IKK uses small-scale extruders to demonstrate big recycling opportunities

Introduction

The plastic materials used in modern-day packaging and equipment as well as in many other technical applications are often complex mixtures of dozens of chemicals. This makes efforts to recycle such plastics and keep them out of a landfill much more complicated than just looking at a number inside some chasing arrows symbol and tossing a piece into the proper waste bin. Researchers seek to develop closed recycling loops from waste collection, separating out individual waste components and determining how to efficiently process them into recycled plastics equivalent to virgin plastic materials.

There are three main methods of recycling, categorized as chemical, mechanical, and solvent-based or physical. Each has their own advantages and disadvantages for any given situation. In the case of polymeric materials like plastics, these methods can produce very different outcomes. Chemical recycling is based on depolymerization and results in a mix of different smaller building blocks or monomers, while in physical recycling, solvents are used to dissolve plastics apart, but the polymer structures are not influenced. Mechanical recycling makes use of techniques like for example grinding, magnetic separation, sorting, vacuuming away volatile compounds (VOCs), and extrusion with melt filtration steps. During these mechanical steps, the polymer structure is not affected, at least not intentionally.

Dr. Madina Shamsuyeva is the head of the Department of Plastic Technology and Recycling, Plastic Analytics at IKK—Institute of Plastics and Circular Economy at the Leibniz University of Hannover, Germany. Her department at IKK focuses on mechanical recycling. “The aim is to use different mechanical processing steps to produce the highest purity plastic recyclates at the end,” Madina said. A small laboratory-scale extruder, like the Thermo Scientific Process 11 or Thermo Scientific Process 16 Extruders, can be a major asset in this testing and recycling research to figure out the best parameters within the recycling routes.

Challenges

Some governmental organizations like the European Union (EU) have proposed directives that will require, for example, the automotive industry to use more recycled materials. Other industries are trying to be environmentally conscious and reduce their waste. The textile industry provides an example of both complex material usage and production waste, both of which create real challenges for efficient recycling. “Look at different sport bags or clothes,” Madina explained. “A certain amount of mixed materials which are often coated additionally are used for manufacturing of the bags or dresses, but still there are a lot of production cut materials that cannot be used, so that becomes waste. Currently all of these waste materials go to incineration or into landfills… It’s disposed in other ways, but it’s not recycled.”

Part of IKK's mission is figuring out how to recycle waste like this and produce useful materials from it. The complex process involves lots of experimentation and many variables, as Madina noted when listing concerns: "What is the chemical composition? Is it suitable to the process of mechanical recycling? Should the material be cut or ground up, and to which size particles? What should be the pre-treatment to make the material processable by the extruder? Should it be pelletized to improve the density for feeding into the extruder? In what order should the pre-treatment steps be carried out to optimize processing? What is the performance of the recyclates? Afterwards, will it go to injection molding? Is fiber-to-fiber recycling possible?"

Solutions

Because it is impractical to test all these possible variables on an industrial scale, IKK uses lab-scale extruders for preliminary work trials. An industrial-scale extruder would require much more starting material—a minimum of approximately 100 kilograms. Besides the fact that running experiments on such large volumes would be wasteful, in some cases such a substantial amount is not even available. "We start with a very small amount of material," Madina said, "and then we use lab extruders like the Process 11 and the Process 16 because we can perform representative trials with 5 kg or 10 kg of material to get a feeling about the purity or the recycling potential of the material."

Madina continued, "We analyze all of these different scenarios and perform different tests in the lab and in the technical center so we can manufacture the end specimens and also analyze them with different material methods." The continuous processing capabilities of an extruder allows the researchers to perform in-line testing to determine material characteristics like rheological properties, color scale, flammability, the composition of captured off-gases, and more. These in-line techniques, which often can be performed in just a few minutes, can make testing easier and more regular compared to off-line laboratory testing, which only uses a small (potentially non-representative) sample of the overall batch material and often takes much longer.

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After a process has been experimentally determined based on a small amount of material, the method can be transferred to larger extruders with relative ease thanks to the scalability of the extrusion process. Madina summarized, "Using a lab extruder, it is possible to achieve representative results with a smaller quantity of plastics. This facilitates decision-making when planning trials with larger extruders."

Additional benefits

The manageable size of a lab extruder provides other advantages. Madina stated that at IKK, they use small-scale extruders if, for example, "we have some materials which are difficult." As noted earlier, there are many variables when recycling plastic waste from products which were not designed for recycling and have never been recycled before—e.g., plastics waste from end-of-life vehicles, electrical scrap, rotor blades, etc.: what additives to use, what size particles work best, and the like. "We can pre-adjust the main processing parameters using lab extruders with a very small amount of material. This is useful because there are a lot of trials which are required to adjust systematically the processing parameters."

The easy operation of an instrument that fits on a lab bench is also a plus. "As we are a university, we do a lot of student projects. A big advantage is that the extruder can be used by one person, and its use is very simple. So we have a lot of students who are also working on the extruders themselves for the student projects."

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Possibilities

The utility of lab scale extruders when recycling a complex sample was made apparent in a test case with an electronic component. "We had a case from electronics," Madina related. "In this sector there are many small components, which may have a mass of just a few hundred grams, and only a part of a component is made of plastics. But, it was more than 12 different types of plastics in one component. So it's very complicated to perform a recycling concept for that. With the amount of each polymer you have at the end, it's very, very small. So I think for such feasibility studies, small extruders have very high potential." Madina added, "A lot of projects would not be possible without them."

IKK researchers were able to demonstrate how the different sizes of extruders could be used on the same batch of source material. An electronics company provides typically approx. 200 – 300 kg of a product to IKK. Those components were first put through grinding and metal separation processes. Then spectroscopic methods were used to help separate the plastics, which resulted in a mixture of polymers in varying amounts. “For some plastics, for example, from the devices’ housing, there were higher material amounts of more than 50 kilograms obtained. This amount was suitable to be processed by a semi-industrial extruder,” Madina said. But of the remaining polymers, in some cases there was only one kilogram of material, or 500 grams or even less. “In those cases, the Thermo Fisher extruders came into play, because there is no other extruder that can process such a small amount. And their smaller injection molding machine was also capable to produce the specimens for subsequent testing with focus on purity, processability and use performance!” The combination of technologies made it possible to manufacture new recycled products from what had been a messy mixture of polymers.

“We compared the results against the virgin plastics. Meaning, we processed a similar amount of virgin plastics using the same extruder. The process parameters are always the same so that we can accurately compare them. When we compared the recycled products for tensile testing, chemical composition and so on, we found that even on the small scale, we obtained materials that were good enough to be reused again, just as if they were virgin plastics.”

Support for the future

The current and future value of smaller lab-scale extruders for recycling is very promising, as many applications are still at the beginning of the transition to a circular economy. As such, there are often only small quantities of input streams available and lab-scale instruments like the Process 11 or Process 16 Extruders might be the only viable options for developing the best recycling strategy. In the event of some novel or hard-to-process materials, Thermo Fisher Scientific can provide assistance. Madina was thrilled with the level of support IKK received. “We had some cases where the material was so specific that our extruders at the technical university were not suitable for processing it, as additional equipment modules were needed. And then we had a possibility to send it to Thermo Fisher, and it was perfectly processed. We got extensive support. We were informed what was done, how it was done, why it was done that way. The Thermo Fisher colleagues were so helpful… We are very, very happy with the cooperation.”

◀ Thermo Scientific™ Process™ 16 Twin-screw Extruder

◀ Thermo Scientific™ Process™ 11 Twin-screw Extruder

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