Solid-State Shear Extrusion Pulverization for Recycling Commingled Plastic Waste

Klementina Khait
Polymer Reclamation Center at BIRL, Northwestern University

A pulverization process will recycle commingled pre- and post-consumer plastic waste without the costly sorting step. This process should be much more energy efficient than conventional repetitive grinding because the pulverization occurs in one step.

Concept Description

A nonconventional pulverization process known as solid-state shear extrusion (SSSE) is being developed for recycling commingled, unsorted, pre- and post-consumer plastic waste. The process uses a specially designed co-rotating twin-screw extruder with integrated heating and cooling. It is currently in operation at BIRL Polymer Reclamation Center. This work is being pursued in cooperation with Hermann Berstorff Maschinenbau GmbH.

This continuous process converts post-consumer waste in chopped or shredded form to a controlled particle-size powder or fluff, which may include ultrafine powders (<200 microns). The pre- and post-consumer plastics include high-density polyethylene (HDPE), low-density polyethylene (LDPE), polypropylene (PP), polystyrene (PS), polyethylene terephthalate (PET), and even small amounts of polyvinyl chloride (PVC). Powdered materials are advantageous in plastics processing because they can be blended easily with other materials and additives if needed and used for other applications, such as powder coating, rotational molding, and compounding.

Introduction

Plastics account for about 20% (by volume) of the municipal waste stream. Decreasing landfill space and rapidly rising disposal costs have forced many municipalities to begin curbside recycling of post-consumer waste.

Most existing processes for recycling plastic waste result in products that are less valuable than the original plastic. Generally, the physical properties of recycled commingled (unsorted) plastics are inferior to the virgin materials because of chemical incompatibilities and varied colors in collected waste. Fillers and other additives make recycling mixed plastics even more difficult and more expensive.
The particle size of the produced powder and fluff is controlled by changes in the screw design and by the design/adjustment of screw elements and process parameters. The formation of powder involves the rupture of chemical bonds. Because of the fine powder size, the number of broken bonds is expected to be high, and the powders consequently will be reactive. This reactivity is being investigated and could allow new polymer blends to be produced from normally incompatible plastics in the post-consumer waste stream.

The process can handle any plastic or mixture of plastics. This process differs from traditional extrusion in that the product is in particle form, rather than large extruded shapes or granules. These powders can be further processed by standard processing equipment.

**Economics and Market Potential**

The high cost of sorting is one reason for the low success of recycled plastics in the marketplace. Collected and sorted post-consumer plastics are usually more expensive than virgin materials. By eliminating the need to sort the plastics, the solid-state shear-extrusion process offers a significant cost advantage over conventional technology.

This process should be much more energy efficient than conventional repetitive grinding because the pulverization occurs in one step. The powders are formed in the solid state by shear deformation under pressure, coupled with a rapid temperature change. When the process conditions are optimal, a spontaneous fragmentation occurs, producing particles that are smaller than any of the clearances in the extruder. This particle formation mechanism is dramatically different than the mechanisms of grinding.

This process should offer new opportunities for developing high value-added products from commingled plastic waste. Examples of such products include compatibilized polymer blends from traditionally incompatible polymers, block and graft copolymers, and reinforced thermostats. Novel products such as these are expected to stimulate interest in recovering post-consumer waste, leading to new markets and applications.

**Key Experimental Results**

Post-consumer, mixed-color LDPE, HDPE, PP, PS, PET, and PVC obtained from various recyclers were processed in a bench-scale, 25-mm twin-screw extruder. Plastics were fed as individual components and as dry blends at various ratios. The final products are strongly affected by the cooling available for the extruder and by the intensity of shearing during the process. The products range from flakes (2 to 3 mm) and fluff (1 to 2 mm) to various particle-size powders, including ultrafine powders below 200 microns.

The post-consumer plastics include various colors, but the products from this process have homogeneous, unusually light colors rather than the conventional dark shades of gray or brown in recycled commingled plastic products such as plastic lumber. Products of a single, uniform color could be formed from this material, and the color could be adjusted by adding additional pigments if needed.

Initial studies of pulverized LDPE and PP prove that reactive sites (ruptured bonds) are formed during processing. These sites are observed with electron spin resonance spectroscopy and are not seen in samples of LDPE and PP before pulverization. This preliminary result provides good support for our concept. Plans are to develop new polymer blends by in-situ compatibilization of dissimilar plastics via SSSE pulverization technology.

**Future Development Needs**

Further development of the pulverization process and equipment is proceeding simultaneously on manufacturing and bench-scales. Additional bench-scale experiments are needed to determine parameters for optimizing process design and operation. Currently at BIRL’s new Polymer Reclamation Center, demonstration trials are being conducted using a bench-scale, twin-screw extruder built by Hermann Berstorff. These trials are aimed at producing powders from various polymer waste streams for testing and application development.

Injection molding of complex parts has been successfully conducted using PP powder as a feedstock. Currently, a rotational molding application is being investigated for recycled polyolefin powder products made by the SSSE pulverization process. These applications include, but are not limited to, extrusion, compounding, and powder-coating processes.

For more information, contact

Klementina Khait
Polymer Reclamation Center at BIRL, Northwestern University
1801 Maple Avenue
Evanston, IL 60201-3135
Phone: (708) 491-2742
Fax: (708) 467- 1022

Compiled by
Pacific Northwest Laboratory for the U.S. Department of Energy, Innovative Concepts Program 90240. This flier was printed on recycled paper.