Design and Development of an Indigenous Drum Dryer for Preheating of Plastic Scrap

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Abstract. In this experiment an indigenous plastic scrap preheating machine has been developed that preheats the plastic scrap very economically and may be used at small scale industries, as such types of industries largely uses sun drying method for heating the plastic scrap. The limitation of such method is that the time taken to heat the scrap is quite large and also there remains porosities inside the plastic scrap, these porosities create voids in these scraps that reduce the strength of the final manufactured plastic item in operations like injection mouldings.

1. Nomenclature

1.1 Symbols

\( I \) = Moment of inertia of the flywheel
\( \omega \) = rotational velocity of the flywheel
\( k \) = inertial constant
\( M \) = mass of the wheel
\( R \) = radius of the flywheel

2. Introduction

Plastic plays an important role in different sectors; the use of plastics varies from general day to day life to complex packing of items. The industries that use plastics are packaging, logistics, manufacturing etc. It is quite evident that plastic is also the main cause of environmental pollution. It is very dangerous to living being and affects the ecological system directly or indirectly. The consumption of plastics has several benefits such as in medical and packaging of surgical items. The quality of plastics is measured in microns, and they should be under 40 microns, as under 40 microns they can be decomposed into the soil after a specified amount of time. Plastics items that are over 40 microns e.g., toys, beverage bottles, etc are very common. Therefore they should be recycled in order to have a safe environment.

As plastics are very light in weight, resistant to moisture, economical and versatile therefore they are very vital and popular in today’s era. The discovery of polymers has further broadened the utility of plastics. Due to their unique property of being easily molded into the desired shape and size it has a very large scope as far as its usage is concerned. The production of plastics is increased at an exponential rate in the few years thus became the first choice for the man made items as per the need. The main source of plastic production is petroleum, and it is non renewable energy source. The production of plastic is about 400 million tons per year and the recycled amount of plastic is very less i.e., around 9\% of its total production. In India on an average around 11 Kgs of plastic is consumed by one person, 60\% of the total is plastic is recycled and rest around 9400 tones is buried inside the
Plastics can be categorized into two categories i.e., thermo sets and thermoplastics and they are fabricated by adding and the condensation polymerization. The main advantage of thermoplastics over thermo sets is their ability of remolding as many times as required on the other hand the thermo sets are unable to remold and are permanent in shape. The manufacturing of thermoplastics is very easy and then precision is higher as compared to thermosets. The other qualities of thermoplastic are its light weight and the strength is also higher. Propylene, low density polythene (LDPE), High density polythene (HDPE).

In 1951 the first polymerization of polypropylene took place and it is later polymerized by German Italian scientists named Rana and Rehn [2]. The various natural methods by which the degradation of the plastic scarp could be done like Hydrolytic degradation, Photodegradation and Biodegradation, etc. Natural methods of degradation as mentioned above takes a very long duration to degrade the plastic waste which is near to 30-40 years. Hence, it is very important to adopt an alternative recycling process, as it will enable in restoring the natural resources. The other benefit of recycling plastic is to reduce the wastes that results from plastic scarp which pollutes the landfills and oceans. Management of plastic waste techniques are very necessary specially in those regions where unsegregated waste is very high. Government bodies that are responsible for controlling and managing the plastic pollution, adopted slogans such as R4 which means “Reduce, Reuse, Recycle and Recovery” and various public awareness programmes the purpose of such slogans is to motivate the public to minimize the waste. Plastic waste could be grouped by number of techniques; the foremost technique among all the methods is the floatation of plastic that depends upon its chemical and physical properties [3]. The most commonly used techniques for recycling the plastic are Mechanical methods [4], Pyrolysis, Solvent extraction [5], etc. The main sources of pollution in India are categorized as follows 64% is LDPE and HDPE wastes, 9.66% is PET, 11% is waste from PP and the remaining 9% is due to other sources of plastic wastes [6]. The data mentioned above clearly shows that HDPE and LDPE are the major pollution causing element followed by PP and PET.

![Figure 1. Bar chart showing percentage of waste corresponding to different plastic [6]](image)
3. Motivation Behind

In this work an indigenous plastic scrap preheating machine has been developed that preheats the plastic scrap very economically and may be used at small scale industries, as such types of industries largely uses sun drying method for heating the plastic scrap. The limitation of such method is that the time taken to heat the scrap is quite large and also there remains porosities inside the plastic scrap, these porosities create voids in these scraps that reduce the strength of the final manufactured plastic item in operations like injection moldings.

![Figure 2. Stages of plastic recycling](image)

4. Experimental Setup

The main motivation behind the design is to minimize the production of voids that are generated in the scrap due to ineffective procedure of heating the plastic scrap. As far as the small scale and cottage industries are concerned they do not adopt proper procedures for treating the plastic scraps due to the lack of resources and financial constraints (limitations) the mechanical properties of the final manufactured plastic items gets degraded.

| Material name                          | Symbol | Pre-drying temperature (°C) | Drying time (Hrs) |
|----------------------------------------|--------|-----------------------------|-------------------|
| Low-density polyethylene               | LDPE   | 110〜120                     | 4〜8               |
| High-density polyethylene              | HDPE   | 150〜180                     | 8〜16              |
| poly(ethylene terephthalate)           | PET    | 120〜165                     | 4〜8               |
| Polypropylene                          | PP     | 140〜175                     | 6〜12              |
In this work a machine has been designed and developed, for the purpose of optimal pre heating of the plastic scrap. Fig.3 Illustrating the Schematic diagram of Machine. It is V-belt drive system that is having a 12 inch pulley on shaft and motor is having a 3inch pulley system. The motor is having 60 number B-Type belt. Material of shaft is mild steel (MS) and shaft is double bearing having identification number as 6207 manufactured by SKF company.

![Schematic diagram of Plastic Pre heating machine](image)

**Figure 3.** Schematic diagram of Plastic Pre heating machine

The main components of the machine are Bearings, Pulley, Motor, Blade, Frame (Casing). The workings of each part of the machine are as follows:

4.1 **Drum:** Drum acts as a storing agent, the plastic scrap after cutting and washing transferred to the machine drum where the processing (preheating) of the scarp will take place on the rotation of the drum. Inside the drum the blades are fixed, the main aim of the blades attached is to collide with the plastic scraps so that its temperature gets increases, this increase in temperature is responsible for the pre heating of the scarp particles. A thermo couple is also attached to measure the temperature and after a certain (set temperature) range of the heat it directs the motor to stop, but due to the attachment of the fly wheels the drum keeps rotating even after the motor is stopped, thus the setting of temperature is kept below the desired temperature. Another advantage of the fly wheel is the low consumption of electricity.

The centrifugal force that is experienced by the drum can be found out by the equation as discussed below:

\[ \text{C.F} = M \times R \times \omega^2 \]  \hspace{1cm} (1)

Where, \((M)\) is the mass of the drum and the moist scrap of plastic =80 Kgs;

\((R)\) is the radius of the drum 3ft \(\sim0.90\text{m}\) and

\((\omega)\) is the rotational velocity of the drum (1100 rpm) \(\cong 110\text{ rad/sec}\)

Inserting the values in equation 1,

\[ \text{C.F} = 80\times90\times110^2 \]
\[
\therefore \ C.F = 8 \times 10^2 \text{ KN}
\]

In the drum, blades are paced which are at an angle of 22.50 with X-axis inside the drum enables the fast heating of the scrap material. The thermocouple enables the operator to get the real time value of the temperature and they can set the cutoff temperature as many times as required according to the type of plastic or as per the need. The cut portion of the machine is as illustrated in the Fig.4.

![Figure 4. A cut section of the machine](image)

4.2 **Motor:** Motor is placed at the lower side (bed) of the casing or frame. The power of the motor is 5 H.P (horse power) and its rotational speed is 2200 rpm. The main purpose of the motor is to rotate (in circular motion) in order to rotate the pulley, which is further attached to the extended shaft of the drum. As the motor rotate it will rotate the drum in which the plastic scrap is already stored. This circular motion of the drum will change the state of the plastic scrap from rest to motion, thus the temperature of the plastic scrap rises and the preheating of the scrap will come into effect. Various parts of the machine has been shown in Fig. 5.

Calculation for the energy consumed by the motor,

\[
\text{Energy consumed} = 5 \text{ hp} \times 1 \text{ hour} \\
5 \text{ H.P hour} = 5 \times 746 \text{ watts} \\
= 3730 \text{ watts hour} \\
= 3.7 \text{ units (approx)}
\]

Thus the motor will consume 3.7 units of electrical energy in one hour.
4.3 **Flywheel**: Flywheel is too attached to both sides of the drum with a view keeping in mind so that the drum keeps rotating even after given a small start, this saves energy. As flywheel has the amazing ability of storing the rotational energy thus it will resist any change in speed due to its moment of Inertia enabling the drum attached to it to keep rotating. The rotational speed of flywheel is 1100 rpm (110 rad/sec), Diameter of wheel is 2ft (0.61 m) and efficiency of the flywheel is around 80 %. Fig. 6 shows the other parts of the machine that works in line of action of the main parts as discussed in the above sections.

\[
KE = \frac{1}{2} I \times \omega^2
\]

\[
= \frac{1}{2} \times 1.8 \times 1102
\]

\[
= 10.89 \text{ KJ}
\]

Where, \((KE)\) is the kinetic energy stored, \((I)\) is the moment of inertia of the flywheel and, \((\omega)\) is the rotational velocity of the flywheel,

The moment of inertia of the flywheel can be evaluated by the formula:

\[
I = k \times M \times R^2
\]

\[
= \frac{1}{2} \times 40 \times 0.32
\]

\[
= 1.8 \text{ kg m}^2
\]

\(k = \text{inertial constant, } \frac{1}{2} \text{ (for solid disk),}\)

\(M = \text{mass of the wheel = 40 kg (approx.),}\)

\(R = \text{radius of the fly wheel}\)
Figure 6. Showing the Hopper, shaft and pedestal bearing

Figure 7. (a) Shown the actual set up of machine while working (b) Tilting dryer for plastic scrap

5. Results and Discussions

The thermocouple enables the operator to get the real time value of the temperature and they can set the cutoff temperature as many times as required according to the type of plastic or as per the need. The heating process is also a step ahead than the conventional method this brings to the end of the problems of the creation of void and heats the scrap, so that the material gets heated without losing its strength that is nearly impossible in sun drying method, or use of hot blower method. The major advantages are as discussed below:

- Suited for fined grained as well as coarse grained material.
- Relatively less consumption of electricity.
- Sensitive to abrupt changes of the material size, moisture changes etc.
- Lesser price Controlled atmosphere inside the drum for de dusting of the particles
- Tolerant of operating faults
- Less wear and lesser part replacement requirement.
6. Conclusions

Due to its indigenous design the preheating of the plastic scrap has become economical thus can also be employed at small scale industries. The units of energy consumed per hour are 3.6 units which is quite less than conventional ones. Light weight because of the design of thin walls enables to easily carry it from one place to the other and its simple yet innovative design consideration makes the fabrication and manufacturing process easier and simpler.

The thermocouple which placed in drum is enables the operator to get the real time value of the temperature and they can set the cutoff temperature as many times as required according to the type of plastic or as per the need. The heating process is also a step ahead than the conventional method this brings to the end of the problems of the creation of void and heats the scrap, so that the material gets heated without losing its strength that is nearly impossible in sun drying method, or use of hot blower method. The major advantages includes it suited for fined grained as well as coarse grained material, Relatively less consumption of electricity, Sensitive to abrupt changes of the material size, moisture changes etc., controlled atmosphere inside the drum for de-dusting of the particles, Tolerant of operating faults, Less wear and lesser part replacement requirement.

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