Development of a Polythene Chipping Machine for Recycling Purposes

Olalekan Hammed, Sulaimon Abdulkareem, Ogunniyi Oluwadare, Adio Teslim

Abstract— In the environment polythene constitutes a high percentage of municipal wastes which pose a lot of threat to human lives and properties. Hence, the need to manage these wastes comes in. The traditional methods of disposing polythene wastes have proved to be relatively expensive and unhealthy. Recycling of these non-biodegradable wastes will be more economical, healthy and safer for the environment. Thus, polythene chipping machine was developed using locally available materials via well structured designed and construction, and its performance was also evaluated. The machine has four major parts which include hopper, chipping chamber, delivery outlet and the frame. The machine was designed to use fixed and rotary blades which were primed by high-speed electric motor and was able to shred pure water sachets in to flakes. After testing the polythene chipping machine, it shredded the polythene bags into the desired chips. Results showed that the machine produced about 10.2 kg of chipped polythene flakes as output for 30minutes. Conclusively, the efficiency of the machine was 79.69% which indicate that the machine was able to serve its purpose. The successful development of this machine will assist the underdeveloped and the developing countries in cleaning up their environment from non-biodegradable polythene wastes which have constituted a serious health and environmental problems in the society.

Index Terms— Environment, Municipal Waste, Polythene, Recycling, Chipping Machine

1 INTRODUCTION

Wastes as unavoidable by-products of most human activities can be said to be all items that people no longer have any use for, which they either intend to get rid of or have already discarded [1]. Thus, all our daily activities can give rise to a large variety of different wastes arising from different sources which can be categorised into Municipal Waste (including Household and Commercial), Industrial waste (including manufacturing) and Construction or Demolition Waste[1].

Polyethylene (polythene) as a municipal waste is one of the world's most popular plastics [2]. It is an enormously versatile polymer which is suited to a wide range of applications (packaging food, drinks, medical products, merchandise etc, based on chemical inertness alone [3]) from heavy-duty proof membrane for building to light, flexible bags and films [2]. By altering its formation and gauge, one can adjust the impact and tear resistance, transparency and tactility; flexibility, formability and coating, lamination and printing capability of polythene. It has a high strength to weight ratio, allowing for cheaper transportation costs and lower fuel consumption [4]. In addition, they are classified as non-biodegradable municipal wastes and constitute ample percentage of the municipal wastes in our surroundings hence, there is need to manage them [4]. Waste management is the collection, transport, processing or disposal, managing and monitoring of waste materials [5].

Different ways of waste management are prevention, minimisation, re-use and recycling and the best way of managing wastes is through recycling method [6]. Recycling involves the treatment or reprocessing of a discarded waste material to make it suitable for subsequent re-use either for its original form or for other purposes. It includes recycling of organic wastes but excludes energy recovery [1]. Environment experts describe it as the process of transforming used materials into new products [6].

Many countries are proposing or have already enacted laws and taxes to decrease the use of nylon bags because there is currently no environmentally friendly way to dispose them. Most polythene wastes are disposed by burying them underground which can cause underground water pollution. Burying and over stressed of waste in the environment can be reduced by investing in polythene bag recycling plants [4].

In the economic aspect, a nation or individual can economically recover money through recycling or otherwise lose through pollution, burning and burying of waste material [9]. Polythene waste recycling will complement the international concern for our environment and our government's campaign against deforestation and Ozone Layer depletion which leads to climate change. It will reduce environmental pollution caused by sachet water nylon littering the street, bus-stop and blocking our drainage.

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Literatures had shown that much has not been said about the polythene chipping machine unlike the paper, wood, plastic and metal shredders [10], [11], [12]. However, the commonly seen polythene chipping machine is incorporated in an industrial plant use for the recycling of polythene waste. This present work focuses on the development of a polythene chipping machine by designing and fabricating a machine to start the recycling processes of polythene waste, followed by performance evaluation. The performance evaluation of the machine is based on the amount of polythene sachet fed in to the machine and the shredded output. Thus, the efficiency of the machine was calculated to be 79.69%.

2 MATERIALS AND METHOD

The polythene recycling plant comprises of the following processes; shredding/chipping, washing, drying, melting and pelletizing processes. From these processes, the polythene chipping machine as a separate unit working independently is developed consisting of the following four major parts;

1. The hopper
2. The chipping chamber
3. The delivery outlet
4. The frame with electric motor base

2.1 THE HOPPER

The hopper is made of a mild steel of thickness 2mm. The hopper consists of two segments as shown in Fig 2.1. The upper segment is a hollow rectangular prism slanted at an angle of 50 to the vertical and has beneath it is the lower segment, a cuboid-shaped hollow member of 150mm by 230mm by 115mm. Towards the lower part of the upper segment is a movable flat plate for closing the hopper during operation so as to prevent the waste polythene nylon from been blown out of the hopper due to the rotating effect of the shaft. The overall height of the hopper is 430mm and the prism 300mm by 250mm at the top and 150mm by 230mm at the lower part. The lower segment of the hopper is designed as to fit perfectly on the upper chipping chamber.

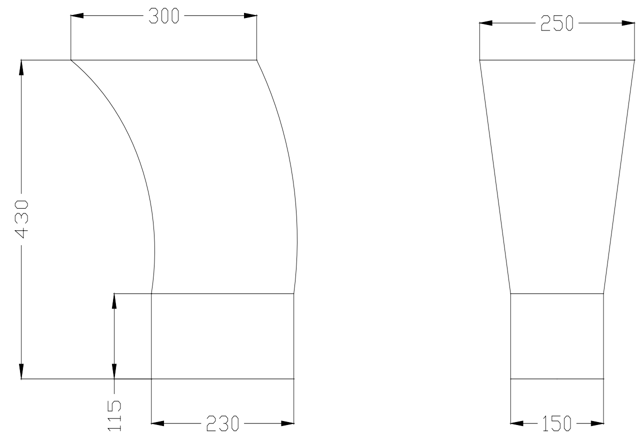


Fig. 2.1. Front and End View of Hopper

2.2 THE CHIPPING CHAMBER

The chipping chamber is made of mild steel and cylindrical in shape with diameter 220mm and length 230mm. It is divided into two halves, the upper part and the lower part as shown below. The inner end dimension of the hopper is marked and cut out of the surface of the upper half of the cylinder. The lower part of the hopper is mounted on top of the upper part of the chipping chamber. The lower part of the chipping chamber is also cut in the same dimension and a sieve is welded on it. The chipping chamber houses the following components.

2.2.1 SHAFT

The cylindrical shaft is made of mild steel of diameter 40mm and 380mm long. The shaft was stepped down at both sides to a diameter of 30mm so as to accommodate the bearings of diameter 30mm on the shaft. The shaft is machined on the lathe machine.

2.2.2 CUTTING BLADES

The blades are made of high speed steel (HSS) and of length 200mm and thickness 10mm as shown in Fig 2.2. The blades are divided into two parts, the fixed blade and the movable blades. The movable blades are bolt on the blade carrying bars welded on the shaft while the fixed blades are bolt on the edge of the lower hemisphere of the cutting chamber.

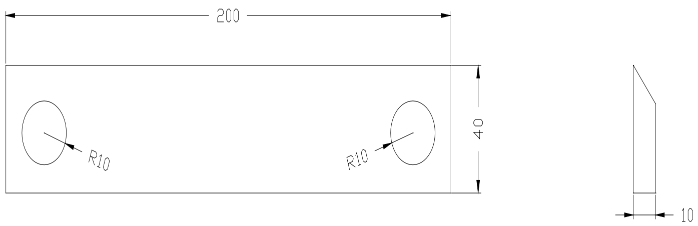


Fig. 2.2: Front and End View of the Cutting Blade

2.2.3 BLADE-CARRYING BARS

The blade-carrying bar is also made of mild steel. They are three in number with dimensions 210mm×50mm×10mm each. These bars are welded on the shaft at angle of 1200 apart. The bars serve as support for the blades. Holes are drilled on the bars and the blades are bolted to the bars using bolts and nuts.

2.2.4 SIEVE AND DELIVERY CHAMBER

The sieve is welded below the lower half of the cutting chamber. It is made by cutting circular holes of 19mm diameter on a metal sheet. This is just to specify the sizes of chips that would get to the delivery chamber. The delivery chamber is made of mild steel of thickness of 2mm. It is slanted at an angle of 450 to the horizontal to make the chips fall down freely. It is 400mm long and 150mm wide.

2.3 THE FRAME AND ELECTRIC MOTOR BASE

The frame is shaped in form of a pyramid frustum with four legs slanting at an angle 600 and height of 620mm as shown below. It is 350mm by 300mm at the upper end and 450mm by 400mm at the lower end. The structure is constructed using a mild steel angle plate material welded together.

3 DESIGN SPECIFICATIONS/CALCULATIONS

The following components were identified to be determined in order to design parts for the polythene chipping machine.

3.1 ELECTRIC MOTOR

A 3-phase electric motor with 2.2 kW (2.94 hp), 1400 rpm (rotational speed) and 50 Hz was used.

3.2 TRANSMISSION DRIVE

The power transmission drive used for the machine is belt and pulley drive.

3.2.1 DESIGN FOR DRIVEN PULLEY

The driven pulley diameter was selected using the equation for speed ratio shown in (1):

Let

d_2 =driven diameter,

d_1=driver diameter,

N_2=driven speed in rpm,

N_1 =driver speed in rpm

But,

Length of belt that passes over the driver in one minute = $\pi d_1 N_1$

Similarly,

Length of belt that passes over the driven in one minute = $\pi d_2 N_2$

Since length of belt is equal, therefore

$$\pi d_1 N_1 = \pi d_2 N_2$$

Then,
$$\frac{N_2}{N_1} = \frac{d_1}{d_2} \quad (1)$$

Assuming, $N_1 = 1400$ rpm i. e the speed of electric motor

d_1 = 76.2mm

d_2 = 100mm

Therefore,
$$N_2 = \frac{d_1 N_1}{d_2}$$

$$N_2 = \frac{1400 \times 76.2}{100}$$

$$N_2 = 1067 \text{ rpm}$$

Note: N2 is the speed of the shaft arrangement at no load [13].

3.2.2 DESIGN FOR SHAFT

A shaft is the rotating machine element which transmits power from one place to another. The power delivered to the shaft by some tangential force and the resultant torque set up within the shaft permits the power to be transmitted to various parts linked up with the shaft [13]. The shaft of the polythene chipping machine which is rotating the cutting blades will be subjected to twisting moment only.

Torque T, produced by the shaft [13],

$$\text{Torque}, T = Fr \quad (2)$$

Where:

F = Force required by the shaft to turn the polythene

r = Distance of the blade end from the centre of the shaft

$$\text{Angular Velocity}, \omega = \left(\frac{2\pi N}{60}\right) \quad (3)$$

Where:

N = Speed of the motor in revolution per second

$$\text{Linear Velocity}, v = \omega r$$

$$v = \left(\frac{2\pi N r}{60}\right) \quad (4)$$

But,

From Newton's Second Law of Motion: $F = \frac{mv}{t}$ (5)

Where:

m = mass of the shaft in Kilogram

t = time in second

Substituting (4) into (5) gives:

$$F = \left(\frac{2\pi mNr}{60t}\right)$$

For one second, the force required will be:

$$F = \left(\frac{2m\pi Nr}{60}\right) \quad (6)$$

Substituting (6) into (2) gives:

$$\text{Torque, T of the Shaft} = \left(\frac{2\pi mNr^2}{60}\right) \quad (7)$$

$$T = \left(\frac{2 \times \pi \times 10 \times 1067 \times 0.1^2}{60}\right)$$

T = 11.17 Nm

Power required to overcome the torque and to rotate the shaft [13],

$$\text{Power, P} = \text{Torque, T} \times \text{Angular Speed, } \omega \quad (8)$$

Substituting (7) and (3) into (8) gives:

$$P = \left(\frac{2\pi mNr^2}{60}\right) x \left(\frac{2\pi N}{60}\right)$$

$$P = \left(\frac{2\pi Nr}{60}\right)^2 m$$

$$P = \left(\frac{2 \times \pi \times 1067 \times 0.1}{60}\right)^2 \times m$$

$$P = 124.85 \times 10$$

$$P = 1248.5W = 1.25KW$$

3.2.3 DESIGN FOR BELT

Selection of belt type

Based on the power transmitted (3.7 KW) and according to the Indian standards (IS: 2494-1974), belt type A was selected from the dimensions of standard V-belt table.

Calculation of belt length, L

The length of the belt was calculated using Fig. 3.1. below;

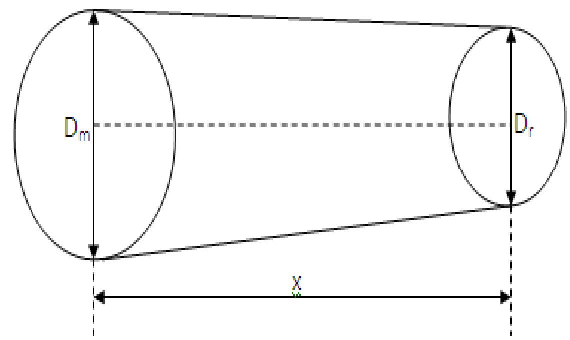


Fig. 3.1: Open belt drive [13]

$$L = \frac{\pi}{2}(d_1 + d_2) + 2x + \frac{(D_m - D_r)^2}{4x} \quad (9)$$

Where:

L = Length of belt (mm)

D_m = Diameter of driver pulley

D_r= Diameter of driven pulley

x = Centre distance of pulleys (mm)

3.2.4 SELECTION OF BEARING

Ball rolling contact bearing of standard designation 307 was used for the polythene shredding machine. This selection was based on the type of load the bearing will support when at rest and during operation and also based on the diameter of the shaft. The designation 307 signifies medium series bearing with bore (inside diameter) of 30mm.

4 RESULTS

There are several ways of determining efficiency of machines but with respect to this polythene chipping machine the efficiency is calculated as follows:

$$\text{Efficiency} = \frac{\text{Output weight(Kg)}}{\text{Input weight(Kg)}} X100\%$$

Input = 12.8 Kg

Output= 10.2 Kg

Therefore;

$$\text{Efficiency} = \frac{10.2(\text{Kg})}{12.8(\text{Kg})} X100\%$$

= 79.69%

After testing the polythene chipping machine, it shredded the polythene bags into the desired chips. Conclusively, the efficiency of the machine is 79.69% which is an indication that the machine will be able to serve its purpose.

5 CONCLUSIONS

i. The polythene chipping machine has been developed using locally available materials.

ii. The recycling machine produced about 10.2 kg of chipped polythene flakes as output for 30minutes.

iii. The flakes can be re-extruded for production of coloured plastic products and composites.

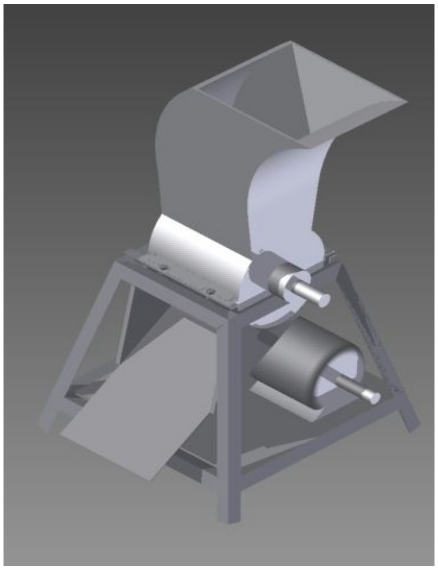
iv. The successful development of this machine will assist in cleaning up our environment from non-biodegradable polythene wastes which have constituted a serious health and environmental problems in our society.

v. This will serve as a source of employment and revenue generation.

6 END SECTIONS

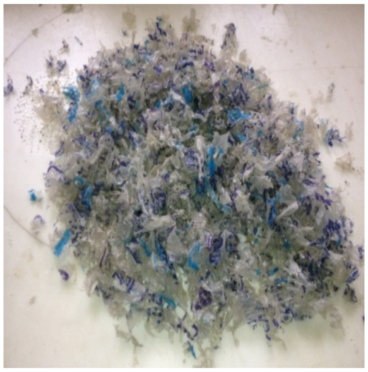
6.1 APPENDIX

The polythene Chipping Machine



Drawn polythene Chipping Machine

Polythene (purewater sachet) bags



Chipped/Shredded Polythene bags

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