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Design and Fabrication of Plastic Shredder

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Abstract: Prior to being transformed into useful items, plastic trash is first shredded into little pieces using a plastic shredder machine. The shredder machine that is currently on the market has a concept design that is quite similar. The performance of the shredding machine is mostly dependent on the shaft and blades. It was discovered that the geometry and orientation of the blades installed in the double-shafts had a direct impact on the shredding efficiency. The feeding unit, shredding unit, power transmission unit, and machine frame make up the shredder.
Keywords: Plastic, blade, shaft, shredder, recycling.

I. INTRODUCTION

Plastic shredders are being an emerging solution for turning the waste plastic into reusable resources. Plastic shredders are quite useful in the process of plastic waste management by shredding the plastic waste into fine pieces which can be recycled and can be reused again thereby helping the environment. This low-cost plastic shredder is surely an effective solution meanwhile keeping the cost low and with hampering the overall process of shredding. It is a robust machine which is used to shred the plastic bottles into small pieces, it has a set of cutting blades mounted on double shaft arrangement which will be further connected to the chain coupling arrangement; the worm and worm wheel gearbox has been used to reduce the rpm and increase the torque required to cut the plastic. The whole setup will be powered with the help of a 1 HP induction motor having 1440 rpm.

A. Objectives

1) To build a functioning plastic shredding machine for shredding plastic waste, hence reducing the plastic waste.
2) To study and apply the design procedure for shredder machine parts such as shaft, cutting blade, bearing and hopper respectively.
3) To analyze the performance of cutting blade by using finite element analysis.
4) To shred the plastic waste into small pieces by using set of cutting blades so as to help in the process of plastic waste management.

B. Analytical Calculations of Components

1) *Cutting Blade:* We are using a shredder blade with three cutting edges for plastic shredding. The calculate the cutting force required for the cutting, we have studied the Mechanical properties of the PET (Polyethylene Terephthalate) material which are given below.

TABLE 1
Mechanical Properties of PET material

Coefficient of friction (μ)	From 0.2 to 0.4
Hardness (RC)	From 94 to 101
Poisson’s ratio (υ)	From 0.37 to 0.44
Tensile modulus (GPa)	From 2 to 4
Tensile strength (Mpa)	80
Yield strength (Mpa)	64

- τ(breaking)Plastic = 80 MPa
  We have considered 90 MPa for safety.

- Cutting Force Required:
  = τ(br)*(Area of blade)
  = 90*5
  Fc = 450 N.

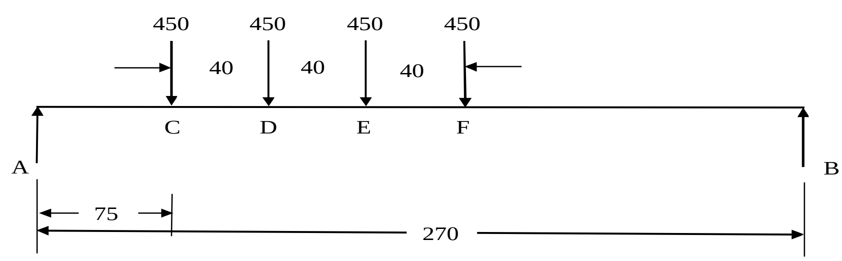
- Torque exerting on the blade:
  T = Force*Perpendicular distance (r)
  = 450*40
  = 18000 N.mm
  T = 18 N.m.
- Power transmitted or required:
  P = 2*π*N*T*(No. of blades)/(60*1000)
  = 2*π*(50)*(18)*(7)/(60000)
  = 659.73 W
  P = 0.659 KW.

2) Shredder Shaft

Material Selected for Shaft – Mild Steel
Properties:
Syt = 320 MPa. Sut = 400 MPa.
μ = 0.31.
Young's modulus = 200 GPa.

- Design of Shaft (By using Maximum Shear Stress Theory)
  τmax = Ssy/Fs
  = 0.5 Syt/1.5
  = 0.5(320)/1.5
  τmax = 106.67 N/mm2.

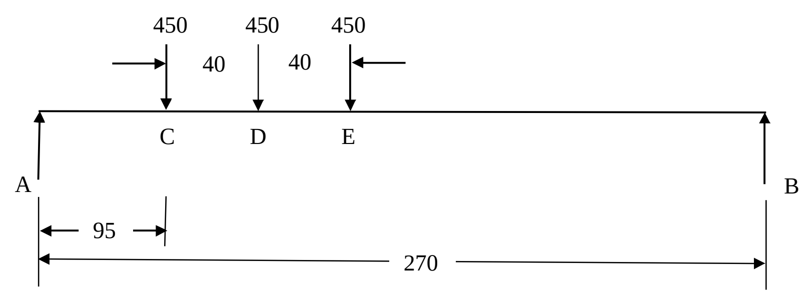
Shaft 1:



RA + RB = 1800 N
RA = 900 N.
mA = 0
mC = (900*75) = 67500 N.mm.
mD = (900*115) – (450*40) = 85500 N.mm.
mE = (900*155) – (450*80) – (450*40) = 85500 N.mm.
mF = (900*195) – (450*120) – (450*80) – (450*40) = 67500 N.mm.
mB = (900*270) – (450*195) – (450*115) – (450*155) – (450*75) =0

Maximum bending moment (mb) = 85500 Nmm
Maximum torque (mt) = 18000 N.mm
τmax = 16/πd3 * (√(kb*mb)2 + (kt*mt)2)
106.67 = 16/πd3 * (√(1.5*85500)2 + (1*18000)2)
d = 18.35 mm.

Shaft 2:



RA + RB = 1350 N
RA = 675 N.
mA = 0
mC = (95*675) = 45125 N.mm
mD = (675*135) – (450*40) = 73125 N.mm
mE = (675*175) – (450*80) – (450*40) = 64125 N.mm
mB = (675*270) – (675*175) – (450*135) – (450*95) = 0

Maximum bending moment (mb) = 73125 N.mm
Maximum torque (mt) = 18000 N.mm

$\tau_{max} = 16/\pi d^3 * (\sqrt{(kb*mb)^2 + (kt*mt)^2})$
$106.67 = 16/\pi d^3 * (\sqrt{(1.5*73125)^2 + (1*18000)^2})$
d = 17.44 mm

3) *Bearing Selection*
Fr (Radial load) = 1800 N.
Fa (Axial load) = 0
V (Rotation factor) = 1.0 Ka = 1.5
Lh10 = 8000
d = 20 mm
n = 50 rpm

Bearing selected is 6204
Co = 6.55 kN and C = 13.55 kN

Pe = V*Fr*Ka
= 1*1800*1.5
= 2700 N.

$L10 = (Lh10*60*n)/10^6$
$= (8000*60*50)/10^6$
L10 = 24 million rev.

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$L10 = (C/Pe)^a\ 24 = (C/2700)^3$
C = 7788.15 N
C = 7.78 kN
Selected bearing is 6204 with dimensions 20mm*47mm*14mm, Co = 6.55 kN and
C = 13.55 kN is Safe

4) Volume of the Hopper

= 1/3[A1 +A2 + √]* h
Where,
A1 = Area of top base
A1 = 275 * 205
= 56375 mm^2
A2 = Area of Bottom Base
A2 = 185*205
= 37925 mm^2
h = Height of Hopper
= 145 mm

Volume of Hopper (V)

V = 1/3 [56375 + 37925 + √ 1+2] * 145
= $455*10^6\ mm^3$
= $0.004\ m^3$

5) Area of PET (Coca cola bottle)

= $7.7*^{10-4}\ m^2$
Therefore No. of bottle to fill the Hopper
= Volume of hopper / volume of PET bottle
= $0.004 / 7.7*10^{-4}$
= 5.19 = 5 Bottles.

C. Solid Modelling, Analysis and Manufacturing of Parts

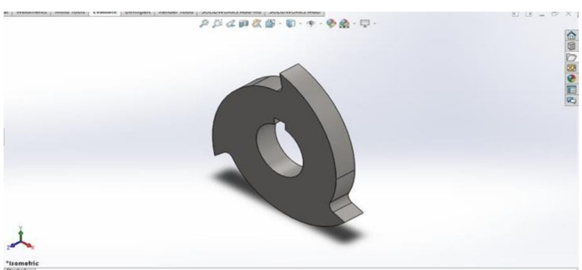

Fig. 1. Modelling of Cutting Blade

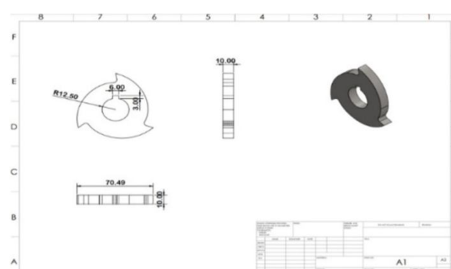

Fig. 2. Drafting of Cutting Blade

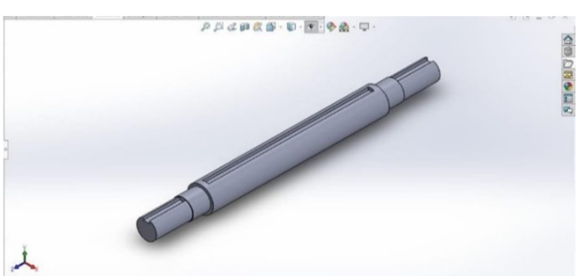

Fig. 3. Modelling of Shredder Shaft

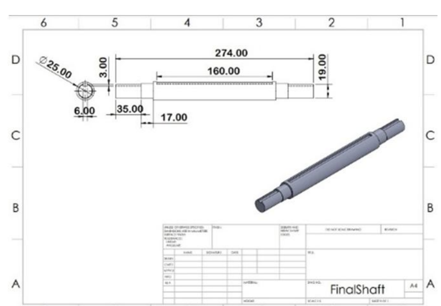

Fig. 4. Drafting of Shredder Shaft

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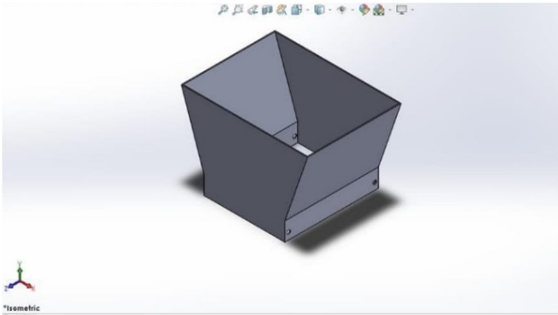


Fig. 5. Modelling of Hopper

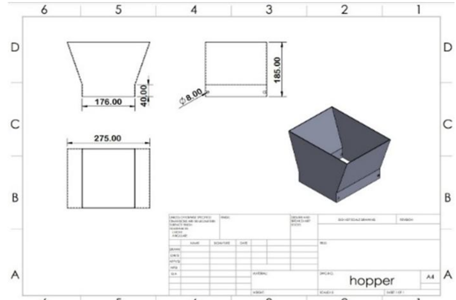


Fig. 6. Drafting of Hopper

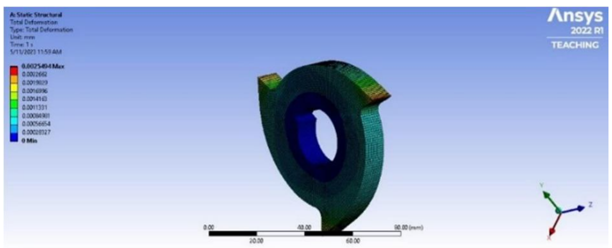


Fig. 7. Total deformation analysis of blade

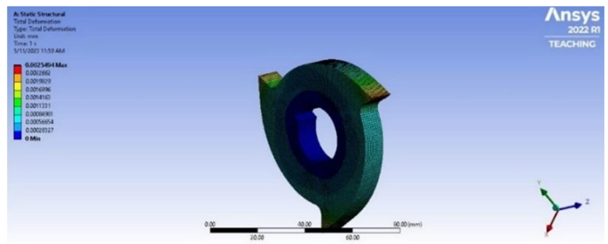


Fig. 8. Von-mises stress analysis of blade

Fig. 9. Shaft

Fig. 10. Blade

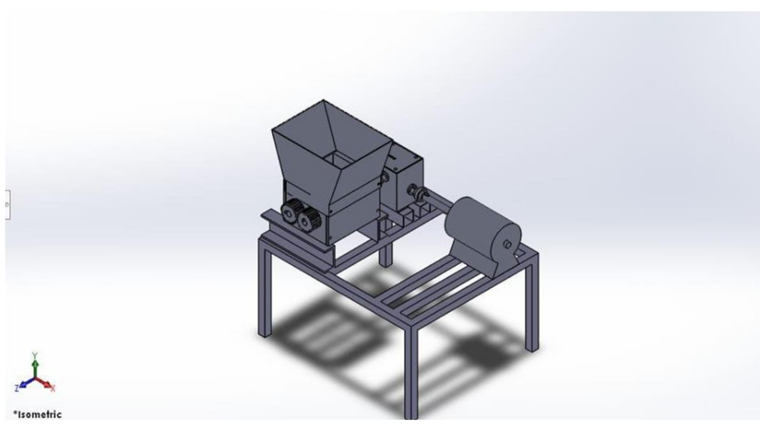


Fig. 11. Assembly of Shredder

D. Details Of Auxiliary Equipments Required For Operation

1) 1 HP Induction Motor

As per the calculations, the power required is 659.73 W, hence we have chosen 1 HP motor with 1440 rpm for powering the shredder.

2) Worm and Worm Wheel Speed Reduction Gearbox

The working or required rpm for the plastic shredder is 50 rpm, to achieve this, we have used worm and worm wheel gearbox with a reduction ratio of 30:1.

3) Chain Coupling

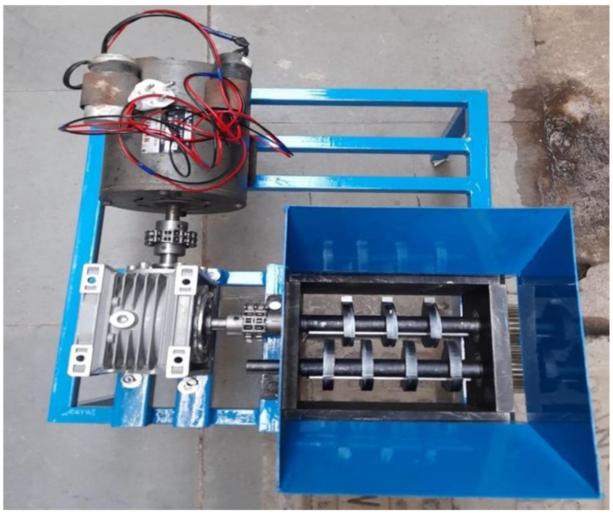
To enhance better transmission between two connecting shafts and to cater any misalignment, we have used Chain couplings to ensure smooth flow. It has an outer diameter 50 mm and bore diameter 15 mm respectively.

4) Transmission Gears

The power or drive has been given to one shaft, as there are two shafts rotating in opposite direction, we have used Spur gears to transmit the drive from one shaft to another. They have outer diameter 60 mm with number of teeth 40 respectively.

E. Assembly And Results

All parts have been assembled and the overall structure look like this, the assembly of shaft and blade has been enclosed in a shredder cover which is made of Mild steel plates with holes for shafts.



As the plastic bottle is fed into the shredder, it falls as a shredded plastic, which will be further used for recycling purpose.

II. CONCLUSION

1) The plastic bottle has been successfully shredded with the help of set of blades, the Fig. 26 shows the shredded pieces of plastic bottle.
2) The Cutting blade selected is having three cutting edges with cutting force of 450N per blade.
3) The material selected for cutting blade is EN8 steel.
4) The shaft material selected is 40C8 with diameter of 18.35 mm, rounded off to 25 mm with a span of 270 mm.
5) There are 4 blades mounted on one shaft with a distance of 40 mm in between them, and there are 3 blades on second shaft with a distance of 40 mm between each other.
6) There are two shafts with blades on each rotating in opposite direction with the help of gears.
7) The shredder is powered with the help of 1 HP Induction motor having 1440 rpm, the speed has been reduced with the help of Worm and worm wheel gearbox with reduction ratio 30:1. The required rpm for working of the shredder is 50 rpm.
8) A hopper has been designed to feed the plastic bottles into the shredder with a decreasing cross-sectional area.
9) The whole setup is mounted on a fabricated stand with appropriate dimensions.

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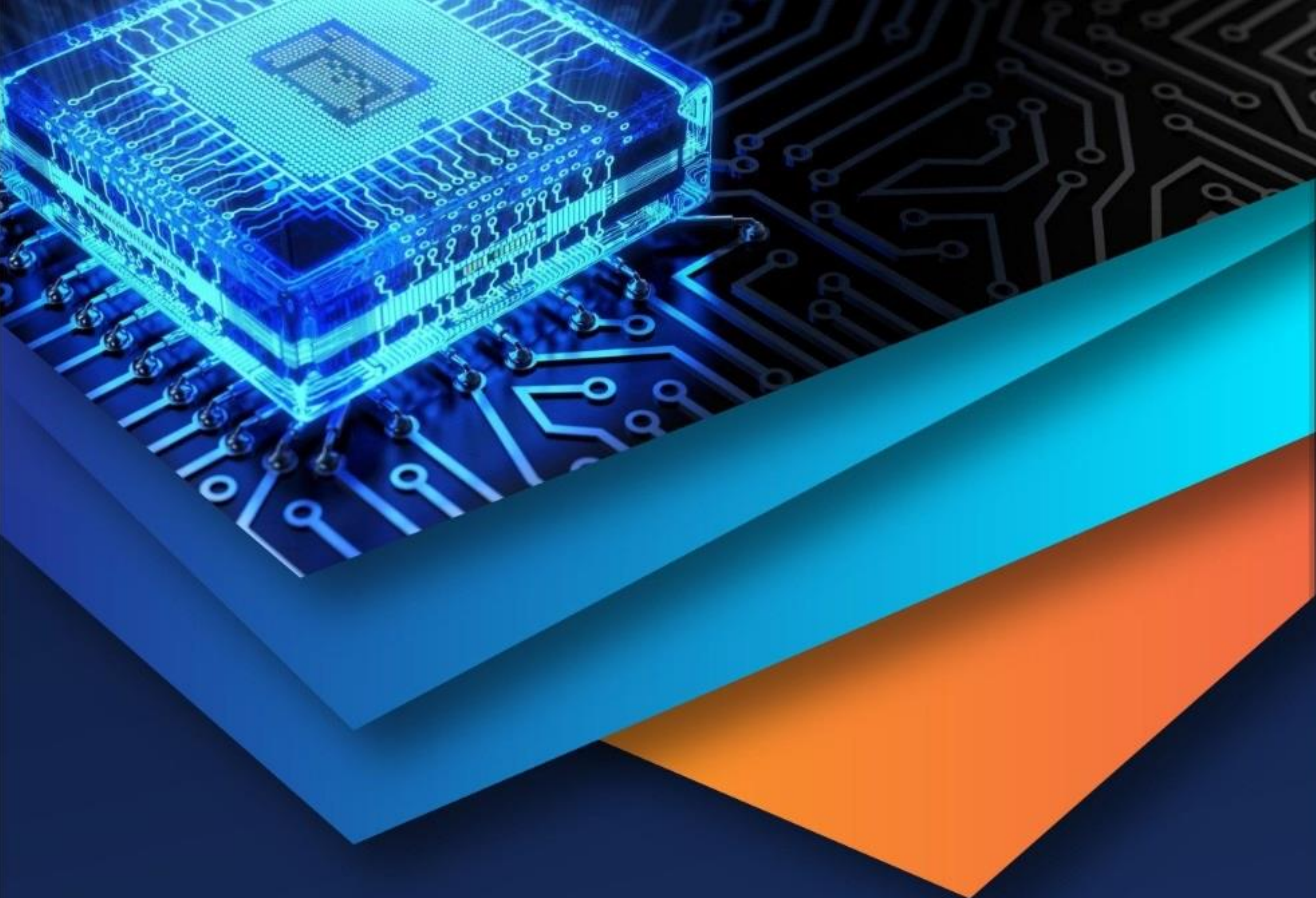

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