SCRAP-Shredding, Collecting and Remoulding of Acquired Plastics

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Abstract

Plastic is one of the most common used materials in the world today. But, they cause serious environmental pollution and exhaustion of landfill space. Among all the plastic products used, the role of plastic bottles in the pollution of our surroundings may it be land, oceans and other water bodies is high. Roughly 200 billion water bottles are produced globally each year. This plastic usually ends up in our landfills to remain for many hundreds of years. This is due to the improper handling of the used plastic bottles. Our project, SCRAP aims at reducing the waste plastic bottles that are dumped recklessly and shredding it into fine granules and later remoulding it into much compact form or to other useful products. An incentive is provided for each plastic bottle deposited. This will encourage active participation in the current generation and makes the users to deposit the bottle inside the device itself and thus reducing the need for additional human resource in collecting the waste plastic bottles. In short SCRAP aims at creating a new revolution in plastic waste management and developing a sense of efficient disposal of waste among public.
Keywords: Plastic, Pollution, Landfill, Shredding, Remoulding, Waste Management

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I. Introduction

Plastics have become invaluable components of modern building and have led to a plastic age in which it has become a part of our daily lives. Plastics reach our hands in various forms including Polyethylene terephthalate (PET), High density polyethylene (HDPE), Polyvinyl chloride (LDPE), Polypropylene (PP), Polystyrene (PS) etc. Most of the plastic products that we use are bottles, bags, trays, pipes, electrical insulations etc. It is clear that these products are part of our day to day life cycle. It is found that 299 million tonnes of plastic has been produced in 2013 and the production has always been rising every single year.

The problem arises when these large margin of plastics are disposed in unscientific and unhygienic manner. Improper management of plastic wastes has ultimately led to negative impacts like health related problems and environmental and ecological effects. It is found that an average Indian uses 11kg of plastic a year and around 15000 tonnes of plastic wastes are produced in India. Among all the products mentioned above, the major part of the pollution is caused by plastic bags and plastic bottles. Floating bags and bottles in our water resources and landfills are a common sight in India. Even though 60% of the plastics are recycled, the amount of presence of plastic waste in our surrounding is still large when compared with the total land area of the country.

In India, plastic bottles are widely used and are easily available. They are used for the supply of mineral water and other aerated drinks. Since the consumption rate of both these products is so high in India, the amount of plastic bottles sold is also high. In public areas like railways stations, bus bays etc, the presence of plastic products are high. The disposal of these used bottles is found out to be terrible. The usual procedure followed is that the thrown away bottles are fetched by other agents or workers and are later transported for recycling or incineration. A lot of human resources and capital is thus lost in the process. Moreover the sense of clean environment is being lost among people.

Plastic bottles that are used to carry potable water and other drinks are made from polyethylene terephthalate (PET). These materials are strong and light. The main advantage of this material is that it can be recycled and reused easily. It melts at a temperature around 200^0C. Due to this comparatively lower melting point, they can be easily remoulded into other useful shapes. Due to all these mentioned factors, need for a machine that helps in collecting and recycling of plastic bottles are found to be necessary in India. This led to the development of a device that collects, shreds, melts and remoulds the used plastic bottles into compact form.

II. LITERATURE REVIEW

Akinfiresoye Waleola Ayo et al. (2017) [1] found that the recycling of waste plastic recovers the material, which can be used to make new plastic products such as containers, plastic lumbers and particle boards. For this to happen, the waste plastic will first be shred into small bits making it ready for transportation and further processing. This necessitated the development of a plastic shredder to recycle the waste plastic .The shredder has the feeding unit, the shredding unit, power transmission unit and the machine frame. The performance of the machine was evaluated and test results showed that there was a correlation between the machine speed with a regression < 1 and there was a linear relationship with all variable parameters (The Shredding time (T), the Specific Mechanical Energy (SME), Throughput (TP) and Recovery Efficiency (RE)) and the variable operation speeds (1806.7 rpm, 1290.5 rpm and 1003.7 rpm). In this study it was found out that PET when shredded by blades moving at a rate of 1800rpm produced a 37.3% of shredded plastic with an average size of 12.23sq.mm and at 1290rpm produced 41.5% of shredded plastic with size of 7.32sq.mm.

A.M. Al-Sabagh et al. (2015) [2] reviewed the different routes for recycling of polyethylene terephthalate. Chemical recycling processes are divided into six groups: methanolysis, glycolysis, hydrolysis, ammonolysis, aminolysis, and other methods. In a large collection of researches for the chemical recycling of PET, the primary objective is to increase the monomer yield while reducing the reaction time and/or carrying out the reaction under mild conditions. This article also presents the impact of the new recyclable catalysts such as ionic liquids on the future developments in the chemical recycling of PET.

J.M.L. Reis et al. (2010) [3] investigates the fracture properties of the obtained composites. A reduction of the specific weight of the polymer mortars and a significant improvement of their post-peak flexural behaviour are observed. The present study has shown quite encouraging results and opened new way for the recycling of PET waste in polymer mortars .The shredded waste PET bottle granules used as aggregate were obtained by picking up waste PET bottles and washing, then crushing in granules by a shred machine. The machine shredder determines PET aggregate size. Polyethylene terephthalate (PET) is a thermoplastic polyester with tensile and flexural elasticity modulus of about 2.9 and 2.4 GPa, respectively, tensile strength up to 60 MPa and excellent chemical resistance. It is a semi-crystalline polymer, with a melting point of about 260°C and a glass transition temperature ranging from 70 to 80°C, in relation to the amount of crystalline region enclosed in the amorphous phase.

L. Canopoli et al. (2018) [4] reviewed information available on the opportunities and challenges in recovering plastics from landfill sites. In this study the impacts of landfill chemistry on the degradation and/or contamination of excavated plastic waste are analysed. The feasibility of using excavated plastic waste as feedstock for upcycling to valuable chemicals or liquid fuels through thermochemical conversion is also critically discussed. The limited degradation that is experienced by many plastics in landfills (>20 years) which guarantee that large amount is still available is largely due to thermos-oxidative degradation and the anaerobic conditions. However, excavated plastic waste cannot be conventionally recycled due to high level of ash, impurities and heavy metals

Narinder Singh et al.(2016) [5] compiles the different research work done by researchers in this field of recycling and progress in recovery and management of PSW by different methods (i.e. Primary, secondary, tertiary and quaternary) along with the various identification/separation techniques. Further, this paper reviews the effect on properties of virgin and recycled HDPE/LDPE/Nylon PSW with different reinforcements like sand, natural fibre, hemp fibre, metal powder etc. in this study it is discussed how PSW is a major contributing factor towards the waste generated on a global level. Disposal of polymer is becoming a global issue due to high production and consumption of polymer materials It can be clearly seen from this data that consumption and production of polymer faces some huge gap. To fill these gaps usage of virgin material is getting high. Use of plastic product can only be reduced up to certain extent but use of new material for manufacturing can be reduced by using recycling and managing techniques.

Shafferina Dayana Anuar Sharuddin, et al. (2016) [6] reviewed the pyrolysis process for each type of plastics and the main process parameters that influenced the final end product such asoil, gaseous and char. It also reviews how PET has become the great choice for plastic packaging for various food products, mainly beverages such as mineral water, soft drink bottle and fruit juice containers. This is due to its intrinsic properties that are very suitable for large-capacity, lightweight and pressure-resistant containers. Other applications of PET include electrical insulation, printing sheets, magnetic tapes, X-ray and other photographic film.

The extensive applications of PET would cause an accumulation of PET waste in the landfill. Recycling PET waste was the current practice of handling accumulated plastic waste. However, the bulkiness of the containers causes high frequency of collections and therefore, increases the transport costs

1) Primary recycling involves the use of pre-consumer industrial scrap and salvage.
2) Secondary recycling involves physical reprocessing, for example grinding, melting and reforming.
3) Tertiary recycling involves subjecting waste PET to chemical treatment whereby its components are isolated and reprocessed for use in manufacture.

III. DESIGN AND WORKING METHODOLOGY

A. Components

1) Inlet Chute

Inlet is located at the top of the device. It is conical in shape and allows the plastic to go directly into the machine. The converging shape of the inlet chute make sure that bottles once inserted are properly guided into the next component and that it won't spill outside throughout the whole process.

2) Shredder Mechanism

Down the line, shredder mechanism follows the rollers. Shredder is made of shredder blade (Figure 3.1) attached to a vertical shaft. The shaft is coupled with a motor that rotates at a speed of 1300rpm. The blades are placed in such an angle that maximum penetration is obtained and the plastics are converted to smallest piece as possible.

Fig. 3.1: Shredder Blades

3) Molding system

Molding system is the final section of the device. It consists of a mould, heating coil, electric circuits and thermal insulated mould basin. This system is located at the bottom most portion of the device. Mould is located inside the mould basin which is supported by a stand. The basin is provided with heating coils on its walls. There is adequate insulation done so that the high temperature generated inside the basin stays inside the mould itself. The mould is in the shape of a cylinder and is designed in such a way that it can be taken out manually. Heating coil can be activated using electric current or through solar power.

B. Methodology

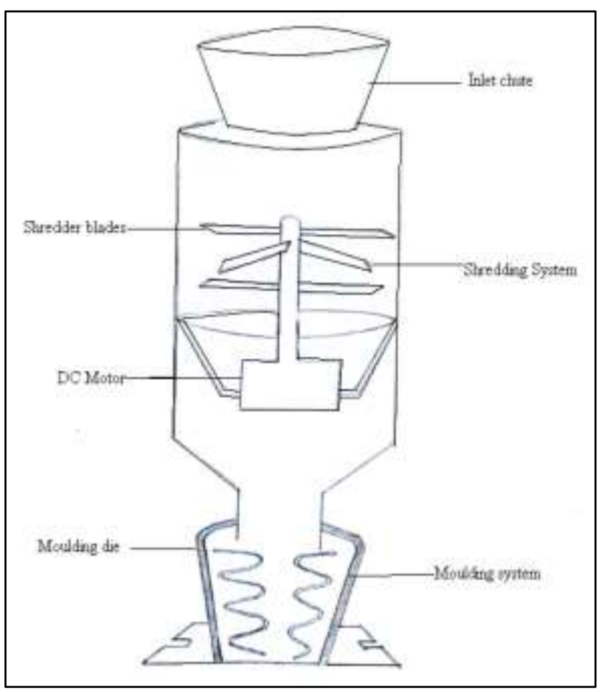

Fig. 3.2: Initial sketch

Once installed in a public area like railway station or bus stands, SCRAP will be connected to an electrical source. The schematic diagram of the device is shown in Figure 3.2. Figure 3.3 shows the project after fabrication.

The process begins when the user inserts plastic bottle into the device. The bottle goes through the inlet chute to a shredder. Since the shaft contains multiple series of blades, more minute will be the plastic fragments obtained. Shredding is done to make the molding process easier. Through the sieve beneath the blades, granules of plastic fall into mould cavity. The mould which is in contact with heating coil gets to a temperature sufficient enough to melt the plastic. When the temperature of the mould gets to 260℃, the shredded plastic inside the cavity starts to melt. As time passes, the molten plastic fills the mould cavity. Later when the process is done, the plastic cools back to its solid state by getting back to the room temperature. This mould is then manually taken out and the cube of PET plastic is taken out. This cube is then either used for other applications like manufacturing of fibers, mixed as aggregate in concrete, used as building blocks etc.

Fig. 3.3: Completed prototype

C. *Circuit Diagram*

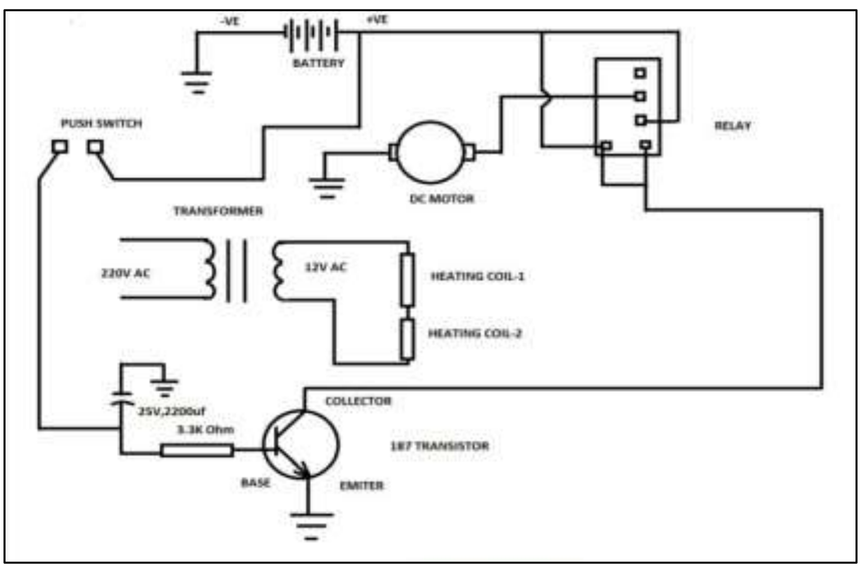

Fig. 3.4: Circuit diagram

Figure 3.4 shows the electric circuit diagram of the model. A DC motor is connected to a 12V battery in an electrical circuit containing a relay and a timer system consisting of a capacitor (2200µf) and resistor (3.3kΩ). When the plastic bottle is inserted into the inlet chute the push switch in circuit gets activated and circuit is closed. Initially, the current flows from the battery to the capacitor and the capacitor gets charged. When the push switch connection is terminated, the connection between the battery and capacitor is lost. This triggers the capacitor to discharge. The discharged current flows through a transistor which is now in ON state and into the motor through relay. The motor rotates for a time period of 10s till another bottle is dropped.

The melting of the plastic is done with the help of heating coils which are activated by a separate AC power supply. A 220V AC supply is connected to the device. With the help of a step down transformer the 220V is reduced to 12V. This 12V is supplied to the two heating coils which are coupled to the walls of the mould cavity and thus heating is done.

IV. CALCULATIONS

A. For Transformer

Power consumed by transformer, P= V*I
Input Voltage V= 12V
Input Current I= 30A
P= 360W
Core Area of transformer,
CA= 1.152*√(output voltage*output current)
CA= 1.152*√(12*30)
CA= 21.875sq.cm
CA= 3.49≈ 3.5sq.in
Stack Length, L= (Gross core area)/(tounge width)
Taking Standard value fortounge width = 1.25
L=3.5/1.25
L=2.8in
Turns per volt, TPV= 1/(4.44*f*B*CA)
Frequency f= 50 hz
Flux density B= 1.2 Wb/(m^2)
Core Area CA= 21.875*(〖10〗^(-4))(m^2)
TPV= 1/(4.44*50*1.2*.0021875)
TPV= 1.8181
Primary winding
N_1= TPV*V_1
〖 N〗_1= 1.8181*12
N_1= 21.8≈ 22
Secondary winding
N_2=TPV*V_2
N_2= 1.8181*220
N_2= 220

B. For Motor

Torque T= (P*60)/(2πn)
Speed n= 1300rpm
Power P= 360W
T= (360*60)/(2π*1300)
T= 2.64Nm

V. RESULTS AND DISCUSSION

Plastic bottles that are used to carry potable water and other drinks are made from polyethylene terephthalate (PET). These materials are strong and light. The main advantage of this material is that it can be recycled and reused easily. It melts at a temperature around 260^{0}C. Due to this comparatively lower melting point, they can be easily remoulded into other useful products.

Considering the above mentioned factor, a machine that helps in collecting and recycling of plastic bottles are necessary. This led to the development of the project SCRAP a device that collects, shreds, melts and remoulds the used plastic bottles into compact form.

One kilogram of Polyethylene Terephthalate (PET) was shredded at varied motor speed of 2000 rpm, 1300 rpm and 1000 rpm. The shredded waste plastic was weighted and sieved into three different sizes to obtain average size of the shredded chip.
The result obtained is shown in the table below:

Table - 4.1
Shredder readings

SI no.	*1000 rpm*		*1300 rpm*		*2000rpm*	
	Average Size (mm)	*% shredded*	*Average Size (mm)*	*% shredded*	*Average Size (mm)*	*% shredded*
1	*7*	*28*	*4*	*21*	*2*	*24*
2	*15*	*24*	*10*	*30*	*7*	*27*
3	*22*	*37*	*17*	*42*	*12*	*39*

From the above table it is clear that motor running at a speed of 1300 rpm gives the best output for shredded plastics at considerably low input and vibration.

PET on burning causes the release of harmful toxic gases like Carbon monoxide, dioxins and furans. But if PET is treated within a suitable temperature range of 250^0C and 260^0C (a temperature range around their melting point), the emission can be reduced exponentially. Moreover if melt under inert or vacuum conditions, the emission rate and gases produced can further be reduced.

A. Future scope

1) SCRAP can be used as an aid to re-establish the long lost sense of cleanliness. An additional incentive system which provides a reward for the user for every single use of the machine will help in providing a cause for public to take initiative in proper waste disposal.
2) The shredded plastic can be used in reinforcing concrete. The presence of plastic in the concrete will help in making the structure more water resistant. Elasticity and shock absorbing capacity are increased with the presence of plastic materials in it.
3) The chips of plastics can be mixed with bitumen which is used in tarring of roads. This helps in increasing the life of the construction.
4) The mould used in SCRAP can be made of different shapes so that the final product obtained can be of much variant in shape and application. When cooperated with an additional cooling system and injection molding mechanism, a ready to use product can be obtained.
5) Combining solar power system with the machine helps in reducing the expense created due to the excess electricity.

VI. CONCLUSION

In today's world where we focus on environmental protection, a main problem we face is the disposal of plastic. In the case of plastic bottles, the process of collecting and accumulating of bottles is a tedious task and requires lot of human resources. The waste management of plastic is a very difficult.

SCRAP shreds the plastic bottles into pellets, melts it using heating coils and remolds into small cubical units that can be sold to plastic manufacturing companies. These PET can be later be used in producing cheap fibers, strapping, bottles or film sheets. We also envision a system where the general public is involved in the collection and deposition of plastic into our SCRAP machine. An incentive can be provided for each plastic bottle deposited which will encourage active participation in the current generation and create a good example for coming generation to follow. SCRAP provides a reason for the public to deposit the bottles inside the device itself. The used plastic bottles are given a value by the device.

Thus, if implemented, SCRAP can produce a new face in waste disposal management. The fact that this idea can be developed into another dimension adds the potential it holds in itself.

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