

## RECYCLING OF TEXTILES FROM AUTOMOTIVE AND THEIR POSSIBILITIES OF REUSE IN PRACTICE

Lydia Sobotova\*, Miroslav Badida, Marek Moravec, Miroslava Badidová, Tibor Dzuro

Technical University of Kosice, Faculty of Mechanical Engineering, Letna 9, 042 00 Kosice, Slovakia

### Abstract

*The development of the automotive industry in the world as well as in the Slovak Republic is key to the overall development and prosperity of the company. In Slovakia, thanks to four (in the future up to five) final manufacturers, the automotive industry has worked its way up to the first rank within the individual branches of the industry. In the contribution, the authors focused on the classification of problematic waste from the point of view of their further recovery from cars after their useful life, namely on the recycling of textile materials. The experimental part is focused on the applications and prediction of the use of selected problematic wastes from the point of view of their recovery (in compact and bulk form), on the evaluation of the performed experiments with the use of regression and correlation analysis in sound insulation products and heat insulation products. In their work, the authors of the contribution focused on researching the possibility of using different textiles applied in the car in order to use recycled materials of these textiles for the development of sound and thermally insulating materials with a wide range of applications.*

**Keywords:** automotive, textile recycling, technology, reuse, material properties

### 1. INTRODUCTION

End-of-life vehicles represent a whole range of components (waste) of various material composition which should be further recovered. Furthermore, from 1 January 2015, Directive 2000/53/EC on end-of-life vehicles and from 13 July 2023 Proposal for a Regulation of the European Parliament and of the Council on circularity requirements for vehicle design and on management of end-of-life vehicles, amending Regulations (EU) 2018/858 and 2019/1020 and repealing Directives 2000/53/EC and 2005/64/EC entered into force, setting detailed quantified targets stating that 85% of vehicles must qualify for re-use - recycling and 95 % for re-use – renewal. The European commission has given directives of how to handle waste for the member states of the EU, the guidelines for the waste management can be illustrated as a waste hierarchy and is shown in Fig. 1 [1, 2, 3].



**Fig. 1.** The waste hierarchy

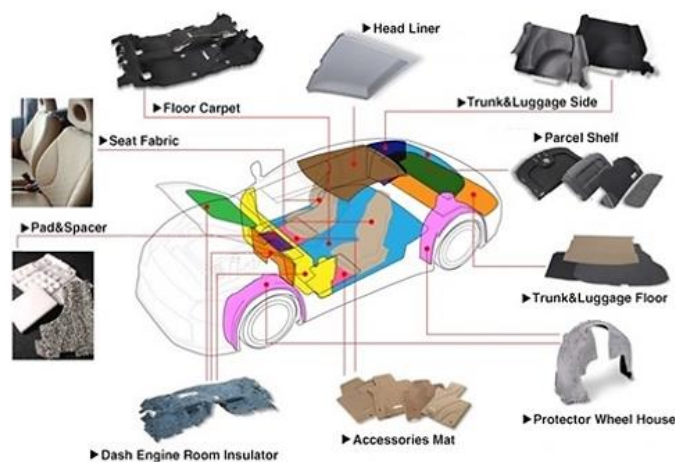
Source: Anna Fältholm, Hugo Thomasson: Development and visualization of a recycling plant, Stockholm, 2016, pp.71

This has pushed car manufacturers to consider the use of sustainable production materials, such as natural fibers especially for sound and heat insulation. In the Table 1 is shown an overview of the most used materials in vehicles. The ability to isolate mechanical noise, vibrations, thermal and thermal insulation properties of the vehicle interior leads to driving comfort and significant energy savings from the point of view of using air conditioning. These insulating materials can be used on floor coverings, under seat covers, door trim, bal panels, engine compartment and on the ceiling. Non-woven fabrics, which can be easily made into different densities, thicknesses and shapes, have been applied in car interiors due to their low weight, easy processing, flexibility, porosity and sound insulation properties [4, 5, 6].

Metals	Cuprum	Alluminium	Accumulators/ baterries, catalysts	Liquids	Plastics	Rubbers	Other parts
auto body – panels	cables	motor	leads	diesel, gasoline	plastics near the engine	tyres	carpets
engine	motors	alternator	NiCad	antifreeze mixture	bumpers, tanks	seals	insulations
car axle	alternator	gears	Lilon	oil	seals	hoses	foams
disks	starter	disks	-	windshield washer fluid	hoses	-	textiles
gears	electronics	-	-	brake fluid	-	-	glasses
starter	-	-	-	-	-	-	upholstery
seats	-	-	-	-	-	-	reflector, lamps
motors	-	-	-	-	-	-	air-bags
alternator	-	-	-	-	-	-	-

**Table 1.** Overview of the most used materials in vehicles

In car interiors, sound absorbing non-woven materials are used attached to various components such as floor carpet, headlining, trunk and luggage side parts, parcel shelf, door linings, trunk and luggage floor, wheel protector, accessory mat, dashboard insulator and washer and washer, Fig. 2 [7].



**Fig. 2.** Samples of textile components in vehicle

Source: Zeliha ÇAVUŞ; Mustafa Sabri ÖZEN; Aysun GENÇTÜRK; Serdar EVİRGEN; Mehmet AKALIN: Sound Absorption Properties of Natural Fibre Reinforced Polypropylene Needle-Punched Nonwoven Fabrics Used in Automotive Interior

Nonwovens used in automotive interiors have superior properties compared to textiles, including cost-effectiveness, easy forming, recyclability, and an attractive price/performance ratio. In addition, nonwovens can be designed with specifically targeted properties such as thickness, weight, and bulk. Due to their porous structure and high surface area, nonwovens are attractive for use in technical textile applications where sound absorption is required. [4, 6]

The authors have focused mainly on problematic materials from components, such as tyres, car seats, carpets, upholstery, airbags, glass, etc., and on the development of technologies and techniques for waste recovery into acoustic, thermal insulation, and other products.

## 2. MATERIALS AND METHODS

### 2.1. Materials - Production technologies of sound absorbing materials or elements

The products from used car recycling that can be used for the production of sound absorbing elements are products from recycled tyres, car seats, seat covers, carpets and airbags. The technology for car textile or car seat recycling is a special process which is basically universal for the following recovery of the recycled products. Therefore, in the next part we will focus on the processing of crushed mixed textile with plastics rubber (abraded material), crushed textile cords, and crushed car seats and seat covers, i.e. the raw materials used in the production of sound absorbing and thermal insulation elements. It is necessary to state that the principles of the technologies used for individual components are essentially the same – it is a compaction by connecting under the effect of heat and pressure. The technologies processing and grating of new recycled materials can be divided according to used methods as following:

- production technology by pressing,
- production technology by microwave heating,
- Production technology of sound absorbing elements from soft foam (polyurethane foams).

#### Production technology by pressing

The pressing technology uses large-scale presses – hydraulic or steam. Pressing is carried out under high pressure – at least 20.265 bar with heated pressing instruments. The bottom part is heated to 120 °C, while the upper part is heated to a temperature of 90 °C. The compression mould must have a good heat transfer, i.e. the heating of the mould and compressed material must be as short as possible. Compression mould is usually metal, two-piece. It has the shape of the required product and from the top is it covered by a pressure metal plate. For the easier removal of the pressed piece from mould, a thin metal plate is located on the bottom of the mould and this is mechanically pushed out of the mould through a small opening on the lower side, thus pushing out the product itself. For the easier removal of the product, the inside of the mould is regularly sprayed with silicone oil.

The entire technological process is discontinuous – while the first mould is in the press, the second is being prepared. It is favourable to use presses with two work tables – one is used to prepare and fill the mould for compression while the other is used to take out the finished product.

The mixture of crushed recycled materials and binder is prepared in mixers. The number of mixing devices must correspond for example to the number of layers. Each layer must be mixed separately. The charge of raw materials (crushed rubber, textile cords, textile, crushed car seats, seat covers or carpets) is determined based on the thickness of the individual layers. The concentration of the binder ranges between 12 – 16 % of the weight. The concentration of the binder is determined based on the absorbability of the material and the demanded toughness of the product. In order to accelerate the chemical binding reaction, compaction, a catalyst is added to the binder in the maximum concentration of 0.2 % of the weight. If a non-flammable treatment is required, the mixture is enriched with 6 – 8 % flame retardant. The binder is based on polyurethane/polybutadiene, while flame retardant is based on bromine aroma and antimony oxide. The mould is closed by the upper part and hot pressed under pressure for 12 – 15 minutes depending on the thickness of the sandwich. Then the mould moves to the

next position on the work table and the product is removed (still relatively hot and matures after being released from the mould).

A disadvantage of this technology is the high energy demand and rather long technological work cycle. The production of a single product takes at least 25 – 30 minutes, which has an impact on its price. The price of the mould is also rather high [5].

### **Sandwich production technology by microwave heating**

The high energy and economic demands of production by pressing are resolved by microwave heating technology. An advantage compared to classic pressing lies in the fact that the technological cycle is significantly shortened from 12 – 15 minutes to 4 – 5 minutes. It is not necessary to heat the moulds to high temperatures. Nor is it necessary to apply a high pressing pressure or use expensive moulds. The essence of the technological process lies in the fact that the necessary mixture is prepared in a mixer. The moulds can be simple and usually wooden. After its filled, layered, the mould is closed with the wooden upper part. Closing is carried out under moderate pressure and the upper part of the mould is fixed by pins. The closed mould is transported by conveyor to the microwave tunnel where the connecting takes place. The speed of passing through the tunnel allows the mould to remain there for approx. 4 – 5 minutes. There can be several moulds in the tunnel at the same time (depending on their size). With regard to the cheap structure of the moulds, there can be several pieces for one type of product, making the production almost continuous. Moreover, the structure of the moulds makes it possible to change the product dimensions without any major interference. The voltage generating microwaves is approx. 5 kV. The binder, catalyst, or flame retardant are used as in case of classic pressing.

Attempts to replace the binder with another binder, e.g. based on acrylate, were not successful. Although the price had decreased (acrylate binder is considerably cheaper than polyurethane/polybutadiene), the toughness of the products significantly deteriorated. The sound absorption had slightly increased, but the products were falling apart during their application.

This technology produces even combined products when one of the external layers (usually the bottom one) can be made from a hard material, e.g. rubberised concrete, Cetris, or concrete. This firm wall can be used as the upper board of the mould within the production process. Due to the simpler structure of moulds, microwave heating technology is also suitable for more demanding products in terms of shape, as well as for embossed surfaces. The products and technology are subject to the copyright of the project authors (utility model No. 5721 “Compact elements from recycled rubber produced using microwave heating technology”) [5].

### **Production technology of sound absorbing elements from soft foam (polyurethane foams)**

Car seats and seat covers are produced mainly from soft “firm” materials. With its highly porous structure, the crushed material has excellent preconditions for the production of sound-absorbing elements. The first technological attempts to produce composite elements were based on the knowledge about the technological process of pressing the recycled material from car tires. The same technology and binder were applied. It turned out that although this technology is suitable, it is economically very demanding. The high porosity of the material results in higher binder consumption than in the case of crushed rubber processing. The high consumption of the binder at its high price is commercially uninteresting. Good sound absorption could be achieved at a thickness of 20 mm. The disadvantage of products produced with this technology is the fact that their strength/compactness decreases with their decreasing thickness. It is a technology where the compaction process takes place by the effect of **hot steam without the need for high pressure** as in case of pressing. Basically, this technology has three technological nodes: **mixing, steaming, hardening (maturing)**.

Within the “mixing” process the crushed car seats and seat covers mix with the connecting adhesive. The mixture is prepared in such a quantity to fill one batch in the mould at 0.3 m. The mixing cycle takes approx. 10 minutes and the prepared mixture is filled in the mould. After it is closed, the “steaming” process begins. Within the “steaming” process the mixture connects by the effect of hot steam with a temperature of 160 °C. This node takes approx. 10 minutes and during this time the mixture

compacts. The steamed mixture is left to mature/harden for another 10 minutes, and after that the finished product is taken from the mould. Most often blocks are produced with a thickness of 100 mm, but it is also possible to produce a greater thickness. The greater the thickness, the longer the technological times. The produced block is compact and sufficiently tough to be chopped or cut into the necessary thickness or length and width. By chopping it is possible to get 10-mm-thick products.

These products can be applied e.g. by fixing into the frame. Products can also be made with incorporated reinforcement, such as metal mesh and steel rods, which make the product self-supporting and the value of sound absorption does not change. The technological production process does not change either. After filling half of the mould, install the reinforcement and complete the mould, then continue in the process of steaming and maturing. Thanks to the reinforcement it will be possible to make fixing anchors for the formation of movable and easily dismantlable noise management measures.

With regard to the fact that this method of crushed rubber or foam compacting is not described in the literature, it could be an original solution applicable not only in Slovakia, but also abroad. In the case of a positive result, it would make the production more efficient and this would also be favourably reflected in the price of the products. Lower prices would use of secondary raw materials from old vehicles [5, 6, 7].

### **Production technology and Design of products made on the basis of bulk granulates**

One of possible solutions for the use of recycled granulated (but also chopped, cut, torn and crushed) materials in acoustic applications without the use of binders is the application of these materials in noise barriers in the form of bulk material. A precondition for such application is the suitable structure of the noise protection panel and proper application of the bulk material with subsequent compaction. The project authors have focused on the research and comparison of acoustic properties of sandwich materials with various bulk material in the core of the panel.

The project authors set themselves the objective to partially replace the acoustically and thermally suitable materials made on the basis of recycled materials from the selected components of end-of-life vehicles with the use of compression at certain pressures, temperature at use or the omission of the proper binder with bulk materials produced on the basis of granulates from the recycling processes (bulk granulate). The advantages of the use of these so-called “green” materials in the acoustic (and also thermal) applications, such as noise barriers, in comparison with the commercial material, are the combination of a very light substance, high physical and chemical stability, low costs and high sound absorption values. The activities of the authors in 2021 will focus on researching the acoustic, vibration, and thermal properties of products made on the basis of such materials. [5, 6, 7]

#### **2.2. Materials - Textile material**

Textiles in an average car make up to 2 - 2.5 % of its total weight, which is 23 - 26 kilograms, by 2025 it is expected to increase to 35 kg. During the production of a new car, 2.5 - 4 kg of technological waste is created. Among the textiles from the car, we can also include pull-on covers, textiles from child seats, airbags, etc.

The textile material used for experimental tests measuring thermal insulation properties and noise measurement was supplied by the company Stered, s.r.o. [5, 6] Currently, the research is focused on the processing and recycling of automotive materials in cooperation with PR Krajne, s.r.o., where the experiments were carried out. The experiments began with the selection, collection and storage of used waste materials from textiles, textile waste from automobiles, Fig. 3. and Fig. 4.



**Fig. 3.** Landfilling and sorting of textile material from vehicle



**Fig. 4.** Example of waste textile from insulating material from cars

The next step was the processing of waste textile materials into approximately equal particles on the dividing and crushing line by cutting operations, Fig. 5. [5]. The form pressing is shown in the Fig. 6. The final shape of the bulk recycled binded textile is shown in the Fig. 7.



**Fig. 5.** Textile waste after second cutting operation and filling the forms for pressing [5].



**Fig. 6.** Form for compacting of recycled textile **Fig. 7.** Final shape of the compact material from recycled textile

All the specific properties of the original material are transferred to the properties of the new construction material STERED. The output of the recycling unit is the homogenized STERED S recyclate. The homogenized material is shaped into a board format with the addition of a polyurethane prepolymer-based binder, Fig. Properties of recycled textiles are listed in Tab. 3.

Measured technical parameters	Unit	Value
Thickness	mm	50
Format	mm	1200 x 600
Plate area	m <sup>2</sup>	0,72
The weight of the board	kg	7,2
Volumetric weight of the material	Kg/m <sup>3</sup>	200
Thermal conductivity $\lambda$	W/m.K	0,054
Coefficient of sound absorption $\alpha_w$	-	0,90
Tensile stress at 10 % compression	kPa	20,3
Tensile strength perpendicular to the plane of the board	kPa	32,2
Short-term absorption in partial immersion $W_{lp}$ , method A	Kg/m <sup>2</sup>	11,8
Long-term absorbency in partial immersion $W_{lp}$ , method A	Kg/m <sup>2</sup>	13,4
Compressibility	mm	3,68
Water vapor permeability $\mu$	-	2,9
Reaction to fire	-	E
Health harmless	-	in accordance with the relevant provisions

Table 2. Properties of compact textile board

The recycled textile material was inserted into the prepared moulds, pressed and dried. The result was recycled boards that were cut into smaller test pieces according to our requirements for further sound and thermal testing. Dimension variability can be varied depending on testing requirements. The supplied textile samples were in the form of as:

- cut or torn individual fractions of textile, measuring approx. 20 x 40 mm, (Material fractions - cut or torn small parts of textiles are from different parts of textiles such as covers, carpets from a car.), Fig. 8,



Fig. 8. Thorn and cut textile recycling material from vehicle

- a compact unit made of materials from cars glued and pressed with dimensions of 300 x 300 mm, Fig. 9. and Fig. 10 (Solid textile boards)



**Fig. 9.** Compact recycled textile samples



**Fig. 10.** Side view of the compact textile sample

The experimental material has very good sound and thermal insulation properties, [4 - 31]: The environmental benefit of recycled textiles is in the use of insulation based on recycled textiles due to their high thermal capacity, it reduces the requirements for heating and cooling buildings, reduces the amount of textile waste and can partially replace the production of insulation from non-renewable sources. Due to the lower energy demand compared to classic mineral insulations, it also reduces the carbon footprint of insulation production.

### 2.3. Methods

Based on the supplied test material, test samples were created:

- in the shape of a cylinder with a diameter of  $\varnothing$  60 mm and a height of 60 mm, made of solid panel board, Fig. 11.,
- cut, torn textile material from a car after its useful life, Fig. 12



**Fig. 11.** Cylindrical sample



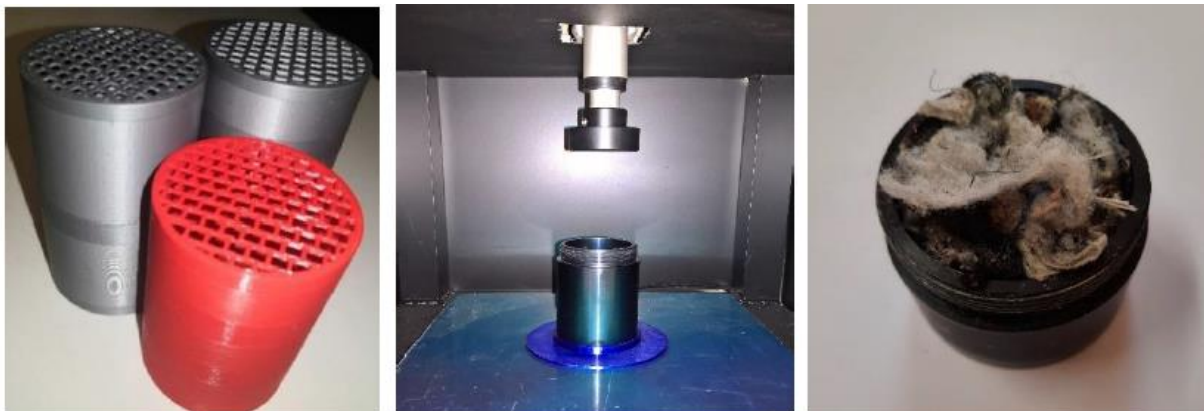
**Fig. 12.** Cut and thorn recycled textile

A BSWA TECH impedance tube was used for the experimental part. The system for measuring the sound absorption coefficient ( $\alpha$ ), (for the frequency bands 100 Hz to 800 Hz and 400 Hz to 2500 Hz) consists of a tube with an internal diameter of 60 mm and a holder for the measured sample with an internal diameter of 60 mm, Fig. 13.



**Fig. 13.** A view of the BSWA TECH impedance tube

Test cassettes designed by the authors were used for the textile bulk part of the collected waste, fig. into which the test torn material was inserted and packed using a laboratory press designed by the authors, Fig. 14.



**Fig. 14.** Tested cassettes, laboratory press and tested sample with thorn and chopped material

### 3. RESULTS AND DISCUSSION

By measuring the acoustic properties of textile recycled materials, 2 types of samples were evaluated. one sample was made from compact recycled textile material STERED. The second sample was prepared from the same recycled bulk textile material that was not compacted.

Based on the measurements of the sound absorption coefficient, we can conclude that the compact textile material achieves better parameters in the frequency bands 100 - 500 Hz and in the frequency band 1600 - 2500 Hz, Table 3. and Table 4.

The loose textile material achieves better absorption parameters in the frequency range of 500 - 1250 Hz. Based on the results of the measurement of the attenuation index, it follows that the compact textile material has better properties in the entire frequency band, Table 5. and Table 6. This result could be expected, since the volume weight of the compact material is 4 times higher than the volume weight of the loose textile material.

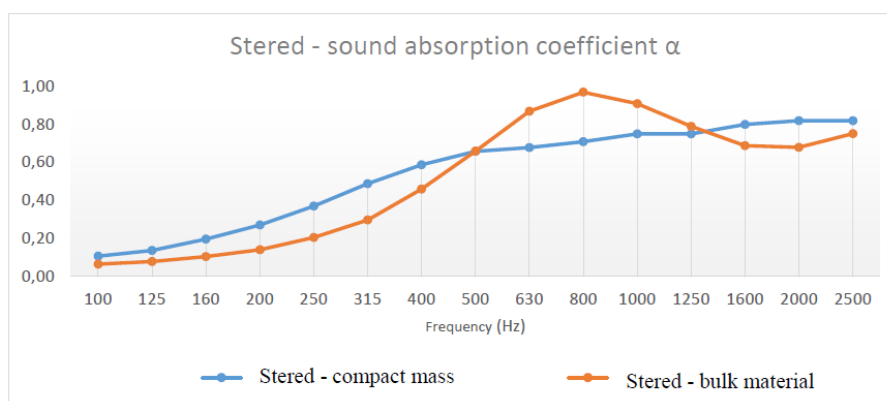
Material:	Stered – compact material sample					
Parameter:	sound absorption coefficient					
Weight:	37,0 g					
Fre.	Measuring 1	Measuring 2	Measuring 3	Measuring 4	Measuring 5	Average
100	0,1	0,1	0,09	0,11	0,13	<b>0,11</b>
125	0,14	0,13	0,14	0,14	0,13	<b>0,14</b>
160	0,2	0,19	0,2	0,2	0,19	<b>0,20</b>
200	0,27	0,27	0,27	0,27	0,27	<b>0,27</b>
250	0,37	0,37	0,37	0,37	0,37	<b>0,37</b>
315	0,49	0,49	0,49	0,49	0,48	<b>0,49</b>
400	0,59	0,59	0,59	0,58	0,59	<b>0,59</b>
500	0,66	0,66	0,66	0,66	0,65	<b>0,66</b>
630	0,68	0,68	0,68	0,68	0,67	<b>0,68</b>
800	0,71	0,71	0,71	0,71	0,71	<b>0,71</b>
1000	0,75	0,75	0,75	0,75	0,75	<b>0,75</b>
1250	0,75	0,75	0,75	0,75	0,75	<b>0,75</b>
1600	0,8	0,8	0,8	0,8	0,8	<b>0,80</b>
2000	0,82	0,82	0,82	0,82	0,82	<b>0,82</b>
2500	0,82	0,82	0,82	0,82	0,82	<b>0,82</b>

**Table 3.** Measuring of sound absorption coefficient of compact textile recycled materials

Material:	Stered – loose tested recycled textile					
Parameter:	sound absorption coefficient					
Weight:	8,4 g					
Fre.	Measuring 1	Measuring 2	Measuring 3	Measuring 4	Measuring 5	Average
100	0,07	0,07	0,04	0,07	0,07	<b>0,06</b>
125	0,09	0,07	0,07	0,08	0,08	<b>0,08</b>
160	0,11	0,1	0,11	0,1	0,1	<b>0,10</b>
200	0,14	0,14	0,14	0,14	0,14	<b>0,14</b>
250	0,21	0,2	0,2	0,2	0,21	<b>0,20</b>
315	0,29	0,3	0,3	0,29	0,3	<b>0,30</b>
400	0,46	0,46	0,46	0,46	0,46	<b>0,46</b>
500	0,66	0,66	0,66	0,66	0,66	<b>0,66</b>
630	0,87	0,87	0,87	0,87	0,87	<b>0,87</b>
800	0,97	0,97	0,97	0,97	0,97	<b>0,97</b>
1000	0,91	0,91	0,91	0,91	0,91	<b>0,91</b>
1250	0,79	0,79	0,79	0,79	0,79	<b>0,79</b>
1600	0,69	0,69	0,69	0,68	0,69	<b>0,69</b>
2000	0,68	0,68	0,68	0,68	0,68	<b>0,68</b>
2500	0,75	0,75	0,75	0,76	0,75	<b>0,75</b>

**Table 4.** Measuring of sound absorption coefficient of loose tested recycled textile

The measured and processed values of the sound absorption coefficient  $\alpha$  are shown in Fig. 15. and of recycled textile in the Fig. 16.



**Fig. 15.** Values of the sound absorption coefficient  $\alpha$  for tested materials

Attenuation index values for compact and bulk material in the Table 5. and Table 6.

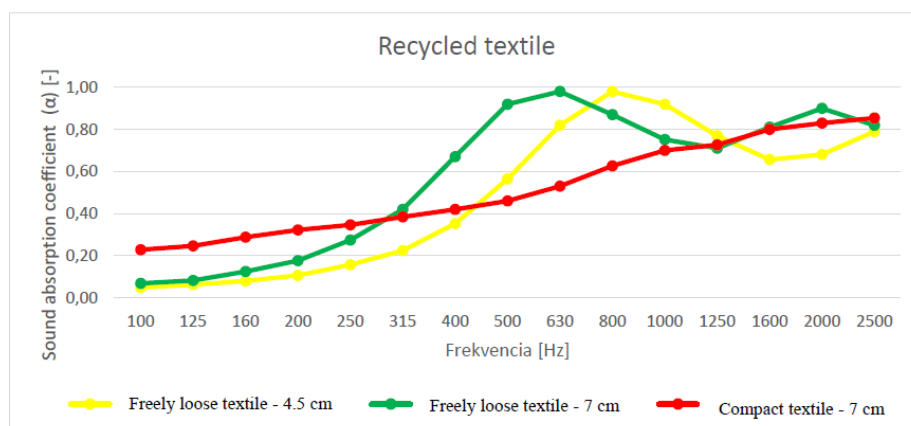


Fig. 16. Values of the sound absorption coefficient  $\alpha$  for tested materials

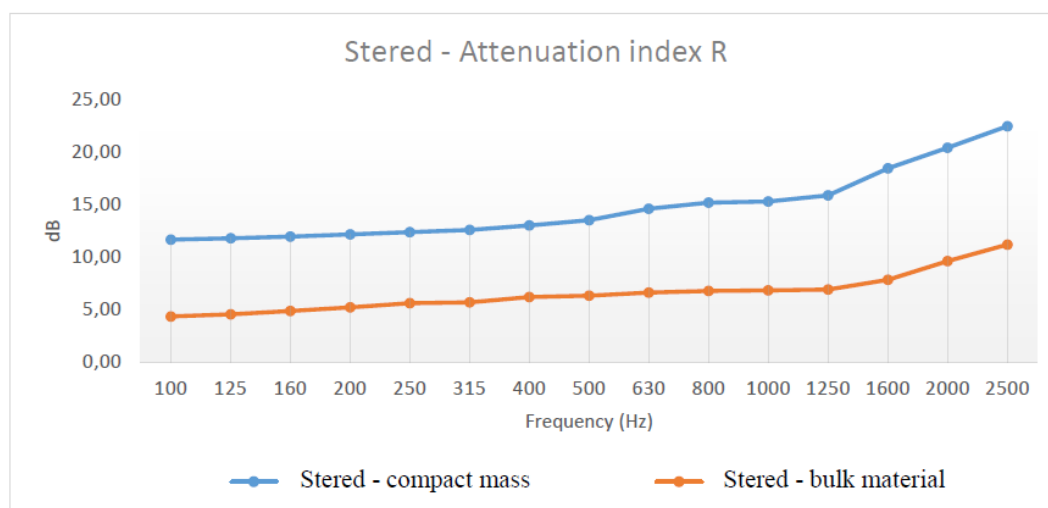
Material:	Stered - compact					
Parameter:	Attenuation index R					
Weight:	37,0 g					
Fre.	Measuring 1	Measuring 2	Measuring 3	Measuring 4	Measuring 5	Average
100	11,49	11,85	11,85	11,6	11,59	11,68
125	11,66	11,9	11,92	11,74	11,73	11,79
160	11,91	12	12,03	11,96	11,97	11,97
200	12,08	12,17	12,18	12,2	12,21	12,17
250	12,09	12,4	12,42	12,52	12,52	12,39
315	11,79	12,75	12,76	12,82	12,81	12,59
400	12,27	13,23	13,24	13,23	13,21	13,04
500	13,36	13,56	13,59	13,56	13,55	13,52
630	14,45	14,64	14,66	14,68	14,66	14,62
800	15,13	15,23	15,26	15,24	15,21	15,21
1000	15,29	15,32	15,34	15,31	15,27	15,31
1250	15,87	15,9	15,91	15,91	15,87	15,89
1600	18,44	18,46	18,49	18,49	18,46	18,47
2000	20,44	20,44	20,45	20,47	20,46	20,45
2500	22,48	22,51	22,57	22,48	22,46	22,50

Table 5. Attenuation index R for compact material

Material:	Stered – bulk (loose)					
Parameter:	Attenuation index R					
Weight:	8,4 g					
Fre.	Measuring 1	Measuring 2	Measuring 3	Measuring 4	Measuring 5	Average
100	4,27	4,37	4,27	4,41	4,4	4,34
125	4,5	4,56	4,47	4,6	4,62	4,55
160	4,82	4,9	4,82	4,91	4,93	4,88
200	5,17	5,2	5,17	5,23	5,24	5,20
250	5,61	5,6	5,63	5,62	5,63	5,62
315	5,68	5,67	5,71	5,69	5,7	5,69
400	6,18	6,2	6,18	6,22	6,22	6,20
500	6,31	6,33	6,31	6,34	6,34	6,33
630	6,62	6,62	6,63	6,61	6,62	6,62
800	6,75	6,76	6,77	6,79	6,79	6,77
1000	6,81	6,82	6,82	6,84	6,84	6,83
1250	6,92	6,92	6,92	6,91	6,91	6,92
1600	7,82	7,83	7,83	7,83	7,83	7,83
2000	9,64	9,65	9,65	9,6	9,6	9,63
2500	11,18	11,19	11,2	11,21	11,22	11,20

**Table 6.** Attenuation index R for bulk (loose) material

Single dependences of attenuation index R are shown in Fig. 17. and Fig. 18.



**Fig. 17.** Dependences of attenuation index R of tested materials

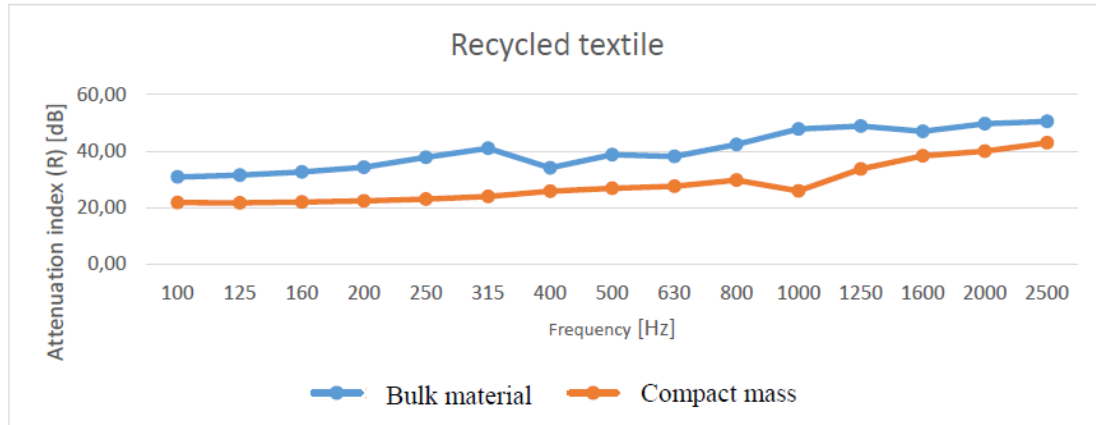


Fig. 18. Dependences of attenuation index R of tested materials

#### 4. CONCLUSIONS

The aim of the contribution was to focus on the development of technologies and techniques for the recovery of waste into acoustic and thermal insulation products. Emphasis was put on the use of such components from end-of-life vehicles with problematic recycling and especially the subsequent utilisation of the extracted raw material. The authors have focused on: car seats, seat covers, seat belts, carpets, airbags. They tried to establish contact with companies which recycle or are considering recycling these components. They have gained many fractions of various materials for their current or future work.

The authors of the project have also focused on the production technologies of sound absorptive materials or elements. Emphasis was placed on technology for producing absorptive elements from textile and other waste materials from vehicle. As an example can be mentioned sandwich structures made by compressing and microwave heating. They have also focused on technology for producing sound absorptive elements from soft foam (polyurethane foams). The example in the practice is shown in the Fig. 19.

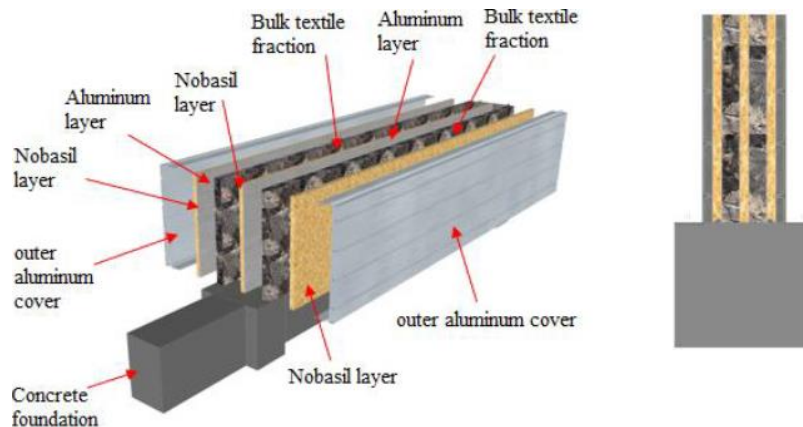


Fig. 19. Utilisation of the compact recycled material in the sandwich structures

## ACKNOWLEDGMENTS

This work was supported by the projects: UNIVNET No. 0201/0004/20: „University and industrial research and educational platform of recycling society” and VEGA 1/0485/2022: “Development of methods for increasing the acoustic quality of product sound by visualization and psychoacoustic methods”.

## REFERENCES

1. Directive 2000/53/EC of the European Parliament and of the Council of 18 September 2000 on end-of life vehicles - Commission Statements, <https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:02000L0053-20180704>.
2. Proposal for A Regulation of the European Parliament and of The Council on circularity requirements for vehicle design and on management of end-of-life vehicles, amending Regulations (EU) 2018/858 and 2019/1020 and repealing Directives 2000/53/EC and 2005/64/EC, <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM%3A2023%3A451%3AFIN&qid=1689318552193>
3. Fältholm, A., Thomasson, H. 2016 ”Development and visualization of a recycling plant”, Stockholm, pp.71, <http://www.diva-portal.org/smash/get/diva2:1034467/FULLTEXT01.pdf>
4. Moravec, M., Dzuro, T., Badida, M., Sobotova, L., Badidová, A. 2020, ”Potential of using components from old cars for production of thermal and sound isolation materials.”, In: Scientific Letters of Academic Society of Michal Baludansky. - Kosice (Slovakia), 8, č. 5 (2020), pp. 30-32.
5. Stered, s.r.o., 2020, Recycling of the textile, Properties., <http://www.stered.sk/stered-a-media>
6. Sobotova, L., Badida, M., Dzuro, T. 2023, Recycling and Recycling technologies (in Slovak Recyklácia a recyklačné technológie), TYPOPRESS, pp. 485.
7. Badida, M., Dzuro, T., Badidova, A., Moravec, M., Sobotova, L. 2019 “ The Utilization of Recycled Materials from Automobiles in Noise Barrier Structures “. In: Waste Form, 1, pp. 12-27.
8. Cavus, Z., Ozen, M.S., Gencturk, A. Evirgen, S., Akalin, M., 2021” Sound Absorption Properties of Natural Fibre Reinforced Polypropylene Needle-Punched Nonwoven Fabrics Used in Automotive Interior” , Turkey, pp.1-10.
9. Xinwu, X., et al., 2018, “Sound Absorbing Properties of Perforated Composite Panels of Recycled Rubber”, Fiberboard Sawdust and High Density Polyethylene. Journal of Cleaner Production Vol. 187, p. 215 – 221.
10. Bhingare, N., H., Prakash, S., Jatti, V., S., 2019, “A Review on Natural and Waste Composite as Acoustic Material”. Polymer Testing. Vol. 80.
11. Arunkumar, B. - Jeyanthi, S., 2017, “Design and Analysis of Impedance Tube for Sound Absorption Measurement”. Journal of Engineering and Applied Sciences. Vol. 12, No. 5, pp. 1400 – 1405.
12. Niresh, J. et al, 2015, “Review of Acoustic Characteristics of Materials using Impedance Tube. Journal of Engineering and Applied Sciences”. Vol. 10, No. 8, pp. 3319 – 3326.
13. Niresh, J., Neelakrishnan, S., Subharani, S., Prabhakaran, R., 2015, “Performance Testing for Sound Absorption Coefficient by Using Impedance Tube”. In: Research Journal of Applied Sciences, Engineering and Technology. Vol. 11, No. 2, pp. 185 – 189.