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DESIGN AND FABRICATION OF A POLYTHENE/NYLON WASTES RECYCLING MACHINE

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Abstract: *The traditional methods of disposing polythene/nylon 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, the objective of this research work is to design and develop a motorized polythene/pure water nylon recycling machine, using locally available materials. The machine is designed to use fixed and rotary blades, which are rotated by high-speed electric motor. Heat is provided for softening of the polythene prior to shredding by the blades. Tests were performed on the recycled machine to determine its possible output, and the results showed that 30-40 kg of recycled flakes was produced per hour at a machine speed of 2880 rpm. The flakes are used with recycled plastic wastes and/or virgin materials for production of colored plastic product.*
Keywords: *polythene/nylon, wastes, recycling machine, mild steel, local materials*

INTRODUCTION

Plastics have become more popular materials for industry and its household uses have also increased tremendously. This has led to increase in the volume of plastic wastes of several types being generated in our society (Wilson, 1981). Most of these wastes are non-biodegradable and thus cannot be broken down by microbial action into simple inorganic forms like most other biodegradable wastes (Andrew and Subramaman,1992). Most plastics and polythene/pure water nylon wastes are usually thrown in public drains, roads and open places to public view in most parts of the country. These wastes are used at times as a combustion aid for burning other organic refuse, and this liberates toxic vapours or gases that pollute the air and causes inconveniences to residents living near the landfill sights (New, 1986). Their values as reclaimed or recycled waste is considerably higher than their values as energy source (Andrew and Subramaman, 1992). Accordingly, well-known destructive techniques, such as incineration or pyrolysis (Leidner, 1981), seem quite wasteful, and hence, recycling of plastic wastes is the best method for solving both the environmental and economic problems associated with plastic waste disposal.

Recycling of plastic wastes is rapidly developing in almost every society and this is largely based on the environmental awareness, need to conserve materials and energy, and growing demand to increase production economy (La Mantia, 1993 and Chatterjee and Kumar, 2009). Many private industries and few government agencies are now engaging in recycling of plastic and polythene/nylon wastes. Recycling of plastic/nylon wastes could be achieved through chemical or mechanical recycling method. The chemical means involve solvent recycling process (Kampouris et al., 1995), flotation separation (Dilly-Louis, 1997) and selective dissolution techniques (Herberg et al., 1992). On the other hand, mechanical recycling involves the use of machines in converting the waste into recycle products, which can be re-used in new application (Jost, 1995). However, some of these machines are either non-available or expensive. Thus, the objective of this study is to design and develop a polythene/pure water nylon recycling machine from locally available materials, which will be cheaper and available.

MATERIALS AND METHODS

Machine Components

The polythene/nylon waste recycling machine consists of the following main components/units: the inlet-hopper/drum through which the wastes are fed into the machine, the recycling unit which consists of fixed blades and rotary blades performs the grinding and cutting operations. Three pieces of well sharpen fixed blades are firmly attached to the drum internally at a distance of less than 20 mm from the bottom of the drum. These blades are attached by sturds and bolts for easy removal and maintenance of the machine. Two pieces of rotary blades are welded to the spindle, which is attached to the shaft. The third unit is the driving unit, which consists of belts, bearing and pulleys transmit electric motor power to the drum and driving shaft. Figure 1 shows the assembly drawing (isometric view) of the recycling machine.

The inlet-hopper/drum, which determines the quantity of wastes to be loaded, is made of galvanized sheet based on its ability to withstand working stress, thermal conductivity and good wear resistance. Both the fixed and rotary blades are made of spring steel for good wear and corrosion resistance. A 3 KW electric motor is the power source and mover of the machine by shaft and belt drive. Heat is generated as the blades are rotating over one another during operation, and thus soften the nylon and then cut it into smaller pieces. The speed of the electric motor also contributes to the cutting rate of the machine.

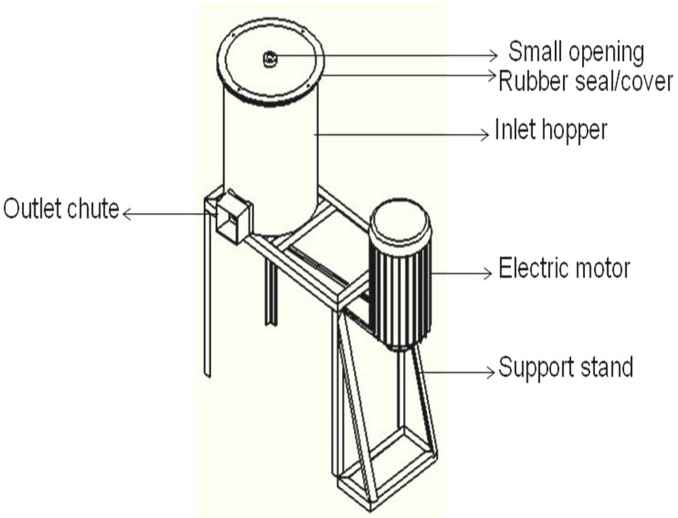

Figure 1. Assembly drawing of the recycling machine (isometric view)

Design Theory and Calculations

During the design process of the recycling machine, there are considerations for manufacturability, cost reliability and maintainability of the design product. The primary objective is to design a functioning product within given economic and schedule constraints.

Drum/Inlet Hopper designs

The drum is cylindrical in shape and its size can be obtained using the formula for obtaining the volume of cylinder, V, as given in Eq. 1.

$$V = 2\pi r^2 h \qquad (1)$$

where r is the radius of the drum and h is the height of the drum. The drum wall thickness, t, is 6 mm, while the height is 400 mm and the diameter, D, is 310 mm. The value t/D for the drum is less than 0.05, which shows that its thinned wall, and thus reinforced with flat bars to increase its ability to withstand any form of pressure.

Drum Shaft Design

The shaft is the rotating member having a circular cross section much smaller in diameter than the shaft length. Energy transmitting elements such as pulley, belts and bearings are attached to the shaft. The loading on the shaft can be various combinations of bending (almost always flunctuating), shock or axial, normal, or transverse shear. Thus, shaft design primarily involves the determination of the correct shaft diameter to ensure adequate strength and rigidity when the shaft is transmitting power under various operating and loading conditions. Strength, using yield or fatigue (or both) as a criterion; deflection; or the dynamics established by the critical speed are also considered in designing shaft (Hamrock et al., 1999).

The dimension of the shaft is:

- Length = 760 mm
- Diameter = 25 mm

The resultant internal moment, M_X, at any section along the shaft may be expressed as:

$$M_X = (M_{XY}^2 + M_{XZ}^2)^{½} \qquad (2)$$

where M_{XY} and M_{XZ} are the bending moments in x-y and x-z planes respectively.

The force exerted on a shaft in the transverse direction (perpendicular to the shaft axis) produces a maximum stress of:

$$\sigma_b = \frac{M_b r}{I} \qquad (3)$$

$$\tau_{xy} = \frac{M_t r}{J} \qquad (4)$$

For a circular cross section, where $r = d/2$, $I = \pi d^4/64$ and $J = \pi d^4/32$, the bending stress according to Hall et al. (1982), will be given as:

$$\sigma_x = \frac{32 M_b}{\pi d^3} \qquad (5)$$

For torsional stress, the expression is:

$$\tau_{xy} = \frac{16 M_t}{\pi d^3} \qquad (6)$$

For a solid shaft combining torsion and bending loads by applying the maximum shear equation modified by introducing shock, fatigue and column factors, the ASME code equation is given as:

$$d^3 = \frac{16}{\pi \sigma_s \left[\sqrt{(K_b M_b)^2 + (K_t M_t)^2} \right]} \qquad (7)$$

where, τ_{xy} = torsional shear stress (N/m^2); M_t = torsional 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; σ_b = bending stress; σ_s = allowable stress; d = shaft diameter (m)

If the shaft diameter is known and safety factor, n_s, is unknown, then,

$$n_s = \frac{\pi d^3 S_y}{32\left(\sqrt{(M^2 + T^2)}\right)} \qquad (8)$$

where S_y is yield strength.

Blades Design

The recycling machine is designed to use both fixed and rotary blades (Figure 2). These blades are well sharpened for effective cutting of the nylon waste. Two pieces of rotary blades were welded to the spindle, which is attached to the shaft.

The fixed blades are attached firmly to the drum internally with sturds and bolt for easy removal and maintenance. They are attached very close to the bottom of the drum at a distance of about 1.5 mm in between each of them.

The choice of other components such as bearing and belt depends on the diameter of the shaft and or its pulley, while the quantity of waste to be recycled, power required by the machine as well as the required speed rate of the machine will assist in the choice of the electric motor to be used.

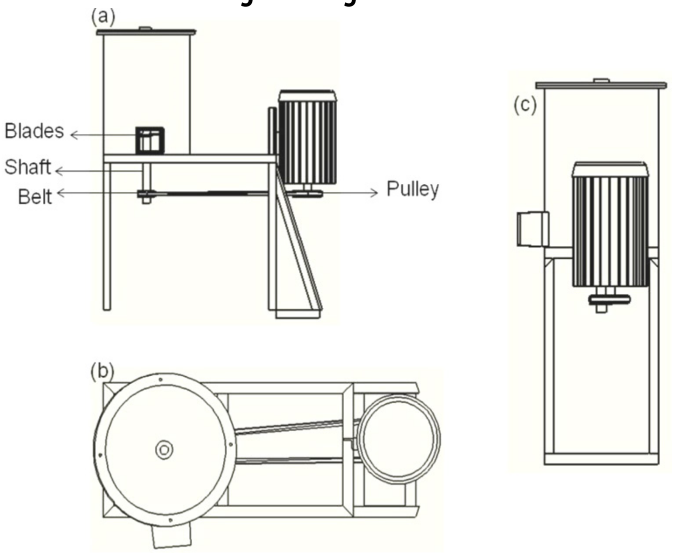

***Figure 2**. Different views of the machine showing the blades and Pulley (a) Front view (b) Top view (c) Side view*

The Fabrication and Testing of the Machine

Figure 3 shows the diagram of the recycling machine after components design, fabrication and coupling. The processes entailed are listed below:

- *Measuring, marking out and cutting of the various parts of the mild steel*
- *Bolts, nuts and stud machining*
- *Holes formation*
- *Joining of machined parts*
- *Finishing and aesthetics*

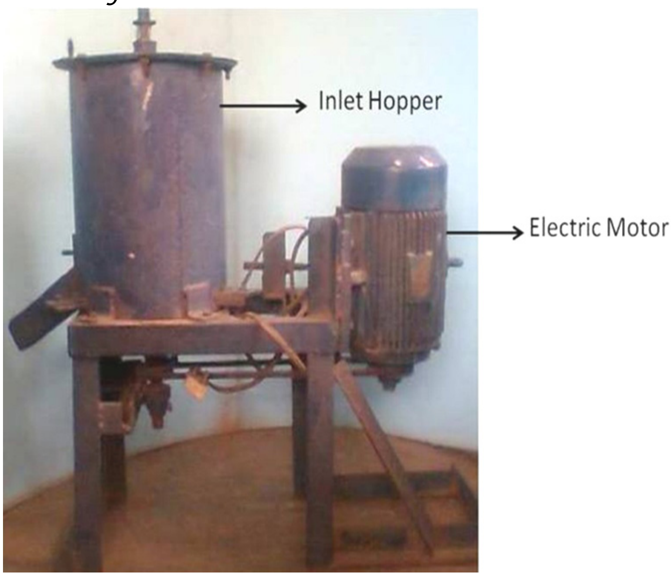

***Figure 3**: Polythene/Nylon Waste Recycling Machine*

Machine Testing

Pure water sachets were sorted, cleaned and dried prior to weighing and charging into the machine through the inlet hopper. The charged sachets were pressed close to the fixed blades using the holder inside the hopper. The friction between the fixed and the rotary blades generated heat which help to soften the nylon waste prior to cutting. The flakes from the cut were collected through the outlet chute.

RESULT AND DISCUSSION

The product obtained after recycling the waste pure water sachets nylon by the machine is in form of flakes of different sizes. Although, the target is to obtain pellet of recycled waste or small grains similar to result of Kampouris et al, (1988) during recycling of polystyrene (PS) by solvent recycling process. However, the shredded nylon waste can be re-extruded with other plastic waste for production of coloured high density plastic or composite (Sasaki and Tomita, 1993).

CONCLUSIONS

The recycling machine designed produced about 20-30 kg of shredded nylon flakes as output per hour. The flakes can be re-extruded for production of colored plastic products and composites. With these results, the primary objective of designing and fabricating a polythene/nylon wastes recycling machine using locally available materials has been achieved. The machine if successfully improved upon will assist in cleaning up our environment of non-biodegradable polythene/nylon wastes, which have constituted a serious health and environmental problems in our society. The following recommendations are suggested to improve on the machine:

- *The properties of the polythene/nylon wastes should be well studied so as to carry our further work on the machine.*
- *A heating unit as well as sieving unit should be introduced in the machine in order to be able to produce pellets of relatively same sizes from the machine.*
- *Power requirement of the machine equipped with the heating unit must be determined to improve the efficiency of the machine.*

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