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Influence of the type of layered distribution of rubber recyclate as an additive modifying the mechanical properties of epoxy-glass composites

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ABSTRACT

Purpose: The research aimed to determine the effect of adding rubber recyclate as a sandwich layer of sandwich composites made based on glass mat and epoxy resin EPO 652.

Design/methodology/approach: Four types of research materials with a 5% addition of rubber recyclate and with different ways of layer distribution in the composite and one variant without the addition of recyclate as a comparative material were produced for the study. Samples made of the materials in question were subjected to a static tensile test to determine the changes in strength parameters caused by the addition and distribution of the modifier.

Findings: Four types of research materials with a 5% addition of rubber recyclate and with different ways of layer distribution in the composite and one variant without the addition of recyclate as a comparative material were produced for the study. Samples made of the materials in question were subjected to a static tensile test to determine the changes in strength parameters caused by the addition and distribution of the modifier.

Research limitations/implications: As a result of the conducted research, the fundamental influence of the recyclate additive and its distribution method on the changes in parameters recorded during the static tensile test was clearly found.

Practical implications: The analyses carried out enable the selection of the optimal material variant depending on the intended application.

Originality/value: The analysis of the preliminary results obtained during the research showed that epoxy-glass composites based on EPO 652 resin with the addition of rubber recyclate in the form of two and three sandwich layers have better strength parameters than the composite with random addition of recyclate to the matrix. The material characterized by the highest plasticity is a variant with two layers of recyclate spacers. At the same time, it can be stated that the highest values of relative deformation ε obtained a composite with one sandwich layer of rubber recyclate.

Keywords: Epoxy-glass composites, Recycling, Rubber recyclate, Static tensile test, Modification

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PROPERTIES

1. Introduction

Nowadays, polymer materials are used in many industries, including in construction, transport or the production of sports equipment, due to their low weight and favourable flexible parameters [1,2].

The constantly growing consumption of polymer materials and the long-time of their decomposition have contributed to the problem of polymer waste management, which is important for ecology. There are several variants for solving this problem. These are material, raw material and energy recycling, allowing the reuse of rubber waste in the production cycle.

An example of material recycling of rubber waste is the reuse of shredded material as a filler for the production of new products [3]. An example of such a solution may be shredded waste from car tires, used in road construction as a filling of the road embankment, posts for marking road gauges or roadside elements of acoustic screens [4].

In most of the solutions used in composite materials, the addition of recyclate is aimed at using the maximum amount of rubber additive as a filler and elastic material (elastic) with a limited range of strength parameters of finished elements [1].

In epoxy-glass composites with the addition of rubber, the glass fibre reinforcement is filtered with epoxy resin, and the rubber is added as a modifier to the epoxy resin, constituting the composite matrix [5]. Recent studies have shown that rubber in the form of rubber recyclate can be used as a modifying additive for epoxy-glass composites to increase their flexibility and impact strength [6-8].

For some composites, chemical and thermal pre-treatment of the rubber recyclate is necessary to increase its adhesion [9,10]. Such treatment was presented in the works [9] and [11], where the results of research concerning the development and characterization of properties of polyurethane-rubber composites (KPG) produced with the participation of modified rubber recyclate are presented. Studies of mechanical and functional properties obtained from KPG have shown that they are characterized by higher indicators of mechanical and functional properties about their close analogues, currently produced mainly in the form of composite surface products.

In the article [12], the results of research on obtaining new polymer compositions based entirely on secondary raw materials by physical modification are presented. Recyclates of thermoplastics, rubber waste from car tires and thermally treated phosphogypsum and activated chalk were used as a polymer matrix. It was found that porous hoses obtained from such compositions have properties qualifying them for use in irrigation systems, for filling noise suppression screens, as well as fillings for columns for biological wastewater treatment.

In the article [1], the mechanical properties were investigated, and the natural frequencies of the materials that make up composite structural panels for structural applications with the addition of rubber layers were calculated.

At work [13], The mechanical properties of epoxy resin filled with recycled rubber are described. Microparticles of recycled rubber have affected the mechanical properties of the polymer in which they are dispersed. In this work, the cohesion and adhesive properties of the filled epoxy resin were quantitatively determined.

In development [14], Studies of a composite based on granules from used car tires are presented. The composite contained plastic, which acts as a binder. Particular attention was paid to the use of this material for the manufacture of noise-dampening screens as well as vibration isolation in the food processing industry.

In research [15] a new design of lightweight and cost-effective composite materials for the aerospace industry was proposed, using recycled rubber, epoxy resin and graphene nanoplates. After the composites were manufactured, their bending strength and fracture characteristics were examined using three-point bending tests. The results of mechanical tests showed that the addition of graphene nanoplatelets increased the elastic modulus and fracture toughness of the new composites.

Current research also examines the feasibility of using surface-processed recycled rubber particles to cure epoxy polymers. In the article [10], It was shown that the addition of recyclate, in this case, resulted in an increase in the plastic zone and ensured significantly higher resistance to cracking.

This work aims to produce and test newly developed epoxy-glass composites with a limited edition of recyclate (maximum 20% of weight) with maintaining or slightly reducing the strength parameters. At the same time, the intention is to obtain a material with increased vibration damping and acoustically insulating properties about the same composite without using rubber recyclate.

2. Description of the approach, work methodology, materials for research, assumptions, experiments etc.

2.1. Creation of research materials

EPO 1w, 2w and 3w epoxy-glass composites were manufactured using a glass mat with random fibre direction and a weight of 350 g/m^2, epoxy resin EPO 652 with IDAR hardener and rubber recyclate. The research material was made as a sandwich composite containing 1, 2 and 3 layers of rubber recyclate, respectively. All composite variants produced contained 5 weight by weight, rubber recyclate. The rubber recyclate came from car tires subjected to a mechanical shredding process. As a sandwich layer, a rubber recyclate fraction with a grain size of ≤1.5 mm was used. This fraction was used in the process of sieving rubber recyclate on the laboratory sieve shaker LAB-11-200 from EKOLAB. The tested composite materials were produced by manual lamination. For manual lamination, a rectangular steel mould with dimensions of 300 x 900 mm, brushes and rollers were used.

The reinforcement of the manufactured materials was EPO 652 epoxy resin, characterized by high mechanical resistance, among others, for abrasion. As a hardener, modified cycloaliphatic amine IDA was used in the amount of 50g hardener per 100g resin. Table 1 presents the physico-chemical parameters of the resin and hardener used [16,17].

As the base material about which the results obtained from other variants of composites were compared, EPO 0 composite was used, which is a material without the addition of rubber recyclate, based on epoxy resin EPO 652 and glass mat with a random direction of fibres and a weight of 350 g/m^2. The EPO 0 composite consisted of 12 layers of glass mat successively filtered with EPO 652 resin mixed in a fixed proportion with the hardener.

Table 1.
Reinforcement characteristics of research materials

		EPO 652	IDA
Parameter	Unit	Value	Value
Epoxy number	mol/100g	0.48-0.51	-
Amino number	KOH/g	-	200-350
Density at 25°C	g/cm^3	1.10	1.03
Viscosity at 25°C	mPa*s	500-900	150-300
Gelation time of 100 g at 20°C	min	40	-
Curing time at 20°C	days	7	-

Table 2 presents the composition of the produced variants of research materials.

From the manufactured variants of composite materials, they were cut using the water-cutting method of the sample to carry out a static tensile test. The water-cutting method was used to minimize the influence of temperature on the structure of the tested material variants. The shape and geometry of the samples made for the impact test on the Charpy Hammer were made following the PN-EN ISO 527-4_2000P [15] standard for plastics.

Table 2.
Composition of tested composite materials with the addition of rubber recyclate

Composite designation	Number of mat layers	Resin content, %	Mat content, %	Number of layers of rubber recyclate	Recyclate content, %
EPO 0	12	60%	40%	0	0%
EPO 1w 5%	12	60%	35%	1	5%
EPO 2w 5%	12	60%	35%	2	5%
EPO 3w 5%	12	60%	35%	3	5%

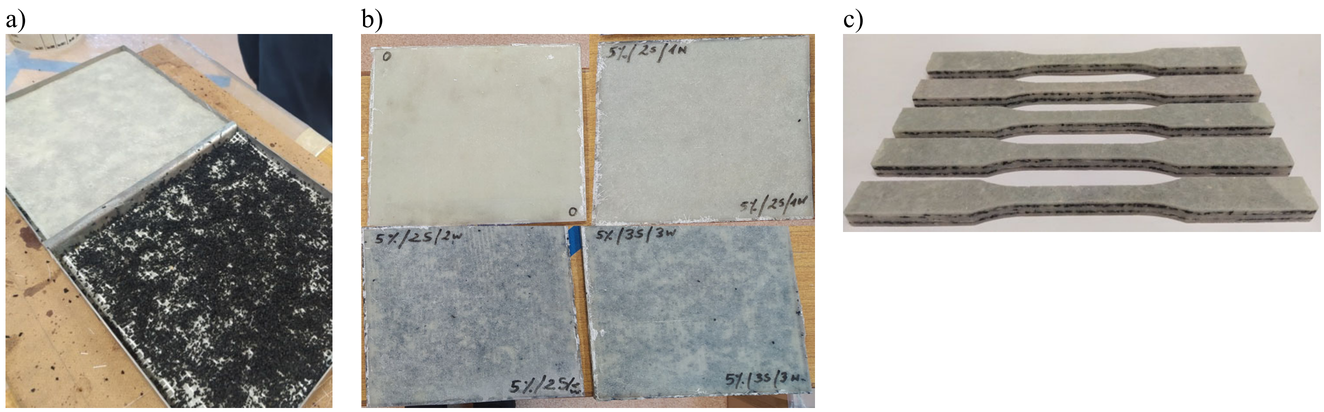


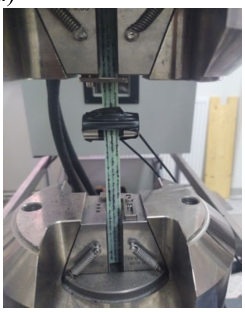
Fig. 2. a) Manufacturing EPO 2w 5% composite; b) Research materials, From the left: EPO 0, EPO 1w 5%, EPO 2w 5%, EPO 3w 5%; c) 2w 5% EPO samples for static tensile testing

Figure 2 shows the individual stages of preparation of EPO 2w 5% test materials and samples from EPO 2w 5% material cut by water cutting, used to carry out a static tensile test.

2.2. Experiment planning and conditions

Samples from four variants of composite materials subjected to static stretching on a universal Zwick & Roell testing machine, with variable load parameters, with hydraulic drive type MPMD P10B. TestXpert II version 3.61 was used for the trial. Test results for samples were recorded using Zwick & Roell-TestXpert II version 3.61 software. The tests were carried out on four variants of manufactured composite materials; each variant, a series of 10 measurements were carried out.

a)



b)

Fig. 3. a) Sample with EPO 3w 5% during static tensile post; b) view of EPO samples 3w 5% after breaking

Figure 3 shows a view of the EPO 3w 5% composite sample fixed in the holders of the testing machine and the broken specimens after a static tensile test.

3. Description of achieved results of own research

3.1. Research results

As a result of the research carried out on variants of composite materials, graphs of tensile curves and values of parameters regarding elasticity, plasticity and strength of composites were obtained.

Table 3 presents the values of the strength parameters of the tested materials obtained as a result of a static tensile test.

Table 3.
Strength parameters of epoxy-glass composite materials based on EPO 652 resin

Material designation	σ_m, MPa	ε, %	E, MPa
EPO 0	97.53	2.41	6530
EPO 1w 5%	67.52	2.43	4436
EPO 2w 5%	52.19	2.15	4785
EPO 3w 5%	73.09	2.10	4827

Figure 4 shows selected examples of tensile curves for the tested materials. Three curves representing the course of the static tensile test of each composite were selected.

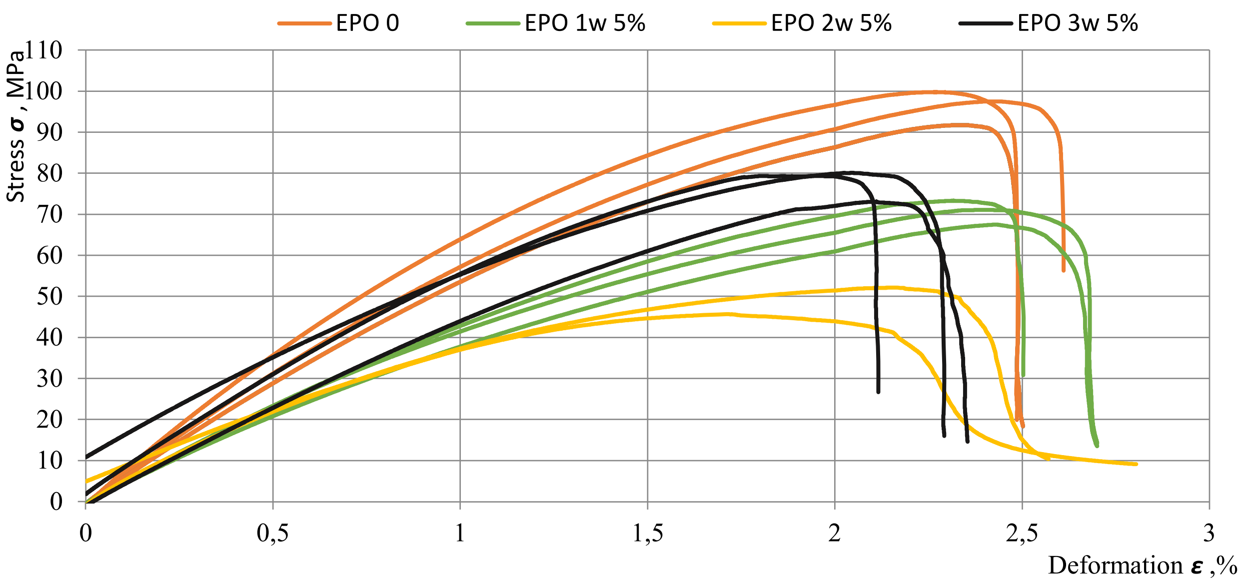


Fig. 4. Tensile curves for EPO 652 resin-based composites

3.2. General remarks

As a result of the analysis of the obtained test results, it can be concluded that the addition of rubber recyclate to the epoxy-glass composite may modify the properties of the strength and elasticity of such a composite. The tensile strength of the modified composite decreases significantly, while its elasticity decreases slightly. The tensile strength value of σ_m in the case of EPO 1w 5% material was lower by 30.77% compared to the material without the addition of recyclate. The tensile strength value of σ m in the case of EPO 2w 5% material is lower by 46.49% compared to the material without the addition of recyclate, while the EPO 3w 5% material shows the best tensile strength properties of σ_m at a level of 25.06% decrease compared to the reference material, without the addition of recyclate.

However, the plasticity of the material with the addition of recyclate to the resin does not decrease significantly. It is worth noting that the value of relative deformation ε composite with the addition of rubber recyclate is more advantageous in the case of the addition of rubber recyclate in the form of one sandwich layer. In this case, the decrease in the strain value compared to pure composite was 0.83%.

Table 4 presents a summary of the percentage differences of σ_m, E and ε values for variants of materials with the addition of rubber recyclate compared to the values of these parameters for *material EPO 0*.

Table 4.
Percentage differences in strength parameters for material EPO 0

Material	σ_m, MPa	E, MPa	ε, %
EPO 1w 5%	-30.77	-32.07	-0.83
EPO 2w 5%	-46.49	-26.72	-10.79
EPO 3w 5%	-25.06	-26.08	-12.86

4. Conclusions

The analysis of the results obtained during the research showed that the epoxy-glass composite based on EPO 652 resin with the addition of rubber recyclate as a sandwich layer in the composite has weaker strength parameters than a pure composite based on the same resin. These types of material have lower tensile strength values than pure EPO 0 epoxy-glass composite, but they have promising elastic properties. The authors intend to continue research on the materials presented in the article. The research will be focused on developing a technology for making a composite with the addition of rubber recyclate, which will have higher elasticity parameters compared to the material without the addition of recyclate and will additionally have soundproofing and sound-damping properties. Such materials can be used for the construction of bulkhead walls on small composite yachts and elements of gym walls on a vessel.

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