RESEARCH PAPER | International Journal of Agricultural Engineering | Volume 6 | Issue 2 | October, 2013 | 304–310

Design and development of self propelled weeder for field crops

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Received : 03.01.2013; **Revised :** 05.09.2013; **Accepted :** 04.10.2013

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ABSTRACT : Weed control is major problem in India. Majority of farmers do control weed using hand tools like khurpi and so on. Though, this method proves useful yet it is very demanding of labour and full of drudgery. To solve, weeding problem, self propelled weeder was designed, developed at the CAE, University of Agricultural Sciences, Raichur. The self propelled weeder was designed on the basis of agronomic and machine parameters. The main feature of prototype self propelled weeder were, a 4 hp petrol start kerosene run engine, power transmission system, weeding blade (Sweep) and cage wheel. The rated engine speed 3600 rpm was reduced to 23 rpm of the cage wheel by using chain and sprocket mechanism in three steps.

KEY WORDS : Cotton, Self propelled weeder, Weeding, Red gram

HOW TO CITE THIS PAPER : Kankal, U.S. (2013). Design and development of self propelled weeder for field crops. *Internat. J. Agric. Engg.*, **6**(2) : 304-310.

Weeding operation is one of the important intercultural tillage operation which control unwanted plants between the rows which consume more fertilizers and reduce the crop yield. Controlling weed is one of the serious, problems faced by the farmers. The reduction in the yield due to weed alone is estimated about 30-60 per cent depending upon the crop and location, and one third of the cost of cultivation is being spent for weeding alone Rangasamy *et al.* (1993).

In India, this operation is traditionally carried out with the indigenous hand tools. In single hand weeding labour requirement is as high as 300 to 1200 man-h/ha (De Datta *et al.*, 1974). Weeding is usually performed manually with traditional hand tools (Khurpi) in upright bending posture inducing back pain for majority of labour and require considerable time and labour. It is costly and many times, availability of the required number of laboures during peak season of the year is a problem. In India, diverse farm mechanization scenario prevails in the country due to varied size of the farm holdings and socio-economic disparities. Status of land holding in contexts of Indian agriculture and Karnataka state is reveals that about 80% of land holdings were below 2 hectare (small and marginal land holding). At present, small capacity power weeder are available in market whose field capacity normally 0.07 ha/hr, (Veerangouda *et al.*, 2010) which is greater than bullock operated weeders having field capacity is 0.058 ha/h (Manian *et al.*, 2004).

Recently power weeders are introduced with rotary tillage equipment having 3.75-5 kW capacity and engine weight of 300-400 kg. These machines are not become popular due to clogging of weeds in between tines and intermediate cleaning is required when used in higher moisture content. Present pattern of row cropping concept widely adopted by Indian farmers and development of self propelled sweep or drag type weeder is the need of our today. In this view, self propelled small engine operated weeder is better option due to it's medium cost and small size implying better manoeuverability in the small land holding.

Keeping the above point in view, the present investigation was undertaken with the objectives. To design and develop a self propelled low cost drag type weeder for field cops.

METHODOLOGY

The design of prototype weeder is consist of power transmission system, lugs on gauge wheel, sweep blade and shank of the weeder.

Design and development of self propelled weeder:

The self propelled weeder was designed and developed by considering agronomic and machine parameters. The agronomic parameters likes crop, variety, row spacing and others parameters like weeding interval and physical properties of soil. Crop variety is an important parameter, which influence the mechanical weeding operation, since the growth factor and foliage varies for each variety. Row spacing that helps on allowing the weeding tool for its effective operation. Row spacing for different crops vary depending on the specific crop canopy growth. The row spacing of cotton and red gram varies from 900 to 1050 mm. In the view of this row spacing overall width of machine was taken as 680 mm. The ground clearance of self propelled weeder was chosen as 265mm. The critical period of weed control is defined as an interval in the life cycle of the crop when it must be kept weed free to prevent yield loss. The soil parameters influencing mechanical weeding. The soil properties relevant to the design of tool for weeding were identified as soil type, moisture, bulk density. The types of soil influence on the design of weeding tool. A soil resistance varies with type of soil. Moisture content of soil affects the draft required for weeding tool of the weeder and slip of cage wheel. Soil having more moisture content gives more slip. Optimum soil moisture is needed at time of weeding to minimize the field losses and energy input. Bulk density of soil is the measure of a compaction of soil condition which influences draft required for weeding.

Based on crop and weed parameters, it was proposed to develop self propelled weeder for 90 cm row spacing crop. Considering the draft limitations of weeder and ensure good maneuverability. Walk behind type self propelled weeder was designed and developed.

Selection of engine:

Selection of proper engine is very important while developing the machine. Power requirement for self propelled weeder are computed by using formula Sahay (2006).

$\mathbf{Power = \frac{Draft\ x\ Speed}{75}}$, Draft = Soil resistance x Cross sectional area of cut =0.75 x ½ x 25 x 5 = 43.75 kg, total draft for two sweep = 2 x 43.7 = 87.5 kg, draft = 87.5 kg

$\mathbf{Power = \frac{87.5\ x\ 0.7}{75}}$ = 0.81 hp, power requirement for self propelled was 0.81 hp

Hence, according to the power requirement, commercial 4 hp, (Honda GK-200) petrol start kerosene run engine was selected as the source of power. Engine was mounted in front of the cage wheel axle, such that the engine crankshaft and wheel axle were parallel to each other.

Design of power transmission system:

The power transmission system was designed to reduce engine output shaft speed from 3600 rpm to 23 rpm on cage wheel shaft. The power reduction was designed in 3 stages. Three speed reduction stages are given below :

First stage speed reduction:

In first stage reduction, a chain and sprocket has been selected. For the power 4 hp, 10-B-ISO chain number was selected as per IS: 2403-1991. Assume no. of teeth on sprocket which mounted on engine shaft as 11 with speed ratio 2.27:1.

No. of teeth of sprocket on counter shaft was calculated by using formula Khurmi and Gupta (2003):

$$\mathbf{Speed\ ratio = \frac{T_2}{T_1}} \qquad (1)$$

where, T_1 = No. of teeth on sprocket which mounted on engine shaft; T_2 = No. of teeth on sprocket which mounted on counter shaft.

From eq. (1) $\mathbf{\frac{T_2}{T_1} = 2.27 = \frac{T_2}{11} = 2.27 = T_2 = 24.97}$, available sprocket with 25 teeth was selected. The speed of counter shaft in power train of transmission system is calculated using the formula Khurmi and Gupta (2003)

$$\mathbf{N_2T_1 = N_2T_2} \qquad (2)$$

where, N_1= speed of engine output shaft (rpm), N_2=speed of counter shaft (rpm); T_1 =no. of teeth on sprocket which mounted on engine shaft; T_2 =no. of teeth on sprocket which mounted on counter shaft.

N_1 = 3600 rpm, T_1 = 11 teeth, T_2 = 25 teeth so From eq. (2) $\mathbf{N_2 = \frac{N_1T_1}{T_2}}$ so, $\mathbf{N_2 = \frac{3600\ x\ 11}{25}}$

N_2 = 1584 rpm, in first reduction stage engine speed reduced form 3600 rpm to 1584 rpm.

Second stage speed reduction:

In second stage speed reduction was obtained using crown and pinion mechanism. Assume no. of teeth of pinion mounted on counter shaft as 8 with a speed ratio 9:1. No. of teeth on crown shaft was calculated by using formula Khurmi and Gupta (2003);

$$\mathbf{Speed\ ratio = \frac{T_4}{T_3}} \qquad (3)$$

where, T_3 = no. of teeth on pinion shaft; T_4 =no. of teeth on crown shaft . From eq. (3) $\mathbf{\frac{T_4}{T_3} = 9}$, $\mathbf{\frac{T_4}{8} = 9}$, T_4 = 72; So 72 teeth on crown gear was selected. The speed of crown shaft in power train of transmission system was calculated using the formula Khurmi and Gupta (2003)

$$\mathbf{N_3T_3 = N_4T_4} \qquad (4)$$

where, N_3 = speed of pinion shaft, rpm; N_4 = speed crown shaft, rpm, T_3 = No. of teeth on pinion shaft; T_4 = No. of teeth on crown shaft, N_2 = N_3 = 1584 rpm, T_3= 8 teeth, T_4=72 teeth; From eq. (4) $\mathbf{N_4 = \frac{N_3T_3}{T_4}}$, $\mathbf{N_4 = \frac{1584\ x\ 8}{72}}$ So,

N_4=176 rpm, thus in second stage the speed was reduced from 1584 rpm to 176 rpm.

Third stage speed reduction :

In third stage speed was reduced using set of spur gear. Assume no. of teeth of small spur gear mounted on other end crown shaft as 9 teeth and speed ratio 7.66:1. No. of teeth on spur gear mounted on cage wheel shaft was calculated using formula Khurmi and Gupta (2003)

$$\text{Speed ratio} = \frac{T_6}{T_5} \quad (5)$$

where, T_5= No. of teeth on spur gear mounted on crown wheel shaft; T_6 =No. of teeth on spur gear mounted on cage wheel shaft. From eq. (5) $\frac{T_6}{T_5} = 7.66, \frac{T_6}{9} = 7.66, T_6 = 68.94$; thus 69 teeth on spur gear was selected. The speed of cage wheel shaft in power train of transmission system was calculated using the formula Khurmi and Gupta (2003)

$$N_5 T_5 = N_6 T_6 \quad (6)$$

where, N_5 = Speed of spur gear mounted on crown wheel shaft, rpm; N_6= Speed of spur gear mounted on cage wheel shaft, rpm, T_5= No. of teeth on spur gear mounted on crown wheel shaft, T_6= no. of teeth on spur gear mounted on cage wheel shaft, $N_4 = N_5$ = 174 rpm, T_5 = 9 teeth, T_6 = 69 teeth, From eq. (6) $N_6 = \frac{N_5 T_5}{T_6} = \frac{176 \times 9}{69}$, N_6 = 22.95 rpm. In third stage of speed reduction speed was reduced from 176 rpm to 23 rpm.

In power transmission, engine speed reduced from 3600 rpm to 23 rpm for weeding operation.

Design of lugs :

The lugs are providing on the circumference of the cage wheel to obtain proper traction. The lugs are welded on the outer circumference of the cage wheel. The soil acceleration force was calculated using equation as given Srivastava (2003).

$$F_{S1} = \frac{P_g}{g} \, b \times d \times V_0^2 \, \frac{\sin\theta}{\sin(\theta+\alpha)} \quad (7)$$

where, F_{S1}=soil acceleration force, N; b = width of penetration lugs, m; d = depth at penetration of lugs, m; V_0 =forward speed of weeder, m/s θ= tool lift angle, degrees α= angle of forward failure surface, degree; ρ=bulk density of soil, kg/m³; g = gravitational force, m/s²; The sizes of lugs on cage wheel were selected as 25 mm width and 10 mm thickness. The projection of lugs is considering form the tip of circumference of cage wheel as 18 mm, depth of lugs penetrated in the soil. Lugs are welded perpendicular to ground wheel with 90º to soil surface. The bulk density of soil was 1500 kg/m³. It is assumed internal angle of friction as 36º, maximum forward speed as 2.5 km/hr. Angle of forward failure surface is calculated using formula :

$$\alpha = \frac{1}{2}(90 - \varphi) \quad (8)$$

where, =angle of internal friction; $\alpha = \frac{1}{2}(90 - 36)$ so, =27⁰; $F_{S1} = \frac{1500 \times 9.81}{9.81} 0.025 \times 0.018 \times 0.7^2 \frac{\sin 90}{\sin(90+27)} = 0.330\,N$. Considering three lugs are in contact with soil, total soil acceleration force is given by

$$B_0 = 3 \times F_{S1} \quad (9)$$

where, B_0 = Total soil acceleration force on cage wheetl, N; F_{S1} = total soil acceleration on each lugs, N; B_0=0.99 N. The total soil acceleration at the centre of the projected length of lugs and hence the maximum bending moment is given at this point. The maximum bending moment is given by

$$M = B_0 \times L \quad (10)$$

where, M = maximum bending moment, N-mm, B_0 =total soil acceleration force on cage wheel; L= distance between point of action of soil resistance and top edge of cage wheel, mm; substitute value in equation (10).

M=0.99 x 9 = 8.91 N-mm. The bending stress induce in the material of the lugs was calculated following formula given by Khurmi and Gupta (2003).

$$F_b = \frac{M}{Z_z} \quad (11)$$

where, M = maximum bending moment on the lugs, N-mm; F_b=stress induces on the material of lugs N/mm²; Z_z=section modules of cage wheel, mm³; section modules for rectangular section is given by Varshney *et al.* (2005)

$$Z_z = \frac{1}{6} bt^2 \quad (12)$$

where, Z_z=section modules, mm³; t = thickness of lugs, mm; b = width of lugs, mm; putting value in equation (12); $Z_z = \frac{1}{6} \times 25 \times 5^2$ = 104.16 mm³, putting values of Z_z and M in equation (12) $F_b = \frac{8.91}{104.66}$ = 0.085 N/mm², bending stress produces (0.085 N/mm²) is less than allowable bending stress 70 N/mm². Hence, design is safe. Considering the spacing between lugs as 67 mm and numbers of lugs wheel is obtained

$$N = \frac{\pi \times D_g}{S} \quad (13)$$

where, D_g =diameter of cage wheel, mm. S = spacing between lugs. N= numbers of lugs. $N = \frac{3.412 \times 600}{67}$ =28.11. Hence, 28 lugs have been provided on the cage wheel. Lugs 28 in number welded on the outer periphery of the wheel at 67 mm equal interval to facilitate easy traction in soil. The lugs 18 mm in height welded at an angle of 25 to 30 degree with the axis of rotation to reduce the slip.

Design of sweep blade :

Sweep type blade was selected to the fixed on self propelled weeder frame. The performance of sweep blade was better than straight and curved blade with minimum draft force per unit working width and having highest performance index reported by Biswas and Yadav (2004). While designing the sweep blade following assumptions were taken in to consideration. Cotton row to row spacing = 90 cm, depth of the cut (d) = 5 cm (Tajuddin *et al*., 1991).Crop protection zone = 15cm. Angle of internal friction, ϕ=25 degree (Sharma and Mukesh, 2008). The cutting width of the sweep type tyne can be found by using formula Sharma and Mukesh (2008).

$$S_c = Z_f - Z_P \qquad (14)$$

where, S_c =row spacing, cm. Z_f=effective soil failure zone.

$$Z_f = S_c - Z_P \qquad (15)$$

Z_P = 90 - (2 x 15) = 60 cm (Protection zone is multiplied by 2since protection zone has to be provided on both side of the crop). Effective soil failure zone is calculated by using formula Sharma and Mukesh (2008)

$$Z_f = [W + 2d \tan¤_s] + 2\,[W_1 + 2d \tan¤_s] \qquad (16)$$

where, W=width of full sweep, cm, W_1=width of half sweep, cm

$$60=[W+2x5x\tan 25^0] + 2\,[W_1 + 2x\,5\,x\,0.46] = 2\,W+9.2$$

$$W = \frac{60 - 9.2}{2}$$

W=25.4, So, width of sweep was taken 250 mm. While designing the sweep, the apex angle, condition for easy undercutting the weeds by the sweep blade should be taken in account. In practice approach angle of sweeps ranges 60 to 90 degree. Four shape of sweep with different approach angle like 60, 70, 80, and 90 degree were fabricated using 20MN CR-5 grade steel. The sweeps were attached to the shank with the help of nut and bolt. During the fabrication of sweep parameters were followed as per test code (IS: 6451-1972)

Design of shank of the weeder :

The square shank was designed to have proper fixing on tool frame of self propelled weeder. Following assumption was considered while designing shank. For design of the shank unit draft of the soil is assumed 0.75 kg/cm^2, Width of the sweep = 25 cm, depth of the soil = 5 cm, Factor of safety = 2 (Sharma and Mukesh, 2008).

$$\text{Draft = Soil resistance x Cross sectional area of cut} \qquad (17)$$

= 0.75 x ½ x 25 x 5 = 43.75 kg

Total draft for two sweep = 2 x 43.7 = 87.5 kg, power requirement for self propelled weeder were computed by using formula Sahay (2006), $\text{Power} = \frac{\text{Draft x Speed}}{75}$ From equation (17), draft = 87.5 kg

$\text{Power} = \frac{87.5 \times 0.7}{75}$ = 0.81 hp. The maximum draft on sweep type tyne is = $\frac{\text{Maximum draft}}{\text{No. of tynes}} = \frac{87.5}{2}$ = 43.75 kg-f, So Maximum force at a tip of the sweep = 43.75 kg-f .Taking factor of safety 2 and taken 2 times of maximum force for impact loading, Bending sweep in sweep will be = 43.75 x 2 x 2 = 175 kg. Let the height of the shank suitable for the cotton crop be 500 mm Sharma and Mukesh (2008).The maximum bending moment (M) for the cantilever length of 500mm. M=175 kg x 500 mm = 87500 kg-mm. Bending stress is given in the formula, Sharma and Mukesh (2008).

$$f_b = \frac{MC}{I} \qquad (18)$$

where, f_b=bending stress, kg/cm^2, M=bending moment, kg-mm, C = distance from the neutral axis to the point at which stress is determined. I = moment of Inertia of section, mm^4.

$Z = \frac{I}{C} = \frac{M}{f_b} = \frac{87500}{30}$ = 2916.66 mm^3. Moreover, where, f_b=bending stress, kg/cm^2

$$Z = \frac{b^3}{6} \qquad (20)$$

$$2916.66 = \frac{b^3}{6},\ b^3 = Z \times 6 = 2916.66 \times 6 = \sqrt[3]{2916.66 \times 6}$$

b=25.9 mm

So, 25x25mm size of square shank was developed. A square shank was made mild of steel material in size 25X25 mm. Projected end of shank was fitted to the sweep with nut and bolt and other end to the tool frame of self propelled weeder with the help of clamp .

RESULTS AND DISCUSSION

The experimental findings obtained from the present study have been discussed in following heads:

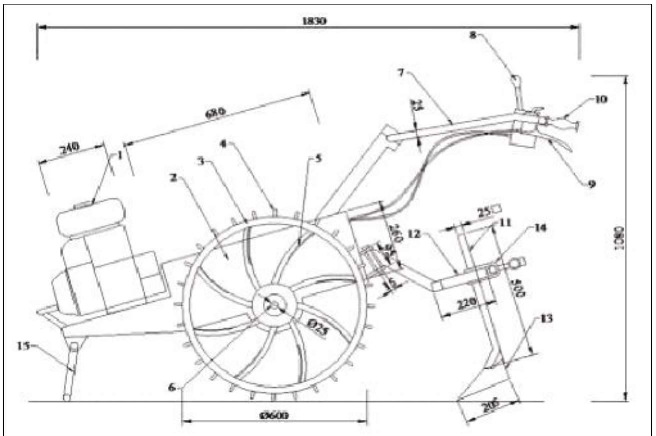
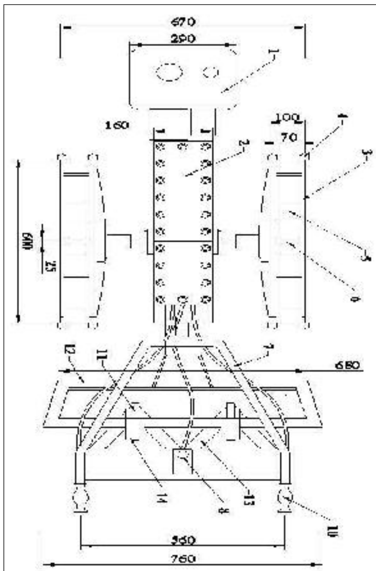


Fig. 1 : Side view of self propelled weeder

Development of self propelled weeder :

The prototype self propelled weeder was fabricated based on dimensions obtained from design. The prototype self propelled weeder was consisted of tool frame, power transmission system, cage wheel, sweep blade, shank, stand and handle. The side and top view of self propelled weeder are shown in Fig. 1 and Fig. 2, respectively. Components of prototype self propelled weeeder are presented in Table 1. The specification of prototype self propelled weeder are presented in Table 2. The overall dimension of prototype self propelled weeder 1830 mm in length, 780 mm in width and 1080 mm in height. The self propelled weeder was fabricated by using standard production techniques. The prototype self propelled weeder is shown in Plate 1.



S.No.	Description
1.	Engine & Petrol, Kerosene tank assembly
2.	Gear box
3.	Drive wheel
4.	Lugs on drive wheel
5.	Spoke
6.	Ground wheel axle shaft
7.	Handle
8.	Gear shifting lever
9.	Clutch
10.	Handle grip
11.	Shank
12.	Frame
13.	Sweep blade
14.	Clamp
15.	Stand

Fig. 2 : Top view of self propelled weeder

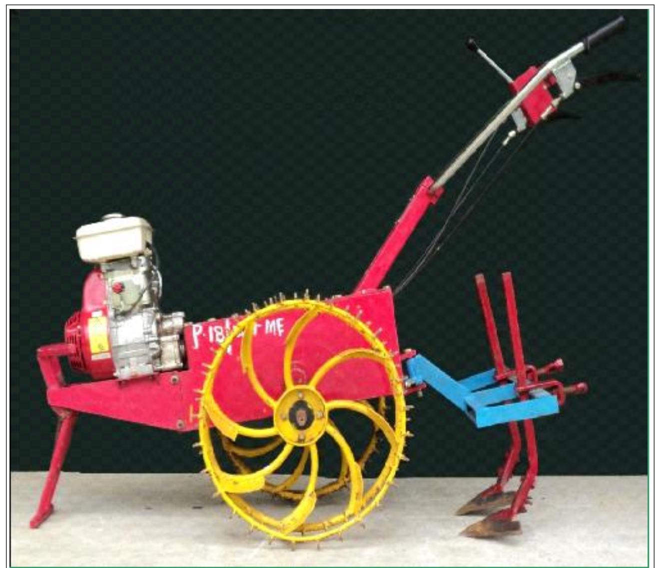


Plate 1 : Prototype self propelled weeder

Table 1 : Components of self propelled weeder

Sr. No.	Component name	Material	Section	Dimension	Quantity
1.	Implement frame	Mild steel	ISA 40406	780 x 220 x 35 mm	1
2.	Shank	Carbon steel	……	25 x 25 x 500 mm	2
3.	Sweep	Spring steel, 20 MNCR-5	V-shape	250 x 4 mm	4
4.	Clamp	Carbon steel	……	140 mm in length	2
5.	Cage wheel	Mild steel	Round	10 mm Φ	2
6.	Lugs on cage wheel	Mild steel	Square	25 x 25 mm	28
7.	Spoke	Mild steel	Curved	220 mm curved length	8
8.	Cage wheel shaft	45-C8	Round	25 mm Φ	2
9.	Sprocket	CI	Round	11 and 25 teeth	2
10.	Roller chain	St-50	……..	Std. pitch 15.87 mm	1
11.	Handle	Mild steel	……..	25 mm Φ, 560 mm Curved length	2
12.	Handle grip	Rubber	……..	110 mm length	2
13.	Hitch pin	Carbon steel	……..	20 mm Φ	1

Table 2 : Specifications of self propelled weeder

Sr. No.	Particulars	Details
1.	Name of machine	Engine operated power weeder
2.	Make of machine	CAE, Raichur
3.	Model of machine	MPIC -63001
4.	Overall dimension of machine (L x B x H)	1830 × 780 × 1080 mm
5.	Weight of machine	56 kg
6.	Power source	4 hp petrol start kerosene run engine
7.	Fuel used	Kerosene
8.	Fuel tank capacity	3.9 lit
9.	Engine details	4 stroke, 1 cylinder
10.	Speed at engine	3600 rpm
11.	Displacement	197 cc
12.	PTO shaft rotation	Counter clockwise from drive end
13.	Weight of engine	18 kg
14.	Ground clearance	265 mm
15.	Gear type	Bevel and spur gear
16.	Chain drive	ISO 10 B bush roller chain
17.	Clutch	Dog clutch
18.	Axle	25 mm in diameter
19.	Cage wheel	600 mm in diameter
20.	Lug	28 no. 25 x 25 mm in size lugs welded at periphery of ground wheel
21.	Details of weeding components	
	Frame dimension (L × B) mm	780 × 220 mm
	Type of blade	Sweep type
	No of blade	6
	Distance between blade	Adjustable
22.	Shank	25 mm in dia. and 500 in length

Cage wheel:

The cage wheel provides good traction, in addition to saving in cost compared to pneumatic wheel. The cage wheels were used to get traction in field condition. Two steel lugged cage wheels of 600 mm diameter were mounted on opposite end of the cage wheel shaft both ends of central shaft connected to the transmission box. The spacing between two wheels can be adjusted based on row spacing of crop. MS rods of 10 mm diameter 8 in numbers were welded as spokes on the central hub of cage wheel. The 50 mm long hub was made to fit on the 25 mm diameter cage wheel shaft.

Tool frame :

The trapezoidal tool frame of size 760 x 680 x 220 mm was fabricated using 35 x 35 x 6 mm MS angle. Front end of tool frame attached to the power transmission box.

Throttle lever:

Speed control was done through accelerator (engine throttle). It was nothing but just a knob which was provided on or near to the handle to facilitate the easy access for the operator. It was connected to the governor. When it was rotated clockwise more fuel was injected to engine speed increases and *vice-versa*.

Handle:

Two handles were made of circular steel pipe 40 mm in diameter was attached to the main frame of the machine. It could be adjusted as to suit the ergonomic working height of the operator. Two handle grip provided to the handle because handle yoke affords maneuverability so that will be affected smoothly and uniformly. Two turning clutches were provided to the both side of the handle.

Stand:

Stand was made MS rod and a spring provided to make stand in position.

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