Techniques for separation of plastic wastes

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***Abstract*— Rapid industrialization and urbanization have led up to various environmental issues likes deforestation, clean water storage, plastic pollution, global warming, etc. Recycling of plastic wastes is one way to minimize the effect of plastic pollution. Recycling of the plastic waste entails several steps and the most important is sorting techniques, which is the focus of this paper. Separation of plastic wastes during recycling determines the quality of the end product. This paper presents an overview of recycling of waste by mechanical recycling mainly focusing on various current sorting techniques used during recycling of the plastic wastes. Limitations of mechanical recycling are also discussed. Future scope (chemical recycling) and opportunities is presented as well.**

Index Terms: **Mechanical recycling, Chemical recycling, sorting techniques.**

I.INTRODUCTION

Plastics are inexpensive, lightweight and durable materials, which can be readily moulded into variety of products which find its applications in various fields [1].Packaging, building and construction, automotive, and electrical and electronic equipment all use plastics, with packaging being the most common. Despite the fact that plastic items are generally durable, more than half of them are discarded as waste each year. Increased demand for plastic has resulted in fast increases in both manufacturing and disposal of plastic garbage. Plastic garbage has risen to become one of the most significant forms of municipal solid waste (MSW), particularly in industrialised countries[2].Humans have turned to recycling anytime they have difficulty getting raw materials or fundamental resources that are vital to their life. As a result, it is not a modern-day method [3]. Any practise in which a waste material (organic or inorganic) is subjected to a recovery treatment or transformation process before being reused in the manufacture of a new product or applied to another valuable use is referred to as recycling [4].Researches in 21st century have shown that the global plastic production has increased about 20-fold in the last 50 years. With increased production, generation of plastic wastes (PW) also increases. As a result, we need proper management of PWs.PW management follows an order of (1) no waste generation, (2) waste reduction, (3) reuse, (4) recycling and (5) land filling & incineration. Recycling is an old concept but its true effect can be seen with the advent of technology [5,6].

II. RECYCLING OF PLASTIC WASTES

Polymer recycling follows a preference with ascending order, from primary to quaternary recycling [4]

1. Primary recycling: Only semi-clean and high-purity PW can be recycled directly. As a result, it is a rare choice for recyclers. Due to the high purity and ease of identification of their plastic wastes, industries frequently use this recycling technology to recycle polymer waste from their own production processes, aiding to waste reduction in their industrial process [7,8].

2. Mechanical recycling: It is a physical process which includes collection, screening, manual and/or automatic sorting, size reduction, washing, extrusion and granulation of plastic wastes [9].

1). Collection: Varied systems are used for collection, based on the different sources, such as plastics from domestic waste and industrial waste. Plastic can be collected as a source-separated fraction or as part of a multimaterial collection with other packaging materials.

2). Manual Sorting: It is frequently required at the start of the recycling process to remove films, cardboard, and bulky materials, and it is normally done by operators inspecting the waste stream on the conveyor belt.

3). Screening: Small items, such as glass and stones, are removed via screening. Drum or vibrating screens are common screening devices. Waste is usually categorised into three categories: undersize (less than 50 mm), middle size (50 to 300 mm), and oversize (more than 300 mm). Plastic is usually found in the medium size portion.

4). Sorting: The goal of sorting is to produce high-quality recycled plastic products, preferably from a single polymer stream. Different physical-chemical features of waste items, such as shape, density, size, colour, or chemical makeup of objects, are used to sort waste materials. Material sorting is the process of removing undesirable pollutants from the plastic waste stream, such as metals, glass, and paper.

5). Resizing/Size reduction: Shredding or cutting procedures are commonly used to reduce size; depending on the plant structure and the kind of plastic waste stream, these activities may occur before or after the sorting stage. Plastics are typically shredded into flakes of 5-10 mm.

6). Extrusion and granulation: This procedure is required to create a granulate that is easier for converters to use than flakes. Polymer flakes are fed into an extruder, heated, and pressed through a die to form a continuous polymer product (strand) that can then be cooled in a water bath before being pelletized. The granulation procedure is used to convert the strands into pellets that can then be used to make new products.

3. Chemical recycling: A chemical process, in which plastic is depolymerised into monomers using chemical reagent. Chemical recycling involves the treatment of post-consumer polymers using a variety of thermal (gasification, pyrolysis, and hydrocracking) and chemical (chemolysis) processes. Biological degradation is regarded by some experts as a form of chemical recycling [4,10].

4. Quaternary recycling: Energy recovery is an alternative to traditional recycling methods for mixed and severely contaminated polymer waste that cannot be recovered simply or affordably. As a result, it's an excellent recycling technology for medical waste and hazardous product packaging. It involves incineration of wastes to generate heat, steam and electricity [10].

The focus of this paper is techniques involved in sorting of different plastic wastes during mechanical recycling.

III. MECHANICAL RECYCLING

Before the actual reprocessing of recycled plastic wastes, plastic goes through a number of steps which are [11]:

1 Separation and sorting: based on color, chemical composition, size, or shape.
2 Baling: Plastics are baled in between transport processes if the plastic is not processed where it is sorted.
3 Washing: It is often done to remove contaminants.
4 Grinding: Size reduction of plastics to flakes.
5 Compounding and pelletizing: Optional process of the flakes into a granulate.

Sorting techniques are employed in recycling to separate different PWs into its component streams. Techniques are of two types [9]:

(1) Dry technique
(2) Wet technique

IV. SORTING TECHNIQUES

(1) Sink-float:

Flotation also called sink-float method is a simple density-based separation technique. It uses water or other agents denser than water as a flotation agent. It is a dominant method to separate plastic wastes into mixed streams. Lighter fraction (PP & PE) floats whereas denser fraction (PET, ABS, etc) sinks when water is used as a floating agent. Sink-float fails to separate mixed PWs streams into mono streams in a single step. Hence, it requires further flotation to separate PWs into mono streams [11].

Fig 1: Sink-float separation [9]

Sink-float can be used as primary sorting technique to separate PWs and later the mixed streams can be segregated into mono streams using froth flotation, MDS, tribo-electric and optical sorting.

(2) Froth flotation:

Froth flotation is similarly to sink-float with difference being the addition of frother, depressants or surfactants to make surface of one plastic more hydrophilic than other plastic. It is a technique used to separate binary plastic mixture [12].Froth flotation is achieved by four methods which are

Gamma radiation-It is accomplished by lowering the liquid surface tension to a level between the two polymers' critical surface tensions.

Adsorption- Mechanism involved in adsorption of wetting agents onto the plastic surfaces is due to van der Waals force, Lewis's acid-base force, electrostatic force and hydrogen bonds.

Surface modifications- It is done by flame treatment, ozonation, corona discharge, surface oxidation and photografting. Main aim of surface modifications is grafting hydrophilic funtionalities into the polymer chains.

Physical regulation- It does not use chemicals instead sorting techniques are used in combination to separate PWs. Physical regulation exploits the intrinsic properties of plastic to achieve separation.

(3) Tribo-electric separation:

It is a dry separation technique used to separate binary mixture of plastics. Plastic particles are rubbed against each other to charge the surface developing polarities in the process and later the charged particles are passed through electric field [2]. Positively charged particles gets attracted towards negative electrode and it is later collected in the collector. Based on tribo-electric charging sequence, separation of plastics can be applied to several polymers:

(+) ABS – PP – PC – PET – PS – PE – PVC – PTFE (-)

Tribo-charging takes place in solid single phase in a rotating tube with ribs inside the tube to make mixing better. In gas-solid phase tribocharging, fluidized bed,c yclone tribocharger or propeller type device is used [2]. Gas-solid phase recommended when rub frequency required is high whereas solid single phase is recommended for its mechanical simplicit
y.

(4) Magnetic density separation:

Magnetic density separation (MDS) is an advancement of density-based technology in which a magnetic fluid is used as a separation medium in the mixture of multiple polymers.Plastic particles with marginal density differences, like PE and PP, PVC and rubber can be separated [9,11].Bidirectional magnetic projection was thereby developed; the process separates mixed materials simultaneously in a container full of paramagnetic medium by sending the materials from the releasing position to their corresponding landing zones upwardly or downwardly, with the aid of the resultant force of buoyancy and gravity, and the magnetic force provided by a permanent magnet placed beside the container.

(5) Optical sorting:

Optical sorting is defined as a process which uses optical instruments like camera, lasers etc. for sorting process.Traditionally sorting was done manually which required a lot of labour and time and the sorting was not that proper.To replace manual sorting automated sorting was preferred which is done using optical devices or using different spectral instruments like infrared spectroscope.At present, near infrared radiations are used to separate plastics of different materials like polyethylene, polyvinylchloride, polyethylene terephthalate [11].Using radiation of near infrared range (1-7μm) plastic material is made to pass through the sensor which according to the spectral wavelengths absorbed by different plastic

segregates them.It fails to detect black or dark plastics [9].

Overview of sorting techniques with its advantages and challenges:

Sorting technique	Advantages	Challenges	References
Sink-float	Efficient in separating plastic waste with large density Cost-effective	Difficult to separate mixtures with close density range	[11]
Electrostatic	Applicable for various mixture of plastic	Pre-treatment required to remove dirt,paper,etc.	[2]
Magnetic density separation	Separates multiple plastic type in one go	Proper feeding,separating and collecting to avoid the turbulence in the feed stream. Wetting,to make polyolefins(PP,PE) hydrophilic.	[9,11]
Sensor sorting	NIR spectroscopy Multiple detection High identification speed X-ray fluorescence High accuracy	Dark polymers are almost impossible to identify due to their low color reflectance. Cost-effectiveness Not able to distinguish different polymers.	[9]

V. CHALLENGES IN MECHANICAL RECYCLING

(1) Thermal-mechanical degradation:

It is caused by heating and mechanical shearing of polymers during melt processing. Common mechanisms observed when the plastics are subjected to combination of shear and temperature are chain scisson and chain branching. Parameters affected are physical properties (surface properties, color, etc), thermal properties (melting temperature, crystallisation, etc), mechanical and rheological properties. To minimise the effect different compatibilizers, heat stabilizers, crosslinkers, pigments, fillers and impact modifiers can be used [11].

(2) Degradation during lifetime

The main degradation is due to photo-oxidation processes. Presence of oxygen(absent in processing machines) forms oxygenated groups in the polymer chains which affects the final properties of materials [13].

Future option – Chemical recycling:

Chemical recycling is a chemical process of depolymerization of polymers into oligomers and monomers using chemical reagents. Depending upon the chemical reagent used, different routes can be followed like methanolysis, glycolysis, amminolysis, ammonolysis, etc. This recycling also requires proper cleaning and drying of PWs before it is reprocessed. Complex polymers like vulcanized rubber/cross-linked polymers can be easily processed. Solvolysis, biological treatment are new technologies which show promising results in recycling of themosets, thermoplastics and elastomers [4].

The technologies involved in PW chemical recycling are much more expensive than primary and secondary recycling practises because (1) they require high-cost chemical engineering equipment because the processes generally require high temperatures and pressures; (2) chemical reactions require efficient catalysts, which are relatively expensive and generally are selective for each polymer type or polymer group; and (3) it inherently requires high-cost chemical engineering equipment because the processes generally require high temperatures and pressures; and (3) it inherently requires high-cost chemical engineering equipment because the processes generally require high temperatures[4].

VI. CONCLUSION

With rapid urbanization and industrialization, human kind is facing various environmental issues like climate changes, deforestation, plastic pollution, etc. Over the years, production of plastics has increased and therefore it is necessary to properly manage the plastic wastes generated. Recycling is one of the options to minimize plastic pollution and at the same time it is an opportunity to develop techniques and technology to deal with it. Mechanical recycling is the widely accepted the process when it comes to recycling of PWs. Sorting step which is one of the most important part of recycling was discussed in this paper. Major challenges associated with mechanical recycling were also discussed and future option (chemical recycling) was briefly discussed.

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