

Application of Recycled Plastics in Automotive Industry: a short review

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Abstract – The paper describes application of recycled plastic materials in the automotive industry. It deals with various types of recycled plastics used in vehicle interiors / exteriors. Introduction of plastics into cars brings about reduction in weight of the vehicle, resulting in reduced fuel consumption and increased performance. Since the quantity of generated plastic waste is extreme, the issue of recycling is highly topical.

Keywords – PET bottles, plastic waste, automotive industry, recycled plastic, composite material.

1. Introduction

Official sources indicate that 26 million tons of plastics are produced annually in the EU (an increase in their applications or use in various sectors is plotted on the graphs below: Figure 1, Figure 2, Figure 3), but only about 30-40% of them are recyclable. The remaining share of waste is exported to third world countries, to landfills, incinerators or illegal landfills (plastics can be used through incineration – for energy generation). Plastic waste contains dyes / stabilizers / plasticizers that cause air pollution. Thus, from the ecological point of view, repeated recycling is a priority [1].

European Green Deal is the European Commission's plan for green transformation of the EU economy for sustainable future. It is a concept for achieving a neutral circular economy and climate neutrality (zero emission balance). The Commission calls for all plastic packaging to be either profitably re-used or recycled by 2030 (ban on single-use plastics, returnability of PET bottles, etc.).

Is plastic recycling a problem? A major problem in the area of “upcycling” is:

- the price and quality of recycled plastics compared to virgin plastics;
- the quantity of types of plastics materials, which is associated with costly recycling process and questionable value of the recycled material.

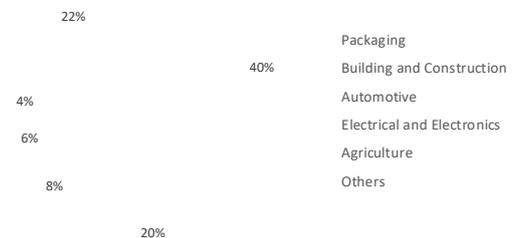


Figure 1. Use of plastics in individual sectors (others – household and consumer products, furniture and medical products) [2]

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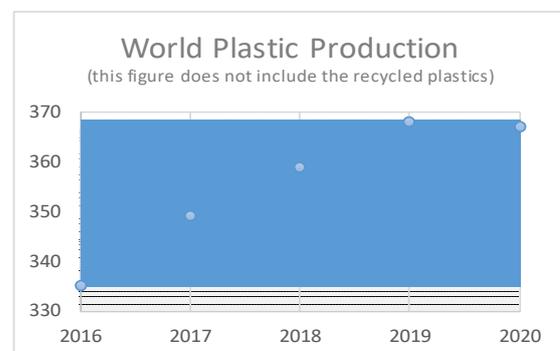


Figure 2. World plastic production [2]

Note: (includes: Thermoplastics, Polyurethanes, Thermosets, Elastomers, Adhesives, Coatings and Sealant and PP-fibers, not included: PET, PA and Polyactyl-fibers)



Figure 3. European plastic production [2]

Note: (includes: Thermoplastics, Polyurethanes, Thermosets, Elastomers, Adhesives, Coatings and Sealant and PP-fibers, not included: PET, PA and Polyactyl-fibers)

2. Application of Recycled Plastics in Automotive Industry

Application of recycled plastics in the automotive industry is a complex problem (it is analytically processed in the study by Maudet, C. et al., 2006: “A method for recycled plastic integration in the automotive industry”), consisting of a number of risk factors – ranging from questions related to quality of recycled materials (in terms of the required properties), the price and volume of the recycled materials produced (approximately 25 % of the plastic materials used in the automotive industry are recycled plastics). Recently, however, companies have applied recycled plastic material to parts in interiors / exteriors (see factsheet below, compiled from available sources) [2], [3].

Škoda:

Application of PET bottles – used in production of rug fibers, floors and luggage compartment (example: Škoda Scala contains 14 kg of parts made from recycle). An example of the use of recycled plastics is given in the diagram below – Figure 4 [4].

The Czech car manufacturer (Mladá Boleslav / Czech Republic, 2022) combines wool reinforcement with recycled polyester (PET bottles) for the seat covers (for interior of the all-electric ŠKODA ENYAQiV).

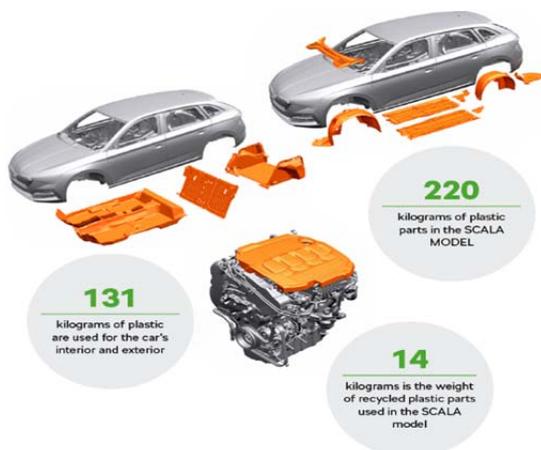


Figure 4. Component from recycled plastic material in ŠKODA SCALA (orange parts are from recycled plastics) [4]

Jaguar / Hyundai:

In cooperation with the German agrochemical company (Badische Anilin & Soda Fabric, in short BASF) and as part of the ChemCycling program, the company developed a super-strong plastic applied in the Jaguar I-Pace electric vehicle (in pilot cars). It is a material made of waste plastic transformed into pyrolysis oil in a thermochemical process. The material can be tempered and colored, making it an ideal sustainable solution for designing the next-generation dashboards and exterior-surfaces in Jaguar and Land Rover (Figure 6). Jaguar also uses recycled PET bottles to make seats to achieve Destination Zero vision (minimal impact on the environment).

Last year, the mentioned car makers (Jaguar + Hyundai) also included the so-called Econyl® (yarn manufacturer: Aquafil) into its applied materials portfolio. It is a fabric made of nylon waste from the oceans; the resulting fabric has properties similar to the original nylon (see an example of use in Figure 5). Hyundai has been cooperating with the Healthy Seas Marine Conservation Organization for a long time now [5], [6], [7], [8].



Figure 5. Floor mats velour IONIQ5 (ECONYL®) (HUYNDAI) [9]

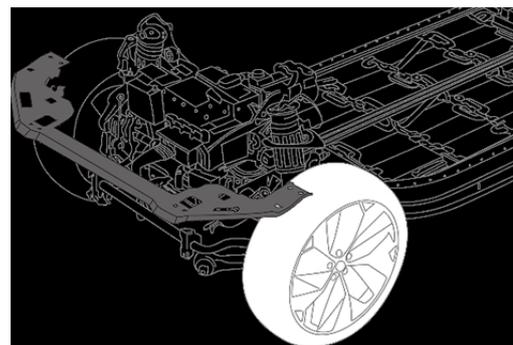


Figure 6. Component from recycled plastic material in a Jaguar I-Pace front-end carrier [7]

Volvo:

Replacement of plastic components with parts containing recycled plastics (automobile: SUV plug-in hybrid XC60 T8). The interior of the SUV XC60 T8 has an applied tunnel bracket made of recycled fibers and plastics – coming from ship ropes and

fishing nets. Volvo cars made a commitment that all new Volvos from 2025 and beyond will have 25 % plastics made from recycled materials (in cooperation with Axion Polymers), which can be seen in Figure 7 [10].

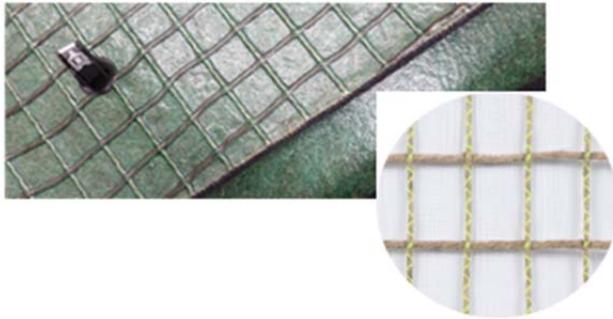


Figure 7. Unique material powerRibs™ (composite material with natural reinforcement and matrix from recycled plastics) [11], [12]

Toyota Motor Corporation:

The corporation has developed a special recyclable plastic called TSOP (Toyota Super Olefin Polymer, launched in 1995 in several versions: TSO P2 / TSO P3 / TSO P5 / TSO P6 with different properties/ compounds and applications), presented in Figure 8. These are “non-conventional high-performance PP”, along with three other resins compounds (rubber + talc). Performance of the new material is equivalent to that of TSOP but at about 30 % lower cost, lower specific gravity, injection moldability, economics, recyclability, and noise performance (according to a group of Toyota researchers) [13], [14], [15].

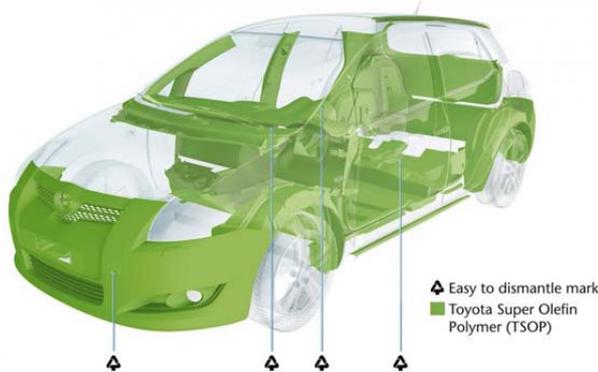


Figure 8. Toyota AURIS 2008, green parts – material TSOP [16]

Ford:

Recycled plastics are used to create upholstery for passenger seat cushions in numerous models (for example, the seat fabric for each Focus is made with approximately 22 plastic water bottles). The company recycled and reused more than 23,000 tons of recycled plastics in exterior parts of the Ford vehicles manufactured in North America. Examples

of recyclates applied to the Ford Escape – see Table 1. Ford also made 300 car parts from renewable and sustainable materials (for example: soy, wheat, rice, agave, jute, coconut, etc.) [1], [17].

Table 1. Components made from environmentally friendly material sprout up all across the all new Ford Escape

Carpet	made form 25 recycled plastic bottles
Seats and head restraints	contain 5 % soy foam
Dash insulation	contains scrap cotton from jeans, sweaters and others items
Climate control gasket	contains 100 % recycled tires
Wheel arch liners	contains 100 % recycled plastics

Source:

<https://media.ford.com/content/fordmedia/fna/us/en/features/recycled-plastic-bottles-find-new-use-in-carpeting-of-ford-escape.html>

Continental (tire manufacturer):

Currently, Continental is introducing recycled polyester from plastic bottles (the PET bottles) into its tires production (Figure 9). The fibres are obtained from waste bottles by a mechanical process followed by application to the structure of the tire (a passenger car tire consists of about 40 grams of polyester fibers, 60 PET bottles are recycled to be used in the complete set of tires) [18].



Figure 9. Continental tire made from recycled materials and renewable raw materials (Conti GreenConcept) [19]

There is an ongoing research on selected plastics recycling, preparation of compounds with fibers / reinforcements, testing of mechanical properties, and etc. For modification of the PET recyclate properties, suitable particles – for example glass fibers (GF) or basalt fibers – can be added to the resulting compound. Glass fibers are usually adopted as reinforcement due to their:

- remarkable mechanical and physical properties;
- rather low price [20].

The study [21] describes the use of rPET in conjunction with glass fibers (production of canopy strip fitted at the middle window part of the vehicle). Three different types of samples (differing wt % of the components) are tested. Prior to the actual application of rPET into the resulting composite, the bottles were recycled in the classic procedure (process steps: sorting, crushing the bottles to convert

them into flakes, pre-washing, friction washing, hot washing, cold washing, friction washing, post washing, magnetic separation, spin drying and finish inspection of flakes). Samples: 30 % glass fiber + 70 % rPET was found to meet the required specification (after long-term testing). A similar issue of the application of recycled PET bottles into glass fiber reinforced composite material is also addressed by Volpe, V et al. in their study titled: “Characterization of Recycled/Virgin Polyethylene Terephthalate Composite Reinforced with Glass Fiber for Automotive Applications.” [22]. In 2011 Mondadori et al. [23] developed composites of recycled PET and different percentages of short glass fibers (it is demonstrating increases in mechanical performances with increasing glass fiber content). Percentage share of PET bottles in individual sectors can be seen in Figure 10.



Figure 10. Percentage share of PET bottles in individual sectors / industries (32.6 % new PET bottles, 29.4 % manufacturers of industrial films, 21.8 % manufacturers of textile fibers, 16.2 % other applications) [24]

The comprehensive study [25] includes a chapter on the recycling of polymers, rubbers (describing four methods of mechanical recycling of polymers) and their re-application in the production of composite materials with natural fibers – referred to as NFRC (Natural Fibers Reinforced Composites), Figure 11.



Figure 11. Biodegradable reinforcement fiber production for composite materials

In relation to a number of natural types of biodegradable reinforcement (such as: wood, kenaf, hemp, flax, areca, fruit, pineapple leaf, oil palm, sisal, jute, banana, abaca, etc.) a wide range of composite materials with exceptional properties have been created (e. g. application of recycled HDPE + sugarcane bagasse → buildings material / rHDPE + hemp fibers → materials for automotive, buildings, constructions / rHDPE or rPP + Pinus radiata sawdust, which is application in automotive, furniture and buildings industries) [25], [26], [27], [28].

The Pesante study, P. (2021) focuses on experimental evaluation (including predictions made through a software application) of the mechanical properties of wood filled plastics (WPC) made from recycled PET and Chilean radiata pines flour (samples produced have different weight fractions, sizes and aspect ratios of wood fillers) [29].

A number of expert studies, as well as car manufacturers themselves, demonstrate a desire to reuse various types of plastic recyclates (rPET, rHDPE, rPP, etc.) in production. Applying those materials supports the idea of neutral circular economy and the Zero Waste vision.

3. Conclusion

Plastics have been applied in cars since about 1950 to achieve reduction in the vehicle weight, consumption, and increase in power. In relation to the extreme quantity of plastic waste, car companies are also trying to incorporate recyclates in their production of parts. Current research on the recycling process itself, the production of new compounds (composite materials consisting of a recycled matrix + reinforcing fibers) and their testing / implementation in practice are ongoing in this area. In relation to the extreme amounts of plastic waste produced, the issue of re-use of recycled material is highly topical. The European Union aims to achieve a neutral circular economy and climate neutrality.

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