Design and Analysis of Shredder Machine for Waste Management

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Abstract— Fertilizers are necessity of farmers. With the use of synthetic fertilizers land fields get damaged and also it is costlier. Organic compost is a better option for synthetic fertilizers. Designed shredder machine for chopping agricultural waste and convert it into powder. This chopped powder is used to prepare the compost. A Concept was developed with reference of four different shredder machine and operating processes. Concept was developed considering the safety factor users operating environment and maintenance. The machine consists of three-phase 1.5 HP motor, spur gear, bearings, structural frame, cutter and two shafts. Twenty eight cutters are mounted on two shafts, which rotate parallel driven by a spur gear. The power from the electrical motor is transmitted to cutter shaft through a chain drive. Cut is made inside the chopping house due to the effect of tensile, friction, and impact effect in chopping process. The garbage gets chopped and powder is collected at the bottom.

Keywords: Organic Waste; Shredder Machine; Design & Calculations; Agricultural Waste

I. INTRODUCTION

A shredder is a machine which is used for reducing the size of all kinds of material. The materials which are commonly shredded are tires, metals, car wrecks, wood, plastics, garbage and agricultural wastes. The Shredder is commonly used to process materials into different sizes for separation or to reduce recycling cost of transport. Some common types of shredder are horizontal hammer mills, vertical hammer mills, slow speed shear type shredders of single, dual, triple and quad shaft design, single shaft grinders of single or dual shaft design, granulators, knife hogs, cracker mills and refining mills. Waste Equipment Manufacturers Institute defines shredding equipment as a mechanical device used to break up solid waste and recoverable materials into smaller pieces.

Use of synthetic fertilizers has led to land pollution and the solid waste is increasing day-by-day. By proper use of method, the solid waste can be converted in to the organic compost by reducing the size of garbage into small particles and adding culture to it. This compost increases the fertility of the soil leading to organic farming and reduces the cost of land fields and dumping land. To reduce the size of garbage and for making compost, Shredder plays an important role.

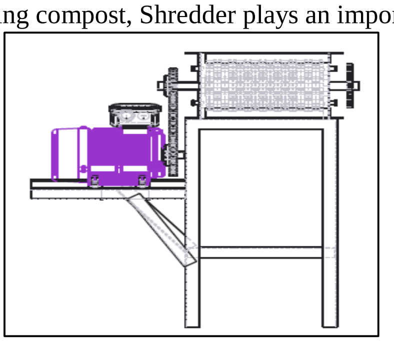

Fig. 1: Drawing of shredder machine

II. DESIGN OF SHREDDER COMPONENTS

A. Shaft Design

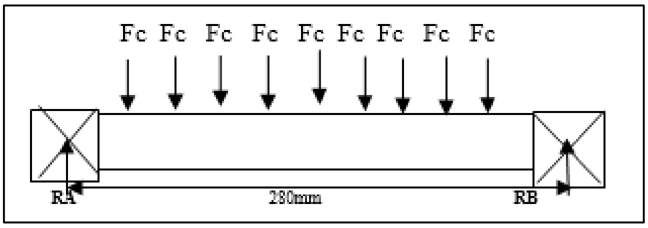

Fig. 2: Loading diagram for shaft

Fc = 210 N.

1) $\sum Fy = 0$
2) $R_A + R_B = 2940N$

Taking moment about point A,

R_B x 280 = 210 x 10 + 210 x 30 + 210 x 50 + 210 x 70 + 210 x 90 + 210 x 110 + 210 x 130 + 210 x 150 + 210 x 170 + 210 x 190 + 210 x 210 + 210 x 230 + 210 x 250 + 210 x 270.

R_B = 411600 / 280 =1470 N.

R_A = 1470 N.

Maximum Bending Moment,

(Mb)max = 1470 x 140 - 210 x(10+30+50+70+90+110+130) = 102900 Nmm.

Torque on Shaft,

Fc = 210 N r = 75 mm n = 14

T = 210 x 75 x 14 = 220500 Nmm.

N = 50 rpm

N = 50 rpm

$$P = \frac{2 \times \pi \times N \times T}{60}$$

$$P = \frac{2 \times \pi \times 220500 \times 10^{-3} \times 50}{60}$$

Power of the Motor , P = 1154.5353 Watt.

ASME Code for Shaft,

τ_{max} = 0.3 Syt
or
τ_{max} = 0.18 Sut
} whichever is minimum

If keyway is there, so reduced value by 25%.

& Kb, Kt factors are also considered.

ASME code based on Max. Shear Stress theory of failure.

$$\text{Therefore, } \tau_{max} = \frac{16 \times \sqrt{(KbMb)2 + (KtMt)2}}{\Pi d^3}$$

Material of shaft = 10C4 (Plain Carbon Steel) [6]

Sut = 340 N/mm^2

τ_{max} = 0.18 x 340 = 61.2 N/ mm^2

$$\tau_{all} = \frac{0.5 \times 340}{2}$$

τ_{all} = 85 N/mm^2

The lower value is 61.2 N/mm^2

Therefore, τ_{max} = 0.75 x (61.2) = 45.9 N/ mm^2

$$d^3 = \frac{16 \times \sqrt{(KbMb)2 + (KtMt)2}}{\Pi \tau_{max}}$$

$$d3 = \frac{16 \times \sqrt{(1.5 \times 102900)2 + (1 \times 220500)2}}{\Pi \times 45.9}$$

(Kb= 1.5, Kt = 1, gradually applied)
d = 31.02 mm
d = 32 mm
Take d = 40 mm

B. *Key Design :*

The material of the key = 7C4
Sut = 320 N/ mm^2
Power P = 1.2 KW, N = 50 rpm
Sut = 320 N/mm^2, F.O.S = 2, d = 40 mm.
Permissible Compressive & Shear stress,
Syc = Syt = 320N/mm^2
6c = Syt / F.O.S
6c = 320/2
6c = 160 N/mm^2
According to Max. Shear stress theory,
Ssy = 0.5 x Syt = 0.5 x 320 = 160 N/mm^2
τ = 160 / 2
τ= 80 N/mm^2
Torque transmitted,

$$Mt = \frac{60 \times 10^6 \times 1.2}{2 \times \pi \times 50}$$

Mt = 229183.11 N-mm
Key Dimensions:
Square Key,

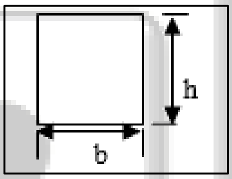

Fig. 3: Cross-section of Key

b = h = d/4 = 40/4 = 10 mm
Length of key,
Considering Shear failure,

$$l = \frac{2\,Mt}{\tau\, db}$$

$$l = \frac{2 \times 229183.11}{80 \times 40 \times 10}$$

l = 14.32 mm
Considering Crushing failure,

$$l = \frac{4Mt}{6cdb}$$

$$l = \frac{4 \times 229183.11}{160 \times 40 \times 10}$$

l = 14.32 mm
Length of the key should be 16 mm
l x b x h = 16 x 10 x10 mm

C. *Gear Design*

It is required that the centre distance between the two shafts should be 105mm, so we have selected the following gear and pinion parameters.

Parameters	Gear	Pinion
Teeths	39	32
Pitch Circle Diameter	115 mm	95 mm
Bore	25 mm	18 mm
Centre Distance	105 mm	

Table 1: Gear and Pinion parameters

Module = 3 mm ,
Power = 1.2 Kw ,
Service Factor = 1.2 ,
Material = (40 Ni14)

1) *Beam Strength :*

6b = 800/3 = 266.67 N/mm^2
Sb = 6_b x M x b x Y
= 266.67 x 3 x 30 x 0.433
Sb = 10392.12 N
Tangential Force due to rated torque (Pt)
dp = 95 mm

$$Mt = \frac{60 \times 10^6 \times 1.2}{2 \times \pi \times 60}$$

= 190985.93 Nmm

$$Pt = \frac{2Mt}{dp} = \frac{2 \times 190985.93}{95}$$

Pt = 5226.94 N
Effective load (P_{eff})

$$V = \frac{\pi \times dp \times Np}{60}$$

$$= \frac{\pi \times 95 \times 60}{60}$$

=298.45 mm/s

$$\text{Velocity Factor, } (Cv) = \frac{3}{3 + v} = \frac{3}{3 + 0.298} = 0.9095$$

$$Peff = \frac{Cs \times Pt}{Cv} = \frac{1.25 \times 5226.94}{0.9095}$$

= 7183.66 N

$$\text{Factor of Safety (F.O.S)} = \frac{Sb}{Peff} = \frac{8735.78}{7183.66}$$

= 1.21
So the design is safe.

2) *Checking of gear in wear strength, Surface Hardness*

K = 0.156 x (BHN / 100)^2

$$Q = \frac{2Zg}{Zg + Zp} = \frac{2 \times 39}{39 + 32}$$

Q = 1.098
Sw = b x Q x dp x K= Peff x F.O.S ,
30x1.098x95 x 0.156 x (BHN/100)2 = P_{eff} x F.O.S
5827.68 x 0.156 x (BHN/100)^2 = 7183.66 x 1.21
BHN = 132.47=135
Therefore the material has enough wear strength
Hence, design is safe.

D. *Bearing Selection:*

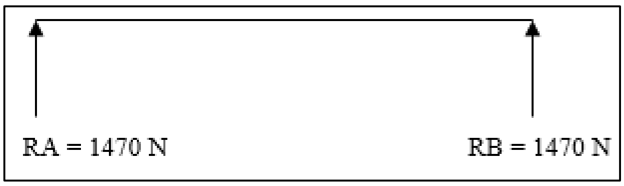

Fig. 4: Reaction forces diagram.

Radial Force on each shaft,
Fr = 1470N
Since, there is no axial thrust
Fa = 0
Dynamic Load Capacities
$P_1 = F_{r1} = 1470$ N
$P_2 = F_{r2} = 1470$ N
The relationship between life in million revolutions and life in hours is given by

$$L_{10} = \frac{60 \times n \times L_{10h}}{10^6}$$

L_{10h} = rated life (hours).
n = Speed of Rotation.(rpm)
Bearing life for Application
Machines used intermittently such as lifting truck & household applications (4000- 8000hrs) [8]

$$L_{10} = \frac{60 \times 50 \times 8000}{10^6}$$

L_{10} = 24 million revolutions.
Considering the load factor and using ball bearing equation,
The dynamic load carrying capacity is
$C = P(L_{10})^{1/3} \times 1.4$
$C = P(L_{10})^{1/3} \times 1.4$ [6]
$C = 1470 \times (24)^{1/3} \times 1.4$
C = 5936.29 N
The available bearing ,
d = 30 mm
D = 55 mm
B = 9 mm
Bearing Selected is 16006
E. Cutter Design

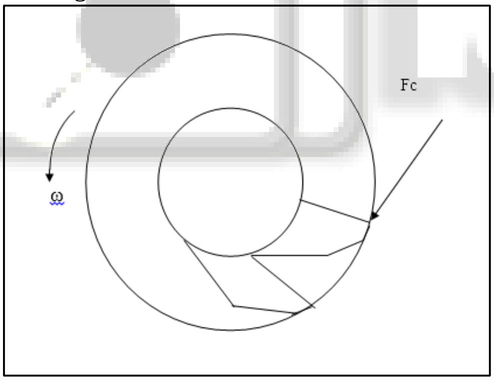

Fig. 5: force acting on a cutter.

Fc = Cutting Force,
Torque transmitted is given by
Torque = Pt x D/2
This torque is useful for design of shaft, gears & cutter.
Fc causes bending of the shaft.
We have Torque to be transmitted, T = 210x75=15750 Nmm,
& Tangential Force Pt = 210N
Diameter of the cutter blade, D = 150mm.

II. Result Analysis

A. Catia Modelling

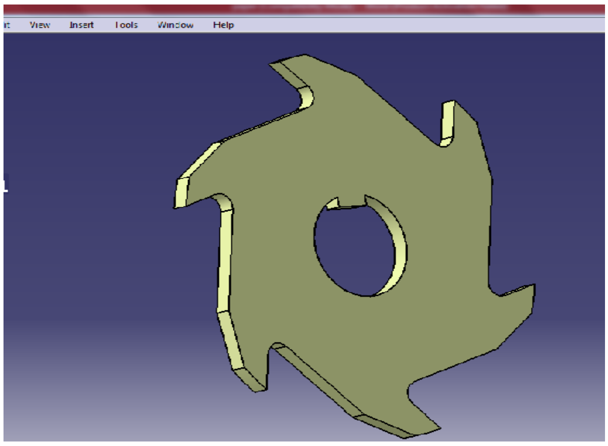
Fig. 6: Catia model of cutter

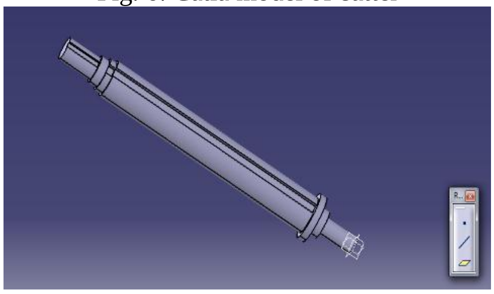
Fig. 7: Catia model of Shaft

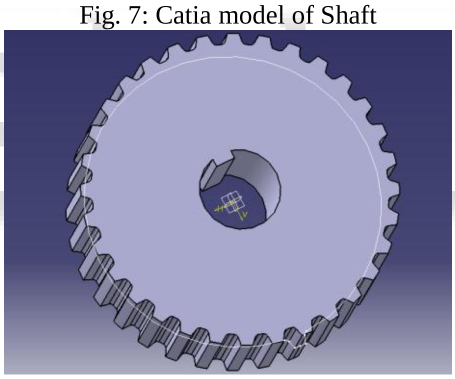
Fig. 8: Catia model of Spur Gear

B. ANSYS Analysis

The analysis of the Cutter, Spur gear and Shaft are performed on the ANSYS software.

1) Cutter

a) Equivalent Stress Analysis:

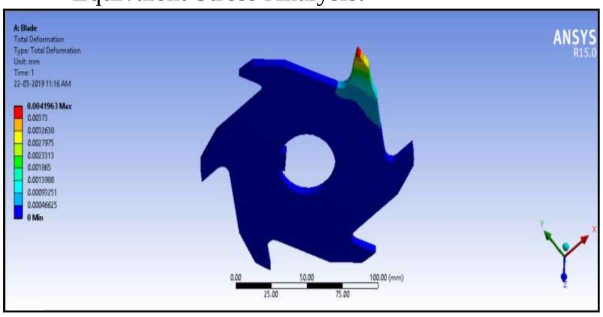

Fig. 9: Equivalent stress analysis

b) Total Deformation analysis:

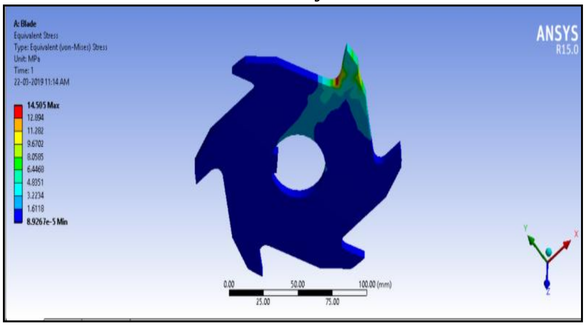

Fig. 10: Total deformation analysis

2) Shaft

a) Equivalent Stress Analysis:

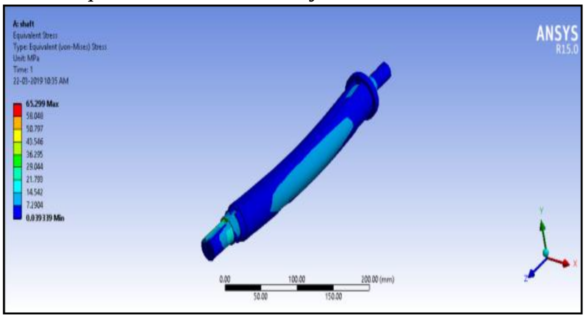

Fig. 11: Equivalent stress analysis

b) Total Deformation analysis:

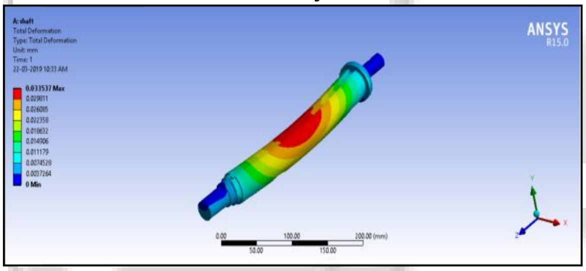

Fig. 12: Total deformation analysis

3) Spur Gear

a) Equivalent stress analysis:

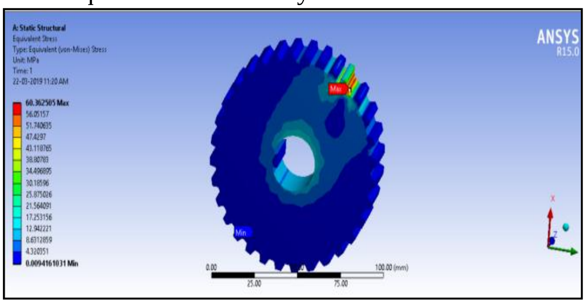

Fig. 13: Equivalent stress analysis

b) Total Deformation analysis:

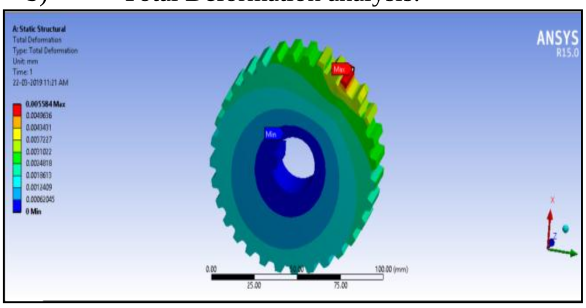

Fig. 14: Total deformation analysis

III. Conclusions

The paper concludes that,

1) Model which designed is simple in construction, efficient, requires less time and cost effective when compared to the existing available model.
2) Importance is given towards user friendly in operation towards safety.
3) Chopped size of waste is 4mm
4) Compost will be available for farmers almost free of cost.
5) Various kinds of blade can be used for the chopping and powdering operation like sawing blade, triangular blade and rotary shape blade.

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