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ABOUT EXPERIMENTAL RESEARCH OF TENSILE LOADED COMPOSITE MATERIALS USED IN AUTOMOTIVE INDUSTRY

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Abstract: *This paper presents an experimental study about 3 sets of composite materials: glass fibers MAT 300, COREMAT and composite sandwich with glass fibers MAT 300 and COREMAT core. In today's society, the automotive industry is constantly evolving and perfecting, which requires finding new materials, compatible with new trends: reducing the weight of car, increasing corrosion resistance, increasing protection against shocks, increasing comfort, increasing operational safety, using an expanding variety of technologies or reducing the cost of production. We made a new composite material, a composite sandwich with COREMAT core. Due to results obtained in this work, this composite sandwich will be used to make some car elements, which will be studied at impact in future research.*
Key words: *glass fibers MAT 300, COREMAT, composite sandwich, specimen, tensile test.*

1. INTRODUCTION

Today, the automotive industry is constantly evolving and perfecting, which requires finding new materials, compatible with new trends: reducing the weight of car, increasing corrosion resistance, increasing protection against shocks, increasing comfort, increasing operational safety, using an expanding variety of technologies, or reducing the cost of production. The materials that best meet these conditions are the composite materials.

In this work, we present three of these materials, that were tested in tension: the first set is a MAT 300 glass fiber composite material, the second set is COREMAT material, the third set is a sandwich composite material consisting of MAT 300 glass fibers with COREMAT core. Composite materials are combinations of two or more components with different properties, resulting a composite material with superior properties to the properties of each component.

There are many studies about composite materials in specialized literature, each research being original, due to the composite materials studied, research methodology and future fields of use of composite materials. [5] shows structures of layered composites and [4] gives us a calculus code of a layered composite material reinforced with fibers. [1] presents a theoretical and experimental study of strength and deformability of composite materials used in transport field. For vehicle construction, [2] give structures with high rigidity, made of composite materials. [10] and [11] study robots, another field of composite materials in the future. Aeronautic field is one of the most important fields of use for composite materials, according to [16], [18], [20] and [21].

[3] and [6] study the thermal behavior of composites. Mechanical characteristics of plastics and new composite materials are studied in [7], [8], [9],[24].

[14] presents a theoretical study about structure of ultra-lightweight sandwich composite.

Studies about composites using the Finite Elements Method are presented in [8], [13], [17], [23].

Dampers studies in [12] may be a future research area for composites. Composites are again tested in [15], [19] and [22].

Our research was an original study about tree original composite materials, in order to be

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applied in the future, to impact study of a car body.

2. PREMISES FOR EXPERIMENTAL TESTS

Mechanical characteristics of composite material are determined starting based on specific characteristics of each component.

Values of these characteristics can be determined by tests on specimens, with a well-established, standardized geometry (according to [30]), cut from the same plate and subjected to simple stresses, in event of stretching or traction.

2.1 Manufacture of specimens

Manufacturing of specimens from new composite materials and their use in construction for various structures with increased strength, required a better definition of mechanical and strength composites characteristics.

In this paper, we studied the behavior of 3 sets of specimens made of different composite materials, subjected to tensile stress. We used a test stand consisting of Lloyd's Instruments testing machine, type LR5K Plus and 3 sets of specimens from different composite materials.

Specimens were produced in accordance with standards, after which tensile tests can be performed. Specimens were manufactured by S.C. Composites S.R.L. Brașov, Romania and experimental research was carried out in Materials Testing Laboratory, Department of Mechanics, Transylvania University Brașov, Romania. Specimens made of composite materials, from the three sets to be tested, were subjected to traction or stretching with different forces with increasing values, according to standards, [25], [26], [28] and [29].

We manufactured specimens of type 1B (dumbbell, Fig. 1., [30]), which is type of specimen where failure must occur within the reference length. This type of specimen is used for composite materials reinforced with short or ground fiber.

Geometrical characteristics of type 1B specimens are given in Table 1. and were used as input data for software *Nexygen* that the test machine uses for each test sets.

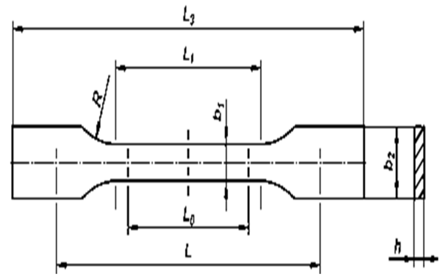

Fig. 1. Test piece type 1B (dumbbell), [30].

Table 1. Characteristics of type 1B specimens, [30]

Notation	Name	Dimension [mm]
L_3	Total length	$\geq \mathbf{150}$
L_1	Total length of the narrow parallel part	$60 \pm \mathbf{0,5}$
R	Radius	$\geq \mathbf{60}$
b_2	Width at the ends	$20 \pm \mathbf{0,2}$
b_1	Width of the narrow part	$10 \pm \mathbf{0,2}$
h	Depth	2 up to 6
L_0	Reference length	$50 \pm \mathbf{0,5}$
L	Initial distance between clamps	$115 \pm \mathbf{1}$

After applying calculus using Nexygen software, for each specimen required for traction, are obtained the following values: Stiffness [N/m], Young's Modulus [MPa], Load at Maximum Load [kN], Stress at Maximum Load [MPa], Machine Extension at Maximum Load [mm], Extension at Maximum Load [mm], Strain at Maximum Load, Percentage Strain at Maximum Load, Work to Maximum Load [Ncm], Load at Maximum Extension [kN], Stress at Maximum Extension [MPa], Machine Extension at Maximum Extension [mm], Extension at Maximum Extension [mm], Strain at Maximum Extension, Percentage Strain at Maximum Extension, Work to Maximum Extension [Ncm], Load at Break [kN], Stress at Break [MPa], Machine Extension at Break [mm], Extension at Break [mm], Strain at Break, Percentage Strain at Break, Work to Break [Ncm], Tensile Strength [MPa].

2.1.1 First set of tensile test specimens, composite based on polyester and glass fabric MAT 300

Composite material with glass fiber fabric MAT 300 is made of continuous threads of ECR type glass fibers, bidirectionally woven, with a density of 300 g/m^2. ECR type glass fiber combines mechanical and electrical properties of traditional E type glass fiber, with high resistance to chemical corrosion, superior thermal resistance, dielectric strength and better surface resistivity. MAT 300 type glass fibers are used together with polyester or epoxy resin in automotive industry as well. MAT 300 glass fibers must be kept in their original packaging until they are used, at temperatures below 35°C and at a relative humidity below 65%. At least 24 hours before use, product must be kept in work area at room temperature (to avoid possible problems that could arise due to moisture condensation). For tensile test of the composite material of MAT 300 glass fibers and polyester, 10 samples were made for the first set.

Table 2. Geometrical characteristics for the first set-composite based on polyester and glass fabric MAT 300

Speci-men no.	Gauge Length [mm]	Width [mm]	Thick-ness [mm]	Area [mm²]
1	50	10,1	3,7	37,37
2	50	10,1	3,3	33,33
3	50	10,2	3,8	38,76
4	50	10,3	3,9	40,17
5	50	10,3	3,7	38,11
6	50	10,4	3,3	34,32
7	50	10,1	3,6	36,36
8	50	10,3	3,8	39,14
9	50	10,2	3,4	34,68
10	50	10.0	3,5	35,00

Geometrical characteristics, that are input data for software *Nexygen*, that testing machine uses, are presented in Table 2.

2.1.2 Second set of tensile test specimens, COREMAT composite material

We used COREMAT Xi composite material with 4 mm thickness from Lantor Composites Company. COREMAT is a material used in composite laminates and is made by pressing, a felt in form of a sheet with a thickness of 4 mm. That is placed between the layers of glass fibers and is impregnated with polyester resin by brushing. It is used to absorb the excess of resin. COREMAT is a polyester non-woven material, made up of 50% microspheres, which results in a saving of almost 40% resin compared to a 100% fiberglass laminate. Economy of glass fibers and resin leads to a decrease in weight of pieces. It is used as a thin core or lining in laminates reinforced with glass fibers. It is necessary to completely soak COREMAT with resin and microspheres, that are in COREMAT interrupt the excessive uptake of resin. Advantages of using COREMAT material are: low weight, resin and glass fibers economy, high rigidity, adequate thickness, perfectly finished surface. Most important properties of COREMAT Xi material are: very good impregnation, being a resin indicator for identifying dry spots and its high resistance.

For tensile test of COREMAT composite material, 10 samples were made for the second set. Their geometric characteristics are given in Table 3.

Table 3. Geometrical characteristics for the second set - COREMAT composite

Speci-men no.	Gauge Length [mm]	Width [mm]	Thick-ness [mm]	Area [mm²]
1	50	11	3,5	38,5
2	50	10,6	2,7	28,62
3	50	10,2	3,3	33,66
4	50	10,2	3,5	35,7
5	50	10,6	3,2	33,92
6	50	10,5	3,7	38,85
7	50	10,7	3,5	37,45
8	50	10,9	3,8	41,42
9	50	10,3	3,5	36,05
10	50	10.6	3,4	36,04

2.1.3 Third set of tensile test specimens, sandwich composite material with COREMAT core

For future uses of new composite materials, tested and presented in this work, the aim is to obtain increased rigidity at a low weight and, above all, good mechanical shock absorption properties.

Composite sandwich with core of COREMAT required for traction has following structure:

- a surface layer - gelcoat - pigmented isophthalic polyester gelcoat;
- a layer of glass fiber - glass fiber type MAT 300 (300 g/m^2);
- the core of COREMAT - 4 mm thick COREMAT core;
- 2 layers of fiberglass - glass fiber type MAT 300.

Applied gelcoat is from manufacturer ITALBEIT, code 109491 P. Surface layer or gelcoat is used to obtain an uniform, glossy surface, to mask the glass fibers, but also to improve the resistance to adverse situations, chemical agents and for possibility of perfecting mechanical characteristics of products, in this case, constituent parts of a vehicle's body. Gelcoat layer has the following composition:

- unsaturated polyester resin, particularly reactive;
- thixotropic agent - the thixotropic agent is an effective additive for resin - based systems;
- pigments for purpose of coloring;
- additions to catalyze and speed up the curing process for the resin;
- possible additions with filling materials.

For manually manufactured parts, gelcoat is especially important, its use guarantees good quality for surfaces made of reinforced materials. Gelcoat must meet the following conditions:

- to have a high reactivity;
- to have a reduced connection to the mold;
- to not have reactions with the separating agent - the separating agent, also called mold release or de-moulding agent, represents the surface between mold and formed piece;
- to not negatively affect the polymerization of molding resin;
- to not move on inclined surfaces;
- to be water resistant;
- to be homogeneously colored.

Amount of pigment used for coloring remains very important when preparing gelcoat. Outward displacement of certain pigments increases fineness of piece's surface. Pigments can affect speed of solidification and water resistance. Thickness of gelcoat layer must be between 0,3 and 0,6 mm, with a consumption of 350 - 700g/m^2. If a layer is applied too thick, cracks will appear. If the layer is too thin, there will be an unfavorable reaction regarding hardening. Gelcoat we use for sandwich composite material is isophthalic polyester resistant to UV, weather and temperature variations and can be applied with a brush or pneumatic gun. Gelcoat is applied to mold surface, after introducing amount of hardener (methyl ethyl ketone peroxide (MEC)), recommended according to temperature of environment in which application takes place. After application, gelcoat is left to harden until next day.

MAT type glass fiber with 300 g/m^2 was used for glass fiber layers. MAT is a product of basic, chopped glass fibers, arranged randomly in absence of a specific direction and immobilized with a binder. The binder is an unsaturated polyester resin, having a melting point between 80 and 130°C, lain down homogeneously over chopped glass fibers with a dusty appearance, with particle sizes between 0,42 and 0,74 mm. To increase adhesion of binder to glass fibers after binder application, water is sprayed, following which conveyor belt passes through an oven that is heated to 180-240°C, where resin melts and ensures adhesion between glass fibers. If MAT layer is for the surface, then look for an even surface layer with a lot of resin. This MAT surface consists of particularly narrow felts made of glass filament with a good capacity for absorption of unsaturated polyester resin. Preparation of specimens for tests was done in accordance with [27] and [30]. The stretching or tensile tests were performed in accordance with [25], [26], [28] and [29]. A plate will be made from which set of specimens will be cut from flat portions of plate. During processing when manufacturing specimens, following conditions were taken into account:

- an intense heat increase in specimen during its processing was avoided (use of a cooling liquid is proposed, but on the condition that specimens are cooked as soon as possible after they have been processed);

- all processed surfaces of specimens were checked so that they did not have processing defects. On the worktable, when preparation of specimens began, de-moulded wax was applied in three successive layers, with complete drying between layers and polishing of each layer with a soft cloth. Fiberglass was cut to size and placed next to worktable. Gelcoat was applied, spread evenly and then allowed to harden. Polyester resin was prepared by homogenization, after weighing amounts of resin and hardener beforehand. First layer of fiberglass was placed over gelcoat and impregnated with resin. COREMAT core was placed over the first layer of fiberglass and impregnated with resin until saturation. Then the other two layers of fiberglass were placed and impregnated. Any air bubbles between the layers of glass fibers and COREMAT were removed with a ribbed aluminum roller. After complete hardening, it was removed from the table with help of a putty knife. Each plate was weighed, then specimens were drawn. Specimens were cut with an angle grinder, adjusted with aluminum files and abrasive cloth, on the contour. When cutting it was taken into account that the material should not be burned by the flex cloth to preserve its integrity. For tensile tests of sandwich composite material with COREMAT core, 10 specimens were made for third set and their characteristics are given in Table 4.

Table 4. Geometrical characteristics for third set - sandwich composite with COREMAT core

Speci-men no.	Gauge Length [mm]	Width [mm]	Thick-ness [mm]	Area [mm²]
1	50	10,7	5,8	62,06
2	50	10	5,8	58
3	50	11,2	5,6	62,72
4	50	11	5,7	62,7
5	50	10,9	6,3	68,67
6	50	10,7	5,6	59,92
7	50	10,7	6	64,2
8	50	10,5	6,1	64,05
9	50	10,9	6	65,4
10	50	10.4	5,6	58,24

3. RESULTS

In the diagrams obtained by the tensile test machine, longitudinal modulus of elasticity was between two points with the highest tangent in the obtained graph. Two points are automatically generated by tensile testing machine's Nexygen data processing software.

Tensile behavior of 10 specimens from the first set of tensile tests, composite based on polyester and glass fabric MAT 300 from Table 2., is given by curves, the force (on the ordinate) that is dependent on the extension (on the abscissa). As an example, we present the tension variation curve for specimen no. 3, (Fig. 2.).

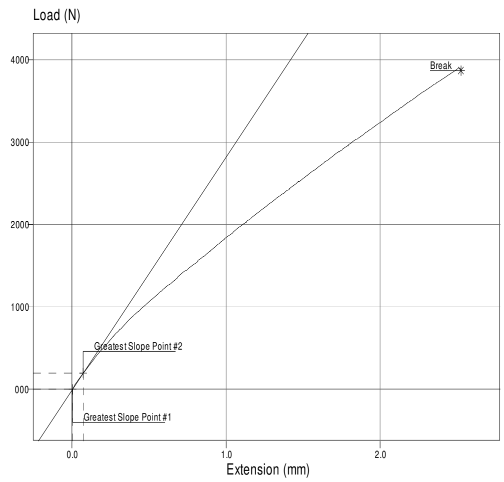

Fig. 2. Stress - total strain diagram (elongation) for specimen no. 3.

In these stress - elongation diagrams, it was observed that the force up to the moment when the irreparable damage occurred in the material, oscillated between 3500 - 4500 N. Strain where the irreparable damage occurred in MAT 300 type glass fiber composite material oscillated between 2 - 3 mm. Most common value of deformation where irreparable damage occurred was 2,5 mm. Tensile behavior of 10 specimens from the second set, COREMAT composite of tensile test specimens, composite material from Table 3., is shown in diagrams: load on the ordinate, depending on the extension on abscissa. We present an example, the tension variation curve for specimen no. 6, (Fig. 3.).

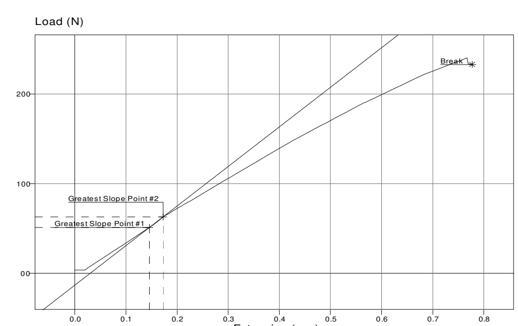

Fig. 3. Stress - total strain diagram (elongation) for specimen no. 6.

In tension - elongation diagrams and for the second set, longitudinal modulus of elasticity is determined by the interval between two points with highest tangent in obtained graph. Two points are automatically generated by Nexygen data processing software used by tensile testing machine. In all these stress - elongation curves, we can notice that the force oscillated between 180 - 280 N until the moment when irreparable damage occurred in material. Strain where irreparable damage occurred in COREMAT composite material oscillated between 0,4 - 0,95 mm. Most common strain value where irreparable damage occurred was 0,85 mm.

The first rupture occurred when specific strain became 0,01, due to delamination. These tensile tests were stopped when specimens ruptured. These special properties of MAT 300 type material are the reason for its use in various fields that employ composite structures based on polyester resin.

Tensile behavior of 10 specimens from the third set, sandwich composite with COREMAT core from Table 4., is also shown in diagrams: load on the ordinate, depending on the elongation on the abscissa. We present an example, the tension variation curve for specimen no. 10, (Fig. 4.).

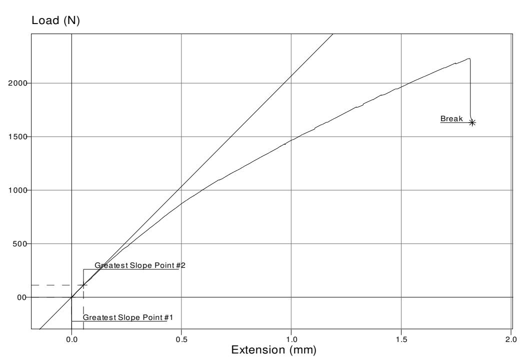

Fig. 4. Stress - total strain diagram (elongation) for specimen no. 10.

Likewise, in case of set 3, sandwich composite with COREMAT core, in the tension - elongation diagrams, longitudinal modulus of elasticity is given between two points with highest tangent in the obtained graph.

The two points are automatically generated by Nexygen data processing software used by tensile testing machine.

In all these stress - strain diagrams, it was observed that the force oscillated between 1300 - 2000 N until to the moment when the irreparable damage occurred in material.

Strain where the irreparable damage occurred in sandwich composite material with COREMAT core and MAT 300 fiberglass ranged between 0,5 - 2 mm.

The most common value of deformation where irreparable damage occurred was 1,8 mm.

In Table 5. we show the average values for some of mechanical characteristics obtained after tensile test for the third set of specimens.

From Table 5, which shows average numerical values for tensile tests of 3 sets of composite materials, it can be seen that the values obtained for set 3 are intermediate values between those obtained for sets 1 and 2.

Exception is represented by stiffness, which, for sandwich composite materials with COREMAT core is much higher than for the other two sets of composite materials studied.

Table 5. Medium values for mechanical characteristics obtained after tensile test for the three sets of specimens

No	Name	Set 1	Set 2	Set 3
1	Stiffness [N/m]	2789122	599719,5	2338810
2	Young's Modulus [MPa]	3806,881	876,7016	1872,425
3	Load at Maximum Load [kN]	4,146124	0,237356	1,912283
4	Stress at Maximum Load [MPa]	112,9831	6,635811	30,61675
5	Machine Extension at Maximum Load [mm]	2,631606	0,817117	1,43106
6	Extension at Maximum Load [mm]	2,631606	0,817117	1,43106
7	Strain at Maximum Load	0,052632	0,016342	0,028621
8	Percentage Strain at Maximum Load	5,263212	1,634234	2,862119
9	Work to Maximum Load [Ncm]	609,144	10,58021	160,1215

10	Load at Maximum Extension [kN]	-0,13381	-0,01344	-0,05554
11	Stress at Maximum Extension [MPa]	-3,6863	-0,38172	-0,87812
12	Machine Extension at Maximum Extension [mm]	2,644171	0,830605	1,564345
13	Extension at Maximum Extension [mm]	2,644171	0,830605	1,564345
14	Strain at Maximum Extension	0,052883	0,016612	0,031287
15	Percentage Strain at Maximum Extension	5,288342	1,66121	3,12869
16	Work to Maximum Extension [Ncm]	613,7332	10,86627	181,8113
17	Load at Break [kN]	4,098461	0,23569	1,591109
18	Stress at Break [MPa]	111,7017	6,586743	25,51009
19	Machine Extension at Break [mm]	2,640869	0,828436	1,560273
20	Extension at Break [mm]	2,640869	0,828436	1,560273
21	Strain at Break	0,052817	0,016569	0,031205
22	Percentage Strain at Break	5,281737	1,656871	3,120545
23	Work to Break [Ncm]	612,91	10,85181	181,4528
24	Tensile Strength [MPa]	112,9831	6,635811	30,61675

The most important result of this experimental research is that the sandwich composite material with COREMAT core is the composite material that lends itself best to applications that interest us, namely, manufacture of a car body and other elements of a car with high impact resistance. Body and other elements of vehicle will be manufactured and tested as part of future research.

4. CONCLUSION

This work, based on experimental tensile tests, was necessary due to our desire to manufacture automotive elements using new composite materials, with special impact properties.

We have studied 3 types of composite materials: glass fibers MAT 300, COREMAT and sandwich composite with glass fibers MAT 300 and COREMAT core.

The first 2 types of composite materials were studied due to their mechanical properties and the third material, the sandwich composite, was manufactured, combining the other 2 materials, thus obtaining a new composite material, hoping for improved properties in rapport to the other 2 materials.

According to existing standards, 3 sets were made, each set containing 10 specimens.

Each set of specimens was subjected to traction on the test machine, Lloyd's Instruments testing machine, type LR5K Plus.

Numerical results obtained were entered in Table 5. and were obtained from the test machine variation curves too, of which one was presented for each set.

From Table 5, it can be seen that the values obtained for set 3 are intermediate values between those obtained for sets 1 and 2. Exception is represented by stiffness, which, for sandwich composite materials with COREMAT core is much higher than for the other two sets of composite materials studied, which for us is very important for future research and applications.

The most important conclusion of this experimental and original research is that the new sandwich composite material with COREMAT core is the composite material that lends itself best to future applications, the manufacture of a car body and other elements of a car with high impact resistance. Body and other elements of vehicle will be manufactured and should further be tested as part of future research, that is very important for automotive and aeronautical industries and other domains.

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Asupra cercetării experimentale a unor materiale composite solicitate la întindere utilizate în industria autovehiculelor

Rezumat: Această lucrare prezintă un studiu experimental asupra a 3 seturi de materiale compozite: fibre de sticlă MAT 300, COREMAT și compozit sandwich cu fibre de sticlă MAT 300 și miez de COREMAT. Industria autovehiculelor, în societatea actuală, este în continuă evoluție și perfecționare, ceea ce necesită găsirea unor noi materiale, compatibile cu noile tendințe: reducerea greutății mașinii, creșterea rezistenței la coroziune, creșterea protecției împotriva şocurilor, sporirea confortului, creșterea siguranței în exploatare, utilizarea unor varietăţi extinse de tehnologii, reducând costurile de producție. S-a realizat un nou material compozit, un sandwich compozit cu miez COREMAT. Acest material, datorită rezultatelor obținute în această lucrare, va fi utilizat pentru realizarea unor elemente ale autovehiculelor, care vor fi studiate la impact în cercetările viitoare.

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