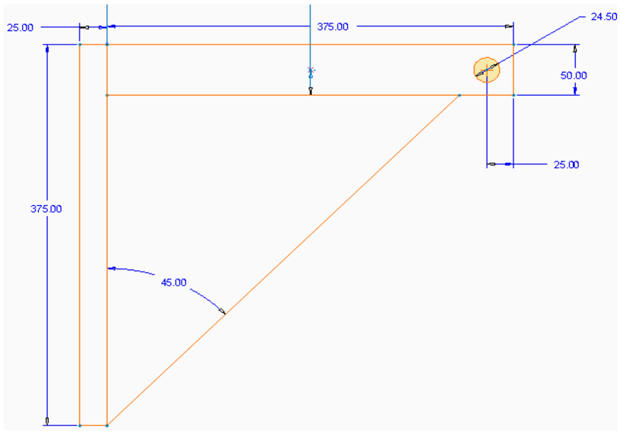

Fig. 7. The design of design of the support plate

The design and safe considerations of support plate is analysed and calculated below.

$$A = b \times d = 6 \times 50 = 300\ mm^2$$

$$P = 15 \times 9.81 = 147.15\ N$$

Total bending moment at fix end pt is zero.

Bending moment of the cantilever beam is given by

$$M_B = 76.2 \times 147.15 = 11212.63\ Nmm.$$

Bending equation is given below

$$\frac{m_b}{I} = \frac{\sigma_b}{y}$$

i.e., Section Modulus, $Z = \frac{I}{y} = \frac{6 \times 50^3}{12 \times 25} = 2500\ mm^3$

Maximum bending stress for cantilever beam is given by,

$$\sigma_b = \frac{(M_b)_B}{z} = \frac{11212.83}{2500} = 4.4851\ N/mm^2$$

Now, Calculate $\sigma_{b(th)}$

For the Material of plate is 30C8,

i.e. Syt **is 400** N/mm^2

Similarly, the theoretical bending stress of the cantilever beam is,

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$$\sigma_{b(th)} = \frac{Syt}{f.s} = \frac{400}{1} = 400\ N/mm^2$$

Here, $\sigma_b < \sigma_{b(th)}$

So, Design is safe.

Similarly, for AB is cantilever beam

Z = 2500 mm^3

$$(M_b)_{\max} = \frac{5wl}{32}$$

$$= \frac{5\times147.5\times381}{32}$$

=8780.8593 N/mm^2

$$\sigma_b = \frac{(M_b)_{max}}{z}$$

$$= \frac{8780}{2500} = 3.51\ N/mm^2$$

Now, calculate $\sigma_{b(th)}$

$$\sigma_{b(th)} = \frac{Syt}{f.s} = \frac{324}{1} = 324\ N/mm^2$$

Here, $\sigma_b < \sigma_{b(thero)}$

So, the design is safe.

3.6. Fabrication and Assembly

3.6.1. Body

The specifications of body material used in design and development of mulching machine are as given below-
.

Material- Grade YST 310

Size: =$25 \times 25\text{mm}$, Thikness-2mm

Shape- Square Hollow Pipe

Fig. 8. Finished Design and developed Mulching machine

Process of Fabrication

1. Cutting of raw material in required dimension with the help of cutter.
2. Grinding and chamfering of cut material to remove bur and sharp edges with the help of hand grinder.
3. The pipes are welded together.

3.6.2. Support Plate

Specifications

Material- 30C8 YST 400

Size- $460 \times 50 \times 6mm$

Shape- Rectangle plate.

Process of Fabrication

1. Cutting of raw material in required dimension with the help of hacksaw machine.
2. Grinding and chamfering of cut material to remove bur and sharp edges with the help of hand grinder.
3. Drill($\varnothing 24.5mm$) on the plate by vertical drilling machine.
4. The plate welded to the body.

3.6.3. Punching material and specifications

Material-stainless steel

Size- $\varnothing 50.8mm$, Length-101.6mm

Shape- Circular hollow pipe

Process of Fabrication

1. Cutting of raw material in required dimension with the help of hacksaw machine.
2. Create teeth on pipe by tool and cutter machine.
3. The pipe welded to the nut.

3.6.4. Plough material and specifications

Material-MS plate of 2 mm thickness. Figure 9 shows the ploughing material used for movement.

Fig. 9 ploughing material

Process of Fabrication

1. Cutting of raw material in required dimension with the help of gas cutter.
2. The curvature shape is given by press machine.
3. Then welded to solid bar.

4. CONCLUSION

The designed, developed and technologically updated range of Mulching Machine is available to clients that offer great relief to farmers in a best possible and effective manner. This machine is user friendly; with fine finish, glitch free and easy to operate. This machine is made up of quality raw materials that are reliable and easily available in the market. We accept and agree that the machine will have wider demand across the market for the long life span and best performance. The mulching machine meets the growing needs of farmers who wish continuously to improve the profitability of their farming by using this machine. This equipment is manufactured using standard and high grade best quality raw materials with best affordable price range for all farmers and labours.

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