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Editorial corner – a personal view

Material circularity in rubber products

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The total rubber production worldwide in 2019 amounted to over 28.8 million tons, of which 13.6 million tons of natural rubber and 15.2 million tons of synthetic rubber (www.statista.com). Rubber products are used for various industrial applications, the most important in terms of volumes being tyres (accounting for about 70% of the total production), followed by other non-tyre automotive applications (such as seals, hoses, belts, anti-vibration mounts for about 13%) industrial applications (8%), footwear (7%) and other applications (2%). In most cases, for a good balance of mechanical strength and wear resistance, rubber products require a vulcanization process with sulfur (most common), peroxide or metal oxides, which ultimately leads to crosslinked polymers. This makes effective recycling and reuse of the scraps generated during the production of parts and rubber products at the end-of-life (EOL) a quite challenging issue (https://doi.org/10.1515/9783110644142). The main current EOL options for tyres are represented by i) stockpiling, ii) landfilling, iii) civil engineering applications (*i.e.* retention walls), iv) energy recovery (incineration), v) retreading, and vi) recycling or reuse.

Despite the fact that in Europe and the USA the recovery rate of scrap tyres is around 90%, around 4 billion EOL tyres are still disposed in landfills and stockpiles worldwide and this amount will increase up to 5 billion by 2030 (https://doi.org/10.1016/j.aiepr.2022.08.006). In addition to the associated loss of valuable resources, stockpiles of waste tyres may also cause environmental problems due to the potential fire hazard and the proliferation of insects caused by water stagnation. Rubber recycling consists of the recovery of materials, converting rubber waste into an economically useful form that is achieved through a shredding process. For tyres, the removal of steel, fibres, and other non-rubber components is also required. Crumb rubber can be used for the production of rubber-modified-asphalt, playground surfaces, artificial turfs, insulating panels, and in small quantities (less than 20 wt%) mixed with virgin rubber for manufacturing of new products.

Reuse is the preferable EOL option since the material is returned to its original application, thus creating a virtual circularity in the materials used. Nevertheless, the reuse of rubber is an obstacle due to the crosslinked nature of rubber products.

Therefore, intense research efforts have been conducted in the last 50 years to find efficient devulcanization methods (https://doi.org/10.1016/j.resconrec.2018.02.016). In an ideal situation, the breakage of the sulfur-carbon or the sulfur-sulfur bonds is induced to obtain a polymer that can be handled and vulcanized similarly to virgin rubber. The principal devulcanization strategies include chemical, ultrasonic, microwave, biological and thermo-mechanical methods (https://doi.org/10.3390/ma13051246). A successful devulcanization allows the use of higher amounts of recovered rubber mixed with virgin rubber (https://doi.org/10.1002/pen.25615) or in brittle thermoplastic matrices to improve their fracture toughness (https://doi.org/10.1007/s10924-020-01717-8). Remarkable progress in the next ten years is expected in both chemical and thermo-mechanical devulcanization methods.

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