Design and Development of Plastic Reprocessing Grinding Machine

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ABSTRACT
Plastic is undoubtedly to reign among the variety of materials for its varied applications; engineering machinery parts to domestic appliances to packaging's. Plastic causes serious environmental problems. Although they are not intrinsically dangerous, they take up a huge amount of space in landfills and they are made from a non-renewable resources, namely fossil fuels for this reasons it is important that, where possible plastics are recycled. The use of plastic is increased now days in many industries like automobile, packaging, medical, etc. as it is easier to manufacture, handle and reliable to use and also at large scale with low cost.

The available machines used to recycle the plastic waste are very costly. They pack this waste and give them to the local processing plants. So the process of packaging and transporting is much costly. So our intension behind this project is to process the waste plastic bottles as cheap as possible by cutting where it is made for reducing of labor work which results in cost reduction. A new cutting machine is designed to increase the output of the existing grinding machine.

This project describes about the design and experimentation of modified plastic bottle grinder. The idea behind the project is to increase the output of the existing machine without completely changing its whole assembly and only changing its cutter-rotor assembly and obtain required size of flakes.

Keywords
Polyethylene terephthalate, savior material, 3D Hopper

1. INTRODUCTION
It is a universal truth that plastic facilitated the mankind with a comfortable alternative to wood, leather, glass, metals, etc. Plastic proves compatible when it comes to working condition; it acts neutral in heterogeneous working environmental situations. Plastic products are featured with multi-color; also, the single color with different shades on color bandwidth is possible. Plastic products can be formed into complicated shapes which otherwise is difficult and not economical with other materials. Plastic can be molded into products; exhibiting desired mechanical and physical properties by blending it with performance enhancer additives. Plastics are durable and also offer a wide range of aesthetic appearance. Plastics have become so versatile in its functioning that it is making inroads in all sorts of applications; may it be consumer, industrial, utilities, civil structures, etc. If any new product is foreseen for development, plastic is revived first because it facilitates the purpose. Once hailed as a 'savior material', now plastic is being realized to the intensity of disastrous it can cause to the planet earth in terms of its environmental and health hazard due to its non-biodegradable nature. [1]

Waste is now a global problem, and one that must be addressed in order to solve the world's resource and energy challenges. Everything we consume becomes waste including plastic bottles. Plastic is most commonly used material in the world today. They come in five major categories, the Polyethylene terephthalate (PET), High density polyethylene, Polyethylene (HDPE), the polyvinylchloride (PVC), the polypropylene (PP), Low density polyethylene. The disposal of waste plastics (PET, PP, etc.) is a biggest challenge, as repeated recycling of PET bottles poses a potential danger of being transformed to a carcinogenic material and only a small proportion of PET bottles are being recycled. Plastic are synthetic organic materials produced by polymerization. [2]They are typically of high molecular mass and may contain other substances besides polymers to improve performance and or reduce cost. These polymers can be molded or extruded into desired shapes.

Plastic bottles are made from a petroleum product known as polyethylene terephthalate (PET), and they require huge amounts of fossil fuels to both make and transport them. It's harder to recycle plastic bottles than we think. Some plastic bottles consumed throughout the world, most of them are not recycled because only certain types of plastic bottles can be recycled by certain municipalities. They either end up lying stagnant in landfills, leaching dangerous chemicals into the ground, or they infiltrate our streets as litter. There is a big disadvantage of plastic that is difficult to decompose. So we have to recycle the plastic and there are various methods for plastic recycling. As well as the scrap collectors also avoid to taking the plastic bottles because of its high volume and less weight. Machinery available is costly, so overcome this problem it is need to develop a low cost cutting machine. The project is about development of plastic bottle crushing machine with increased output and high material cutting ratio.[3]

Polyethylene terephthalate (PET) is widely used in several key products, as fiber for textile applications and into backing materials for audio and video tapes .Biaxial oriented polyester film is used for packaging and as thermoformed sheet. Pet films are used in electric devices as well.[4]

The best known product made from aromatic polyester (PET), however is the blow molded water and soda bottles for soft drinks and other household and consumer products. PET is a relatively new packaging resin. Soft drink bottles remain the biggest user of PET resin. 'consumer' bottles are used for other products such as, salad dressing, peanut butter and jellies, Half of the polyester carpet made in united states is made from recycled PET bottles .The rise of use of custom bottle and the increased consumption of water and soft drinks away from home have created challenges for increasing the PET recycling rate.PET use has reduced the size of the waste stream because PET has replaced heavier steel and glass containers.[5]

One of the approaches to solution of the plastic waste problem is through recycling for its numerous benefits justifying the aim of this study that essentially meant to contribute to sustainable consumption and production of PET bottles in particular. Recycling of plastics should be carried in such a manner to minimize the pollution level during the process and as a result to enhance the efficiency of the process and conserve the energy.

Plastic recycling or reprocessing is usually referred to as the process by which plastic waste material that would otherwise become solid waste are collected, separated, processed and returned to use. [6]

Waste plastic shredder is a machine that reduces used plastic bottles to smaller particle sizes to enhance its portability, easiness and readiness for use into another new product. The design principle of this machine was got from the ancient tradition method of using scissors to cut materials into reduced form and scratching used by rabbits when digging or tearing. [7]

These two traditional methods were applied in the design of the machine by fabricating cutting blades to cut the waste plastic while some of the cutting blades have sharp curved edges to draw in the plastic into the cutting blades teeth. The waste plastic shredder comprises of four major components, namely; the feeding unit, the shredding unit, the power unit and the machine frame. The machine can be powered by electric motor.

The project is about a plastic grinder machine. It is a sponsored project by ANKITA ENGINEERING WORKS, located in Ambad MIDC, Nashik. The company is specialized in manufacturing of grinder machine.

1.1. Problem Statement:

In today's scenario, plastic is the biggest issue in the world which is causing danger to life due to its big disadvantage of being difficult to decompose, so we have to recycle the plastic and there are various methods for plastic recycling. The basic problems faced during the recycling of plastics are:

a. The scrap collectors also avoid to taking the plastic bottles because of its high volume and less weight.
b. The available setup required for plastic bottle grinder has less output and undefined size of flakes.

Fig 1.1: Plastic Scenario

1.1 Objectives :

a. To increase the output of the conventional grinder machine.
b. To increase the cutting ability of existing machine.
c. To improve the quality of the flakes.
d. To improve the efficiency of the machine.

2. Methodology

1 .We studied the conventional grinder machine which was manufactured by ANKITA ENGINEERING WORKS.
2 .We studied the different parameters and working of conventional grinder machine.
3. We redesigned the cutter- rotor assembly to increase the output of the machine.
4. We manufactured the machine according to new design.
5. Testing the new design.

3. DESIGN AND DRAFTING

3.1. Working Principle

The plastic bottles have more volume compared with its weight, so due to this plastic bottles take more space than other scrape so the scrap collector avoids taking plastic bottles. If we crush or cut this plastic then it is convenient and economical to scrap collector to transportation and this cut plastic can be directly used for further processing. So we decided to make plastic cutting machine which is motor operated so it is affordable to the customer. The bottle crusher is cutting the parts from the bottles with rotary cutting tool within a specified depth and the speed limit, then the two parts separately or it will be truncated. The machine is powered by motor. The principle of operation is a follows

• Align the plastic bottle into the hopper.
• Cutter will rotate when the shaft is rotated after starting of motor.
• Bottle will cut when contact with the cutting tool.
• The scroll will fall in the collector provided.

Specifications:

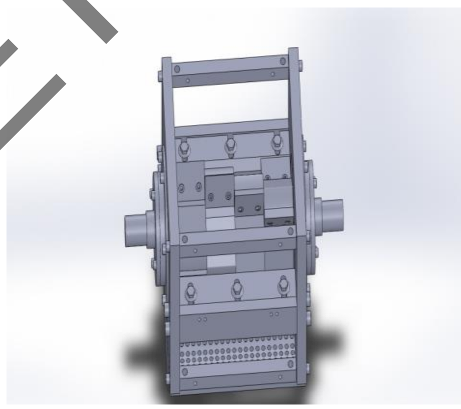
Internal Diameter = 55mm

Outer Diameter = 120mm

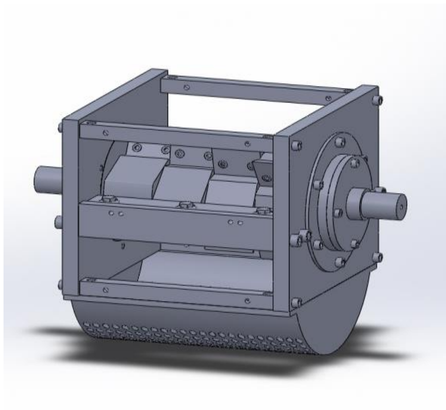
Thickness = 29 mm

3.2. Proposed design:

In the proposed design of grinder machine, we have increased the thickness of rotor to 75mm and instead of three rotors we have introduced four rotors. The length of rotating cutter is reduced to 75 mm and each cutter is mounted on each rotor with the help of nut and bolt. The two stationary cutters are kept of same length as that of existing design. Rest of the assembly is same as that of existing design. Due to increased number of cutters are cutting rate will be increased due to increase in cutting force. Due to reduced length the cutting will be more efficient and cutting rate will be increased.



(a)



(b)

Fig 2.3: Proposed design

3.6. Components of proposed design:

3.6.1. Cutter:

In new design 6 cutters are used with reduced length. 4 cutters are mounted on the rotors and 2 rotors are mounted on the blocks. The holes are drilled on the cutter to mount on the rotors.

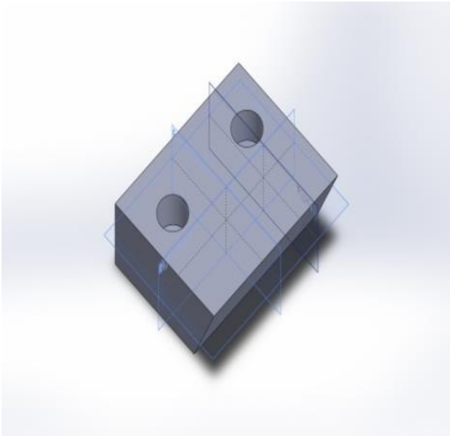


Fig 3.24: 3D Cutter

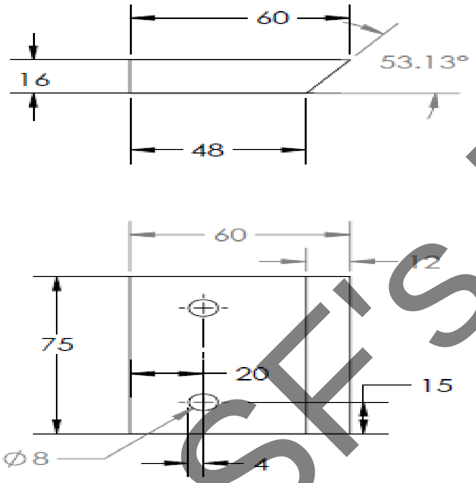


Fig 3.25: Detail dimensions of cutter

Dimensions of cutter:

Length of rotor= 75mm

Height of rotor= 16mm

Upper width of cutter= 60mm

Lower width of cutter= 48mm

Diameter of hole= M8 counter bore

Distance between two holes= 45mm

3.6.2. Rotor:

In new design 4 rotors are used with increased thickness. The rotors are mounted on the shaft at an angle. Keyway is provided in the rotor at an angle.

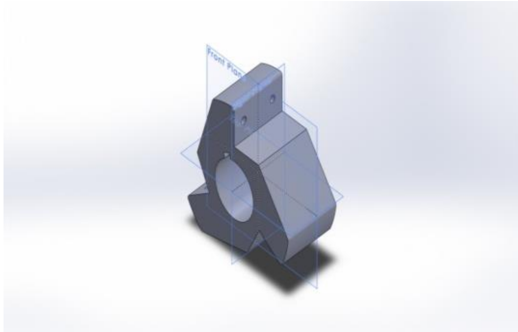


Fig 3.26 :3D Rotor

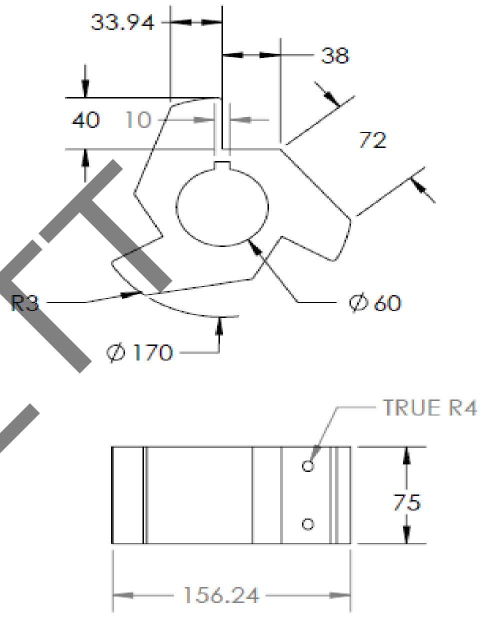


Fig 3.27 : Detail dimensions of rotor

Dimensions of rotor:

Inner diameter of rotor= Ø60mm

Pitch circle diameter= Ø170mm

Thickness of rotor= 75mm

Dimension of keyway= 5*5

Angle of rotor= 120°

3.6.3. Shaft:

In new design keyway is provided on the shaft to mount the rotors at particular angle. The rotors, housing, bearing etc are mounted on the shaft. The shaft is machined on the lathe machine.

Fig 3.28: 3D Shaft

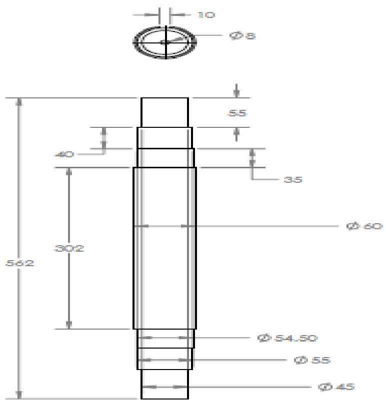


Fig 3.29 : Detail dimension of shaft

Dimensions of shaft:

Diameter of shaft= Ø60mm

Length of shaft= 302mm

Dimensions of keyway: 302*5*10

3.7. Assembly of machine:

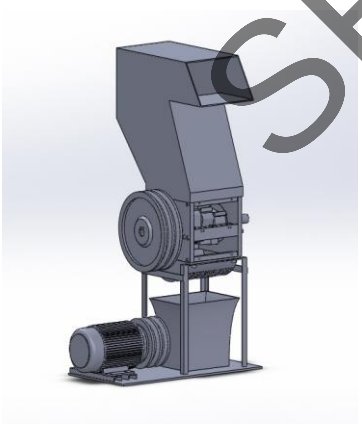


Fig 3.30: Set up of machine

4. PERFORMACE AND TEST

4.1. Calculations:

4.1.1. Estimation of Total Power Requirement:

The weight of plastic material required to fill up the machine hopper chamber is given by,

$W_p = V_h.\rho_h.g$

Where,

W_p = Weight of the plastic material in N

V_h= Volume of the machine hopper unit

ρ_p = Bulk density of plastic material

4.1.2. Volume of hopper:

The required volume is the volume of bigger pyramid minus volume of smaller pyramid,

V_h= LWH/3 - lwh/3

Where,

L and 1=Base length of bigger and smaller pyramid respectively

W and w=Base width of bigger and smaller pyramid respectively

H and h=Height of bigger and smaller pyramid respectively

By principal of similar triangles,

Hence, the volume of the hopper is;

V_h =0.471*0.3*0.424/3 - 0.325*0.302*0.05/3 =0.018334m^3

But, weight of the plastic material required to fill up the machine hopper;

$W_p = V_H * \rho_P * g$

But, density polyethylene=970kg/m^3

W_p =0.018334*970*9.81=174.46N

4.1.3. Design and Analysis of Belt Drive Length of V-Belt drive length of V belt:

$$L = \Pi(r_2 + r_1) + 2x + \frac{(r2 - r1)^2}{x}$$

Where,

r_1 and r_2 = Radii of the larger and smaller pulleys x = Distance between the centres of two pulleys

r_1 = 62.5mm

r_2 = 125mm

x = 540mm

$L = \pi(125+62.5)+2*540+\frac{(125-62.5)^2}{540}$

L = 1676.28mm

L = 1.67m

4.1.4. Angle of lap on smaller pulley:

$\theta = 180^\circ - 2[sin^{-1}\frac{(d2-d1)}{2x}]$

Where,

d2 = diameter of the driven pulley

d1 = diameter of driver pulley

$\theta = 180 - 2[sin^{-1}\frac{(0.25-0.125)}{2*0.54}]$

θ = 166.70

4.1.5.Velocity of the Belt (V) :

$V = \frac{\pi d1N1}{60}$

Where,

d1 = Diameter of the driver

N1 = Speed of the driver in rpm

$V = \frac{\pi*0.625*1440}{60}$

V = 47.12 m/sec

Velocity ratio (VR) = Diameter of driven pulley/Diameter of driver Pulley

VR= 250/125

VR= 2

Output Speed= Input speed / VR

= 1440/2

Output Speed=720rpm

4.1.6. Design for shaft:

Torque required to Produce Power,

P = 2πNT/60

5*746 = 2*π*1440*T/60

T = 24.7 Nm

T=24.7*10^3 N-mm

Maximum Bending moment on the shaft is,

$M = \frac{WL}{4}$

$= \frac{5.4936\times300}{4}$

= 412.02 ×10^3 N-mm

Equivalent Torque on the shaft is,

$T_e = \sqrt{(Kb \times M)^2 + (Kt \times T)^2}$

$= \sqrt{(1.5 \times 412.02 \times 10^3)^2 + (Kt \times T)^2}$

Te = 618.52×10^3 N-mm

According to shear stress theory,

$\tau_{max} = \frac{16Te}{\pi d^3}$

$= \frac{16\times618.52\times10^3}{\pi\times d^3}$

d = 42.17 mm

or

d = 60 mm

4.1.7. Cutting Force:

T = F .r

Where,

T = Torque

F = Cutting force

r = Cutting Radius

$24.7 \times 10^3 = F .95$

F = 260 N

5.1. Manufactured parts of machine:

The materials used for manufacturing of various components are mild steel, SS304, WPS etc**.**

Table 5.1 : Material used for different components

Component	**Material used**
Rotor	Mild steel
Cutter	WPS
Shaft	Mild steel
Hopper	SS304
Plate	Mild steel
Block	Mild steel
Tie Bar	Mild steel
Stand	Mild steel
Cover	Mild steel
Housing	Mild steel
Container	Mild steel
Pulley	Cast Iron

Fig 4.1 : Manufactured plate

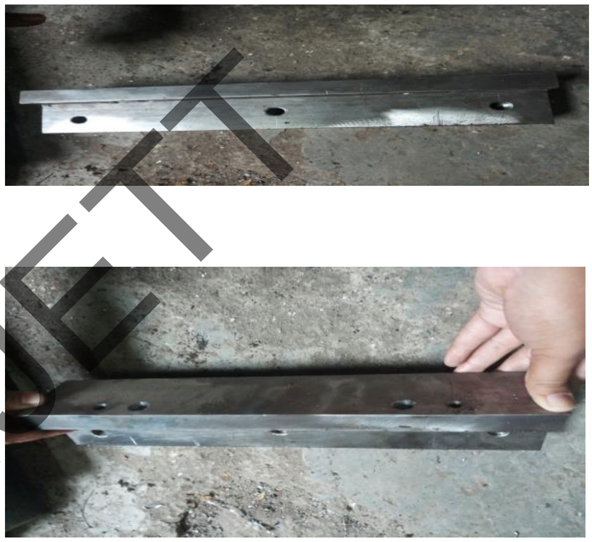


Fig 4.2: Manufactured Block

Fig 4.3: Manufactured Housing

Fig 4.4: Manufactured Bearing

4.1.6. Assembly of new design:

Fig 4.5: Manufactured Assembly Of New Design

Fig 4.6: Manufactured Machine

Table 5.2: List of components, manufacturing process and machines used

5. PERFORMANCE AND COMPARISON

As shows in Table 6.1, testing with the plastic grinder machine was carried out seven times with different masses of plastic wastes that vary in weight and a graph was plotted. The average of waste plastic bottle fed into crushing machine and the mass of plastic bottle properly crushed to require sizes were calculated and it was used to determine the efficiency of the plastic grinder machine and hence we studied the performance based comparison of both the designs.

Table 5.1: Comparison of results

SR NO.	Mass of plastic fed (kg)	Mass of plastic crushed before(kg)	Mass of plastic crushed after (kg)	Time taken (sec)
1	5.2	3.7	3	60
2	11.5	8	7.2	110
3	18.8	13.9	12.8	128
4	25	17.3	16.9	150
5	30	28.7	27.9	180
6	34	32	31.8	200
7	36	35	34.3	220

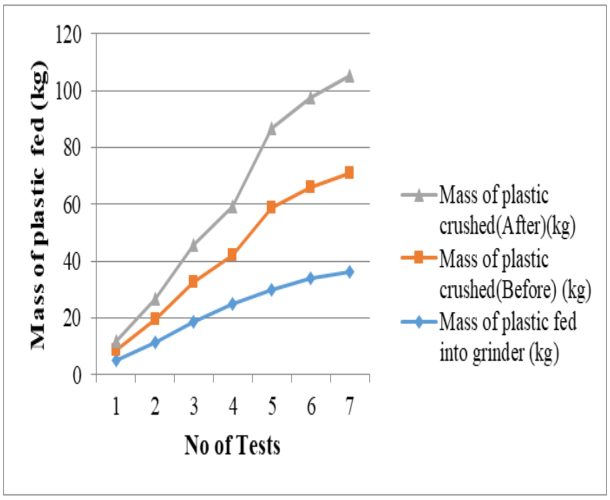


Fig 5.1: Plot of mass of plastic waste

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6. CONCLUSION

The developed model is simple, efficient, requires less time and cost effective when compared to the Existing model. Importance is given towards increasing output and efficiency of the existing setup. The rotating elements like belt and pulley and gears are covered, so it is safe to operator.

The overall performance of shredder machine was satisfactory by considering the quantity of flakes produced with respect to time. By redesigning the existing design the output of the machine is increased due to increased cutting rate. The offset of angle 20º given to the cutters enhances the cutting impact. The strainer provided helps in obtaining the required flakes of output. The modified cutter rotor assembly can be incorporated in the existing setup. It helps in reducing the volume of waste generated and will thus help in effective waste management. The crushed plastic can be used for further reprocessing.

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