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Composites with Short Fibers Reinforced Epoxy Resin Matrix

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Abstract

The paper includes a research on the obtaining characteristics and physical-mechanical properties of the composites with short fibers reinforced epoxy resin matrix. We used four types of resins: T 19-38 / 500, T 19-38 / 700, L 50-54, A 19-00 and two types of reinforcing materials: Kevlar pulp and glass fiber. From the composites prepared in the injection phase (homogeneous mixture of matrix and fibers) were performed the standard samples to analyze the mechanical properties by pressing in a metallic mold. They were then subjected to a study to analyze the actual physical properties (density, component proportions) and mechanical properties (specific resistance, elastic modulus, elongation, etc.).

Keywords: composites; epoxy resin matrix; short fiber reinforcement; mechanical properties; physical properties.

1. Introduction

Short fiber-reinforced epoxy resin composites are an important class of tribological materials that possess significant mechanical properties. These materials are widely used in chemical engineering, sporting goods, automotive, aerospace and defense industry, friction materials etc. [1,2].

Epoxy resin is a commonly used thermosetting polymer matrix which already covers alone some of the demanded properties. However, because the polymer matrix must withstand high mechanical and tribological loads, it is usually reinforced with fillers. These fillers can be chosen as fibers (glass, carbon, and aramid) or particles such as ceramic powders [3,4,5]. Shi et al. [6] incorporated nanometer Si_3N_4 into epoxy. The testing results indicated that the

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composites exhibited significantly improved tribological performance and mechanical properties at rather low filler content.

Kevlar pulp is a kind of short, tough, highly fibrillated aramid fiber which provides improved wear resistance and friction stability [7,8,9]. Wear-resistant thermoplastic composites offer enhanced mechanical properties and higher use temperatures, with significantly lower wear rate and essentially zero abrasive action [10,11,12].

Glass fibers shows the important technological characteristics correlated with low density. For this reason, polymer materials reinforced with such fibers have the best strength-weight ratio. Pihtili et al. [3] investigated the wear behavior of glass fabrics and aramid fibre–reinforced composite materials. The results showed that the weight loss of aramid fiber reinforced epoxy composite is quite low compared with glass fabric reinforced composites. Wang et al. [14] studied the mechanical properties of glass fiber reinforced epoxy composites. In general, additives used in high concentrations lead to the reduction inmechanical properties of the polymer matrix [15,16]. However, the incorporation of graphene improves both flexural and impact modulus but decreases strength and tensile modulus.

Yahaya et al [16] investigated the mechanical properties of the kenaf-aramid fiber reinforced epoxy composites. Kevlar fiber reinforced epoxy resin shows higher flexural and tensile properties compared to kenaf fiber reinforced composites. Instead impact properties of kenaf fiber reinforced composites are higher than Kevlar fiber reinforced composites. As the number of layers is higher the mechanical properties are higher.

The purpose of this paper is to study the obtaining of composite materials with epoxy resin matrices and their behavior. We aimed to clarify some aspects of achieving composites, especially those of mixture homogenization matrix - reinforcing fibers respectively for obtaining a appropriately final product quality.

2. Experimental research

2.1. Materials preparation

For matrix were used four types of epoxy resin (see the table 1) or their curing agents (see the table 2). Reinforcing materials used are Kevlar pulp (type: 1F1417; average weight, 1.02 g / cm^3; moisture, 8%; manufactured by DuPont) and glass fiber (maximum in length, 5 mm) and are shown in fig. 1.

Before of use the Kevlar pulp was dry in oven at 110 °C for several hours for good wetting it [17].

Table 1. Physico-chemical characteristics for epoxy resins

No.	Resin type	Epoxy equivalent, g	Density at 20 ^{0}C , g/cm^3	Viscosity at 25 ^{0}C, mPa*s	Colour, Gardner	Solid content , %	Mixing ratio
1.	T 19-38 / 700 (R1)	180 - 200	≈ 1.13	500 - 900	-	-	100 g of resin / 60 g of curing agent
2.	T 19-38 / 500 (R2)	180 - 200	≈ 1.13	400 - 600	-	-	100 g of resin / 60 g of curing agent
3.	A 19-00 (R3)	182-192	1.14	9000-13000	< 2	-	100 g of resin / 60 g of curing agent
4.	L 50-54 (R4)	450 - 500	1.09	7000-11000	< 2	74 - 76	100 g of resin / 70 g of curing agent

Table 2. Physico-chemical characteristics for curing agents

No.	Material name	Aspect	Equivalent amine, g	Index amine, mgKOH/g	Density at 20 0C, g/cm3	Colour, Gardner	Viscosity at 25 0C, mPa*s	Mixing ratio
1.	H 10-25	liquid	≈ 340	155 - 185	0.94 ± 0.02	< 8	440 - 1200	100 g of resin / 70 g of curing agent
2.	H 10-30	liquid	93	250 - 350	1.03 ± 0.02	< 2	200 - 300	100 g of resin / 60 g of curing agent

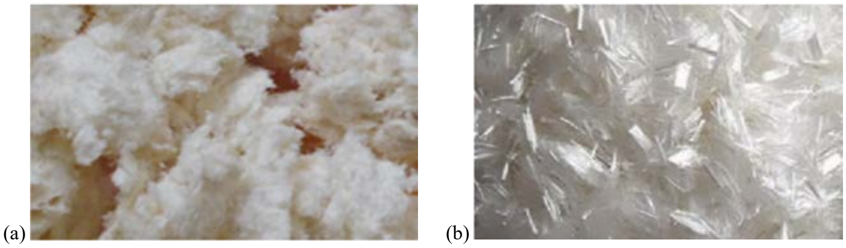


Fig. 1. Reinforcing materials: a) kevlar pulp; b) glass fiber chopped.

2.2. Composites preparation

For achieving each type of composite the base resin was dosed in a appropriately container and was added it over the appropriate proportion of agent curing (see combinations of Table 3).

After 5 minutes mixed to homogenize the two components, was introduced reinforcing material: pulp kevlar or glass fiber, and continued the mixing until to the homogenization composite thus prepared.

The composite material thus obtained was introduced in a mold (fig. 2) that was pressed by hand tightening. Were obtained the standard specimens with dimensions of 250 x 25 x 5 mm (Fig. 3 a and b). They were then subjected to a study to determine the actual physical properties (density, scale components) and mechanical properties (specific resistance, modulus, elongation, etc.).

Fig. 2. Metallic mold

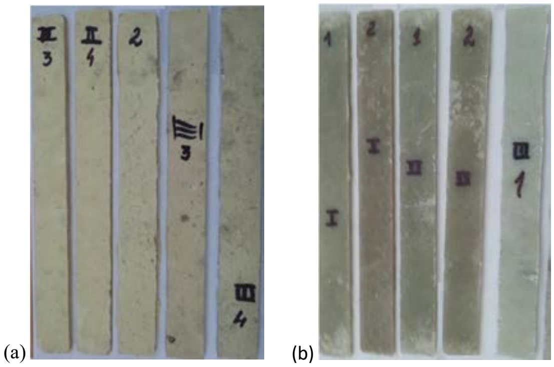


Fig. 3. Composite with epoxy resin matrix: a) reinforced with kevlar pulp; b) reinforced with chopped glass fiber.

2.3. Defining of the physical characteristics

For determining the physical characteristics were measured volume and weight of the samples being calculated composite densities.

For the indirect determination of the matrix and reinforcing filler proportion were performed theoretical calculations using the physical data previously determined and the known physical properties or determined for reinforcing filler.

The results of these calculations are summarized in Table 3.

Table 3. The physical properties (experimental determinated) of the kevlar pulp or glass fiber reinforced epoxy resin composites

No. sample	Composite structure	Mass, [g]	Volume, [cm3]	Density, [g/cm3]
I.1	T 19-38/700 + H 10-30; kevlar pulp	1.24	1.33	0.93
I.2		1.46	1.35	1.08
I.3		1.29	1.25	1.03
I.4		1.34	1.31	1.02
II.1	T 19-38/500 + H 10-30; kevlar pulp	2.22	2	1.11
II.2		1.34	1.33	1.01
II.3		1.54	1.75	0.88
II.4		1.26	1.33	0.95
III.1	A 19-00 + H 10-30; kevlar pulp	1.52	1.42	1.07
III.2		1.4	1.38	1.014
III.3		1.69	1.67	1.011
III.4		2.25	1.88	1.2
IV	L 50-54 + H 10-25; kevlar pulp	1.25	1.33	0.939
I.1	T 19-38/700 + H 10-30; glass fiber	1.42	1	1.42
I.2		1.59	1.22	1.30
II.1	T 19-38/500 + H 10-30; glass fiber	1.59	1.25	1.27
II.2		1.58	1.2	1.316
III.1	A 19-00 + H 10-30; glass fiber	1.6	1.25	1.28
III.2		1.52	1	1.52
IV.1	L 50-54 + H 10-25; glass fiber	1.26	1.3	0.969
IV.2		2.2	2	1.1

2.4. Defining of mechanical properties

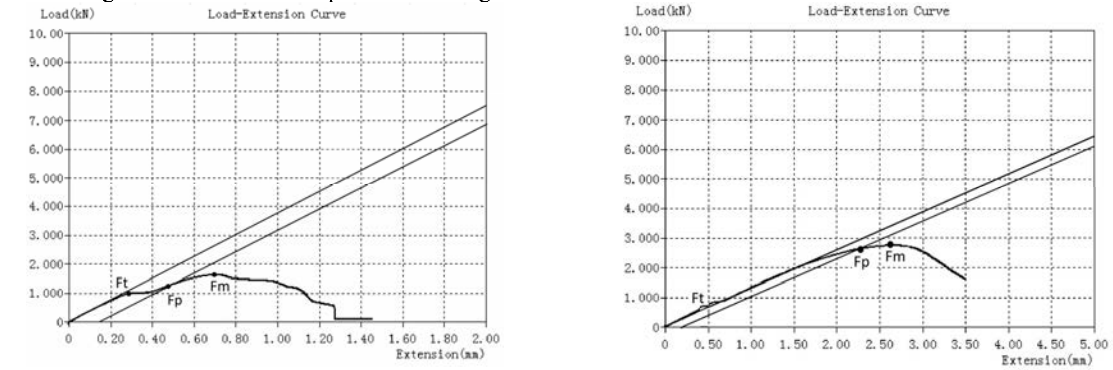
Tensile strength was done according to STAS SR EN ISO 527-1 on testing machine WDW-150S. Test specimens with the dimensions of 250x25x5 mm composite was requested at tensile along their axes until to breaking (fig. 4 a and b).

a.

b.

Fig. 4. The specimens after tensile testing: (a) glass fiber chopped reinforced epoxy resin composites; (b) kevlar pulp reinforced epoxy resin composites

Tests diagrams are of the form presented in Fig. 5.

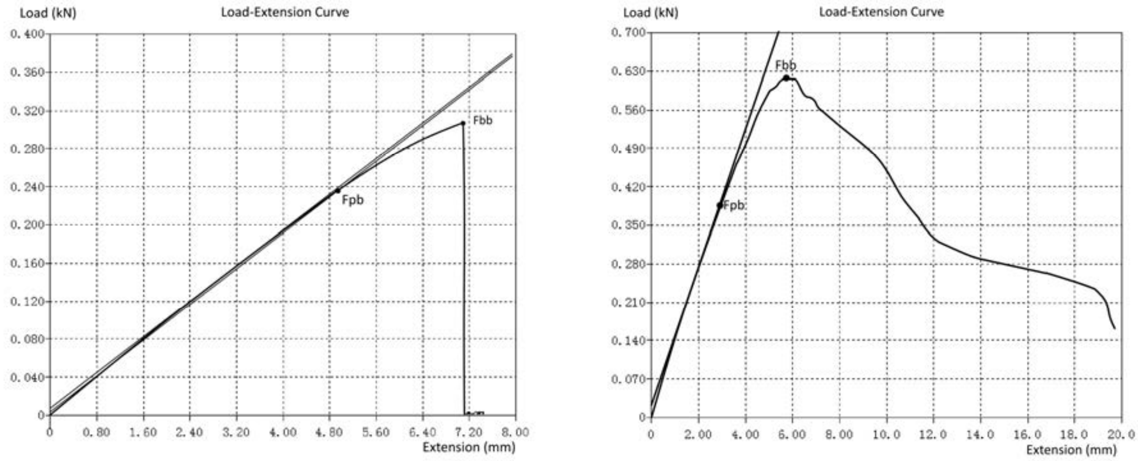


(a) (b)

Fig. 5. Load extension curve for specimen from composite with epoxy resin matrix: (a) reinforced with kevlar pulp; (b) reinforced with chopped glass fiber.

Flexural strength was achieved in three-point bending according to STAS SR EN ISO 14125. WDW-150S test machine is used. Test specimens used for testing were cut after dimensions 80x10x5 mm, taken from the specimens of initial size.

Diagrams flexural tests are of the form presented in Fig. 6.



(a) (b)

Fig. 6. Load extension curve for specimen from composite with epoxy resin matrix: (a) reinforced with kevlar pulp; (b) reinforced with chopped glass fiber.

Impact resistance or resilience was done according to STAS SR EN ISO 13586 on a testing machine pendulum type (Charpy hammer). Test specimens used for testing were cut by the dimensions 55x10x5 mm.

3. 3. Results and discussion

3.1. Tensile strength

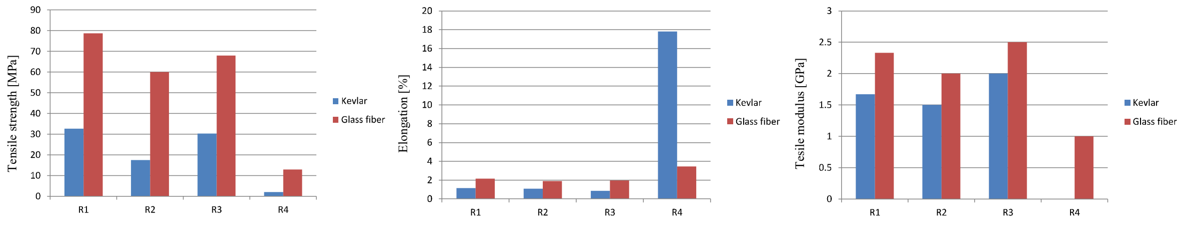
From the diagrams obtained from tensile tests were extracted a number of representative data for testing, which were later processed (Table 4 and Fig. 7 a, b, c).

They found significant differences in the composites behavior achieved at tensile testing. An important role has primarily matrix composite. As seen in table 4 and figure 7. Total inappropriate properties were observed in the case L 50-54 epilox resin+ H 10-25 agent curing, which after preparation remains into a relatively low stage of stiffener (see elongation very high at breaking in the case reinforced with kevlar pulp). Other resin matrix gives a rigid enough structure so that the mechanical characteristics become attractive.

Besides the matrix, the nature and the size of reinforcement fibers are decisive. Short fibers of glass (length, around 5 mm) ensure superior mechanical properties compared with Kevlar pulp: values of 3 times higher for breaking strength, elongation of 1.5-2 times higher and Young modulus values approximately 25% higher. An explanation of this reality may be that the Kevlar pulp geometry not gives it the possibility to takeover of the efforts at stress in a similar way of fibers.

Table 4. Results of tensile test, flexural test and impact test for specimens taken

No. sample	Composite structure	Resistance to tensile			Resistance to flexural		Resistance to impact	
		Tensile strength , [MPa]	Elongation, [%]	Tensile modulus, [Gpa]	Energy at rupture, [J]	Flexural modulus, [GPa]	Energy consumed, [J/cm2]	Resilience, [J]
I.1	T 19-38/700 + H 10-30; Kevlar pulp	22	0.8	1	1.200	3.0	0.06	10.88
I.2		41	1.3	2	0	9.0	0.066	11.14
I.3		35	1.4	2	1.177	2.5	0.065	11.79
I.4					1.177	2.5	0.06	11.05
	Mean	32.67	1.17	1.67	1.185	4.25	0.063	11.22
II.1	T 19-38/500 + H 10-30; kevlar pulp	12	1.3	2	1.141	1.5	0.08	11.63
II.2					0.075	3.0	0.0775	14.28
II.3					0.092	3.0	0.075	13.36
II.4		23	0.9	1	1.313	2.5	0.066	14.23
	Mean	17.5	1.1	1.5	0.655	2.5	0.075	13.38
III.1	A 19-00 + H 10-30; kevlar pulp	10	0.6	2	0.032	3.5	0.06	9.44
III.2		38	1.3	2	0	4.0	0.056	10.54
III.3		43	1.5	2	0.048	4.5	0.076	12.93
III.4		30	0.1	2	1.092	3.5	0.09	12.47
	Mean	30.25	0.875	2	0.391	3.875	0.071	11.35
IV	L 50-54 + H 10-25; kevlar pulp	2	17.8	-	0.447			
I.1	T 19-38/700 + H 10-30 ; glass fiber	107	3.1	2	11.456	11.5	0.58	116.72
I.2		47	1.7	3				
		82	1.7	2				
	Mean	78.67	2.17	2.33	11.456	11.5	0.58	116.72
II.1	T 19-38/500 + H 10-30; glass fiber	46	2	2	13.642	2.5	0.6	112.37
II.2		74	1.8	2	7.202	5.0		
	Mean	60	1.9	2	10.422	3.75		
III.1	A 19-00 + H 10-30; glass fiber	102	2.6	2	0.178	13.5	0.45	69.78
III.2		34	1.3	3	2.024	3.5	0.35	55.55
	Mean	68	1.95	2.5	1.101	8.25	0.4	62.67
IV.1	L 50-54 + H 10-25; glass fiber	9	4.4		2.189			
IV.2		17	2.5	1	1.830	0.5		
	Mean	13	3.45	1	2.001	0.5		

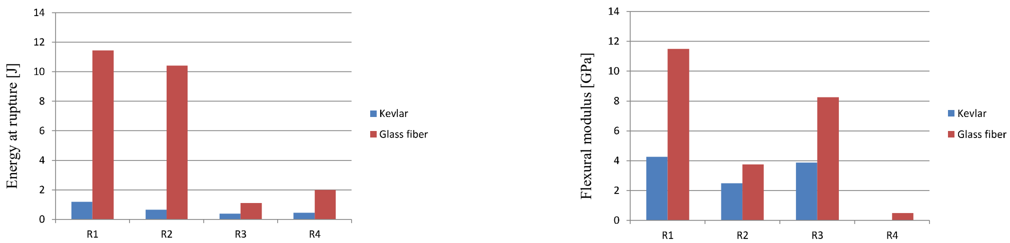


a. b. c.

Fig.7 Variation: a) tensile strength depending on the resin type; b) elongation depending on the resin type; c) Tensile modulus depending on the resin type.

3.2. Flexural strength

From the diagrams obtained from flexural tests were extracted a number of representative data for testing, which were later processed (Table 4 and Figure 8 a, b). The flexural behavior is similar to a tensile testing both in terms of matrix as well as reinforcing materials used.

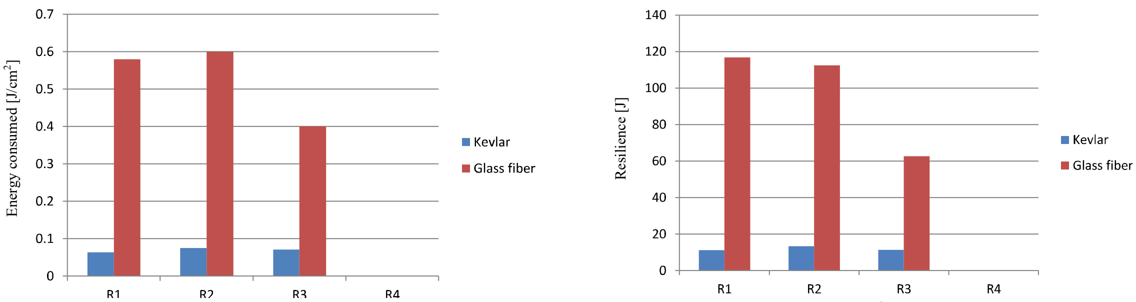


a. b.

Fig.8 Variation: a) Flexural strength depending on the resin type; b) Flexural modulus depending on the resin type.

3.3. Impact strength or resilience

Impact strength test results are shown in Table 4. The impact behavior is similar to a tensile and flexural testing both in terms of matrix as well as reinforcing materials used.



a. b.

Fig.9 Variation: a) Energy consumed depending on the resin type; b) Resilience depending on the resin type.

4. Conclusions

From the results it is observed that the composites reinforced with glass fibers have properties much better than those with Kevlar. The best mechanical properties (tensile strength, flexural strength and resilience) has the composites with the T 19-38/700 epilox resin matrix reinforced with a glass fiber.

Compared with results from the literature glass fiber reinforced epoxy resin matrix composites were obtained approximately equal values to the mechanical properties: tensile, flexural and impact [3,14,15,16,18]. For kevlar pulp reinforced epoxy resin matrix composites they were not found in the literature data on mechanical properties. In conclusion, deduction of mechanical characteristics of the performed composites was allowed to obtain the new data for the field.

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