EPOXY
Tomorrow's technology, today

RECYCLING OF EPOXY

CHALLENGES AND OPTIONS

The aim of recycling is to reduce plastic waste, but also to minimise the carbon footprint of plastics overall. When discussing recycling options, technical feasibility has to be considered, as well as total energy consumption of the waste processing and economic viability. The very properties that make epoxies a desirable material in high-performance applications also limit their options for recycling. Due to the often complex nature of the articles containing epoxies, sole focus on certain recycling technologies cannot be a viable solution. Very often the bulk of the article consists of non-organic materials that might not be compatible with chemical recycling and will have higher priority for recycling.

Aware of the challenges posed by the recycling of epoxy resins, ERC members are continuously striving to explore novel recycling options to contribute to the EU's circular economy objectives.

TYPES OF RECYCLING

There are four primary types of recycling processes for organic polymers.

USE AS FILLER OR SIMILAR

Polymers can be ground and used as filler in road building or other articles.

THERMAL RECYCLING OR COMBINED ENERGY RECOVERY WITH RAW MATERIAL RECYCLING

If the polymer content of an article is very small, this is the most reasonable approach. Also, in cases of composite materials, where components could only be separated via high energy consumption processes, combined raw material use (glass fiber from composites) and energy generation from incineration of the polymer matrix material could be economically the most effective solution.

CHEMICAL RECYCLING (ALSO CALLED FEEDSTOCK RECYCLING), A BREAKING DOWN OF THE POLYMER CHAINS INTO SMALLER UNITS

Polymers get broken down into smaller units, i.e. its monomers or even smaller molecules that can be used to chemically re-build new polymers.

MECHANICAL RECYCLING, A RE-FORMING OF PLASTIC MATERIAL INTO A NEW SHAPE

While this is a highly desirable type of recycling for thermoplastics, it is limited by several factors like the purity of the collected material or its potential to be re-shaped.

GROUPS OF EPOXIES

In terms of recycling possibilities, articles containing epoxies can be placed in two different groups.

1

Articles containing minor amounts of epoxy resins (e.g. less than 5%).

Typical examples are powder coatings used as protective varnish for washing machines or adhesives bonding metal parts securely together in automotive manufacturing.

The energy needed to separate matrix and coating or adhesive is disproportionately larger compared to the material and energy saved.

Due to the strong adhesion to most surfaces, separating the epoxy component from the whole article is not feasible for recycling purposes. Therefore, the main focus is on the recycling of the major components, often metal. For those, the epoxy will be burned during the re-melting process and the combustion heat will make a positive energy contribution.

This so called energy recycling significantly improves the overall footprint of the article and the epoxy resin.

2

Articles containing noticeable amounts of epoxy resins as component.

Prominent examples of products containing noticeable amounts of epoxy are windmill rotor blades, car bodies or insulators for high-voltage applications. If these articles, after decades of operation, have to be dismantled, there are several possibilities to recycle them.

Mechanical recycling is, due to the thermoset properties of epoxy resins, not possible.

Chemical recycling is a possibility, but a rather new technology when it comes to highly complex articles.

The current technology to recycle glass- or carbon fibers (see Annex) focuses on using the epoxy component as energy source, while recovering the fiber (see Annex for details).

In some cases, articles are re-purposed, for instance old windmill blades are used as benches or the articles are ground to small particles and used as filler. This kind of re-purposing is generally not considered recycling.

EPOXY PROPERTIES AND RECYCLING – CURRENT CONCLUSIONS

The very properties that make epoxies a valuable, highly durable material, also significantly impacts the options for recycling.

- Epoxies are frequently used in small amounts. Even in these small amounts they provide significant enhancement of other material's properties. Example would be adhesives or coatings. A small string bead of adhesive can hold together large metal parts, and a thin layer of base coating prevents a container ships hull from corrosion. Recovering and recycling this small amount of adhesive or layer of coating is currently technologically not feasible and economically not viable.
- As thermosets, Epoxies, unlike thermoplastics, metal or glass cannot be re-melted and re-shaped. This very fact rules out any kind of extrusion processing into new articles as commonly performed with thermoplastics.
- Epoxies have excellent chemical and mechanical resistance. They are often used for applications where other materials fail. These properties make them the material of choice for long lived, heavy duty applications. On the other hand, this makes it very hard to chemically convert them back into their smaller building blocks or mechanically break them down.
- Epoxies are a material that can be fine-tuned to individual applications and specific needs. The possibility to cure epoxy resins with a vast range of other chemicals (hardeners) provides the possibility to find customized solutions for the specific requirements of each application. However, chemical recycling to starting materials would lead to a very diverse composition of the resulting recycling feedstock.

ANNEX

When it comes to epoxy-based composite materials, currently, the first step of the recycling process is mechanical reduction in size by crushing, milling, sawing, and so forth. The reduced pieces are then fed into an energetic recycling process where the resin and the fiber reinforcements serve as feedstock in the manufacturing of cement clinker in cement kilns. This is an established recycling process for composites in many European countries, such as Germany. First studies indicate a positive LCA effect for this technology. In a pilot project and calculation partially replacing coal and raw materials by glass-reinforced composites let to a significant emission reduction using glass reinforced composite: 0.9 kg CO2-eq/kg composite. For more information please also see https://etipwind.eu/publications/

CARBON FIBER RECYCLING

Carbon Fiber Reinforced Composites (CFRC) present a very valuable target for recycling, since the reclaimed fibers present technical and economic value due to the high price of virgin carbon fiber and their outstanding strength properties.

The most common practice to separate carbon fiber from the resin matrix is via pyrolysis treatment. For higher performing resin matrices like for example epoxy resins, pyrolysis temperatures of 500 – 550°C are required. As a result of the thermal exposure, the resin matrix is degraded, resulting in oil, gases and solid products like fibers and fillers. A small amount of oxygen is usually added to minimise char formation. Consequently, the resin is broken down into lower-weight molecules and produces mainly gases and an oil fraction which technically could be recovered as chemicals, but in practice are typically burnt, in some cases with energy recovery. It has to be taken into account that the resulting carbon fiber is usually of lower quality, i.e. having lower fiber length, compared to virgin material.

GLASS FIBER RECYCLING

Pyrolysis treatment for glass fibers has gained little economic traction due to the low economic value of reclaimed glass fibers. This is further compounded by the fact that the pyrolysis treatment also destroys the sizing of the glass fibers, which is a prerequisite for the high performing interaction with the resin matrix. In order to re-establish this necessary interaction, a post-treatment of the recycled fibers with new sizing agent is required, which renders the recycling process even less economically viable.

For that very reason, energetic recycling with valorisation of the intrinsic energy content of the resin matrix or landfilling will today still be the most common disposal option for glass fiber reinforced epoxies.