

Development of High Performance Sorting Process for Recycling of Plastics

by

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ABSTRACT

This research is being undertaken by IRIS in collaboration with VISY Plastics, who will provide an industrial test environment for the technological innovations resulting from this work. At the time of preparing this paper, the research program had only been under way for several months and so this paper provides an overview of activities to date. The plastics recycling industry is a major potential reducer of landfill. However, several significant barriers exist which reduce the effective utilisation to much lower percentages than would otherwise be possible. One of the difficulties lies in separating different types of plastic, a necessary step before they can be recycled. Manual sorting is not cost effective and automatic systems are sensitive to dirt and produce high levels of loss when set-up to deliver high purity. One process, which has potential to improve both purity and value retention, is mineral beneficiation technology such as froth flotation. Mineral beneficiation has been used in the past in mining to separate valuable minerals from worthless ore. This research will investigate the application of similar processes to separate different polymers in the recycle stream and may one day be used to mine landfill sites.

1. Background

A significant problem facing the plastics recycling industry is the large variety of plastics and plastic products available and the increasing diversity and volume of the consumer products. Disposable packaging is the largest single category of materials now being recycled. This includes plastic bottles, plastic bags, plastic wraps and films, and foam cups and packaging. Currently, the plastics recycling industry in Australia is primarily concerned with the recycling of rigid plastic milk bottles, detergent and soft drink bottles, which are commonly available, easy to recognise and collect, and relatively easy to reclaim for a new product. Sorting these from large quantities of other material currently collected but not utilised requires new and efficient recycling techniques, which are economical, reliable and can produce a high purity output. Australia, being a major consumer and exporter of food and beverage products, needs to

develop intelligent high performance plastics recycling methods and techniques that will result not only in increasing the quality and application domain of recycled plastics but will also create a safer, cleaner environment.

The recycling procedure for plastic bottles normally involves three basic steps: the collection and sorting of plastic bottles, re-processing into reusable flakes or pellets, and development of market for recycled plastics [1]. The pre-process sorting of plastic bottles involves separating the bottles by colour and type of plastics, into two streams; one mainly PET and PVC, and the other, HDPE and LDPE plastics, to achieve the highest sales values [2,3]. At the re-processing plants, bottles are chopped or ground into small pieces, washed and dried. Any contamination is removed by in-process sorting techniques, resulting in good quality plastic flakes. These can then be used to manufacture new products. The current practice of creating a market for products produced from low grade recycled plastic has been criticised as unsustainable as well as reducing the profitability of recycling operations. Currently only a small amount of containers produced are converted to flake and only a fraction of that is of sufficient purity or quality to re-manufacture into the original products, termed 'closed loop' recycling, which is the industry goal. Only when the larger percentage of materials produced can be recycled back into high-grade products will recycling achieve its ecological goals and long term viability.

The throughput and cost of recycling process depends greatly on the reliability, efficiency and flexibility of the pre-process and in-process sorting methods used. Pre-process sorting may involve manual and automated systems for identification and separation of different plastics (generic types and grades) from mixed plastics and from other materials such as aluminium and paper [4-6]. In-process sorting involves mainly electronics based automated systems to identify and separate ground plastics by colour or type, or to separate plastic material from paper labels and other impurities [7]. The exact processes used by different recycling firms are not known because these techniques are proprietary.

Research and development in the area of sorting recycled plastic bottles has focused on optical technologies such as X-rays, NIR sensors and vision systems (colour cameras), which provide separation based on colour and chemical composition [3,8]. The same techniques have been applied to separating the recycled plastics following the grinding process, which produces the flakes. Some automated systems have been developed by MSS, ROFIN Australia and other manufacturers, which make use of magnetic or optical techniques for sorting plastic bottles and flakes [5]. A robotic sorting system has been developed to improve the working conditions for operators in manual sorting [2,7]. These sorting processes, though automated, are highly dependent on complex electronic systems and involve high initial investment and maintenance. The attainment of higher purity levels in sorting and higher efficiency with low-tech low cost investment and high profit returns is the ultimate goal of plastics recyclers around the world. Mechanical sorting techniques have been successfully used in mining industry, but very little work has been done in the development of mechanical sorting systems for plastics recycling.

The plastics recycling industry in Australia is one of the country's growing industries aimed at harnessing the post consumer plastics waste generated by Australia's flourishing food and beverage industry. Presently only a small amount of plastics waste is reclaimed by the existing recycling methods because of the high costs and efforts required at the collection and sorting stage of the materials. The manual and automated sorting methods used at the pre-processing stage do not yield the purity levels required so there remains a need for in-process sorting at the processing stage. The problem of contamination is compounded by the large variety of plastics used for different products and significant amount of non-plastic material such as metal and paper labelling present in the recycling stream. The quality and applicability of the recycled plastic resins can be enhanced greatly if more efficient and economical sorting methods were made available. Development of such methods will in turn give rise to more recycling plants thus increasing the reclaim volume and value of the recycled plastics.

2. Objectives

The objective of this research project is to develop a new high performance in-process sorting system for recycled plastics with the aim of increasing the quality and application range of recycled plastics. The current methods used for in-process sorting of plastics, although not exactly known to the full extent, are inefficient and unreliable, as evidenced by the poor properties and limited applications of such recycled plastics. The proposed research will involve a comprehensive study of current trends in the area and the development of new techniques and methodologies to develop the most efficient and accurate in-process identification and sorting technology, starting with a comprehensive literature review. The focus of the research will be on development of efficient mechanical methods for sorting different types of plastics. These will include sorting through methods involving centrifugal force, specific gravity, elasticity, particle shape, selective shredding and mechanical properties. Very few plastic sorting systems have been developed using these principles. The research will include the following major activities:

- A thorough investigation and evaluation of existing methods used in the identification and in-process sorting of plastics including technology used, performance, limitations and success rates.
- Assessment of techniques for dry mechanical sorting processes including air separation, magnetic separation and optical sorting techniques with regard to limitations, efficiency and improvements.
- Investigation on the development of techniques for mechanical sorting, especially those involving centrifugal force, surface properties and particle density. Identification of controlling parameters in each sorting technology, which affect the quality and output of sorted flakes.

- Design and development of a sorting system involving mineral beneficiation technology such as froth flotation.
- Design and development of a test prototype of above sorting methods and comparison and evaluation based on efficiency, speed, and accuracy.
- Testing and implementation of the appropriate sorting method at the processing plant of the collaborating company.

It is expected that the project, when completed, will provide some of the following outcomes:

- A high performance in-process mechanical sorting system for plastics recycling industry
- A rapid identification system for different plastics types
- A prototype of an type in-process sorting system
- A high volume process for separation of similar density plastic materials

3. Research Methodology

Sorting by centrifugal force will involve designing a bowl type centrifuge that would separate plastics according to their specific gravity with improved separation performance and lower residual moisture content. The system will use a mixture of plastics and water or salt solution (as a separation media) rotated at high speeds. Centrifugal force in a solid bowl centrifuge will cause plastics with a specific gravity, which is heavier than the liquid phase, to settle against the bowl wall. Plastics, that are lighter than the liquid phase will float and be carried away to the other end of the centrifuge.

Sorting by mechanical properties will investigate the use of elasticity or inelasticity of material. When an object falls on a hard surface, it rebounds according to its elasticity. Soft objects bounce only a short way because much of their potential energy from falling is converted into energy of deformation. Research will include development of ballistic separators involving sloping metal sheets (called paddles) rotating side by side on a crankshaft. Rigid plastic particles will be repeatedly thrown upwards by the movement of the paddles and slide down the slope.

Sorting by froth floatation/particle density will involve designing a variety of systems for accentuating the small differences in density of the plastics that need to be separated before reprocessing. One way to differentiate plastics this way is by modifying the surface properties and then stirring flaked recycle through a stream of small

bubbles. Plastics with bubble friendly surfaces are carried to the surface, while those that don't, sink to the bottom.

The post-consumer plastics, obtained from kerbside collection of plastic bottles, mostly consist of five grades of plastics - high-density polyethylene (HDPE), polyethylene terephthalate (PET), polyvinyl chloride (PVC), polypropylene (PP), and polystyrene (PS). Each of these may be of clear natural type or coloured plastic type. These plastic bottles are baled and transported to the VISY Plastics recycling plant. The make-up of baled plastics includes around 40% of PET, around 40% of natural HDPE, and the remaining 20% of PVC, PP, PS and coloured HDPE [4]. There are some contaminants (eg. caps made of PP, and labels) and other waste products, which still manage to get into the bales. The de-baling stage of a recycling process presents a health risk [5]. Beyond this stage, the recycling process is almost fully automated, with only a few points requiring manual inspection and possible intervention. After de-baling, the waste enters the Magnetic Separation System (MSS) sorting machine. Sorting in the MSS takes place in two phases, one is the sorting of bottles into types of plastics, and the other is the sorting the flakes of plastics.

Australia produces 1.3 million tonnes of plastic products each year, and about 35% of it are disposed of in that time. Until recently, most of that went to landfill. However, Plastics recyclers are playing a major role in recycling this waste. The collaborating company, VISY Plastics is a leader in recycling in Australia, with a strong commitment to R&D. IRIS and VISY Plastics have established a relationship in R&D in improving the quality of recycled plastics. This research into sorting of recycled plastics is of paramount importance to VISY Plastics company because accurate separation and sorting of different grades of plastics and impurities is crucial to the quality and application of final recycled plastics. Current equipment for sorting at VISY Plastics is mainly based on electronic, electro-static and magnetic separation techniques, which are costly, time consuming and not 100% efficient. It is expected that both laboratory trials and full-scale prototypes may be built and trialed at VISY in the future.

4. Conclusions

The increasing quantity of the post-consumer plastic material and the current limited end uses, coupled with the relative low cost of overseas virgin plastic materials, impose greater demands for improved quality of recycled resins. Increasing the sorting efficiency of recycling processes improves the quality and consistency of recycled plastics. It will also increase the market share of recycled plastics, providing economic benefits and reduced waste disposed in the environment. The value of this research will be both commercial and ecological and the techniques discovered might one day be applied to the mining of today's landfill sites really 'closing the loop' in waste reuse.

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6. References

- [1] Brandrup, J., Bittner, M., Michaeli, W. and Menges, G., "Recycling and Recovery of Plastics," Hanser, New York, 1995.
- [2] Sommer, E.J., "Techniques for rapid identification and sorting of plastics," IndentiPlast Conference, Brussels, Belgium, October 1997.
- [3] Massen, R., "Sorting plastics waste by colour and by material," IndentiPlast Conference, Brussels, Belgium, October 1997.
- [4] Kosior, E., Dvorak, R., Iovenitti, P., and Masood, S.H., "Enhanced automatic sortation of post-consumer bottles," Proceedings of ANTEC'99 Conference, Society of Plastics Engineers, USA, pp3174-3178.
- [5] Kenny, G.R. and Bruner, R.S., "Experiences and advances in automated separation of plastics for recycling", Journal of Vinyl Technology, Vol. 16, No. 3, September 1994, pp. 181-186.
- [6] Dvorak, R, Kosior, E., Iovenitti, P. and Masood, S., "Factors influencing the sorting efficiency of commingled post-consumer bottles using an automated sorting system," Proceedings of ANTEC2000 Conference, Society of Plastics Engineers, USA, pp 2941-2944.
- [7] Deck, S.H. and Stikeleather, L.F., "Evaluations of a semi-automated vegetable sorting concept," Applied Engineering in Agriculture, ASAE, Vol. 10, November 1994, pp. 815-821.
- [8] Massen, R. and Simnacher, M., "Optical sortation of plastics by colour and composition," Recycle'94, Davos, Switzerland, March 1994, pp.4.71-4.76.
- [9] Schiers, J. "Polymer Recycling; science, technology and applications", Wiley, New York, 1998.