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Development of an animal drawn manure spreader cum cart

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■ **ABSTRACT :** The research work and testing was undertaken at the site of the AICRP on UAE CAET, V.N.M.K.V., Parbhani.The developed Manure spreader consist a chassis having two iron wheels, axel assembly, bearing, flat type agitator, peg tooth agitator, body frame for mounting the trapezoidal shaped manure box, hitching system, and tool box. The application rate of manure varies from 2.46 to 10.06 t/ha for varies in opining area of cover 0.04 m^2 to 0.16m^2. The co-efficient of variation of uniformity for manure distribution varied from 18 -20%. The designed manure spreader cum cart gave desired manure application rate (9 – 10t/ha) at an opining area of cover 0.16m^2at the operational speed of 2.63km/hr and draft required was 637 N.The draft and power requirement of manure spreader were 637 N and 0.46 kW, respectively within the draft ability limit of pair of bullock.The field capacity and field efficiency of machine were 0.21 ha/hrand 84% at operational speed 2.51 km/hr. The manure spreader cum cart was used for carting with 500 kg load on Tar road and Kaccha road by Red Kandhari bullocks. The draft observed for Tar road with no load and 500 kg load conditions by Red Kandhari bullocks was 37 and 41 kg, respectively. The draft observed on Kaccha road for no load and 500 kg load conditions was 40 and 48 kg, respectively by Red Kandhari bullocks. Speed observed on Tar road for no load and 500 kg load conditions by RK bullock was 4.29 and 3.88 km/hr, respectively. The speed on Kaccha road was 4.04 and 3.48 km/hr, respectively. Power observed for no load and 500 kg load conditions was 0.40 and 0.43, respectively for RK bullock on tar road. And 0.43 and 0.48 Kw for no load and 500 kg load conditions, respectively on Kaccha road for RK bullock. The increased respiration rate and pulse rate was observed after 2 hrs continuous work on tar and Kaccha road is within the safe limit of fatigue score.

■ **KEY WORDS :** FYM, Agitator, Manure box, Cart, Spreader, Field efficiency, Application rate, Draft, Speed

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Animal power is a renewable energy source that is particularly suited to family-level farming and to local transport. Animal power is generally affordable and accessible to the small holder farmers, who are responsible for much of the world's food production. The availability of animal power allows women and men to increase their efficiency and reduce their drudgery, compared with manual alternatives.

As per Singh (2000) with the modernization of agricultural, the use of mechanical power in agricultural has increased but draught animal power (DAP) continuous to be used on Maharashtra farms due to small holdings and mix cropping agriculture. More than 55 per cent of total cultivated area is still being managed by using draught animals against about 20 per cent by tractors and remaining one is managed by man power, power tiller and agricultural related machinery.

Due to introduction of mechanical power sources the population of draught animal is declining but still more than 50 per cent net sown area is cultivated by animal power source. Draught cattle population in Maharashtra is 64 million from which gives draught cattle power of 24,47,302.22 kW. During the year 1991 and 2012, the cattle power availability and total animate power available in Maharashtra state was 0.162 kW/ha, 0.213 kW/ha and 0.139 kW/ha, 0.203 kW/ha, respectively. (Quinquennial livestock census, 2012)

Organic manure :

Organic manure is considered as the eco-friendly bio-fertilizer for the highly polluted modern era. Proper application of manure to the land is essential to prevent pollution of land, ground and surface water and to prevent loosing of ammonia and other nutrients from the manure. Timely application of manure in accordance with the nutrient requirements of the crops will result in improved crop production.

Farm yard manure (FYM) :

The farmyard manure application is a basic input operation in crop production. The application system includes equipment for loading of manure at storage facilities, transporting to the application sites, and applying the proper quantity of manure uniformly to soil-crop systems.

As our agriculture is facing the problems of soil degradation, loss of fertility and soil health, the use of farm yard manure and organic materials is the way out. A larger portion of nitrogen is made available as and when the FYM decomposes. Availability of potassium and phosphorus from FYM is similar to that from inorganic sources. Application of FYM improves soil fertility (Reddy, 2005). Therefore, there is wide scope to its application. Constituents of FYM are dung, urine and litter. The estimated dung production for cattle is 4.5 kg/head/day (Ravindranath, 2005).

The research for development of manure spreader cum cart was conducted at VNMKV Parbhani

Theoretical design considerations :

Design capacity of FYM spreader :

It has been calculated based on the density of FYM and volume of the developed spreader as given below.

The volume of trapezoidal manure box was 0.3m^3 calculated by formula :

$$V = \left[\left(\frac{l_1 + l_2}{2}\right) x\, wh\right]$$

where, V= Volume of trapezoidal manure box, m^3

l_1 and l_2 are top and bottom length (l_1= 1.7 m and l_2= 0.2 m)

w is width of manure box (1.2 m)

h is height of manure box (1m)

Total volume (V) of manure spreader; V=1.14m^3

The capacity of manure spreader was 500 kg by considering the density of FYM as 438 kg/m^3,

Design consideration for farm yard manure spreader cum cart :

On the base of 500 kg pay load and force required for spreading of manure in the field a chassis having two iron wheels, axel assembly, bearing, and body frame for mounting the trapezoidal shaped manure box and hitching system were designed and developed.

Design of rotating shaft (axle) of manure spreader cum cart :

On the basis of strength,

Diameter of shaft d is calculated as,

$$d = \left[\frac{16T}{\pi f_s}\right]^{1/3} \qquad (1)$$

We have, Design HP = 1, rpm of shaft (n) = 13 at 2.5 km/hr speed of bullock and wheel dia. 1000 mm

$$T = \frac{75 \text{ x HP}}{2\pi n}$$

where, T = Torque kg-m,

HP = Horse power,

n = Revolution per min

$$T = \frac{75 \text{ x } 1}{2 \text{ x } 3.14 \text{ x } 13}$$

T=0.9186 kg-m

d=20 mm

Considering the shaft is subjected with suddenly applied load on ploughed field condition, diameter of shaft is selected 30mm.

Considering the combined shock and fatigue factor:

Equivalent torque (Te) :

$$T_e = [(K_t T)^2 + (K_m M)^2]^{1/2} \qquad \text{(Jain, 1983)} \qquad (2)$$

Taking diameter of shaft 30 mm :

$$\text{Bending moment of the centre of shaft} = \frac{WL}{8}$$

where, W = Weight of shaft + Total axial load on shaft

$$\text{Weight of shaft} = \frac{\pi \times d^2 \times 1 \times \rho}{4} = 5.55\ \text{kg}$$

where, l is total length of shaft is 100 cm,

P is 7800 kg/m^3

D is diameter of shaft, 30 mm and

Total weight, W=5.55 + 250 (axial load of manure) = 255.55

$$\text{Bending moment at the centre of shaft, } \frac{WL}{8} = \frac{255.55 \times 100}{8} = 3194.3\ \text{kg - cm}$$

where L= (100 cm) distance between the bearings

Equivalent torque :

Te = [1.5 x 91.86)^2 + (1.5 x 3194.3)^2]$^{1/2}$

= 4792.75 kg-cm

$$\text{Design stress in sheat} = \frac{\text{Surface coeff. x Yield point stress}}{\text{Factor of safety}}$$

= (0.954 x 1200)/2

= 572.4 kg/cm^2

$$\text{Shaft diameter, } d = \left[\frac{16\,Te}{3.14} \times 760\right]^{1/3}$$

= 2.98 cm say 3.0 cm = 30 mm

Horsepower required for operating the design shaft at 13 RPM considering the combine shock and fatigue factor.

$$HP = \frac{2\pi\, n\, Te}{4500} = 0.86\ \text{hp}$$

Design of manure spreading agitator shaft under axial loading :

$$T = 9.55 \times 10^6 \times \frac{F}{n}$$ Varshney *et al.* (2004)

where, T = Tensional moment N-mm,

F = Axial load on shaft, 264 N,

n = Speed of shaft, 37 rpm,

d = Diameter of shaft, mm,

f_s = Maximum permissible shear stress (600 kg/cm^2).

Weight of the manure over feeding auger in kg = Volume x density (1.14 x 0.050 x 0.8 x 600)=27.36kg

T= 9.55 x 10^6 x 274/37

= 70.72 x 10^6

= 707.2 kg-cm

On the basis of strength,

$$f_s = \frac{16\,T}{\pi\, d_0^3} \times \frac{1}{1 - k^4} \qquad (3)$$

where k = d_i/d_o

Inside diameter of pipe/Outside diameter of pipe=0.80

d_o= 3.09 selected outside diameter of pipe is 50 mm, d_i = 40 mm

Considering the combined shock and fatigue factor:

Bending moment (M) at the centre of shaft = WL/8

where, W =Weight of shaft + Total axial load on shaft

Weight of pipe+Weight of sheet = 12.72 kg

Weight of the manure over feeding auger in kg =27.3 kg

Total weight including wt. of manure, kg = 40.02 kg

Bending moment at the center of shaft, WL/8 = (40.02 × 100)/8

where L = (100 cm) distance between the bearings = 500.25 kg-cm

Equivalent torque:

$T_e = [(K_t T)^2 + (K_m M)^2]^{1/2}$

[(1.5 x 707.2)^2 + (1.5 x 500.25)^2]$^{1/2}$ =1230 kg-cm

$$\text{Design stress in shear} = \frac{\text{Size coeff. x Surface coeff. x Yield point S}}{\text{Factor of safety x Key ways factor}}$$

= (0.84×0.954×1200)/ 1.5×1.14 = 562.35 kg/cm^2

Using the equation,

$$f_x = \frac{16\,T_e}{\pi\, d_0^3} \times \frac{1}{1 - k^4}$$

d_0 = 28 mm

Hence, the selected pipe of outside diameter 50 mm and inside diameter of 40 mm is safe

Maximum horsepower required operating the design shaft at 40 rpm :

$$HP = \frac{2\pi\, nT}{4500} = 0.39\text{hp}$$

Design of bearing :

The selected bearing (Ball bearing no. 6006) was used to take the axial load as well as radial load for manure spreader of 500 kg load capacity. The dynamic capacity of bearing is given in equation (4)

$$C = \left[\frac{L_b}{L_{100}}\right]^{1/k} P \qquad (4)$$

C = Dynamic capacity of bearing, kgf;

Lb = Life of bearing ($1x10^6$h);

L_{10} = Life of bearing in 90 % survival of bearing (9 x 10^5h);

P = 2640 kgf,

Considering the rotation of axial thrust load (Fa) to radial thrust load (Fr) is less than 2.718 in case of slow moving vehicle, hence the value of x and y are 1 and 0. The value of service factor for bearing is taken 1.32 for shock loads of higher magnitude and axial load as 2000 kg [P = (X Fr + Y Fa)S]

K is 3 for ball bearing and 1/3 for roller bearing.

The eq. (4) resulted c as 2724 kg f. The basic dynamic capacity of selected bearing is 13200 kg f, hence bearing is safe for use.

Design of power transmission system for agitating mechanism :

Agitating mechanism consisted of two types of agitators one is peg tooth type present on upper side and another crossed flat type agitator on bottom side of manure box. Four standard straight bevel gears are provided for transmission of power from wheel to agitators. As the load on power transmission shaft is vibrational load, so it is necessary to select a gear type transmission system. Gear can transmit power with less chances of breaking under heavy loads other than chain or belt transmission. Selection and design of gear is done on the basis of number of revolution and torque requirement for agitating mechanism show in Fig. 1.

Available agitator shaft of manure spreader was designed for 13 rpm, the efficiency, uniformity and manure application rate was reduced due to low rpm of agitator shaft.According to previous research work, rpm of the agitator shaft should be in between 35 to 40 rpm for preventing clogging of manure in manure box and better manure application rate.

Assume, No. of teeth on gear present on the axle (z_1) = 18

No. of teeth on gear present on bottom side of vertical shaft (z_2) = 10

No. of teeth on gear present on topside of vertical shaft (z_3) = 16

No. of teeth on gear present on agitator shaft (z_4) = 10

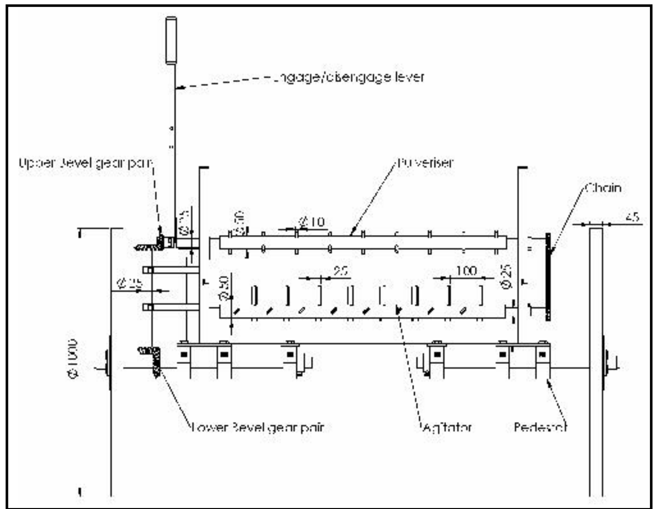

Fig. 1 : Schematic diameter of power transmission system

RPM of gear present on axle (i.e. wheel rpm) (N_1) = 13

Hence,

RPM of gear present on bottom side of vertical shaft

$$N_2 = \frac{N_1 \times Z_1}{Z_2}$$

$$N_2 = \frac{13 \times 18}{10} = 23.4 \approx 23$$

Since $N_2 = N_3$ = 23. (N_3 = RPM of gear present on top side of vertical shaft)

RPM of gear present on agitator shaft (N_4)

$$N_4 = \frac{N_3 \times Z_3}{Z_4}$$

$$N_4 = \frac{23 \times 16}{10} = 36.8 \approx 37 \text{ rpm}$$

Hence, rpm of agitator shaft are 37 rpm which are considered to be normal for agitating shaft.

Design of gear for power transmission system :

Lower pair of gears:

No. of teeth on gear present on the axle (z_1) = 18

No. of teeth on gear present on bottom side of vertical shaft (z_2) = 10

Shaft angle (Σ) = 90^0

Module (m) = 3

Pressure angle (α) = 20^0

Pitch diameter (d_1) = z_1 x m = 54

Pitch diameter (d_2) = z_2 x m = 30

$$\text{Pitch cone angle } (\delta_1) = \tan^{-1}\left[\frac{\sin\Sigma}{Z_1/Z_2 + \cos\Sigma}\right] = 29.05^0$$

Pitch cone angle (δ_2) = $\Sigma - \delta_1$ = 60.94^0

$$\textbf{Cone distance}\ (R_e) = \frac{d2}{2\sin\delta 2} = 17.32$$

Face Width (b) = It should be less than R_e / 3 or 10m = 5.77

Addendum (h_a) = 1.00 m = 3

Dedendum (h_f) = 1.25 m = 3.75

$$\textbf{Dedendum angle} = \theta_f = \tan^{-1}\frac{h_f}{R_e} = 12.21$$

$$\textbf{Dedendum angle} = \theta_a = \tan^{-1}\frac{h_a}{R_e} = 9.82$$

Outer cone angle (δ_a) :

$$\therefore \delta_{a_1} = \delta_1 + \theta_a = 38.87$$

$$\therefore \delta_{a_2} = \delta_2 + \theta_a = 70.76$$

Root cone angle (δ_f) :

$$\therefore \delta_{f_1} = \delta_1 - \theta_f = 16.84$$

$$\therefore \delta_{f_2} = \delta_2 - \theta_f = 48.28$$

Pitch apex to Crown (X) :

$$\therefore X_1 = R_e\cos\delta_1 - h_a\sin\delta_1 = 13.68$$

$$\therefore X_2 = R_e\cos\delta_2 - h_a\sin\delta_2 = 5.79$$

Axial Face Width :

$$(X_{b1}) = \frac{b\cos\delta_{a1}}{\cos\theta_a} = 4.55$$

$$(X_{b2}) = \frac{b\cos\delta_{a2}}{\cos\theta_a} = 1.92$$

Inner outside Diameter (di) :

$$di_1 = \delta_{a_1} - \frac{2b\sin\delta_{a_1}}{\cos\theta_a} = 31.52$$

$$di_2 = \delta_{a_2} - \frac{2b\sin\delta_{a_2}}{\cos\theta_a} = 59.70$$

Upper pair of gears:

No. of teeth on gear present on the axle (z_3) = 10

No. of teeth on gear present on bottom side of vertical shaft (z_4) = 16

Shaft angle (Σ) = 90^0

Module (m) = 3

Pressure angle (α) = 20^0

Pitch diameter (d_1) = z_3 x m = 30

Pitch diameter (d_2) = z_4 x m = 48

$$\textbf{Pitch cone angle}\ (\delta_1) = \tan^{-1}\left\{\frac{\sin\Sigma}{\frac{z_3}{z_4} + \cos\Sigma}\right\} = 58^0$$

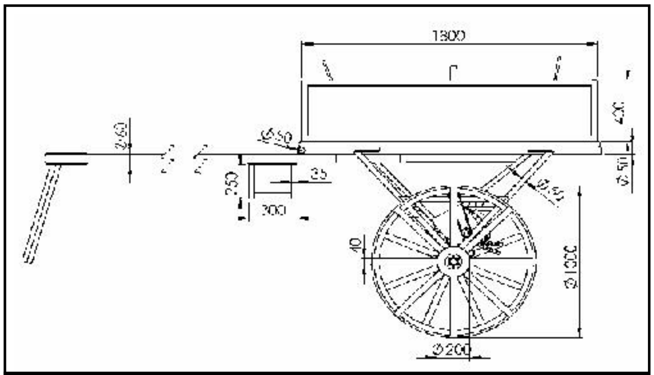

Fig. 2 : Side view of developed manure spreader cum cart

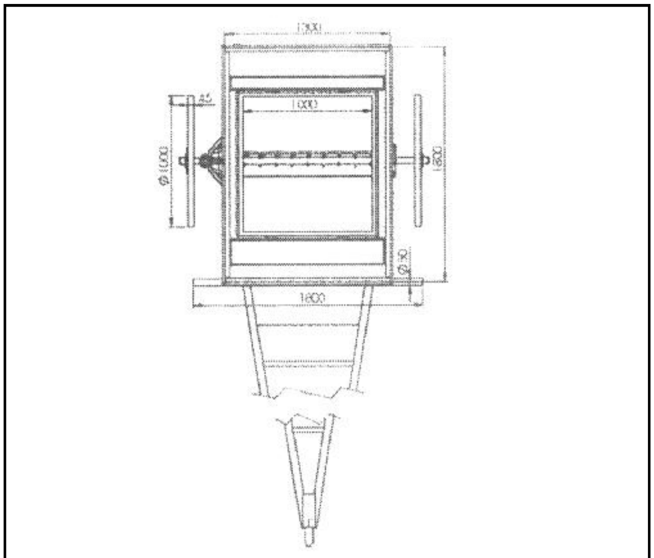

Fig. 3 : Top view of developed manure spreader cum cart

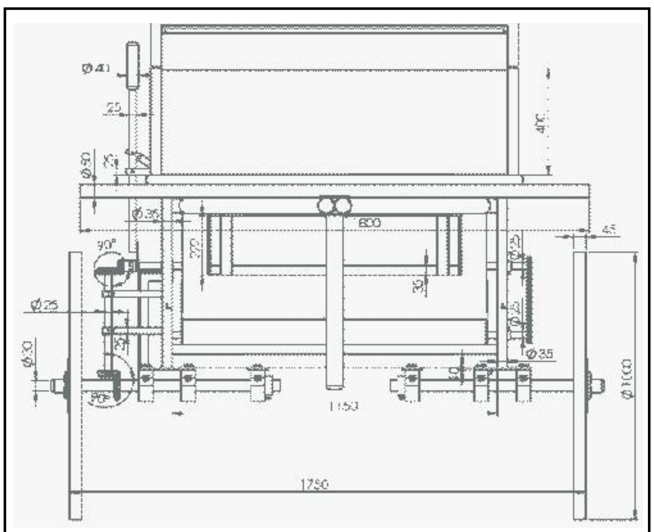

Fig. 4 : Front view of developed Manure spreader cum cart

Pitch cone angle (δ_2) = $\Sigma - \delta_1 = 32^0$

$$\text{Cone distance } (R_e) = \frac{d_2}{2\sin\delta_2} = 45.28$$

Face width (b) = It should be less than Re / 3 or 10m = 15

Addendum (h_a) = 1.00 m= 3

Dedendum (h_f) = 1.25 m = 3.75

$$\text{Dedendum angle} = \theta_f = \tan^{-1}\frac{h_f}{R_e} = 4.73$$

$$\text{Addendum angle} = \theta_a = \tan^{-1}\frac{h_a}{R_e} = 3.79$$

Outer cone angle (δ_a) :

$$\therefore \delta_{a_1} = \delta_1 + \theta_a = 61.79$$

$$\therefore \delta_{a_2} = \delta_2 + \theta_a = 35.79$$

Root cone angle (δ_f) :

$$\therefore \delta_{f_1} = \delta_1 - \theta_f = 53.27$$

$$\therefore \delta_{f_2} = \delta_2 - \theta_f = 27.27$$

Pitch apex to crown (X) :

$$\therefore X_1 = R_e\cos\delta_1 - h_a\sin\delta_1 = 21.45$$

$$\therefore X_2 = R_e\cos\delta_2 - h_a\sin\delta_2 = 36.80$$

Axial face width :

$$(X_{b1}) = \frac{b\cos\delta_{a1}}{\cos\theta_a} = 7.10$$

$$(X_{b2}) = \frac{b\cos\delta_{a2}}{\cos\theta_a} = 12.19$$

Inner outside diameter (di) :

$$di_1 = \delta_{a_1} - \frac{2b\sin\delta_{a_1}}{\cos\theta_a} = 35.29$$

$$di_2 = \delta_{a_2} - \frac{2b\sin\delta_{a_2}}{\cos\theta_a} = 18.2$$

Conclusion :

It is necessary to quantify the rate of application at desired rate during the operation and spread uniformly, covering the whole surface of the field. Therefore, unit like animal drawn manure spreader cum cart is desirable.

The developed manure spreader consist a chassis having two iron wheels, axel assembly, bearing, flat type agitator, peg type pulveriser, power transmission system with bevel gear, body frame for mounting the trapezoidal shaped manure box, tool box and hitching system.

The developed animal drawn manure spreader cum cart has capacity of 500 kg. Application rate of manure during manure spreader operation varies from 2.46 to 10.06 t/ha for different opening areas of cover from 0.04 m^2 to 0.16m^2, respectively.

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