Successful Pilot Test

Physically Recycled Post-Consumer Recyclate from End-of-Life Vehicles

The German automotive industry is currently developing solutions to meet the challenging requirements of the European End-of-Life Vehicles Directive, which is currently being revised to be replaced by a regulation. According to the current draft regulation , 25 percent of the plastic weight in a new vehicle should consist of post-consumer recycled plastic (PCR) – a quarter of which should come from end-of-life vehicles. Together with the Fraunhofer Institute for Process Engineering and Packaging IVV, Audi has used a physical recycling cascade to recover high-purity PC/ABS from shredded end-of-life vehicles on a pilot scale, which is also suitable for reuse in vehicle interiors.

Audi has set itself the goal of continuously increasing the proportion of secondary materials in the Audi fleet. For example, several components in the Audi Q6 e-tron are made from recycled materials. (Note: This does not apply to the PC/ABS described in the article).

Sorting plastics from end-of-life vehicles – whether by dismantling components or shredding the entire vehicle – is a challenge. Due to the high proportion of composites and the carbon black used in the components, sorting using near-infrared technology is not feasible. The high proportion of engineering thermoplastics, in particular ABS, PC/ABS, PA6 and PA66, as well as filled and fiber-reinforced PP, occurs in density fractions >1.0 g/cm^3 and is therefore not yet sorted and recycled on a relevant scale in the industrial processing chain.

However, these plastics are considered standard materials in many applications in the automotive industry. It is therefore important to close this gap in the material cycle. Audi and the Fraunhofer Institute for Process Engineering and Packaging IVV, among others, are cooperating on this together with partners from industry [1]. Their approach is to sort the above-mentioned technical thermoplastics from shredder residue fractions and then to separate and clean them with a high degree of purity using a solvent-based recycling process. The declared goal is to obtain pure recyclates that can be used in new automotive components with targeted property optimization through compounding. This article describes the pilot test for recycling PC/ABS blends (**Fig. 1**).

Mechanical and Chemical Processes Unsuitable

Plastic-rich fractions from shredded Audi vehicles were post-cleaned and spectroscopically sorted by Indra to remove foreign materials such as glass, metals, wood and non-target plastics using modern post-shredder technologies. A combination of density-based, X-ray spectroscopic, laser spectroscopic and triboelectrostatic techniques has proven to be a viable method for both recovering valuable metals and producing recyclable plastic fractions.

The resulting target fractions are divided into:

- a polyolefin fraction (including filled and fiber-reinforced PP grades),
- PC/ABS, ABS, PC, ASA fraction,
- polyamide fraction with the main types PA6 and PA66.

Although the fractions contain target plastic contents of up to 80 to 90 %, they are not suitable for thermo-mechanical recycling. This would require an effective downstream process. The fractions are also unsuitable or uneconomical for use in chemical recycling

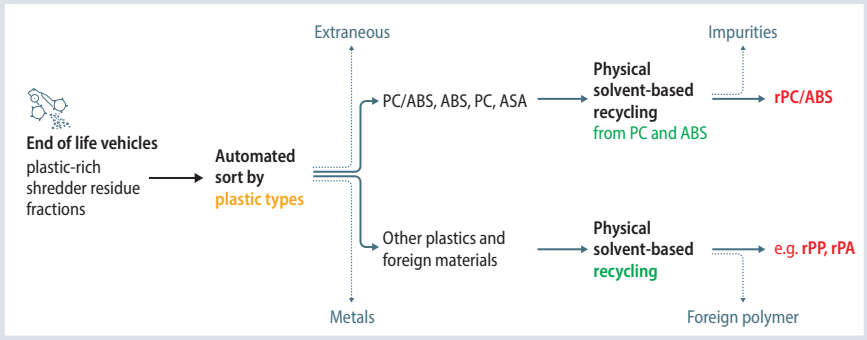

Fig. 1. Process chain for the production of thermoplastic recyclates (PC/ABS, PA6, PA66 and PP) from shredder residues. © Audi AG

processes due to high nitrogen loads (PA), potential presence of halogenated flame retardants (PC/ABS, etc.) and/or a high filler content (PA, PP) [2]. A more suitable process for further treatment of pre-concentrated plastic fractions is solvent-based recycling.

20 Years of Experience

The Fraunhofer IVV has been developing and optimizing the physical dissolution process for cleaning and recovering pure thermoplastics from sorted plastic waste streams and complex pre-consumer composites for more than two decades [3]. The process uses special CreaSolv solvent formulations developed jointly by Fraunhofer IVV and CreaCycle GmbH. These allow the selective separation of the target plastics from heterogeneous input streams. In further steps, the polymer solution is freed from inert and soluble impurities, as this is the only way to ensure that it can be used in high-quality applications due to the various cross-contaminations caused by operating materials such as oils in automotive shredder residues.

Finally, the solvent is separated from the purified polymer and reused in the process. The recyclate is then available as commercially available polymer pellets and can be used directly or after a compounding step as recycled material for the production of new plastic components (**Fig. 2**).

High Purity Confirmed

When the solvent process was applied to pre-concentrated plastic fractions from PCR automotive shredder residues, the remaining 10 to 20 % of foreign plastics were successfully separated. This means that additional glass fibers and fillers were removed, as well as odors and contaminants such as residues of operating materials (oils, fuels, etc.). To this end, the process parameters were first adapted on a laboratory scale to the special challenges of PCR automotive shredder fractions. Using the small-scale process line at Fraunhofer IVV, PC/ABS was then selectively extracted from the pre-sorted fractions, purified and recovered as granules. Product analysis confirms high purity, uncritical element contents and good mechanical-rheological properties of the recycled pellets produced. During development, special attention was paid to the setting of application-oriented mechanical properties and the avoidance of odor and VOC (Volatile Organic Compounds) emissions in order to meet the high requirements of the automotive industry for interior components (e.g. door panels, decorative trim).

The process chain described for PC/ABS from post-consumer automotive shredder residues has already been demonstrated on a small scale. To improve the impact strength, the physically obtained PC/ABS regranulate was treated with specific additives and compounded by our partner Hoffmann+Voss with a further 50 % of »

pre-consumer regrind to produce a PC/ABS recompound.

Interior Applications Possible

In addition to recovering the plastic, the project also evaluated the potential for reuse in the vehicle using a specific component. For this purpose, decorative frames from the bumper area were selected and the components were extensively characterized (**Fig. 3**).

The compound was processed in a series mold of the decorative frame in the injection molding production of Eckerle. A batch of parts was produced as part of the test sampling, with no differences compared to series production. Dimensional accuracy requirements were met.

The ornamental frames were passed on for subsequent painting with two paint variants (high-gloss black and matt silver). The visual appearance of both variants was flawless. The requirements for paint adhesion after climate change testing and condensation storage were met.

In order to assess the application potential for interior components, Audi conducted extensive emission and odor tests. The results showed that the PCR-containing PC/ABS recyclate meets the requirements for emissions and odor behavior in accordance with the applicable VW group standards and is therefore also suitable for interior applications.

The Story Continues

Together with HKS Metals and TSR Recycling GmbH & Co. KG, the project partners are currently investigating how the developed process chain can be applied to mixed, real-life shredder residue fractions containing the plastic waste of all car manufacturers. To this end, the solvent-based recycling process must first be scaled up and commercialized. As soon as advanced plastics sorting and the capacity of physical recycling plants are available on an industrial scale, high-quality PCR automotive recyclates such as PC/ABS can be recovered from end-of-life vehicles and help to increase the use of recyclates.

Audi supports such projects and the goal of recovering plastics from end-of-life vehicles and advocates the establishment of an industrial mechanical processing and sorting chain. The common goal of Fraunhofer IVV and Audi is to demonstrate these cycles for polyolefins, PC/ABS, PA6 and PA66. The project shows that this challenging task requires close cooperation between the partners along the value chains and can only succeed together. ■

Fig. 2. Foreground: shredded feedstock, back left: polymer in solution, back right: compounded pellets of post consumer recyclate (PCR). © Audi AG

Fig. 3. Demonstrator components (decorative frame from the bumper area, approx. 370 x 180 mm) made from physically recycled PC/ABS recyclate (PCR). © Audi AG

Info

Text

Jutta Schoberer, plastics engineer at Audi since 2009, develops solutions for recycling plastics from end-of-life vehicles as part of technology validation.
Frank Fischer, materials engineer at Audi since 2010, coordinates all issues relating to the use of recycled materials in the exterior in the Materials Technology department.
Dr. Martin Schlummer, business development for Recycling and Environment at the Fraunhofer Institute for Process Engineering and Packaging IVV, has been working on the development of solvent-based recycling processes since 1999.
Laura Strobl, research associate at Fraunhofer IVV, has been working on the development of solvent-based recycling processes for polymers from complex and contaminated recycled plastic waste since 2019.
Dagmar Arends, technical assistant at Fraunhofer IVV, has been working on the development of mechanical and solvent-based process cascades for the recycling of plastics from end-of-life vehicles and electrical appliances since 2007.

Glossary

ABS = Acrylonitrile Butadiene Styrene Copolymer
ASA = Acrylonitrile-Styrene-Acrylate Copolymer
PA = Polyamide
PC = Polycarbonate
PP = Polypropylene

References

You can find the list of references at ***www.plasticsinsights.com/archive***