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PERFORMANCE AND TECHNOLOGICAL MODEL FOR PRODUCTION OF SOUND- AND SHOCK-ABSORBING COMPOSITES ON THE BASIS OF WASTE ELATOMERIC MATERIALS

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ABSTRACT

The aim of the present work is to investigate the possibilities of using waste sunflower oil as a modifying additive in order to eliminate some disadvantages of polyurethane adhesives used in the production and performance of insulating composites from ground waste rubber vulcanizates. A composition and a technological model for the production of sound- and shock-absorbing composite material have been developed as a result of the present study. A positive effect of the modifying additive on the technological process and the properties of the composite materials has been established. It is attributed to the composition of the waste sunflower oil comprising different types of fatty acids. The conducted tests and the obtained results give grounds to believe that the composite material developed can find applications as a sealing element in railways of rail and tram transport, in construction for sound insulation of buildings, as well as for covering children's and sports grounds.

Keywords: *ground waste rubber, rubber crumbs, polyurethane adhesives, waste sunflower oil, additives.*

INTRODUCTION

Currently, the world production of raw rubber is 26.7 million tons, of which about 12.3 million tons of natural rubber, and the remaining 14.4 million tons are various types of synthetic elastomers. This quantity is used in the production of passenger tires and various technical rubber products [1]. According to the European Association of Tire and Rubber Manufacturers (ETRMA), about 3.3 million tons of tires are decommissioned in the European Union each year. The data show that for the whole European Union, 98 % of them are recycled or recovered in some other way. Unfortunately, this trend is not typical for Bulgaria, where only about 79 % of waste tires are recycled [2]. The strict directives of the European Union (Directive 2008/98/EU and Directive 1991/31/EU) currently give priority to the possibilities for their utilization and prohibit their disposal [3]. The above is the reason for the increasing efforts, including in our country, to the possibilities for utilization of waste passenger tires, as well as the products obtained as a result of their recycling in various fields of industry. Typically, most methods of recycling scrap tires and rubber products are preceded by a preliminary stage of mechanical grinding, which aims to reduce their size. Ground waste rubber vulcanizates with a particle size of up to 1 mm can be used as a filler in fresh rubber mixtures. However, the filling of elastomers with larger amounts of ground rubber vulcanizates leads to an increase in the viscosity of the rubber mixtures, which increases the energy costs in the production of products based on them. Ground waste rubber vulcanizates with a larger particle size (2 - 5 mm) can be used as a raw material for the production of insulation materials, as well as for the production of flooring elements, which are increasingly used in the construction of sports facilities (tennis, basketball and volleyball courts), as well as in a number of other areas - playgrounds, production of storage facilities [2], etc. Typically, such materials are obtained by mixing ground rubber with various adhesive solutions [4]. The ground waste rubber vulcanizates with a larger particle size are also used in railway transport. In

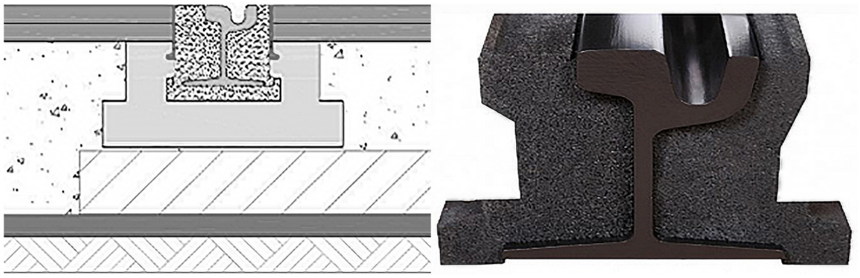

Fig. 1. Application of ground rubber with a particle size of 2 to 5 mm in railway transport [2].

this sector, composites of their and adhesive solutions are used for the production of "beds" on which the railway or tram rails are mounted, as well as for the production of parts that are mounted on both sides of the rails (Fig. 1). These materials significantly reduce the noise and vibration characteristics of this type of transport and make it more tolerable for the modern urban environment [2].

As it has already become clear, the preparation of various coatings for sports and children's playgrounds, as well as various sound- and vibration-absorbing materials from ground waste rubber vulcanizates, requires their pre-mixing with various adhesive solutions. The most commonly used in practice for this purpose are polyurethane adhesives. The reason for their widespread use is due to the unique set of properties they possess. These properties, in turn, are related to the ability of isocyanate groups to react rapidly chemically with any compound containing a mobile hydrogen atom. Despite all the positive properties and characteristics of polyurethane adhesives, in the production of insulating materials and coatings from waste vulcanizates and their solutions, the following problems are observed:

- the strength of the adhesive bond is not always good enough;
- the price of adhesives is high;
- the colorants used for coloring the adhesive solutions settle quickly;
- their open times are too short.

These disadvantages can be overcome by various types of chemical modification of polyurethane adhesives or by the use of modifying additives thereto. In this regard, different data are found in the scientific and patent literature. In their study, Desai [5] and his team investigated the possibility of modifying a polyurethane adhesive by grafting 2-hydroxyethyl methacrylate onto the backbone of the polyol. Their purpose is to increase the strength of the adhesive bond. The authors claim that the use of 2-hydroxyethyl methacrylate as a modifying agent leads to an increase in the molecular mass of the polyol, as well as to the introduction of new and reactive hydroxyl groups, which are subsequently able to participate in the crosslinking process of the polyurethane structure. As a result, the cohesive strength of the adhesive is improved, which in turn leads to an increase in the strength of the adhesive bond. Polyurethane adhesives modified in this way are characterized by greater resistance to various aggressive chemicals, as well as higher "green" strength. Pastor-Sempere [6] et al. modified polyurethane adhesives by adding carboxylic acids, and their purpose is to improve the adhesion between them and some vulcanized synthetic elastomers. The authors used a polyurethane adhesive based on ε-polycaprolactone and diphenylmethane-4,4'-diisocyanate, and fumaric acid as a modifying agent. The obtained results show that this type of modification leads to a positive change in the rheological and viscoelastic properties of polyurethane adhesives. Attempts to modify bio-polyurethane adhesives derived from castor oil are also found in the literature. Valero and Gonzalez, for example, are exploring the possibility of using pentaerythritol transesterification for this purpose [7]. In this case, the resulting polyurethanes are designed for coatings on various surfaces. The authors claim that the bio-polyurethanes modified in this way have better coating properties, and the coating is characterized by better mechanical and anti-corrosion properties. Of interest is also the patent of David M. Hazell [8], which protects a claim concerning the possibility of using vegetable oils (in particular soybean oil) as a process additive, leading to a decrease in the viscosity of polyurethane adhesive solutions. The reason for the development of this patent is precisely the fact that in some cases the adhesive solutions are highly viscous. This leads to significant obstacles in the production of insulating composites from ground waste rubber vulcanizates and polyurethane adhesives, and the resulting products are characterized by poor mechanical properties. According to the patent, using only 10 % soybean oil halves the viscosity.

The interest in the use of vegetable oils in the production and/or use of polyurethane adhesives and composites based on them is not accidental. The reason for this is that oils contain fatty acids and their esters, which can easily participate in various chemical reactions: epoxidation, hydrogenation, ozonolysis, transesterification [9], etc., which can ultimately lead to improved properties of adhesive solutions. We did not find in the literature and patent sources data on the use of waste, already used for other purposes vegetable oils as modifying additives, which we consider as a gap in the research conducted so far.

In this regard, the aim of the present work is to investigate the possibilities of using waste sunflower oil as a modifying additive in order to eliminate some disadvantages of polyurethane adhesives used in the production and performance of insulating composites from ground waste rubber vulcanizates.

This requires research in two directions:

- an investigation of the influence of the amount of the modifying additive on the properties of the adhesive solutions;
- an investigation of the properties of reference composites obtained from waste rubber vulcanizates and adhesive solutions containing used sunflower oil as a modifying additive.

EXPERIMENTAL

Materials used

Adhesive – one-component polyurethane adhesive based on diphenylmethane diisocyanate (ACTIVE PLAY AS H 8003, manufactured by PCC Group, Germany) with the following characteristics: dynamic viscosity 2500 - 6500 mPa.s at 25°C, content of NCO groups 8.5 - 10.5 % and density 1.05 - 1.10 g/cm^3.

Modifying additive – waste sunflower oil with dynamic viscosity at 25°C about 125 mPa.s and density of 0.92 g/cm^3.

Ground rubber obtained from waste vulcanizates based on styrene-butadiene rubber (SBR) with a particle size of 2.0 to 3.0 mm.

Preparation and analysis of the studied adhesive solutions

Preparation of the studied adhesive solutions

About 10 - 40 % of the tested modifying additive is added to the selected adhesive. The homogenization of the adhesive solutions is performed with a mechanical laboratory stirrer for a time of 7 min.

Methods for analysis of the investigated adhesive solutions

A MYR VR3000 rotary viscometer, model V2R from Viscotech Hispania SL, was used to determine the dynamic viscosity of the studied adhesives.

The stability of the adhesive dispersions with respect to the dye solid particles was assessed on the basis of a visual assessment of the time required for the visible occurrence of the process of precipitation of the dye solid particles in the adhesive solutions. For this purpose, 100 ml of the adhesive solutions are pre-mixed with 5 % by weight of the iron oxide pigment 130T with red color. The laboratory determination of the open times of the adhesive solutions was performed according to the methodology for determining the strength of adhesion during delamination and shear, described in [10]. Tensile strength was used to estimate the open times of the tested adhesive solutions.

Preparation and investigation of the studied composites

Preparation of the studied composites

An adhesive solution containing a modifying additive in amounts of 0 to 40 % by weight was added to 500 g of ground waste rubber vulcanizates. The resulting mixtures were homogenized in a laboratory mixer for 7 minutes. At the end of the homogenization, 2.5 wt. % (with regard to adhesive) of catalyst (water) is sprayed on the mixture. The mixture is then compressed in a hydraulic press with electric heating for 15 minutes, at a pressure of 7.0 MPa and a temperature of 120ºC, using special molds with a volume of 190 cm^3.

Methods for analysis of the investigated composites

Determination of tensile strength and elongation at break

From the obtained composites, test samples with dimensions 100x20x10 mm are cut, on which a working section with a length of 30 mm is applied. The determination of tensile strength and elongation at break is performed on a dynamometer at a movable jaw speed of 200 mm/min.

Determination of residual elongation

The measurement of the residual elongation in the working area of the specimens was performed 1 minute after rupture. The two parts of the torn test piece are joined and the length of the working section was measured. From the experimental results the residual elongation is calculated by the formula:

$$\varepsilon_{res} = \frac{l_0 - l_2}{l_2} \cdot 100, \% \qquad (1)$$

where: ε_{res} - residual elongation, %; l_0 - length of the working section before deformation, mm; l_2 - length of the working section one minute after the rupture, mm.

Determination of Shore A hardness

The Shore A hardness of the test samples was determined by a portable hardness tester of the company "Mitotoyo" according to ISO 7619-1: 2012 [11]. The forced penetration into the material of a special nozzle at a certain pressure is measured.

Determination of the glass transition temperature

The glass transition temperature T_g of the tested composites was determined using dynamic mechanical thermal analysis (DMTA). For the purpose of the study, Dynamic Mechanical Thermal Analyzer Mk III system of the company Rheometric Scientific was used. The conditions of the analysis are: single cantilever bending mode, strain frequency 5 Hz, strain size - 64 μm. The temperature range in which the analysis was performed is from -80 to 80ºC. The specimens are 2 - 3 mm thick and 10 mm wide.

Determination of the abrasion of composites

A cylindrical test sample of composite with a diameter of 16 mm and a height of 8 mm is exposed to abrasive fabric (sandpaper) with a certain degree of abrasiveness at a constant contact pressure. One of the flat sides of the cylindrical test piece is wiped. The loss of mass of the test piece is determined and the reduction in volume is calculated by the density of the material.

Determination of residual deformation under pressure

Residual deformation is defined as the ratio of the change in the linear size of the deformed specimen (after recovery) to the initial linear size of the specimen before the application of pressure.

The test is performed simultaneously with the pressure resistance test using a universal test machine - WEW-1000D Computer Display Hydraulic Universal Testing Machine. The height (h) of the sample was measured 30 minutes after unloading. Determine the residual deformation at a compressive force causing a 50 % reduction in the linear size of the sample in the direction of the applied force. From the experimental results the residual deformation is calculated by the formula:

$$\varepsilon_{50} = \frac{h_0 - h}{h_0} \cdot 100, \% \qquad (2)$$

where: ε_{50} - residual deformation in percent after restoration of the sample, when it is deformed up to 50 % of the initial height; h_o - initial height of the test specimen before it is subjected to pressure in mm; h - height of the test specimen, after unloading from the pressure force in mm. The residual deformation was measured on test specimens with sizes 33x30x20 mm, with the compressive force in the direction of height.

Determination of energy characteristics

The potential elastic energy characterizes the ability of elastic materials to accumulate during their deformation and to give a certain amount of energy during their recovery. This is an indicator that characterizes the suitability of materials used for flooring of playgrounds and sports facilities for such purposes. The potential elastic energy is calculated in joules (J) from the graph "force-of-pressure-deformation" using the Riemann sum method. Riemann Sum is an approximation of the face of the figure below the graph of "force of pressure-deformation". For each interval, one arbitrary value of the function is taken, which is multiplied by the length of the interval. Riemann's sum is the sum of all such works. The graphical representation of Riemann's sum is a breakdown of the graph into rectangles, the face of each of which is an approximation of the face below the graph in its interval.

Energy density is a characteristic of elastic materials, expressing the amount of potential energy that they are able to accumulate, absorb, or recover. It is calculated in Joules per cubic meter (J/m^3).

Determination of shock absorption of composite materials

The determination of shock absorption was performed according to EN 1177:2018 [12], using the HIC criterion. The Head Injury Criterion (HIC) is a measure of the likelihood of head injury arising from an impact. The HIC can be used to assess safety related to vehicles, personal protective gear, and sport equipment. Normally the variable is derived from the measurements of an accelerometer mounted at the center of mass of a crash test dummy's head, when the dummy is exposed to crash forces. It is defined as:

$$HIC = max\left\{\left[\frac{1}{t_2-t_1}\int_{t_1}^{t_2} a(t)dt\right]^{2.5}(t_2-t_1)\right\} \quad (3)$$

where t_1 and t_2 are the initial and final times (in seconds) chosen to maximize HIC, and acceleration a is measured in gs (standard gravity acceleration). The time duration, t_2–t_1, is limited to a maximum value of 36 ms, usually 15 ms [13, 14].

This means that the HIC includes the effects of head acceleration and the duration of the acceleration. Large accelerations may be tolerated for very short times.

At a HIC of 1000, there is a 90 % probability of a moderate head injury to the average adult. It is believed that the more the value of the HIC criterion is below 1000, the safer and more suitable is the coating used, as it makes it possible to avoid injuries when falling from a greater height.

Determination of sound insulation and sound absorption properties

The sound insulation properties against impact noise of the composite material are determined in laboratory conditions according to the standard EN ISO 10140-3:2010 [15], for which purpose a composite flooring is made, having an area of 12 m^2, formed by 48 rubber plates with dimensions 500x500x20 mm. The sound-absorbing properties of the composite material are determined in a reverberation chamber according to EN ISO 354:2003 [16]. The time for which the sound pressure level (after sudden attenuation of the noise source) decreases by 60 dB is determined. With the help of standardized indicative forms of frequency characteristics and calculation of so-called weighted sound absorption coefficient α_ω the class of sound-absorbing materials to which the studied composite material can be equated is determined.

RESULTS AND DISCUSSION

Investigation of the properties of adhesive solutions

Table 1 presents the viscosities of the pure adhesive, as well as of the solutions based on it, containing different amounts of waste sunflower oil. Table 1 shows that an increase in the amount of modifying additive leads to a decrease in the dynamic viscosity. This is due to the diluting effect of the pure adhesive, as its dynamic viscosity is much higher than that of sunflower oil.

It was found that the time to the beginning of precipitation of the dye in the pure adhesive is about 2 hours and 30 minutes after their complete homogenization. The addition of various amounts of modifying additive reduces the settling time of the dye. This is due to the decrease in the viscosity of the adhesive solutions due to the larger amounts of additive and the high density (over 5.25 g/cm^3) of the dye due to its iron oxide character. In the same time the densities of the adhesive and the modifying additive are in the range 0.92 - 1.10 g/cm^3.

The open times of the tested polyurethane adhesive and its solutions with waste sunflower oil are presented in Table 2. It can be seen that the open times of the adhesive solutions increase with increasing in the amount of the modifying additive. However, in this case it cannot be said categorically that the changes occurring in this parameter are specifically due to its presence, since usually the open time of each type of adhesive is given in a fairly wide range and depends strongly on the conditions of the measurements. The results obtained by us fully correspond to the data from the manufacturer of the adhesive, which indicates an open time in the range of 25 to 40 minutes.

Table 1. Dynamic viscosity of the tested adhesive and solutions based on it. (The designations 0, 10, 20, 30 and 40 show the amount of the modifying additive in %).

Adhesive	Viscosity, mPa.s
ASH 8003 - 0	7650
ASH 8003 - 10	5040
ASH 8003 - 20	3891
ASH 8003 - 30	1780
ASH 8003 - 40	1280

Table 2. Open times of the adhesive and its solutions (The designations 0, 10, 20, 30 and 40 show the amount of the modifying additive in %).

Adhesive	Open time, min.
ASH 8003 - 0	35
ASH 8003 - 10	40
ASH 8003 - 20	40
ASH 8003 - 30	45
ASH 8003 - 40	45

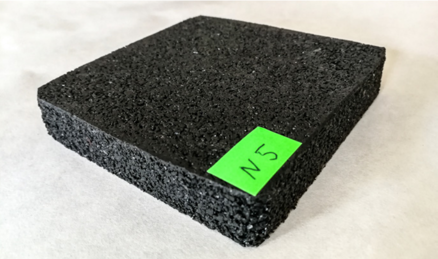

Fig. 2. Composite based on waste rubber vulcanizates and adhesive containing 20 % waste sunflower oil.

Table 3. Mechanical characteristics of composites based on ground waste rubber and adhesive solutions (The designations 0, 10, 20, 30 and 40 show the amount of the modifying additive, %).

Code of the mixture	σ, MPa	ε_{rel}, %	ε_{res}, %	Shore A hardness, rel. units
ASH 8003-0	0.9	43	0	58
ASH 8003 - 10	1.0	48	0	54
ASH 8003 - 20	0.8	42	0	54
ASH 8003 - 30	0.7	39	0	53
ASH 8003 - 40	0.7	37	0	52

Notes: σ, MPa-tensile strength; εrel., %- elongation at break; εres, %-residual elongation.

Investigation of the properties of composites, based on ground waste rubber vulcanizates and adhesive solution modified with waste sunflower oil

A sample of a composite based on waste rubber vulcanizates and an adhesive containing 20 % of waste sunflower oil is shown in Fig. 2.

The figure clearly shows the rubber particles of ground waste vulcanizates glued by means of the adhesive solution under the influence of the applied pressure and temperature.

Table 3 shows the mechanical parameters of the tested composites. It may be concluded that in general, the tensile strength and the elongation at break for all samples tested are close. These parameters are the highest in the composite containing 10 % of the additive. In other composites, as the amount of waste sunflower oil increases, the tensile strength and elongation at break gradually decrease. Shore A hardness is the highest in the composite containing pure adhesive. The introduction of the modifying additive leads to a decrease in this parameter, which correlates with the decrease in the viscosity of the adhesive solutions.

Table 4 shows the glass transition temperatures (T_g) of composites based on ground waste vulcanizates and adhesive solution containing different amounts of waste sunflower oil. It can be seen that with the introduction of the modifying additive the glass transition temperatures decrease, which expands the range of the highly elastic state, i.e increases the cold resistance and leads to the improvement of the performance properties of the final products. The reason can be found in the plasticizing effect of the modifying additive with respect to the ground rubber particles, thanks to which they retain some mobility at lower temperatures.

Table 5 shows the residual deformation under pressure of composites based on ground waste vulcanizates

Table 4. Glass transition temperatures of composites based on waste ground rubber and adhesive solutions (Indications 0, 10, 20, 30 and 40 show the amount of modifying additive, %).

Code of the mixture	T_g, ºC
ASH 8003-0	-30.7
ASH 8003 - 10	-33.6
ASH 8003 - 20	-34.8
ASH 8003 - 30	-34.2
ASH 8003 - 40	-34.7

Table 5. Residual deformation under pressure of composites based on ground rubber and adhesive solutions (The designations 0, 10, 20, 30 and 40 show the amount of the modifying additive, %).

Code of the mixture	h_o, mm	h, mm	Power of pressure, P_{max}, N	Deformation h_{max}, mm	Residual deformation, mm	Residual deformation, %
ASH8003-0	19.8	19.5	1456	10.0	0.3	1.52
ASH8003-10	19.7	19.4	1619	9.75	0.3	1.52
ASH8003-20	19.8	19.5	1594	9.46	0.3	1.52
ASH8003-30	19.7	19.5	1595	9.36	0.2	1.02
ASH8003-40	19.9	19.6	1454	9.84	0.1	1.01

and adhesive solution containing different amounts of waste sunflower oil. It can be seen from the Table 5 that as the amount of the modifying additive increases, the residual deformation gradually decreases, i.e. the composite material acquires a certain elasticity.

The energy characteristics of the tested composite materials and their shock absorption, evaluated according to the HIC criterion, are presented in Table 6. The analysis of the results shows that the modifying additive has a favorable effect on the energy characteristics and shock absorption of the composites, and with increasing its amount they improve. The most promising for the production of coatings for playgrounds and sports grounds is the use of composite materials with an adhesive solution containing 40 % of the modifying additive, where the best energy performance is obtained, especially necessary for such applications. This is confirmed by the results established by the evaluation of the impact assessment on the base of HIC criterion. The low value of the HIC criterion indicates that when using composites as coatings for playgrounds and sports grounds, the probability of injury in a fall is low. Undoubtedly, the use of the modifying additive of used sunflower oil has an effect for this good result, which has a positive effect on the elasticity of materials and its ability to absorb more energy on impact. It can also be seen that all studied composite materials of the developed type have values of the HIC criterion well below 1000, which makes them without exception suitable for such applications [13].

The sound absorption coefficient α_ω of the tested composite materials is presented in Table 7. It is seen that as the amount of the modifying additive increases,

Table 6. Energy characteristics and shock absorption of composite materials based on waste rubber vulcanizates and polyurethane adhesive solutions containing waste sunflower oil as a modifying additive (Indications 0, 10, 20, 30 and 40 indicate the amount of the modifying additive, %).

Code of the mixture	Potential elastic energy, J	Energy density, kJ/m^3	Shock absorption, HIC criterion
ASH 8003 - 0	7.264	35.81	902
ASH 8003 - 10	7.511	37.06	873
ASH 8003 - 20	7.454	36.78	853
ASH 8003 - 30	7.543	37.17	851
ASH 8003 - 40	7.721	37.61	845

Table 7. Sound absorption coefficient of composite materials based on waste rubber vulcanizates and adhesive solutions containing waste sunflower oil as a modifying additive (Indications 0, 10, 20, 30 and 40 indicate the amount of modifying additive in the adhesive).

Code of the mixture	Sound absorption coefficient, α_ω
ASH 8003 - 0	0.58
ASH 8003 - 10	0.58
ASH 8003 - 20	0.60
ASH 8003 - 30	0.61
ASH 8003 - 40	0.62

Table 8. Sound absorption class of composite materials according to their sound absorption coefficient.

Sound absorption class	Sound absorption coefficient, α_ω
A	0.9-1.0
B	0.80-0.85
C	0.60-0.75
D	0.30-0.55
E	0.15-0.25
Not classified	0.00-0.10

the sound absorption coefficient, although insignificant, increases too.

From the comparison with the classification presented in Table 8 it may be concluded that the developed materials with a quantity of the modifying additive over 10 % can be classified in class C, which allows their use as sound-insulating and sound-absorbing sealing material in railway and tramway tracks, as well as in the construction of soundproofing of buildings.

The positive effect of used sunflower oil on the properties of the composites (presented in Tables 3 - 7) can be related to its composition: sunflower oil is composed of linoleic acid, a polyunsaturated omega 6-fatty acid ($C_{18}H_{32}O_2$, density 0.9 g/cm^3), contained in the largest amount (about 62 %) and oleic acid, a monounsaturated-omega 9-fatty acid ($C_{18}H_{34}O_2$, density 0.859 g/cm^3), about 26 %. It contains also small amounts of palmitic (about 6 %), stearic acid (about 3.5 %) and other fatty acids in smaller amounts [14]. Linoleic acid easily reacts with oxygen in air which leads to crosslinking and formation of a stable film thus being a surfactant. Probably this additional crosslinking and the formation of a stable film is one of the reasons for the improvement of the characteristics of the composites. In addition, as a surfactant, it necessarily improves the wetting of the rubber granules and contributes to a more complete interaction with the adhesive, which in turn leads to a stronger adhesive bond. Oleic acid is an emulsifying agent and contributes to the good properties of the adhesive solution, turning it into a stable emulsion. Added to the emulsion with the adhesive, it stabilizes it and prevents its delamination, i.e. it also has a positive effect on the interaction of the adhesive solution with the rubber granules. Palmitic and stearic acid are known for their plasticizing and dispersing action in rubber technology. It has been found that some of the fatty acids contained in unused fresh sunflower oil are retained after heating, in our case after its use for frying. R. Kovalski points out that as a result of heating at 90°C for 120 hours, the content of linoleic acid in sunflower oil decreases from 50.0/100 g of oil to 40.3/100 g [17], i.e. by about 20 %. Frying is usually carried out at temperatures in the range of 160 - 170°C, but in this case also a part of the acids, although smaller, is preserved (according to some authors [18] – 24 - 25 %), which can explain the improvement of the characteristics of the composites. In addition, the ongoing degradation processes result in a wide variety of products [19], some of which probably also have a positive effect on the composite performance.

Technological model for the production of composites

The obtained results show that the most promising for possible production are the composite materials in which the adhesive ASH 8003 with waste sunflower oil in the amount of 30 - 40 % as a modifying additive is used. The following facts contribute to this assessment: under the same other conditions, the adhesive solution used has the lowest viscosity, the processing has the lowest energy costs and the composites have the best sound-insulating, sound-absorbing and shock-absorbing properties. The results of the conducted research in laboratory and industrial conditions made it possible to present a technological model for the production of composite materials (Table 9). The mixing of the rubber particles with the adhesive solution is performed in a planetary mixer as follows: the whole amount of adhesive is loaded, the modifying additive is added (30 - 40 % by weight of the adhesive), after homogenization for 5 minutes the rubber particles are added and homogenization is performed again for 7 min. The optimal mixing speed is 20 - 100 min^{-1}. Water in amount of 2.5 % by weight of adhesive is sprayed on the mixture thus obtained, catalyzing the process of its crosslinking, after that the mixture is transferred to a mold, and the mold is placed in a hydraulic press.

Table 9. Technological model for production of sound- and shock-absorbing composite materials.

	Name of the operation	Temp., °C	Time, min.
1.	Mixing of adhesive and modifying additive	room	5
2.	Mixing the rubber particles with the adhesive solution	room	7
3.	Spraying the catalyst	room	1
4.	Loading the press form and sealing	room	2
5.	Pressing the article (pressure 10 MPa)	120	15
	Total processing time		30

CONCLUSIONS

A composition and a technological model for the production of sound- and shock-absorbing composite material have been developed, for which purpose waste ground rubber vulcanizates with particle sizes of 2 - 3 mm and one-component polyurethane adhesive containing as a modifying additive waste sunflower oil in optimum amount of 30 - 40 % wt. with respect to the adhesive are used. No description of a similar composition with similar applications has been found in the literature.

A positive effect of the modifying additive on the technological process and the properties of the composite materials have been established. It is associated with the fatty acids (mainly linoleic and oleic) contained in the waste sunflower oil, having a surface active and emulsifying action, lowering the viscosity of the adhesive solution, improving wetting of the ground waste vulcanizates and as an effect of the above described -creation of stronger adhesive bonds with the participation of a larger number of particles.The conducted tests and the obtained results give grounds to believe that the composite material developed can find applications as a sealing element in railways of rail and tram transport, in construction for sound insulation of buildings, as well as for covering children's and sports grounds.

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