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EVALUATION OF CAR WASTE IN THE MANUFACTURE OF SOUND AND THERMAL INSULATION PRODUCTS

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Abstract: Various interior non–metal materials contained in the automobiles, mainly such as textiles, synthetic textiles, leather, synthetic leather and foam–based materials, are suitable for the production of sound and thermal insulation products. The presented contribution deals with the proposal of reusing and recycling of these components for the utilization of these non–metal materials for the production of new products, which, due to their sound and thermal insulation properties, will be widely applicable in various fields of industry as civil engineering, transport.
Keywords: waste, material, recycling technology, sound and thermal properties

1. INTRODUCTION

Old cars after end–of–life are usually processed in authorized recycling facilities. The processing of old cars in these facilities must be managed under the strict legislative regulations, but above all, the requirements and the efforts are aimed to save up and to better use of raw materials, from which is build the cars. In the past, when an old car was processed, there was particular interest in recycling of metal materials, as they were the most valuable ones.

Over the time, interest was increasing also in other car parts, especially plastics and textile. At present, up to 95 % of the vehicle weight must be processed in accordance with current legislation EU 2020/53/EC [1]. For this reason, other non–metal materials and components from the car have started to be recycled. These components include textiles, leather, upholstery, airbags, car windows and tires. Recently, attention has been focused on the recycling and subsequent use of these components and materials.

The efforts to evaluate these materials have led to the development of new recycling technologies. The processing of technological waste, but also the use of these materials is today one of the ways to recycle new types of materials. The recycling technology of a material is directly dependent on the composition and subsequent use of these materials. Within these technologies, mechanical recycling technologies are applied on a large scale, mainly tearing, shearing, cutting with next treatment of these materials so that they can be used in various applications as much as possible. Due to the nature and properties of these materials, there is great potential to use these materials in the production of sounds and thermal insulation products.

Close to 5.3 million passenger cars and light goods, vehicles were scrapped in the EU in 2017. In 2017, scrapped passenger cars and light goods vehicles in the EU weighed a total of 5.7 million tonnes; 94 % of parts and materials were reused and recovered, while 88 % of parts and materials were reused and recycled Figure 1 [6].

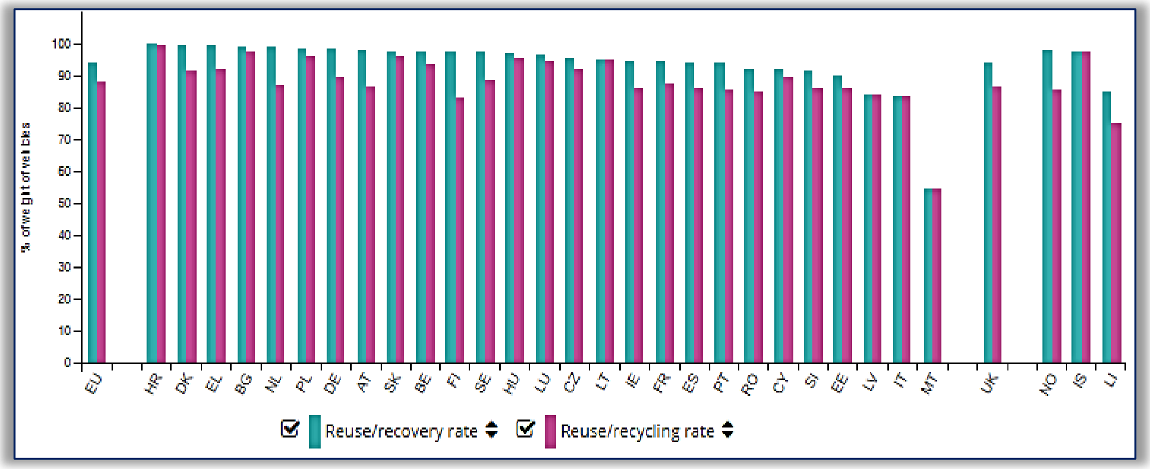

Figure 1. Reuse/recovery rate and reuse/recycling rate for end–of–life vehicles (ELV), 2017 [6]

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2. WASTE TYPE AND RECYCLING

Increasing production of automobiles is the key driver for the growth of this market. Since the production of automobiles involves the generation of waste materials, many manufacturers are now recycling these waste materials as it helps to resolve supply shortage during the manufacturing process. Automotive waste management involves the reuse and recycling of waste materials like metal, solvents, batteries, plastic, textiles, glass etc. Recycling of automotive wastes involves processes that convert the discarded wastes into useful materials and can carry out either at the manufacturing site or at processing facilities. Segmentation by waste type and analysis consist of:

— recyclable,
— non–recyclable waste.

The automotive industry is perhaps one of the leading, when it comes to trying new materials in high volume production. The automotive industry is the subject of much research, it is the largest manufacturing activity, there is a complex supply chain, is resource intensive and emits various hazardous gases and waste products [12].

A typical modern vehicle might contain up to 10 000 different parts made of about 1000 different types of materials that in turn are made from about 10 000 different chemical substances [12].

Automotive upholstery market uses various types of upholstery materials with combination original, recycled or mixed ones. Examples of used material are as:

— automotive textiles ,
— leather,
— plastics,
— smart fabrics,
— synthetic leather,
— thermo–plastic polymers [7].

Textiles

The automotive industry is one of the largest single markets for automotive textiles. The percentage of textile material used in a motor car is 2.2 % of the overall weight of the car [3].

Technical textiles are broadly used in transportation vehicles. Given the rise of the automotive industry and the fact that for the modern car today, uses about 20 to 26 kg of textiles fabric for interior and exterior purposes [4].

Quite a large number of different textiles are used in the production of a car. Some 5 to 8 kg (15 to 18 m^2) of textiles are used in a car interior. This adds up to about 240 million square metres of textiles used for car interiors in Europe and 91 million square metres of carpet and boot linings. The different textile usage for major components is:

— 6 – 8 m^2 – seating,
— 5 – 6 m^2 – floor,
— 2 m^2– headliner,
— 3 – 3.5 m^2 – boot/cargo,
— 0.6 – 0.8 m^2 – door panels,
— 0.4 – 0.5 m^2– pillar cover,
— 0.7 – 0.8 m^2 – parcel shelf [4].

The fabric types of used textile automotive materials according the upholstery market can be non–woven, woven, knitted, warp knitted, tufted and laminated fabrics, and nonwoven, electrostatic flocked surfaces. Fibres are chosen with regard to the demands for fastness, comfort and price. [5].

Figure 2. Non–woven fabric material from safety belts [11]

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Almost two third of the automobile textiles are for interior trim, i.e. seat cover, carpets and roof and door liners and the rest is utilized to reinforce tyres, hoses, safety belts, air bags, etc. An example of nonwoven fabric recycling is shown in Figure 2, where the input material is a nonwoven fabric, and the output is semi–finished product after processing and illustrates the feeding of safety belts for chopping and subsequent crushing [11].

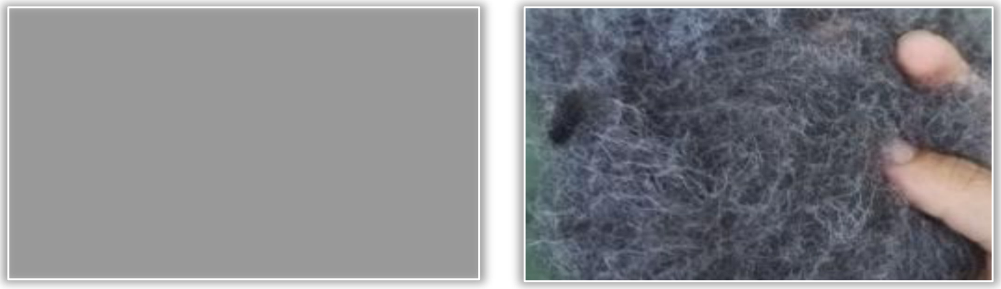

Figure 3. Input – chopped fabric (left) and output – fibrous fabric (right) [11]

Plastics

Plastics make up about 50% of a modern automobile's volume, but only 10% of its weight. Plastics and recycled plastics are playing an innovative and growing role in automotive manufacturing around the world. Engineers and designers looking for cost and weight savings are embracing technologically advanced plastics components for their unique properties and flexibility. By 2020, IHS estimates the average car will incorporate about 350 kilograms of plastic by weight compared to the 200 kilograms averaged in 2014 an increase of 75 %. More parts are being developed with plastics as technology has improved the tensile strength and other properties of plastics when compared to traditional metals like steel and aluminium. Plastic can be found everywhere in the interior of today's cars as well, proving to be the ideal material for creating comfortable, durable, and aesthetically pleasing interior components, while reducing noise, harshness and vibration levels in the interior of the car [9].

Recycled textile and pur–foam in automobile parts and components

Auto recyclers and automotive companies are turning their attention mainly to textile, PU foam and polymers:

- automotive companies are recycling their textile, plastics and mixed textile and plastic scraps, defective parts and other materials as part of their manufacturing processes as well as recycled post–consumer plastics and textile parts;
- recyclers and scrap companies are beginning to recycle ELV components.

There are currently about 39 different types of basic plastics and polymers used to make an automobile today; however, 66 % of the plastic used in autos comes from these three polymers: Polypropylene (32 %), Polyurethane (17 %t) and PolyVinyl–Chloride PVC (16 %). The wide variety of plastics used in automobiles presents a challenge for recyclers and recycling companies to make new products used in automotive and other applications [16].

The distribution of technical textiles used in transport vehicles are shown in the Figure 4.

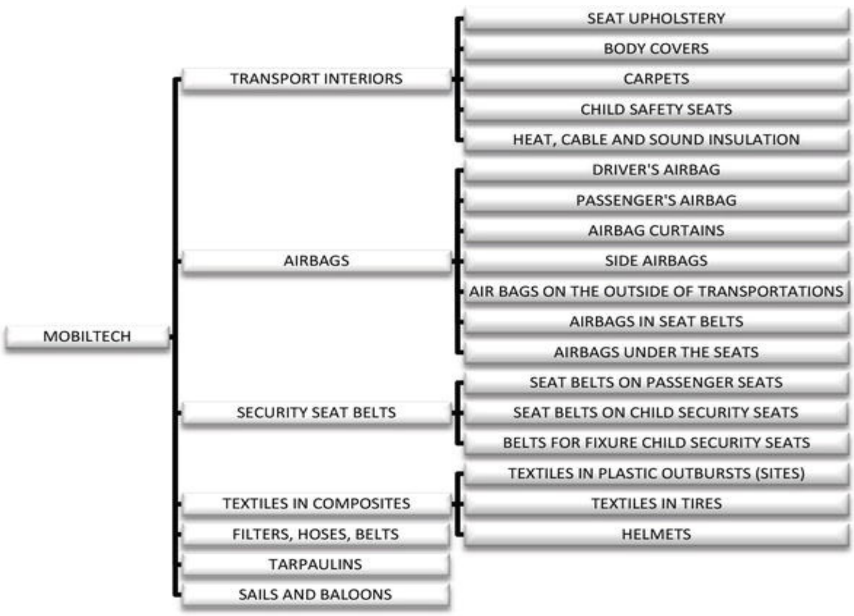

Figure 4. Distribution of technical textiles used in transport vehicles [10]

3. RECYCLED TECHNOLOGIES

Firstly, the people did not sorted and recycled the textile or polyurethane wastes, but put to landfill or burning them. Along with the

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environmental protection consciousness–unceasing enhancement, especially in a sustainable development society today, people more and more realize the reasonable use of resources, has been mentioned at a more important strategic height. Landfill and incineration will not be recommended, so recycling is the most effective treatment method in the future.

Automotive upholster waste are recycled only in the last period. In the Figure 5 is shown the most utilised operation and technologies for textile or foam waste automotive materials.

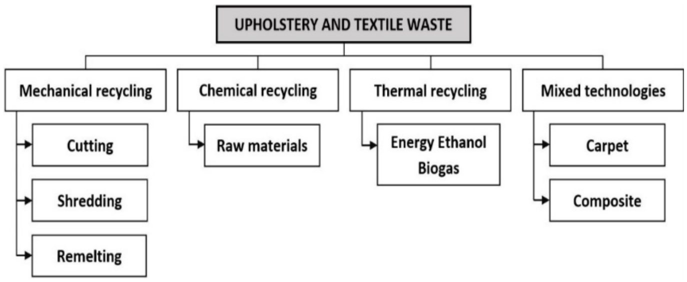

Figure 5. Types of upholstery and textile recycling [2]

Recycled materials after cleaning, sorting, cutting operations are processed by various other technologies according to the requirements and use of market. The production of sound and thermal insulation materials from waste automotive textiles and foams, production of sandwich materials are divided mainly on technologies such as:

- technological production of sandwiches by pressing,
- technological production of sandwiches by microwave heating,
- technological production of hot steam sandwiches,
- technological production of sandwiches by bonding,
- and by combination of the previous technologies.

The processed fabric or foam has approximately the same size, it is the important assumption for future manufacturing.

There are two ways, physical recycling and chemical recycling, for recycling textile and polyurethane foam wastes [19 – 23].Physical/mechanical recycling is directly reusing textile and polyurethane wastes without chemical treatment. Chemical recycling is following the degradation principle. Polyurethane wastes will gradually depolymerize for original reactant or other oligomer and even small molecule organic compound. Physical recycling method presents the crushing of polyurethane foam wastes, where are only changing the physical form of waste material. The smashing solid particles have no reactive activity, but directly make new polyurethane products as recovery processing of raw materials. Through mixed with adhesives, they can make all kinds of mold products by the compression moulding method. This is currently the most widely used method. The usage of waste polyurethane powder can be as high as 90%. Physical recycling method is simple and convenient, with low cost, but there are still certain technical limitations at various physical recycling method processing. Performance of recovery products is poor, which only apply to some of the cheap products, and limit the market. The most common physical recycling method are consisting of, Figure 6:

- grinding operations,
- cutting operations,
- shredding/ crushing operations,
- operations joined with bonding processes,
- operations joined with pressing processes,
- compression molding – extrusion and injection molding process.

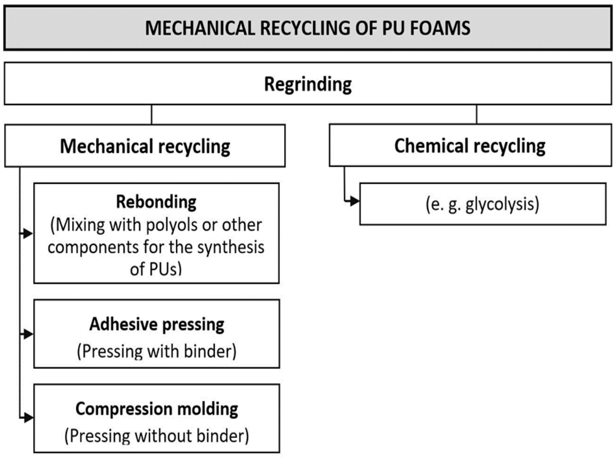

Figure 6. Mechanical recycling

The mechanical recycling methods of PU foam waste are effective recycling methods connected with shredding, milling, or powdering of waste, which resulted in obtaining materials suitable for further processing, e.g., compression molding, blending with others polymers, or mixing with adhesives or polyols.

The most important advantage of mechanical recycling is low cost and simplicity of the realisation. The example of the block scheme of PUR foam re–bonding is shown on Figure 7.

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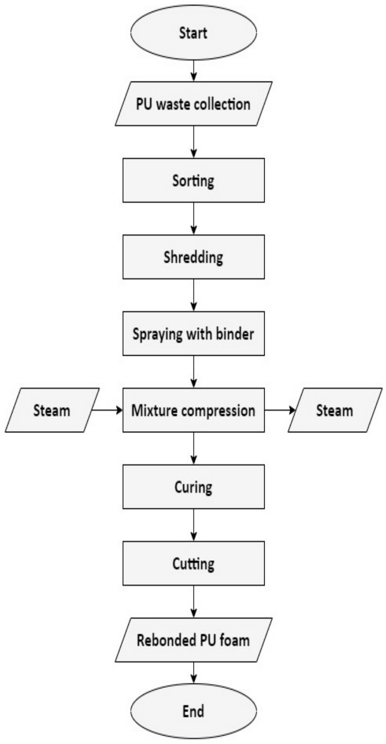

Figure 7. Bloch scheme of PU foam re–bonding

4. DEVELOPMENT OF NEW PRODUCTS FROM RECYCLED MATERIALS

Recycled materials from car wrecks are composed of different size fractions. In the processing of these materials, the following steps are used for compaction:

- various adhesives and binders (most often based on polyurethanes),
- hot steam,
- and a combination of glue and hot steam.

The use of hot steam in compacting and crosslinking has proven to be very technologically efficient. The hot steam perfectly overheats the entire filled form. Even and fast overheating of the mixture has a positive impact on shortening the technological cycle. Positive findings from this technology also have been experimentally verified.

The production technology of new recycled material (textile, molitan and upholster) in principle consists of a compaction process. This technology has three technology stages:

- mixing,
- steaming,
- curing (maturing).

The researchers of the Department of Process developed this technology and Environmental Engineering, Technical University of Kosice, in more research studies and projects (e.g. utility model No. 5982) [13].

The products produced on the basis of recycled car seats and car seat covers are commonly known as eco plastic foam [17], [18]. In the production of sandwich materials based on recycled car seats and car covers are these materials collectively referred as "Ekomolitan". The whole tested Ekomolitan process is made through the pressing of PUR recycled products, or from car seat covers chippings. The ground fraction ranges from 2.0 mm up to 10 mm. The pressing process is carried out at a temperature of 200°C (steaming by superheated steam) and a pressing force of 5,7 kPa. The holding time under pressure at a given temperature is 12 minutes. The Figure 12 shows the specimens of the PUR foam ground fraction. The Figure 13 shows the result after pressing, i.e. Ekomolitan foam.

Due to its density and hardness, it is suitable for the production of all types of upholstery, seats and various isolation components, etc.

Figure 12. Ground fraction of PUR foam

Figure 13. Material Ekomolitan after pressing

Nowadays, the research is oriented on the processing and recycling of automotive materials with cooperation of firm PR Krajne, s.r.o, where the experiments were done.

The experiments started with collection of used materials. Next step was processing of tested materials on the approximately same parts by cutting operations, Figure 8. After that the tested materials were teared and chopped on the small pieces and mixed together, Figure 9.

Figure 8. Textile material (storage), processing of recycled material

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Figure 9. Teared and chopped materials


Figure 10. Finish shape of compact new material from recycled input materials

Processed small parts were mixed with glue (polyurethane binder), heated with hot steam, insert into prepared forms, pressed and dried. The result were recycled plates, which were cut on the smaller tested pieces, Figure 10 and Figure 11 according to our requirements for next sound and thermal testing. The variability of the dimension can be changed in dependence of testing requirements, Figure 11 and all manufactured data are know–how of the producer.


Figure 11. Prepared tested samples for the experiments

This experimental material has very good sound and thermal insulation properties, e.g. which properties are comparable to the patented STERED material, see Table 1 [14], [15].

Table 1. Technical parameters of recycled material

Measured technical parameters	Unit	Value
Width	mm	50
Format	mm	1200 x 600
Area of plate	m^2	0,72
Weight of plate	kg	7,2
Bulk density of the material	Kg/m^3	200
Thermal conductivity λ	W/m.K	0,054
Sound absorption coefficient aw	–	0,90
Compressive stress at 10% compression	kPa	20,3
Tensile strength perpendicular to the plane of the board	kPa	32,2
Short–term water absorption by partial immersion Wlp, method A	Kg/m^2	11,8
Long–term water absorption by partial immersion Wlp, method A	Kg/m^2	13,4
Compressibility	mm	3,68
Water vapor permeability μ	–	2,9
Reaction to fire	–	E
Health safety	–	in accordance with the relevant provisions

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The measurement of the tested material by apparatus Testo 635 showed that the heat transfer coefficient U (W/m²K) shows a minimum value of 0.027 W/m²K and a maximum value of 12.815 W/m²K. The average value for this material is therefore 1.816 W/m²K. In Table 2 and Figure 12 show the outputs from the Testo 635 device for tested material , where: coefficient U – W/m²K, wall temperatures (Tw), interior temperature (Ti), relative humidity (rH), dew point temperature (td).

Table 2. Measured values of parameters during testing

	Min:	Max:	Mean:
C:1 W/m2K	0.027	12.815	1.816
C:2 [°C] Tw	23.69	24.52	24.05
C:3 [°C] Ti	23.67	23.84	23.81
C:4 %rH	33.50	36.40	34.35
C:5 °C	22.50	22.70	22.56
C:6 td °C	5.71	6.87	6.08
C:7 [°C] psyc	13.15	13.62	13.32

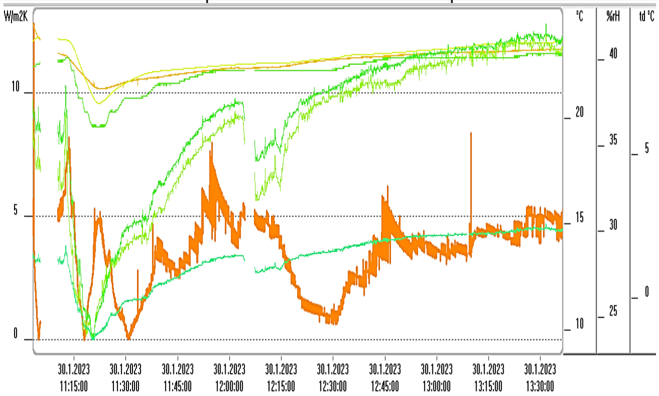

Figure 12. Measured values of thermal insulation of tested materials

5. CONCLUSION

For future research is necessary to verify the used binder and in parallel to experimentally verify the suitability of other types of binders, including their mutual comparison. Due to the fact that these methods are not sufficiently described in the literature, it could be an original solution usable not only in Slovakia, but also abroad.

New tested materials indicate variability of physical and mechanical properties in dependence of type, mass of used binder and material consistence (e.g. percentage of molitan and textile). With a positive result, production would become more efficient, which would be reflected in the price of products and thus the competitiveness of the market. It would be interesting to verify this technology both for single–layer materials and for sandwich types of sound–absorbing and heat–insulating elements.

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