Design and development of manually operated fertiliser spreader

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Abstract - *In order to provide a better alternative to traditional and traditional (scattering by hand) methods for dispersion of fertiliser a manually operated fertiliser spreader is designed and developed. Objective of the equipment is to uniformly disperse fertiliser in farm. Bearing in mind the fact that this equipment is manually operated, ergonomics has been a major factor hence, it is evident to keep the equipment light in weight. The human pushing force is converted into rotational motion of wheel and with aptly designed gearbox unit this motion is further transmitted to impeller disc. This fertiliser spreading equipment works on the principle of centrifugal force, wherein the fertiliser is poured from hopper on the impeller disc which rotates with proportionate speed with that of wheels so that fertiliser is dispersed in a specified range uniformly.*

Key Words: Rotational motion, Centrifugal force, Gearbox unit, Hopper, Human pushing force

1. INTRODUCTION

India is an agricultural country, almost 70% people live in rural areas and 90% of their income is generated from agriculture. Indian economy is heavily dependent on agricultural and contributes about 30% to GNP. Over the years, agriculture has witnessed tremendous changes in methods seed plantation, irrigation, pesticides and modes utilised for its dispersion. Although, a great deal of research and engineering advancements have been made on spray pesticides, granular pesticides and fertilisers lack innovative methods of dispersion [1][2]. Dispersion of fertilisers in traditional way is quite time consuming, expensive and strenuous. Despite the fact, some tractor operated equipment for fertiliser spreading are available, it is viable to look for cheaper alternatives considering financial situation of majority Indian farmers. So, designing a manually operated machine for spreading fertiliser would most certainly help the majority group.

2. MATERIAL SELECTION

Table -1: Selected material for components

Components	Material	Ultimate Tensile Strength (N/mm^2)	Yield Strength (N/mm^2)
Frame	AISI 1018	440	370
Shaft	AISI 4140	800-1100	550-700
Gears	AISI 4340	850-1550	650-1200
Impeller disc	Polyvinyl chloride	52	40
Hopper	Polyethylene	52	42

3. FERTILISER FLOW CALCULATIONS

1. Average person can apply 225 N of pushing force [3][4]
2. Walking speed (V_t) of average human being is 0.7 m/s on rough terrain.

Tyre size d_t= 520mm

$V_t=\pi*d_t*N_t/(60*10^3)$

N_t = 25.72 rpm

Impeller disc diameter (D_i) = 190.5-228.6 mm

Track width = 350 mm

Gear Ratio = 1:4.5

Speed of Impeller = Speed of Wheels/Gear Ratio

N_i = 115.74 rpm

Considering 90% efficiency of the gear box, Speed of impeller is,

N_i = 115.74*0.9 = 104.166 rpm

$\omega = 2\pi N_i/60$

ω = 10.908 rad/s

Velocity of fertilizer while leaving impeller: $V = r*\omega$

1.) For Di = 190.5 mm, V = 1.038 m/s

2.) For Di = 228.6 mm, V = 1.247 m/s

Maximum Displacement of Fertilizer (X) with height of impeller disc (Y)

$Y = X*\tan\theta + g*X^2 / (2*V_i^2*(\cos\theta)^2)$

As $\theta = 0^o$

$Y = g*X^2 / (2*V_i^2)$

Table – 2: Iterations for displacement of fertilizer with variation in impeller height for r = 95.25 mm V = 1.038 m/s

Sr. No.	Y (m)	X (m)
1	0.55	0.347
2	0.50	0.331
3	0.45	0.314
4	0.40	0.296

Table – 3: Iterations for displacement of fertilizer with variation in impeller height r = 114.3 mm V = 1.247 m/s

Sr. No.	Y (m)	X (m)
1	0.55	0.417
2	0.50	0.398
3	0.45	0.377
4	0.40	0.356

Diameter of Impeller (d) = 190.5 mm to 228.6 mm

Displacement (X) range = 300 to 400 mm

4. HOPPER DESIGN

For Fertilizer: Density (ρ) varies between 900 kg/m^3 to 1600 kg/m^3

Assuming (ρ) = 1400 kg/m^3 (for all types of dry fertilizers)

Diameter of Hopper (d_h) = 228 mm (Maximum)

Length of Hopper (l) = 250 mm

Total mass of fertiliser in Hopper,

M = ρ * volume

= 11kg

5. FRAME DESIGN

Table – 4: Specifications of frame

Parameters	Dimensions
Hollow Square Pipe	25 mm*25 mm*1.6 mm
Height of Frame	950 mm
Length of Frame	1110 mm

Forces on Frame: [7]

1. Weight of frame
2. Human Pushing force
3. Support reaction of bearings on shafts

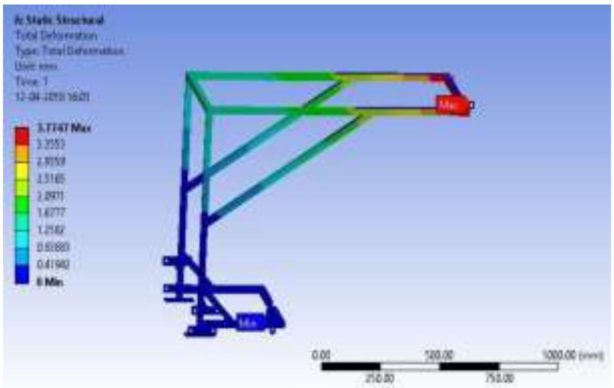

Fig – 1: Static structural analysis showing total deformation of frame

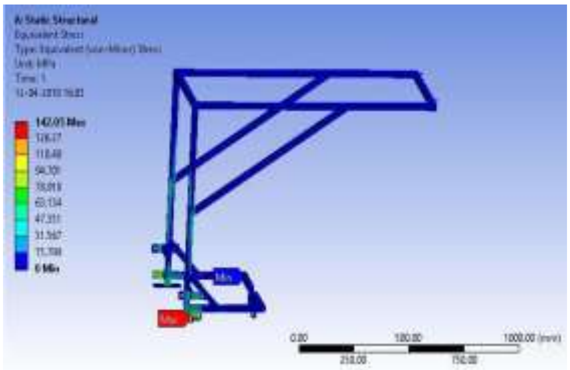

Fig – 2: Static structural analysis showing equivalent stress on frame

6. GEARBOX DESIGN

Required Traction: F = μ*M*g

= 275 N

Torque required: T = F*(d_t/2)

= 71.5 N-m

We need a gearbox which increases the speed from shaft to impeller disc i.e. Overdrive is needed hence gear is driver and pinion is driven member.

Design of Two Stage Gearbox First Stage is bevel gear pair and Second Stage is spur gear pair [5][6]. The required gear ratio is 1:4.5 So, for the first stage Gear ratio i_1 is 1:1.6 and second stage gear ratio i_2 is 1: 2.86.

Hence the resulting gear ratio (G)= i_1*i_2 = 1:4.56.

Table – 5: Specifications of gearbox

Parameters	First Stage	Second Stage
Gear Used	Bevel	Spur
Gear Ratio	1.6	2.86
Module	3.5 mm	2 mm
Teeth on Gear	16	40
Teeth on Pinion	10	14
Diameter of Gear	56 mm	80 mm
Diameter of Pinion	35 mm	28 mm

7. SHAFT DESIGN

Table – 6: Specifications of Shafts

Parameters	Dimension
Diameter of wheel shaft	20 mm
Length of wheel shaft	620 mm
Diameter of intermediate shaft	20 mm
Length of intermediate shaft	80 mm
Diameter of impeller shaft	20 mm
Length of impeller shaft	90 mm

8. BEARING SELECTION

Table – 7: Bearings for various shafts

Shaft	Bearing Number
Wheel	6204
Intermediate	6204 ETN9
Impeller	6204

9. MODEL

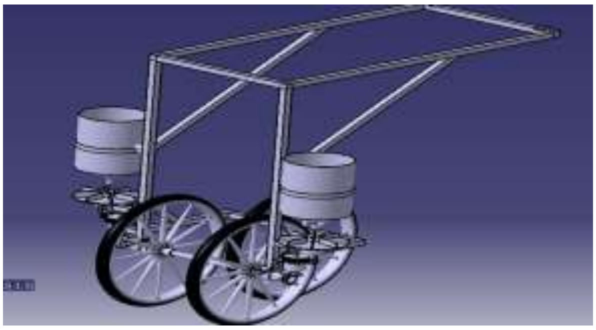

Fig – 3: CATIA model of equipment

10. TESTING

For testing the equipment's working and flow efficiency a simple technique is opted. The important parameters which are tested:

1) Mass flow rate and fertilizer from ball valve.

2) Displacement of fertilizer from tip and impeller.

Procedure is as follows:

1) Mass flow rate of fertilizer is calculated at 60, 75 and 90 degrees of ball valve.

2) The velocity of operator as considered is ranging from 0.7 to 1 m/s respectively.

3) For each angle of ball valve that are 60, 75 and 90 degrees each variation in equipment velocity of 0.7 m/s, 0.85 m/s and 1m/s displacement of fertilizer from impeller tip is measured.

4) This procedure is followed for next angles and displacement readings are noted.

Table – 8: Mass flow rate for various ball valve angles

Angle (Degree)	Mass of fertiliser (kg)	Average mass	Time (sec)	Mass flow rate of fertiliser (kg/sec)
60	0.499	0.5046	15	0.0336
	0.504			
	0.511			
75	0.840	0.8473	15	0.0565
	0.847			
	0.855			
90	1.295	1.2853	15	0.0857
	1.276			
	1.285			

Table – 9: Displacement of fertilizer for valve angle 60° at height of impeller from ground (Y) = 0.45 m

Velocity (meter/second)	X=Displacement of Fertiliser from impeller (m)	Average Displacement (m)
0.7	0.304	0.313
	0.325	
	0.312	
0.85	0.350	0.362
	0.374	
	0.362	
1	0.393	0.402
	0.401	
	0.412	

Table – 10: Displacement of fertilizer for valve angle 75° at height of impeller from ground (Y) = 0.45 m

Velocity (meter/second)	X=Displacement of Fertiliser from impeller (m)	Average Displacement(m)
0.7	0.436	0.427
	0.401	
	0.443	
0.85	0.466	0.480
	0.481	
	0.493	
1	0.517	0.516
	0.531	
	0.501	

Table – 11: Displacement of fertilizer for valve angle 90° at height of impeller from ground (Y) = 0.45 m

Velocity (meter/second)	X=Displacement of Fertilizer from impeller (m)	Average Distance (X)
0.7	0.491	0.496
	0.48	
	0.517	
0.85	0.587	0.598
	0.610	
	0.598	

1	0.61	0.635
	0.641	
	0.653	

11. VALIDATION

Table - 12: Comparison of theoretical and practical displacement of fertilizer from impeller

Velocity	Observed displacement of fertiliser from impeller (m) for various valve angles			Theoretical displacement of fertiliser from impeller (m)
	60°	75°	90°	
0.7	0.313	0.362	0.402	0.362
0.85	0.422	0.480	0.516	0.403
1	0.496	0.598	0.635	0.4324

Hence it is observed that:

1. Required displacement of fertilizer 0.362 m to 0.4324 m for velocity range 0.7 m/sec to 1m/sec is obtained by valve position between 63° to 67° angle.

2. Displacement of fertilizer from impeller increases with increase in velocity of equipment. 3. Mass flow rate of fertilizer is increases with increase in valve opening angle.

12. CONCLUSION

Displacement of fertilizer from impeller increases with increase in velocity of equipment. Required displacement of fertilizer 0.362 m to 0.4324 m for velocity range 0.7 m/sec to 1m/sec is obtained by valve position between 63.0° to 67.0° angle. Mass flow rate of fertilizer is easily controlled by valve mechanism which increases from 0.0336 kg/sec to 0.0857 kg/sec with 60° to 90° valve opening angle. This arrangement is useful for crops where distance between two crop rows is more than 2.3 meter.

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