

Development of a Polythene Recycling Machine from Locally Sourced Materials

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Abstract

Non-biodegradable polythene and nylon wastes constitute a nuisance in all the urban areas in Nigeria. The paper presents the design and manufacture of a waste-recycling machine to convert these waste materials to reusable materials. The machine uses designed to use fixed and rotary blades for slitting the loaded wastes. The rotary blades are rotated by a single phase, high speed electric motor and the friction generated provides the heat required to soften the waste charges. The recycling machine produces an average of 35kg of small flakes of recycled waste per hour at a machine speed of 2880 rpm.
Keywords: Polythene, Nylon, Biodegradable, Waste Recycling, Electric Motor

1. Introduction

Wastes are materials that are not prime products (that is products produced for the market) for which the initial user has no further use in terms of his own purposes of production, transformation or consumption, and of which he wants to dispose. Wastes may be generated during the extraction of raw materials, the processing of raw materials into intermediate and final products, the consumption of final products, and other human activities. Waste includes all the items that people no longer have any use for, which they either intend to get rid of or they have already discarded. All daily activities, therefore, can give rise to a large variety of different waste flows from different sources. These sources include, for instance, waste coming from households (e.g. plastic packaging waste), commercial activities (e.g. cardboard packaging waste from shops, food waste from restaurants and medical waste from hospitals), industry (e.g. fly ashes from thermal processes of energy generation, textile waste and tanning liquor from clothes manufacturers), agriculture (e.g. slurry), construction and demolition projects. A small part of the waste which is generated is hazardous; that is, it poses substantial or potential threats to human health or to the environment. Water management and waste disposal have become a significant cost factor and an important aspect in the running of a brewery operation (Fillaudeau, et al., 2006; Unterstein, 2000). Every brewery tries to keep waste disposal costs low whereas the legislation imposed for waste disposal by the authorities becomes more stringent (Knirsch et al, 1999).

Every year in the United States, consumers throw millions of tons of plastic away and of the 190 million metric tones of municipal wastes produced annually nine percent are plastics (Andrews and Subramaman, 1992). Plastics have become very popular for industry and household uses leading to an increase in the volume of plastic waste being generated in the society (Wilson, 1981). By the year 2005, annual global demand for plastics is projected to exceed 200 million metric tones. As municipal landfills reach capacity and additional landfill spaces diminish alternative methods of reducing wastes are being explored. Some of the options include incineration, source reduction, recycling and making plastics biodegradable. Whereas paper, wood and other wastes may be burned in incinerators with minimum damage to the environment, incineration of plastics can produce hazardous emissions and other pollutants. There is not much information on the volume of plastics generated in Nigeria. Nonetheless, the nuisance created may be inferred from various government campaigns on de-clogging drainages and dirt abeyance.

In recent times, polythene packaging has increased in the area of table water and soft drinks and has replaced the biodegradable leaves traditionally used in wrapping various foodstuffs in Nigeria. They are very light and are easily thrown away after use and this has increased on the abundance of the polythene waste. In addition they can also be recycled for another usage. Due to ignorance some people do not know about the effects of improper waste disposal. Such people dump the polythene bags carelessly. Getting these plastic wastes off the streets is very important. This research is expected to propose ways of cleaning up the environment of non-biodegradable waste. Since not much has been done in the area of recycling of these wastes in Nigeria, the primary objective is to design and fabricate a polythene recycling machine, using locally available materials, capable of converting the polythene-nylon wastes into flakes that can be used in the manufacture of new coloured plastic products.

Chatterjee and Kumar (2009) studied the electronic waste management and recycling process in India. The major source of e-waste is the disposal of the hardware and electronic items from Government offices, public and private sectors, academic and research institutes. Household consumers are also contributing significant volume of end-of-life electronics products and like other parts of the world, India is also facing serious crisis due to growing generation of e-waste (Chatterjee and Kumar, 2009). According to Chatterjee and Kumar, (2009), electronic waste (e-waste) is hazardous in nature due to presence of toxicsubstances like Pb, Cr6, Hg, Cd and flame retardants (polybrominated biphenyls and polybrominated diphenylethers etc.). E-waste disposal mixed with solid municipal waste is posing a greater threat for environmental degradation in the developing countries, where formal recycling technology is not available and non-formal operators are extracting precious metals through crude means for easy money (Chatterjee and Kumar, 2009). The extraction of metals in nonformal units is carried out by dipping printed circuit board (PCBs) in the acidic/alkaline solutions and heating/burning of PCB. In developed countries, well established processes are available for processing PCBs to extract the precious metals with highest yields (Gao et al., 2004; Xuefeng et al., 2005;Mou et al., 2004; Hyunmyung and Yong-Chul 2006).

2. Theoretical Background

A plastic material is any of a wide range of synthetic or semi-synthetic organic solids that are moldable. Plastics are typically organic polymers of high molecular mass and the vast majority of these polymers are based on chains of carbon atoms alone or with oxygen, sulfur, or nitrogen as well. They consist of very long molecules each composed of carbon atoms linked into chains. One type of plastic known as polyethylene is composed of extremely long molecules each containing over 200,000 carbon atoms. This property distinguishes plastics from materials such as metals that have short crystalline molecular structures. Plastics are generally produced from fossil fuels which contain hydrocarbons which provide the building blocks for long polymer molecules. These small building blocks called monomers link blocks together to form long carbon chains called polymers and the process is known as polymerization. Polymers are substances whose molecules have high molar masses and are composed of large number of repeating units called monomers (Kroschwitz, 1990). There are both naturally occurring and synthetic polymers. Synthetic polymers commonly called plastics re produced commercially on a large scale and have a wide range of properties and uses. The carbon backbone of polymer molecules often bonds with smaller side chains consisting of other elements. These include chlorine, fluorine, nitrogen and silicon. These side chains give plastics some distinguishing characteristics. For example, when chlorine atoms substitute hydrogen atoms along the carbon chain, the result is polyvinyl chloride, one of the most versatile and widely used plastics in the world.

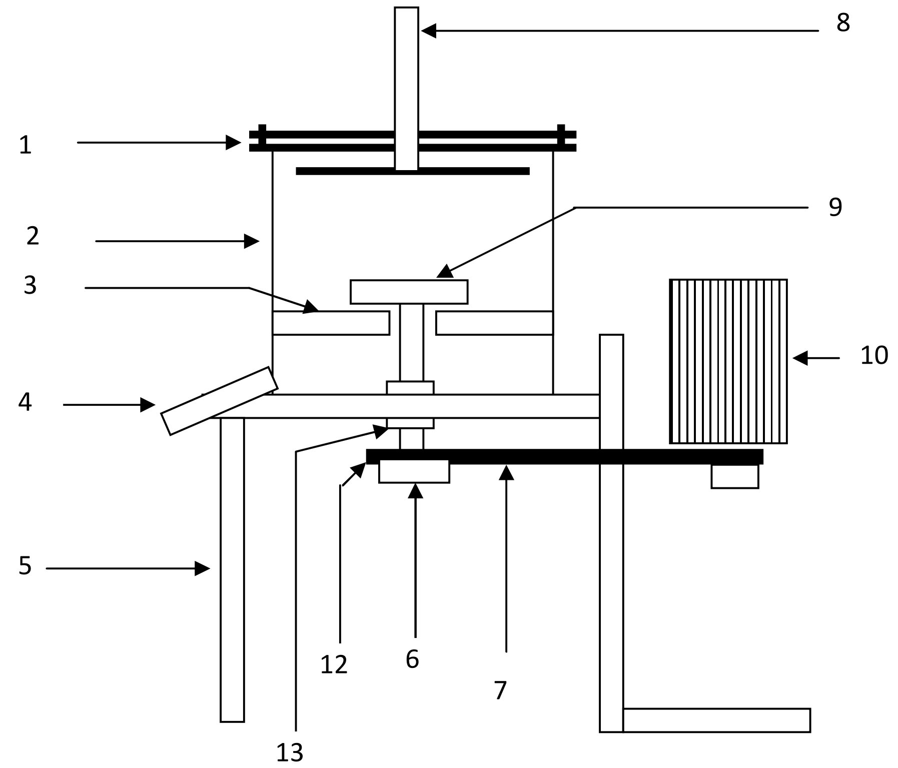
By virtue of their thermal characteristics, plastics are divided into two groups – thermoplastics and thermosetting plastics. Thermoplastics undergo no chemical change in the moulding operation, they may be softened by reheating to the temperature at which they originally became plastic and hence they are easily recyclable. Thermosetting plastics on the other hand harden permanently after being heated once. The difference in response to heat lies in the chemical structure. Whereas thermoplastic molecules are held together by weak Van der Waal's forces, thermosetting plastics consist of chain molecules that chemically bond or cross link with each other when heated. Thermoplastics may be grouped according to the arrangement of their molecules. Highly aligned molecules arrange themselves more compactly resulting in a stronger plastic. For example, molecules in nylon are highly aligned making the thermoplastic extremely strong. The degree of alignment also determines how transparent a plastic is. Other esters of acrylic acid and methylacrylic acid similarly polymerize and copolymerize to transparent thermoplastics, differing somewhat in hardness and in softening temperatures.

3. Materials and Method

The materials used for the recycling machine are angle iron, flat bar, ball bearings, spring blade, metal pipe, spring shaft, V-belt, saw blade, welding electrodes, electric motor and electrical accessories.

3.1 Design Considerations

The components were selected based on power requirements, machine capacity, service requirements and cost. The recycling machine is made up of the following component parts: the drum, blades, shaft, bearing, belt and machine frame, details of which are shown in the schematic diagram in Figure 1.



S/No	Description
1	Cover
2	Drum and hopper
3	Fixed blades
4	Outlet chute
5	Stand
6	Pulley

Figure 1: Schematic Diagram of the Polythene Recycling Machine

3.1.1 Drum

The drum is made of galvanized steel 6 mm thick, 400 mm high and 310 mm diameter. A thickness to diameter ratio $\left(\frac{t}{D}\right)$ of 0.019, which is less than 0.05 shows that the drum is thin-walled. The sides were therefore reinforced to withstand the operating pressure during the waste recycling process.

3.1.2 Cutting Blades

Three blades 120 x 35 x 8 mm each and spaced at 120^o were fixed to the drum at a distance of 20 mm from the base. Two rotary blades arranged in a straight line and sharpened on one side are welded to the spindle to slice the contents against the fixed blades. The blades are made of spring steel because of its wear and corrosion resistance properties.

3.1.3 Main Frame

The main frame of the machine was constructed from 50 x 50mm angle iron bar, which provides support for the other units as shown in Figure 1.

3.1.4 Bearing

The ball bearing was chosen according to ASAE standard (Hall *et al*., 1980). The operating characteristics of a rolling-element bearing depend greatly on its diameter and clearance. The internal diameter of the bearing is 25 mm while its external diameter is 60 mm

3.1.5 Belt Design

The cross-sectional area of the V-belt is found from the formula $\frac{T_1 - T_2}{s_1 - s_2}$

Where T_1 = belt tension in tight side (N)
T_2 = belt tension in loose side (N)
s_1 = maximum allowable stress (N/m^2)
s_2 = stress in slack side of belt (N/m^2)

The required belt width b is calculated from the equation $b = \frac{area}{thickness}$

The angle of wrap is determined by $\sin\beta = \frac{R - r}{C}$

3.1.6 Power drive transmission

For solid shaft having little or no axial loading the ASME Code equation reduces to

$$d^3 = \frac{16}{\pi s_s}\sqrt{(K_b M_b)^2 + (K_t M_t)^2}$$

where at the section under consideration,
M_t = tortional moment Nm
M_b = bending moment, Nm
K_b = combined shock and fatigue factor applied to bending moment
K_t = combined shock and fatigue factor applied to torsional moment
The diagram of the manufactured polythene recycling machine is presented in Figure 2.

Figure 2: Polythene Recycling Machine

3.2 Polythene waste recovery

The most abundant of these wastes were the table water sachets and bottles. These were followed by poly bags and nylon wrappers. They were to be recovered from roadsides and drainages. Since it was difficult to pick up the waste from sewers and other places where they constitute a nuisance, the wastes were purchased from scavengers at an agreed rate per kilogram. This incentive encouraged commercial haulers to supply these wastes at a collecting point, thus eliminating or reducing the nuisance of these wastes in our environment and providing ready feedstock for the recycling industry.

4. Discussion

Knife penetration first causes compaction accompanied by frictional heat. It thus produces a cutting and heating action which partially melts the compacted waste producing thick shreds. The machine was driven at a motor speed of 2880 rpm using 5Hp electric motor. The gap between the rotary blades was adjusted for improved performance. A clearance of 0.9 mm reduced belt slip and produced acceptable flakes. The pre-sorting of the wastes into colours and thermosetting and thermo plastics improved the homogeneity of the yield. The yield was about 30 kg of small flakes per hour. The very high speed of the motor provided enough friction for the required heating of the blend.

5. Conclusion

Waste materials are usually found littering all over the places in our urban cities and villages. A polythene recycling machine was therefore designed and manufactured using locally sourced and available materials. The manufactured recycling machine was found to very useful in absorbing the huge waste materials in our country. The performance test shows that the machine has a capacity of recycling 30 kg of polythene/nylon wastes per hour.

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