DEVELOPMENT OF A WASTE PLASTIC BOTTLES AND TIN CANS OF PLASTICS SHREDDING MACHINE

Ibrahim G.W & Sanni E. O
Mechanical Engineering Department,
The Federal Polytechnic Ilaro, Ogun State, Nigeria
gbenga.ibrahim@federalpolyilaro.edu.ng and enemona.sanni@federalpolyilaro.edu.ng

Abstract

The indiscriminate disposal of waste plastics bottles and tin cans constitutes environmental degradation, health hazards and safety threat. It makes waste management to be more tasking and relatively expensive. These non-biodegradable trash can be shredded, which is more cost-effective, healthier, and safer for the environment. Thus, the goal of this research project is to create a motorized machine for shredding used plastic bottles and tin cans from garbage using resources that are readily available in the area. The machine is made to use both fixed and rotary blades that are turned by a high-speed 1400rpm electric motor. This allows the plastic to soften before being cut into smaller pieces by the blades. The developed commingled waste plastics washing and shredding machine is used in conjunction with an extrusion-injection molding machine in a waste processing facility to produce plastic lumber. The machine performs the cleaning and shredding operation within a single chamber, thereby reducing the need for two separate units. Results show that the shredding of plastic is more efficient than shredding nylon materials. Due to an issue that arose during the fabrication process, the machine was first created to minimize, reuse, and recycle plastic in order to limit the amount of environmental pollution.

Keywords: *disposal, plastic shredding, fabrication, healthy, environmental pollution.*

Introduction

Background theory

When oil and natural gas are used as the primary raw materials, organic compounds that are used to make plastics are created. Plastic is becoming a more widely used industrial material, and residential applications have greatly risen as well. As a result, more plastic wastes of various forms are now being produced in our society (Lin, 2013). According to (Andrew &Subramaman,1992), the majority of these wastes are non-biodegradable and cannot be converted by microbial action into straightforward inorganic forms. Most plastics and plastic/pure water nylon wastes are typically thrown in public drains, roads, and open places to the public view in most parts of the country. Because of the lack of information, awareness, and the requirement for efficient collection and disposal systems, low value plastics trash, also known as commingled waste plastics, has emerged as a severe environmental problem (Armesto et al., 2012). Plastic waste management issues, landfill disposal, and burning of plastics have a negative impact on the environment and contaminate the air, water, and soil. Mechanically shredding low-value waste plastics, also known as agglomerating the plastics or shredding them, is largely required to transform the waste plastics into a more valuable form of recycled plastics using additional shredding techniques like extrusion, injection, or other shredding techniques (Aku et al., 2013).
In recent years, plastic packaging has become more prevalent for soft beverages and table water, taking the role of the biodegradable leaves that were once commonly used in Nigeria to wrap a variety of meals (Adebisi et al., 2011). Due to their light weight and simplicity of disposal after use, the amount of plastic garbage being produced has skyrocketed. Due to ignorance and the result of carelessly disposing of plastics, they can also be recycled for use in different ways. It is crucial to remove these plastic garbage from the streets. The design and construction of a plastics shredding machine are the goals of this research. Since there hasn't been much progress in Nigeria in terms of shredding these wastes, the main goal is to develop and construct a plastics-shredding machine using locally accessible materials that will be more affordable and accessible.

The origin of plastics (plastics materials), its revolution and pollution

In the industrial sector, the use of raw materials is important. Today's lifestyle is heavily reliant on plastics, which also significantly and irreplaceably contribute to almost every product category. The use of natural materials as fillers, adhesives, coatings, and similar things can be found in the Old Testament. These substances served as the

forerunners to contemporary plastic substances. The first commercial development of today's four main thermoplastics, polyvinyl chloride, low density polyethylene, and polymethylmsethacrylate, occurred between 1930 and 1940 (Jha et al., 2014). Plastics became extremely popular in 1939 with the start of World War II, partly as a replacement for resources like natural rubber that were in short supply. High density polyethylene and polypropylene saw significant development during the first ten years following World War II. In 1978, linear low density polyethylene was developed, allowing for the production of polyethylenes with densities ranging from 0.90 to 0.96. The raw materials (polyethylenes) started to compete with the more established materials like wood, paper, metal, glass, and leather as well as with the older plastics (Meyer and Chawla, 2009).
Plastics are increasingly in demand. Designers and engineers today regard plastics as a basic material, alongside more conventional materials. Plastics are used in the automotive sector, for instance, to reduce weight and improve energy efficiencyPolyethylene is not compressible, according to (Genssner, 1981), and when deformed, it tends to stay out of shape while undergoing permanent or plastics deformation. Plastic is a material that exhibits certain behaviors. Plastics typically consist of high polymers, or molecules with long chains of carbon atoms, which are created during or following the transition of a low molecular weight chemical to a high molecular weight solid material. The solid materials' greater molecular weight is a result of additives or components like fillers, plasticizer, etc. Although inexpensive, accessible, and serving society's demands, plastic materials are not as durable as metals (Kandpal, et al., 2014). They are vulnerable to harm. They pose a threat to the ecosystem, therefore. This kind of pollution is inappropriate for a clean, healthy environment. Damaged washing bowls, jerry cans, food storage containers, footwear, buckets, plates, seats, etc. are all examples of plastic solid trash. The drawbacks brought on by the widespread use of plastic are heinous. Because they are synthetic rather than natural, these plastics are typically not degraded by microbes in the same way as natural polymers. They are consequently not biodegradable. According to (Alanaene and Aluko, 2012), the new technological advancement known as shredding can be used to combat the threat of plastics pollution. This is significant because plastic pollution has almost reached the point of no return. Litters of discarded plastic goods are common in cities and towns. They come whole or in pieces. The most obvious threat is posed by packaging plastics, particularly the plastic sheets used to package food, beverages, and confections, as well as pure water.

Disposal and environmental pollution of plastics materials.
According to the Association of Plastics Manufacturers in Europe (AMPE), environmental harm is a byproduct of development activities and is encouraged by human wants and avarice (Campbell, 2006). Manufacturing, processing, transportation, and consumption increase environmental stress by building up waste stocks, in addition to depleting the stock of natural resources. It is better to comprehend the principles of environment and ecology before delving into the factors of environmental degradation.The areas and conditions in which people, animals, and plants live are referred to as the environment. Ecology is the study of the interaction between living creatures and their surroundings, whereas it is a matrix of both living and non-living entities. Pollution damages the environment, which in turn causes the ozone layer to thin out (Pouey, 2006).

Plastics shredding machines
In order to produce plastic products that are comparable to the original parts, especially for primary shredding, shredding machine is typically made to accept processing by injection molding, blow molding, or extrusion methods. Plastics or plastic scraps can be reprocessed on their own, although they are more frequently mixed in at varying ratios with new (virgin) materials (Amori et al., 2015).

Machine Used For Plastics Shredding
PET Shredding Line

Post-consumer PET bottles are without a doubt one of the market's most significant segments. Recycled PET can be applied to a wide range of final products, resulting in very lucrative financial returns for the shredding business.

Since the quality of the PET bottles gathered varies greatly between nations and even within a single nation. Additionally, their circumstances may be dire. In order to properly process the most challenging and contaminated materials and achieve the best final quality, it is essential to consistently stay current on the technologies and technical solutions of PET shredding line.

Materials and method
In the design of the shredding machine in this study, many things were considered when analyzing the system:

Parts Design and Material Selection

The suitability of the materials, their strength, their local availability, and their cost-effectiveness were among the criteria that went into the selection of the materials for this design.

The barrel, the screw conveyor, the gears, the coupler, and the keys are the mechanical components of this system. The heating elements, switches, thermocouple, cables or wires, and geared electric motor are among the electrical components. The screw has a pitch of 50mm, which implies that the plastic components travel 50mm every time it is turned. Up until it reaches the screw's tip, the material is in motion.

Table 1.1 Properties of Materials used

CONDITION OF SERVICE REQUIREMENT			FABRICATION REQUIREMENT	ECONOMIC REQUIREMENT
Mechanical	Physical	Chemical		
Strength Elasticity Toughness Hardness Fatigue Resistance	Density Melting point Thermal and electrical conductivity Effect of temperature	Corrosion resistance	Malleability Ductility Cast ability Machinability Ease of joining Response to heat treatment	Availability and cost of material Time taken to fabricate Cost of machining Cost of joining

Component parts

Table 1.2: Component Part of the Shredding Machine

S/N	Component	Specification	Quantity
1	The Compartment	(1460×1400×8000)mm	4
2	The Base Frame	(920×480)mm	4
3	Drum	(1400×920×440)mm	2
4	The welded angle	90^{o}	
5	Bolted Joint		8

Design and analysis

The main goal is to create a functional product within the limitations of cost and time.

Figure 1: Diagram of Plastic Shredding Machine

Figure 2: Diagram of Plastic Material after Shredding

Drum/Inlet Hopper designs

The formula for calculating the volume of cylinder V was used to determine the size of the drum because its shape is cylindrical,

Volume of the drum (V) $=2\pi r^2 h$……………………………………………………………………………… (1)

r = radius of the drum
h = height of the drum.
The drum wall thickness, t = 6 mm,
height =1020 mm ; diameter, D =700 mm.

The relationship between $\frac{t}{D}$ the drum is less than 0.08mm, which shows that it's thinned wall, and thus reinforced with flat bars to increase its ability to withstand any form of pressure.

Volume (V) = $2\pi r^2 h$
V = $2\pi (350)^2$ x 1020
V = $785185800 cm^3$
V = $7.85 \times 10^8 cm^3$

Drum Shaft Design

The rotating component with a circular cross section significantly smaller in diameter than the shaft length is called the shaft. The shaft is equipped with components for transmitting energy, such as pulleys, belts, and bearings.
Different combinations of bending (nearly usually fluctuating), shock, or axial, normal, or transverse shear can be used to stress the shaft. In order to maintain sufficient strength and rigidity when the shaft is transmitting power under various operating and loading circumstances, shaft design largely entails determining the correct shaft diameter. Deflection, the dynamics established by the critical speed, or strength utilizing yield or fatigue (or both) as a criterion are also taken into account when designing shafts (Hamrock et al., 1999).

The dimension of the shaft used as regards its length and diameter are 760 mm and 25 mm.
Using the Torsion Relationship;

$\frac{T}{J} = \frac{\tau}{R} = \frac{G\theta}{L}$………………………………………………………………………………………………….(2)

The relationship; whereSecond polar moment (J) in M^4

Shear stress (Ʈ) in N/m

Torque (T) in N-mm

Radius (R) in mm

Modulus of rigidity (G)

Angle of twist (θ) in 0^0 or Rad

Length (L) in mm

Table 1.3:Recommended value for Km and Kt

Nature of load	Km (combine shock plus fatigue factor for bending)	Kt (shock plus fatigue for torsion
1. Stationary shaft		
a. Steady applied load	1.0	1.0
b. Rapidly applied load	1.5 - 2.0	1.5 - 2.0
2. Rotating shafts		
a. Steadily applied load	1.5	1.0
b. Rapidly applied load with slight shock	1.5 - 2.0	1.5 - 2.0
c. Rapidly applied load with weighty load	2.0 - 3.0	1.5 - 3.0

Relationship for bending moment of a simple supported shaft carrying a central load

Moment (M) = $\frac{W \times L}{4}$……………………………………………………………………………………(3)

From the test run result

W= 0.9kg = 900g

Length of the shaft = 0.9m

M = $\frac{900 \times 0.9}{4} = 202.5\ N/m$

$T_e = \sqrt{M^2 + T^2}$……………………………………………………………………………………(4)

To determine Torque (T) from the relationship

$Power(P) = \frac{2\pi NT}{60}$………………………………………………………………………………...(5)

Take T as the subject of the formula

Therefore, T = $\frac{P \times 60}{2\pi N} = \frac{746 \times 60}{2 \times \pi \times 1400}$ = 65.84 N-m

Where N is the speed of the driver (main motor)

The speed of the main motor for single phase induction power 1hp = 1400rpm

To determine equivalent twisting moment (T_e):

$T_e = \sqrt{(Km \times M)^2 + (Kt \times T)^2}$…………………………………………………………………………(6)

From table 3.3

$K_m = 1.5$

$K_t = 1.5$

Where K_m = combine shock and fatigue factor for bending

K_t = combined shock and fatigue for torsion

:-$T_e = \sqrt{(1.5 \times 202.5)^2 + (1.5 \times 65.84)^2}$

T_e = 303.78 N-mm

To determine the diameter of the shaft ϕ using the relationship

Torque (T) = $\frac{\pi d^3}{32}$………………………………………………………………….................(7)

Where torque (T) = 65.84 N/m

$$\frac{65.84}{1} = \frac{\pi d^3}{32}$$

$65.84 \times 32 = 3.142d^3$

$3.142d^3 = 2106.88$

$d^2 = \frac{2106.88}{3.142} = 670.55$

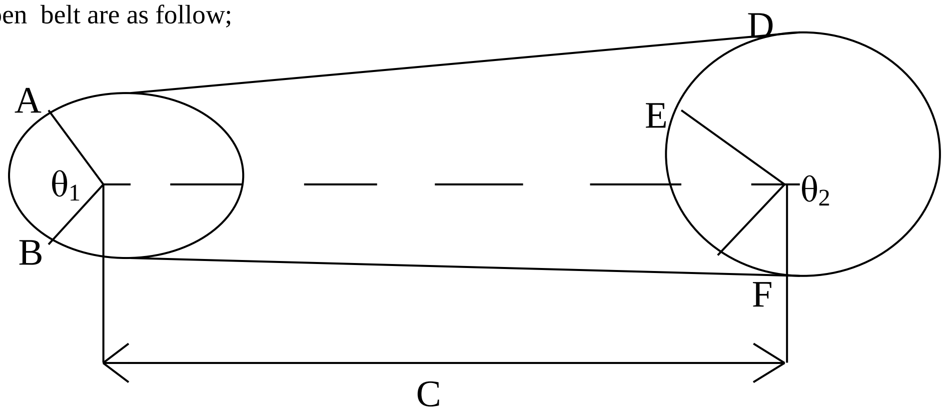
$d = \sqrt{670.55}$

d = 25.89mm

: - d = 25mm

Selection of belt

- Open belt (the equation for the total belt length 'L', centre distance 'C' and the angle of contact 'Θ' , used for the selection of the open belt are as follow;



Blades Design
To determine angle of contact (θ_1)
The relationship for angle of contact;

$\sin \propto = \frac{r_2 - r_1}{c}$ ………………………………………………………………………………………(8)

$\alpha = \sin^{-1}\left(\frac{r_2 - r_1}{c}\right)$

$Angle of contact\,(\theta_1) = \pi - 2\alpha\ (in rad)$

$\theta_2 = \pi - 2\propto\ (in rad)$

$C^2 = a^2 (r_2 - r_1)^2$

$a = (C^2 - (r_2 - r_1)^2)^{1/2}$

Total length of belt (note: length of an arc = rɵ, ɵ in rad

$L = 2a + ArcAB + ArcDF$

$L = 2a + r_1\theta_1 + r_2\theta_2$

$L = 2a + r_1(\pi - 2\propto) + r_2(\pi + 2\alpha)$

Where a = length of straight section of belt;
Therefore;
Length of the belt (L)
L = 2a + Arc AB + Arc EF

$L = 2a + r_1\theta_1 + r_2\theta_2$

$L = 2a + r_1(\pi - 2\propto) + r_2(\pi + 2\propto)$……………………………………………………………………(9)

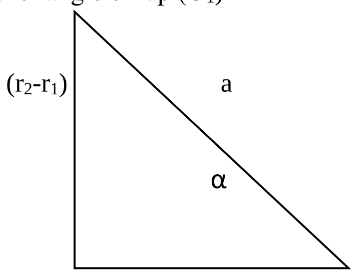
OR

If $L = 2c + \pi\left(\frac{D_2 + D_1}{2}\right) + \left(\frac{D_2 + D_1}{4c}\right)^2$

$L = 2(0.92) + \pi\left(\frac{0.09 + 0.05}{2}\right) + \left(\frac{0.09 - 0.05}{4(0.92)}\right)^2$

$L = 1.84 + 0.2199 + (\frac{0.04}{3.88})^2$
L = 2.1m
Therefore while;
The width of the belt (w)= 120mm = 0.12m
The thickness (t) = 10mm = 0.01
The diameter of the smaller pulley (D_1) = 50mm = 0.05m
The diameter of the bigger pulley(D_2) = 90mm =0.09m
Centre distance between the pulley(C) = 920mm = 0.92m
Co-efficient of friction between the belt and pulley (μ) = 0.25
Speed of the driver (main motor) (N) = 1400 rev/min
The radius of the smaller pulley (r_1) = 50mm/2 =25mm = 0.025m
The radius of the bigger pulley (r_2) = 90mm/2 = 45mm = 0.045m

The relationship to determine the angular velocity (ω);
$The\ angular\ velocity\ (\omega) = \frac{2\pi N}{60}$
$\omega = \frac{2\pi \times N}{60}$
$\omega = \frac{2\pi \times 1400}{60}$
$\omega = 146.6\ rad/s$
The smaller angle of lap (Θ_1)



From the relationship, to determine the smaller angle of lap (θ_1);
$\theta_1 = \pi - 2\alpha$
$sin \propto = \frac{r_2 - r_1}{C}$
Therefore, to determine alpha (α), we make use of equation 2 above
$sin \propto = \frac{0.045 \times 0.025}{0.92}$
$sin \propto = 0.0217$
$\propto = sin^{-1}(0.0217)$
$\propto = 1.24^o$
Convert from degree to rad per second;
$\left(\frac{\pi}{180} \times 1.24\right) = 0.0217$
$\theta_1 = \pi - 2\alpha$
$= \pi - 2(0.0217)$
$= \pi - 0.0434$
$\theta_1 = 3.1rad$
Data given;
Speed of the larger pulley (N_2)
Speed of the smaller pulley (N_1) = 1400rpm
Diameter of the smaller pulley (D_1) = 50mm
Diameter of the bigger pulley (D_2) = 90mm
Speed of the larger pulley (N_2) = ?

Therefore, to determine the speed of the larger pulley (N_2)

$$\frac{N_1}{N_2} = \frac{D_2}{D_1}$$

$$\frac{1400}{N_2} = \frac{90}{50}$$

$$90N_2 = 50 \times 1400$$

$$N_2 = \frac{70000}{90}$$

$$N_2 = 777.7\text{rpm}$$

Velocity of belt (V)

$$V = \frac{D_1}{2} \times \frac{2\pi N_2}{60}$$

$$V = \frac{0.045}{2} \times \frac{2\pi \times 777.7}{60}$$

$$V = 0.0225 \times 81.44$$

$$V = 1.83m/s$$

Power transmitted to the pulley (P)

$$P = T_1\left(1 - \frac{1}{\epsilon^{\mu\theta}}\right)V$$

$$V = r_1 w_1 = r_2 w_2$$

$$= 0.025 \times 146.6$$

= 3.665m/s

$$\epsilon^{\mu\theta} = 2.718^{0.25\times 3.1}$$

g = 2.170

Tension in the tight side (T_1)

The relationship to determine tension in the tight side of the belt (T_1);

$AS_t \leq T_1$

$T_1 = AS_t$

A = b x t

= 0.12 x 0.01

=0.0012

$S_t = 0.5MN/m^2$

$= 0.5 \times 10^6$

$T_1 = 0.0012 \times (0.5 \times 10^6)$

$T_1 = 600$

Power $(P) = T_1\left(1 - \frac{1}{\epsilon^{\mu\theta}}\right)V$

$$P = 600\left(1 - \frac{1}{\epsilon^{0.25\times 3.1}}\right)3.665$$

$$P = 600\left(1 - \frac{1}{2.178^{0.775}}\right)3.665$$

P= 600 x (0.5395) x 3.665

P= 1185.912W

P= 1.185KW

Since 1Hp = 0.746kW,

To convert the result from kW to Hp;

P = 1.185 X 0.746

P = 0.884Hp

As a result, the motor's power transmission to the Drum's pulley is 0.884 HP.

Both fixed and rotary blades can be used with the shredding machine. These blades are properly sharpened to cut through nylon waste with ease. The spindle, connected to the shaft, was joined by welding two sections of rotary blades.

The internal studs and bolts that secure the fixed blades to the drum allow for simple removal and maintenance. They are individually spaced apart by about 1.5 mm and fastened extremely closely to the drum's bottom. The diameter of the shaft and/or its pulley determines the choice of other parts, such as the bearing and belt, whereas the amount of waste to be recycled, the machine's power requirements, and the speed at which the machine must operate influence the selection of the electric motor to be used.

Fabrication procedure
The procedure taken for the completion of this project goes thus;

S/N	WEIGHT OF NYLON (INITIAL) W1 (KG)	WEIGHT OF NYLON (FINAL) W2 (KG)	TIME TAKEN (MINUTES)
1.	1	0.92	14
2.	1	0.9	15

1. Four length angle plate were cut into require constructional size (1.24m) with the aid of grinding machine coupled with a cutting disc, while hacksaw was also used where necessary.
2. A mild steel sheet plate was folded into spherical shapes of 0.6m diameter, and 1.2m depth.
3. The frame was firstly erected by tack-weld at the end of the angle iron, while one lapped on the other.
4. The sheet metal where resting on the frame and were welded against the frame of several points along the length of the frame and the sheet metals.

Results and discussion
The plastic shredding machine fabricated was tested using scrap plastic that littered in the environment. The outcome of five trial runs is presented in the table below:

Table 1.4**:** Result for plastic after Shredding

S/N	WEIGHT OF PLASTICS (INITIAL) W1(KG)	WEIGHT OF PLASTIC (FINAL) W2 (KG)	TIME TAKEN (MINUTES)
1.	1	0.9	06
2.	1	0.85	05
3.	1	0.9	05
4.	1	0.9	06
5.	1	0.8	06

Table 1.5:Plastic Efficiency (η)

S/N	EFFICIENCY
1	$\frac{0.9}{1} \times 100 = 90\%$
2	$\frac{0.85}{1} \times 100 = 85\%$
3	$\frac{0.9}{1} \times 100 = 90\%$
4	$\frac{0.9}{1} \times 100 = 90\%$

5	$\frac{0.85}{1} \times 100 = 85\%$

Table 1.6: Result for Nylon after Shredding
Table 1.7: Nylon Efficiency (η)

S/N	EFFICIENCY
1	$\frac{0.92}{1} \times 100 = 92\%$
2	$\frac{0.9}{1} \times 100 = 90\%$

Discussion
From Table 1.4, I kg of plastics were shredded for a time ranging from 5 minutes to 6 minutes for the five trials carried out. It was seen that the waste plastic introduced into the machine was 0.10 -0.15kg less than that the initial weight. This affirmed and average of 95.5% high efficiency of the equipment which equals 95.5%. Similarly, five trial runs were carried out using nylon as the scrap to be shredded. The outcome shows that the nylon rather than being cut through by the rotating blades, it wound round the blade with insignificant work done. Hence quantification of the performance at instance of the nylon was said to be low.
It was observed that after so many test-running done on the Plastic shredding machine, the machine worked effectively only on plastic materials as there was no or low performance produce on the nylon material due to low Power from the electric motor, and inappropriate placing of the cutting blade on the shaft so as to enable smooth shredding of nylon.

Conclusion
The design, test and outcome show clearly that the design was best fit or suitable for plastic shredding. This is was evidence in the 95.5% performance rating or evaluation of the tested machine. At a very reduced time which might not be possible with human effort. Hence this equipment would help to greatly reduce/ eliminate various plastics materials of types, size and shapes can be gathered for various industrial used and as well reduces pollution in the environment. Certainly, this research effort would assist in ridding of all plastic debris which either pose health risk or other hazards to people who reside in such an environment where plastic waste is huge or dominance.

Recommendation
From the study undertaking the above recommendations are highlighted as a guide for further similar study:

- The number of blade should be increased considerably as they ensure timely shredding of the shredding operation.
- Design analysis should be researched to estimate correctly the power of the electric motor or other prime mover for the operation.
- A rubber mount should be in place to reduce noise and vibration from metal rubbing against metal

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