# Design And Construction Of A Plastic Shredding Machine

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***Abstract*—This paper presents the design and construction of a plastic shredding machine which is an integral part of plastic recycling process. The plastic shredding machine crushes used plastic bottles and helps in municipal waste management and disposal. The machine is designed using locally available raw materials which make it cheap and easy to maintain and repair. The performance test analysis carried out defines the characteristics of the machine and shows that at a speed of 11.5m/s the machine functions effectively and efficiently in performing its task producing a high finished shredding efficiency of 97%.**

***Keywords— Recycling; plastic; shredder; analysis.***

## Introduction

Plastics are one of the most commonly used materials in the world today [10]. The huge quantities of plastic products currently being marketed will ultimately find their way to the waste dump sites [2]. Most plastic materials used now-a-days are non-biodegradable or it takes decades to degrade [6], this leads to an increase in the amount of plastic wastes in dump sites. Moreover, the presence of plastic wastes in the environment is considered to be a hazardous affair for they are liable to catch fire easily, burn for long periods of time and thus pollute the atmosphere. They also abuse arable soil for farm work. Hence, there is the need to promote the recycling of plastic materials. Plastic recycling is bound to realize a lot of savings in production costs, conserve limited resources, and alleviate environmental pollution.

Machinery available to for nylon and plastic recycling is usually of very high cost, and bulky. This, to a great extent, imposes serious restrictions to the recycling of nylon and plastics in the developing countries. Therefore, in order to overcome these shortcomings, it was necessary to develop a machine specialized in its application in order to achieve the set objectives of reduced cost and size optimally using locally available materials.

A typical process to reclaim discarded plastic bottles would be to first sort them based on colour and sometimes on size, and wash them. However, washing them while in one piece is not the most advantageous method. Therefore, to facilitate the washing process, the bottles are shredded or crushed into smaller pieces.

Plastic shredder is the machine designed to cut or reduce large materials into tiny pieces for easy handling. The materials that can be shredded include syringe, glucose bottles, water bottles, pure water nylon, and many other items. Shredder is an integral part of any Plastic Recycling Plant.

Some of the common types of plastic shredders are: single shaft plastic shredders, multiple shaft plastic shredders, high-speed-low torque plastic shredders, low-speed-high-torque plastic shredders, simple plastic shredders, and industrial plastic shredders.

## Design of components

### SPEED OF THE BELT ON THE DRIVEN PULLEY

To determine the speed of belt on the driven pulley, $V$

$$V = \frac{\pi d_2 N_2}{60} \qquad (1)$$

Where $d_2$ = diameter of the driven pulley.

$N_2$ = speed of the driven pulley

Let $N_1$ = speed of the electric motor

$d_1$ = diameter of the drive pulley

Since $d_1 = d_2$,

Then $N_1 = N_2$

Using an electric motor having a power rating of 5 hp, with 1470 rpm, and driven pulley diameter of 0.15m.

i.e, $d_2 = 0.15$ and $N_2 = 1470\,rpm$

$$V = \frac{\pi \times 0.15 \times 1470}{60}$$

$= 11.5 m/s$

**TENSION IN THE TIGHT SIDE OF THE DRIVE BELT**

$$T_1 = T - T_c \quad (2)$$

$$T = \sigma a \quad (3)$$

$$T_c = mv^2 \quad (4)$$

Where $T_1$ = tension in the tight side of the belt

$T$ = Maximum tension in the tight side of the belt

$T_c$ = Centrifugal tension

$m$ = Mass of belt per metre length

$v$ = velocity of the belt

And $a = b.t$ (5)

Where $a$ = cross-sectional area of the belt,

$b$ = Breadth

$t$ = Thickness

For a rubber belt of R10 series, width 50mm and thickness 6.5mm.

If, $\sigma = 2$MPa

$a = 6.5 \times 50 = 325 mm^2$.

$T = 2 \times 325 = 650 N$

$$m = b.t \times density \quad (6)$$

For rubber belt of density, 1140kg/m$^3$

m $= 0.3705 kg/m$

But $v = 11.5 m/s$

Therefore, $T_c = 0.3705 \times 11.5^2 = 49 N$

And $T_1 = 650 - 49 = 601 N$

**TENSION IN THE SLACK SIDE OF THE DRIVE BELT**

Using, $$2.3 \log\left(\frac{T_1}{T_2}\right) = \mu\theta \quad (7)$$

Where $\theta$ = angle of contact in radians

$T_2$ = tension in the slack side of the belt

$\mu$ = coefficient of friction between the rubber belt and the cast iron pulley

$\theta = \pi\ rads$ (Since the diameters of the drive pulley and the driven pulley are equal) and if the coefficient of friction between the rubber belt and the cast iron pulley, $\mu = 0.30$

Therefore,

$$2.3 \log\left(\frac{601}{T_2}\right) = 0.30\pi$$

$$T_2 = 234 N$$

**POWER TRANSMITTED BY THE BELT**

Power transmitted by the belt is given by $P$,

$$P = (T_1 - T_2)V \quad (8)$$

$$P = (601 - 234) \times 11.5$$

$$= 4.22 kW$$

**THE TWISTING MOMENT OR TORQUE ON THE SHAFT**

Twisting moment on the shaft is given, $M$

$$M = (T_1 - T_2)R \quad (9)$$

$R =$ radius of the pulley $= \frac{d_2}{2} = \frac{0.15}{2} = 0.075m$

By substituting the appropriate values equation (9),

$$M = (601 - 234) \times 0.075$$

$$= 27.5 \times 10^3\, Nmm$$

### THE BENDING MOMENT ON THE SHAFT

The maximum bending along the pulley line is got using

$$M_m = F \times L \quad (10)$$

Where $M_m =$ bending moment

$F =$ load on the shaft

$L =$ perpendicular distance

and $F = T_1 + T_2$ (11)

$$F = 601 + 234 = 835N$$

Since, $L = 80mm$

Therefore,

$$M_m = 835 \times 80 = 66800 Nmm$$

$$= 66.8 \times 10^3\, Nmm$$

### THE EQUIVALENT TWISTING MOMENT

The equivalent twisting moment was calculated using the formula below:

$$M_e = \sqrt{(K_m \times M_m)^2 + (K_t \times M)^2} \quad (12)$$

Where $M_e =$ equivalent twisting moment

$K_m =$ combined shock and fatigue factor for bending

$K_t =$ combined shock and fatigue factor for twisting

Let $K_m = 1.5$ and $K_t = 2$

Therefore,

$$M_e = \sqrt{(1.5 \times 66.8 \times 10^3)^2 + (2 \times 27.5 \times 10^3)^2}$$

$$= 114302 Nmm$$

### THE DIAMETER OF THE DRIVEN SHAFT

The driven shaft diameter is given by,

$$T_e = \frac{\pi}{16} \times \tau \times d^3 \quad (13)$$

Where $\tau =$ allowable shear stress on the shaft

$d =$ shaft diameter

But $\tau = \frac{\tau_u}{F.S.}$ (14)

Where $\tau_u =$ ultimate shear stress on the shaft

$F.S. =$ factor of safety

The material used for the shaft is carbon steel of grade 45C8, which has $\tau_u$ = 700MPa

For, $F.S. = 6$

$$\tau = \frac{700}{6} = 116.7MPa$$

$$= 116.7 N/mm^2$$

Therefore,

$$d^3 = 4988.3$$

$$d = \sqrt[3]{4988.3}$$

=17.1mm = 25mm

**RESULTS AND DISCUSSIONS**

The machine test results at various speeds using the same amount of input, gives the best output at a speed of 11.5m/s. The efficiency of the nylon shredding machine is obtain using,

$$efficiency = \frac{output}{input} \times 100\%$$
$$= \frac{16.09kg}{16.6kg} \times 100\%$$
$$= 96.9\%$$

With this shredding efficiency of 96.9%, the machine which was constructed using locally available materials had fulfilled the basic objectives required.

**CONCLUSIONS**

A functional, easy to operate without the use of technically skilled labour due to its compact, less complex nature, low cost machine specifically designed for crushing of low-density nylon and plastics in preparation for recycling process has been developed. If the machine is well maintained, its durability is guaranteed and its maintenance cost is also lower when compared with existing imported machinery.

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