Mechanical recycling of polimer-based composites

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Abstract

This thesis aims to recycle the polymeric matrix composite materials deriving from process waste or end-of-life components in a simple and economical way. The need to recycle composite materials arises from the increasing use of this class of materials and the imposition of European regulations. In the automotive sector, for example, there is an obligation for manufacturers to reuse or recover at least 95% by weight of the vehicle. Among the various methods of recycling composite materials, it has been decided to use the mechanical method which, in addition to being economical and simple, requires less energy compared to thermal methods.

In particular, two different types of products have been recycled: the first is an end-of-life car component usually landfilled made of polyamide 6,6 reinforced with 35% of glass fibers, the latter is a processing scrap of the thermoforming process consisting of a polyamide 6 matrix laminate reinforced with a twill-weave type of continuous glass fibers at 66% by weight.

In this case, the mechanical recycling method involved an initial size reduction of the components by a band saw and a subsequent grinding by a granulator. In the case of recycling of processing scraps, a prior mixing step with virgin polyamide was required to reduce the weight percentage of glass fibers to 30% and 15%. The pellets obtained from the granulator were dried at a temperature of 80°C for 16h and then moulded by injection or compression technologies. For the component at the end of its life, the grinding and moulding steps were repeated two more times.

As regards the end-of-life component it was compared with a composite of the same type in polyamide 6,6 reinforced with the same percentage of fibers but different length (344 μm). The mechanical recycling determines a decrease in fiber length from the 253 μm of the end of life component to the 175, 152 e 124 μm of the recycled product once, two and three times respectively. While recycling has no effect on the orientation of the fibers, which for all three recycling stages remain strongly oriented in the injection direction. The decrease in fiber length affects both the rheological and mechanical properties. The degradation of the composite due to its operational use causes the first drop in viscosity with respect to the reference material, while the difference in viscosity between recycled product and further remoulded ones

is correlated to the loss of the rheological percolative network. The end-of-life component recycled mechanically has worse mechanical properties than the non-aged reference material. The decrease in mechanical properties due to matrix degradation and fiber length reduction becomes less evident in further recycling treatments as it is increasingly difficult to break short fibers. The recycled material always has higher mechanical properties than the same non-reinforced matrix.

Regarding the processing scraps, the recycled material can be injection moulded with a 15% fiber content and compression moulded with both 15% and 30% fiber content. Compression moulding technologies determines an internal porosity of the product which influences the mechanical properties increasing the dispersion of the tensile strength data. The recycled polyamide 6 containing 30% of fibers after compression moulding has a higher elastic modulus and tensile strength comparable to a virgin material not reinforced and processed with the same technology. The recycled polyamide 6 reinforced with 15% of glass fibers presents a higher Young modulus but lower tensile strength compared to a virgin non reinforced compression moulded polyamide. Instead, the injection moulded recycled material with 15% of fibers has both modulus and tensile strength higher than the same non reinforced injection moulded matrix.

The results obtained suggest the use of these recycled materials instead of the products currently made of unreinforced polyamide or reinforced polyamide with percentages up to 15% in glass fiber. In the automotive sector the applications regard components such as carbon canisters, connectors, fasteners, headlight bezels and turbo air ducts.

In conclusion, it can be claimed that mechanical recycling can be a solution to the problem of the accumulation of composite materials in landfills since the products obtained after recycling shows characteristics useful for different applications. In order to upscale the process to an industrial scale, it is necessary the availability of these composite materials, appropriately collected and selected by type. To achieve this goal, under the pressure of European regulations, the creation of a recycling chain for composite materials is essential.