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Design and Development of Plastic Bottle Crushing Machine

Prof. Mangesh A. Ahire, Shrinath S. Kumbhar, Durgeshwar Wangekar, Vivek B. More, Devansh C. Gite
Rajarshi Shahu College of Engineering, Pune, India

Abstract: One of the environmental problems faced by most of the developing countries is waste management. Plastic waste, such as polyethylene terephthalate (PET) bottles and other plastic materials, is one of the waste products that affect the structure and beauty of our environment. This is the result of illegal dumping and indiscriminate burning of waste. The environmental pollution from its constant disposal and incineration is necessary for the creation of plastic shredders to recycle the plastic waste produced in our environment. The main parts of the machine are the hopper, the crushing cavity, the outlet, the counterweight, the horizontal vane transmission shaft and the shaft. The machine works with a 3-phase 5Hp medium-speed electric motor. The efficiency of crushing based on polymers processed, like HDPE, LDPE, PVC and PET bottles.

Keywords: *Polyethylene Terephthalate (PET), High Density Polyethylene (HDPE), Polyvinyl Chloride (PVC), Low Density Polyethylene (LDPE), Plastic Waste Management etc.*

I. INTRODUCTION

Plastic is a synthetic material made from various organic polymers such as polyethylene terephthalate (PET), high density polyethylene (HDPE), polyvinyl chloride (PVC), and low density polyethylene (LDPE), which can be molded into a tight or small elastic. Plastic materials produced by chemical processes from petroleum are non-biodegradable, wearable and non-destructive material. Many synthetic materials, which are mostly organic in nature, have a polymeric structure and can take shape when softened and solidified, are subtypes of a class of materials called polymers.

The plastics industry is one of the largest industries due to its wide area of use such as automobile, construction, electricity, medical, textile, beverage industry is growing businesses. While the world population continues to increase rapidly, the production of plastic waste is also increasing. A bad lifestyle requires simply throwing away items like soda cans or water bottles and, but the combined use of these items has caused pollution around the world. Because plastic is made from major pollutants, it has the potential to cause serious damage to air, water and soil. Plastic pollution is when plastic accumulates in an area and begins to affect the natural environment, causing problems for plants, wildlife and even humans. Often this involves killing plant life and endangering local fauna. Plastic is a great material, but it's also made from chemicals known to cause disease, and it's non-biodegradable due to its durability.

Plastic waste is an important part of waste, of which polyethylene terephthalate (PET) is a part. PET is used to make plastic bottles and many other plastic products. Most bottles made from PET are transparent and can be used for water, soft drinks, used for packaging etc. Plastic is not biodegradable. It prevents or reduces the ingress of water into the soil. They can block domestic water pipes and sewer lines. Direct combustion of plastic can release harmful gases and fumes that can affect human health. Carbon dioxide emissions that occur during the burning of plastic waste increase the temperature of the world, that is, global warming. Better business practices resulted in fewer factory workers being exposed to pollution.

For example, there have been problems in the past from workers' exposure to vinyl chloride vapours during polyvinyl chloride production. Many of the chemicals in plastic are highly carcinogenic. Plastic pollution is when plastic accumulates in an area and begins to affect the natural environment, causing problems for plants, wildlife and even humans. Often this involves killing plant life and endangering local fauna. Plastic is a great material, but it's also made from chemicals known to cause disease, and it's non-biodegradable due to its durability.

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Plastic bottles are made from a petroleum-based material called polyethylene terephthalate (PET) and require a lot of fossil fuels to produce and transport. Recycling plastic bottles is harder than people think. Some plastic bottles are used around the world, most are not, as only certain types of plastic bottles can be used by some cities. It just means more resources are being used to meet the growing demand for plastics. Therefore, these production lines generate more waste, and plastic shredders were created to reduce some of this problem.

Nitulet al (2015) studied the recycling of different types of plastics. According to the report, plastics are generally divided into two categories: recyclable plastics and non-recyclable plastics. Recycled materials include PET, HDPE, LDPE, PVC, etc. Non-recyclable plastics include bakelite, nylon, etc. Sorting, washing, shredding, crushing and extrusion are common steps of recycling.

This research project focuses on the use of plastic recycling, which is one of the main processes involved in plastic shredding. A plastic shredder is a machine that uses plastic bottles to break up into small pieces while helping to reduce shipping costs.

Fig-1 plastic bottle lying location Mumbai.

Fig-2 bottle west at mumbai

Fig-3 Plastic west in kedarnath

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II. LITERATURE REVIEW

1) Shaha & Jadhav (2018) have studied the design and fabricate a plastic bottle shredding machine and evaluate its performance in reducing plastic waste. Their study found that the shredding machine was effective in reducing the volume of plastic waste and increasing the amount of plastic that was recycled.
2) Suryakumar& Balaji (2019) have studied the design and develop a plastic shredding machine and investigate its efficiency in reducing plastic waste. Their study found that the shredding machine was effective in reducing the size of plastic waste and improving the efficiency of the recycling process.
3) Naga. etc.al (2019) have studied to fabricate a plastic bottle crushing machine and evaluate its performance in reducing the size of plastic bottles. Their study found that the crushing machine was effective in reducing the size of plastic bottles, which improved the efficiency of the recycling process.
4) Zhang etc.al (2019) have investigated the effect of plastic bottle shredding on the mechanical properties and processability of recycled high-density polyethylene (HDPE). Their study found that shredding improved the mechanical properties of recycled HDPE and reduced its degradation, resulting in improved processability.
5) Li etc.al (2020) have investigated the key technologies of plastic bottle shredding and recycling, including shredding, washing, and granulating. Their study found that shredding was an important step in the recycling process and could improve the efficiency and quality of recycled plastic.
6) Singh & S.kumar(2020). have studied the existing literature on plastic shredding machines and their applications in reducing plastic waste. Their study found that plastic shredding machines were effective in reducing the volume of plastic waste and promoting recycling.
7) Khan, M. A., & Islam, M. S. (2020). have studied to fabricate a plastic shredding machine and evaluate its performance in reducing plastic waste. Their study found that the shredding machine was effective in reducing the size of plastic waste and improving the efficiency of the recycling process.
8) Sudhakara Reddy, &ThungaRaju, have studied the developed model is simple, efficient, requires less timeandcost effective when compared to the existing available model. Importance is given towards user friendly in operation and mainly towards safety. The rotating elements like belt and pulley and gears are covered, so it is fully safety to operator.
9) Vishal N. Kshirsagar etc.al (2014) have studied that by arranging different mechanical components along with electronic components machine can be made automatic one to crush the Cans as well as plastic bottles solely to reduce the volume.
10) Ikpe Aniekan(2017) have studied that PET bottles crushing machine was successfully designed in this study. The plastic bottle crushing machine was designed for PET bottles as well as plastic waste recycling mainly for commercial and industrial applications.
11) The Federal Polytechnic & Iiaro (2020) have studied that the plastic crusher is widely used in industries for plastic waste management. By using this plastic crushing machine, the overall costing of recycling process is reduced and labour work becomes less. To recycle waste plastic into other forms of plastics, the following machines are involved.

III. PRINCIPLE OF OPERATION

In this machine we use the 5HP motor which is medium power motor. This motor transmit the power to the shaft by using the pully and V shape belt. On the shaft there are horizontal blades are mounted and they are rotate with the help of the motor. This blades cut the plastic bottles in to very small pieces.

3.1 Components in machine

1. Pully

Fig-4 Pully

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V-belt pulleys (also called vee belt sheaves) are devices which transmit power between axles by the use of a v-belt, a mechanical linkage with a trapezoidal cross-section. Together these devices offer a high-speed power transmission solution that is resistant to slipping and misalignment. Rotatory motion is done by pully and reduce slippage. Material used in pully is mild steel.

2. Hopper

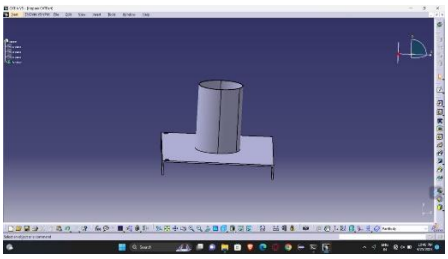

Fig-5 Hopper

The hopper is the machine component that give path to the plastic waste into the shredding chamber. To prevent flying plastic waste from escaping during operation, the top of the hopper is covered. Material used in the hopper is mild steel.

3. Motor

Fig-6 Motor

a 3-phase 5Hp medium-speed electric motor is used to rotate the blades to cut the plastic bottle waste in small pieces. Motor transmit the power to the blades with the help of V shape belt and pully.

4. V shape belt

Fig-7 V shape belt

Synthetic and natural rubber is used in the V shape belt. This is used to transmit the power from motor to blades without any energy loose. It creates proper friction in pulley.

5. Bearing

Fig-8 Bearing

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Bearings perform the function of preventing damage from being done by this force to the part that supports the rotation, and also of maintaining the correct position of the rotating shaft. This function of bearings is what allows us to use our machines over and over again for an extended period of time.

6. Blades

Fig-9 Blades

Blades are used to cut the plastic bottles in the small pieces. This blades rotate at very high speed by using the power of motor. Material used in the blades is mild steel. The blades are mounted horizontally on the rotating shaft which helps to cut the bottles in small pieces.

7. frame

Fig-10 Base

A plastic bottle crushing machine is designed to reduce large solid material objects into a smaller volume, or smaller pieces, for this there is high amount power is required which is came from 5HP motor. This motor creates high vibration in machine so this base helps to absorb that vibration.

3D Module of the machine:

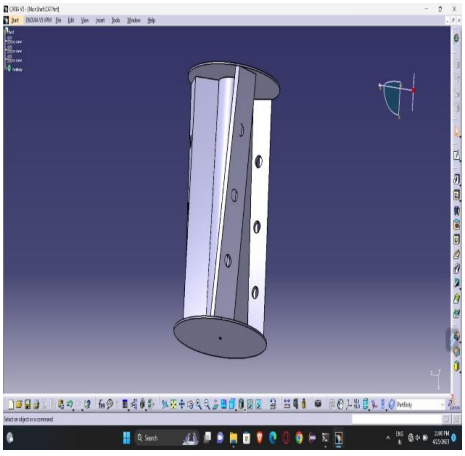

Fig-11 crusher

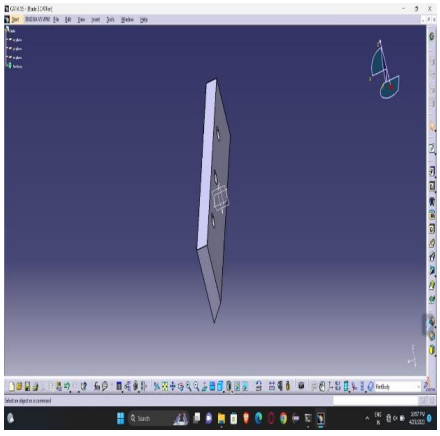

Fig-12 blades

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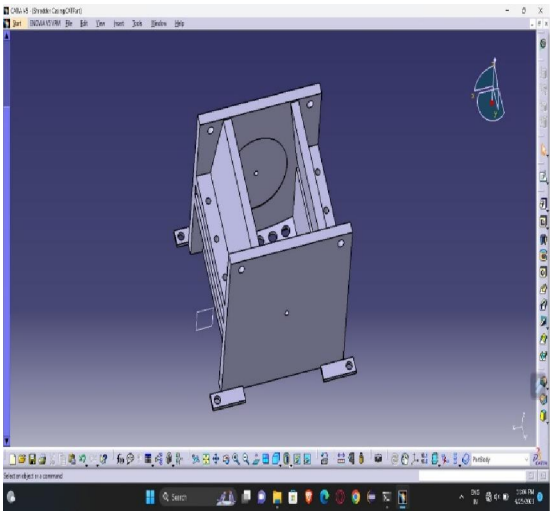

Fig-13 Crushing chamber

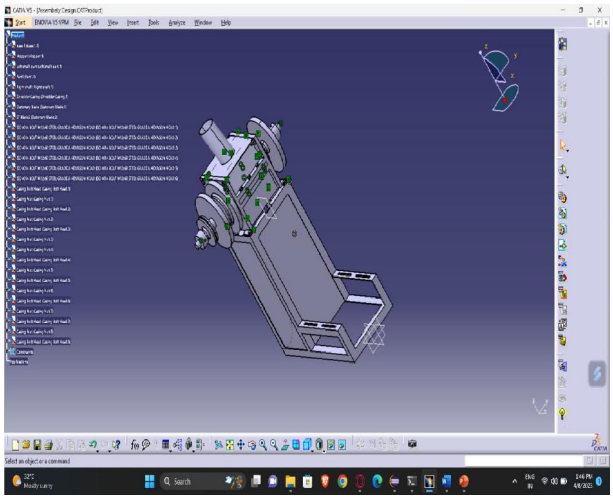

Fig- 14 pictorial view of machine

IV. MATERIAL SELECTION AND DIMENSIONS

Machine Component	Criteria For Material Selection	Material Selected	Dimension
Hopper	Must be strong and able to acquire more material	Mild steel	100mm in diameter
Crushing chamber	Ability to withstand spiral blade vibration and impact force	Mild steel	300mm x 250mm
Shaft	Must be strong	Mild steel	750mm (length)
horizontal blade	Must be strong and have sharp cutting edges	Mild steel	270mm x 74mm
Belt	Must be strong and not flexible	Synthetic and natural rubber	70 inch
Pulley	Ability to reduce the slippage during the rotation	Mild steel	6 inch (diameter)
Bearing	Must be durable and strong	Mild steel	Pillow bearing of 30mm internal bore
frame	Must able to withstand dead load imposed by the self-weight of the crusher	Mild steel	840mm x 690mm x 250mm

Design and Calculation:

Design Calculation for hopper

Upper diameter	=	100 mm
Lower diameter	=	100 mm
Height	=	182 mm
Angle of inclination	=	64 degree
Base	=	290 x 300 mm
Supports	=	50 x 30 mm
Radius of support	=	75 mm

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Volume of the hopper = $\frac{1}{3}$ [A 1 + A 2 + $\sqrt{A1 + A2}$] x h

A1 = Area of top base A2 = Area of bottom base h = Height of hooper

$\frac{1}{3}$ [π * r 1 ^{2} + π * r 2 ^{2} + $\sqrt{\pi * l}$

Volume of the hopper = 102886 mm^3

Volume of bottles = $\frac{\pi d}{4} \times h$

= 7.7×10^{-4}

Number of bottles = $\frac{\text{Volume of hopper}}{\text{volume of bottles}}$

= $\frac{1028.86}{7.7 \times 10^{-4}}$

= 1.3 bottles

1 bottles.

Rotating velocity of blades:

$\frac{n1}{n2} = \frac{DP}{dp}$

Where, n1 = rotating velocity of the electric motor shaft

n2 = rotating velocity of the blade shaft

Dp = Diameter of the driven pulley

dp = Diameter of the driving pulley

$\frac{1440}{n2} = \frac{150}{150}$

n_2 = 1440

Linear velocity of blade:

V2 = $\frac{\pi \times d_p \times n_1}{60 \times 1000}$

= $\frac{60 \times 1000}{}$

= 11.30 m/s.

Calculation of Belt length:

The centre to centre distance between driving and driven pulley is given as:

$C = 2D1 + D2$

Where; D1 = Diameter of the driver

D2 = Diameter of the driving

C= Centre to centre distance between driving pulley and driven pulley

C = 2×150+150 = 450 mm

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The belt length can be obtain as:

$$L = 2C + \frac{\pi}{2}(D1 + D2) + \frac{D1+D2}{4C}$$

Where;

D1 = Diameter of the driver

D2 = Diameter of the driving

C= Centre to centre distance between driving pulley and driven pulley

$$L = 2\times 450 + \frac{\pi}{2}(150 + 150) + \frac{150+15}{4\times 450}$$

$$= 1371 \text{ mm}$$

Design calculation for shaft

From PSG design data book(Page No 6.8)

Ultimate shear stress for MS = 345 – 525 MPa

Power from motor(P) = 5hp = 3730W

RPM from motor given to shaft(N) = 2500rpm

RPM from motor given to shaft(N) = 2500rpm

FOS = Ultimate Shear Stress working Shear stress

Ultimate Shear Stress working Shear stress = FOS

working Shear stress = $\frac{350}{4} = 87.5\ N/mm^2$ we know that, P= T × ω,

Therefore, T=P/ ω

T= $\frac{3730\times 60}{2\times\pi\times 2500}$ =14.25 × 10^3 N-mm.

$T = \tau = G\theta$

$\frac{J}{14.25\times 10^3} \quad \frac{r}{87.5} \quad \frac{L}{d/2} =$

$\pi\times d^4/32$

Therefore, d=29.95mm.

Design calculation for bearing :

Outer diameter of shaft = 50 mm

Inner diameter of bearing = 50 mm

Outer diameter of bearing = 110 mm

Width = 27 mm

Thus, 6310 type bearing is selected (V.B. Bhandari, Page No 654) is selected.

As the load capacities are less than the capacities of bearing that We selected. So, our bearing is acceptable.

Design calculation for nut & bolt :

We have selected nut & bolt having standard size.

Dimension for nut:

Diameter = 12mm

Thread pitch = 1.75 mm

Height = 10 mm

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V. CONCLUSION

This plastic bottle shredding machine presents a practical and efficient solution for addressing the growing problem of plastic waste. This work has highlighted the various aspects and benefits of utilizing such a machine. Firstly, the plastic bottle shredding machine effectively reduces the volume of plastic waste, making it easier to handle, transport, and dispose off. By shredding the bottles into smaller pieces, the machine not only saves valuable storage space but also minimizes the overall environmental footprint associated with plastic waste management. Additionally, the shredded plastic bottles can be recycled and used as raw materials for various manufacturing processes related to plastic. This promotes a circular economy by reducing the reliance on virgin materials and decreasing energy consumption. The shredded plastic can be transformed into a wide range of products such as textiles, furniture, packaging materials, and even new plastic bottles. Furthermore, the plastic bottle shredding machine contributes to the overall sustainability goals by reducing pollution and greenhouse gas emissions. By diverting plastic waste from landfills or incineration, the machine helps to mitigate the negative impacts of plastic on the environment and human health. Moreover, the operational efficiency of the plastic bottle shredding machine makes it a viable option for both small-scale and large-scale waste management facilities. Its user-friendly design, low maintenance requirements, and high throughput capacity ensure cost- effectiveness and productivity. However, it is important to note that the success of implementing a plastic bottle shredding machine relies on a comprehensive waste management infrastructure. Adequate collection systems, sorting facilities, and recycling processes must be in place to maximize the value and potential of the shredded plastic.

VI. FUTURE SCOPE

We can use light weight material to reduce weight & hence cost of machine but keeping strength & machine properly. In current machine due to motor, vibration are there so trying to reduce vibrations. One can develop flywheel operated machine by developing flywheel and using human power. We can use sensors to on and off motor or machine if material is present and if there is no material in machine. We can use sensors to on and off motor or machine if material is present and if there is no material in machine. Current available machine in the market starts ranging from 1 lakh, so we can design and develop the machine upto thirty thousand.

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