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INVESTIGATION OF MECHANICAL CHARACTERISTICS OF PLASTIC COMPOSITES

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Abstract: This paper introduces the present state of plastic composite research on the Technical Faculty. The goal of our examination is to analyze the operational and economy efficiency anomalies with testing and analyzing the mechanical characteristics of the plastic composites used in the aircraft industry in order to make a proposal for such compounds that solve these problems. In the first period we made several tests of materials which were cut out of damaged airplanes. In the latest period of the research we analyzed different composite materials produced directly for our purpose. One part of the composites were produced by supplier, the other part were made by us. First we manufactured the specimens than we made tensile strength tests in order to get the basic mechanical parameters (upper and lower yield points, tensile strength, and elongation at rupture) of the composite materials. Here we introduce all the parameters of the tests. The following step is to test the composites for fatigue with our recently constructed folding machine.
Keywords: plastic composites, material test, mechanical strength characteristics

INTRODUCTION

Aircraft industry has a significant demand for light weight structural materials in order to reduce the costs of fuel, since the payload is only 20% of a presently used cargo aircraft's take-off weight, the circa half of the rest 80% is the empty weight. One of the most obvious ways to reduce weight of planes is using light structural materials with advanced parameters. The composite materials are one of the most promising potentials but their application in large quantities is still limited by their price and some disadvantageous attributions compared to some other structural material.

In this research project we previously purchased and calibrated the necessary instruments, we manufactured the standard test specimens from different damaged airplane wings received from the Airport of Szeged. The main goal was to analyse and compare such materials that are available from trade release. During the tests we analysed the upper and lower yield points, tensile strength, and elongation at rupture which features are essential from the point of view of their application.

The following step is presented by this paper, where the composite materials and specimens were produced directly for our demand. This was partly made by outer supplier but at the end we decided to produce the composites ourselves. This was a brand new production technology in the life of the Faculty, so we prepared it really carefully. After mapping the possibilities we decided which technic to choose, than purchased the necessary basic composite materials and the production tools were only hired. The first production was made together with outer experts, than we made the second production alone. Manufacturing and testing the specimens were done as before.

MATERIALS END METHODS

The cross-linked polymer matrix composites have usually low elongation at rupture and rigid breakage that means disadvantage for hitting or complex loads [Pukánszky, 2011]. At aircraft application there are many fatiguing or impulsive loads so it is an essential demand against the structural materials not to be rigid or break at small deformation. The fibre reinforced epoxy resin composites have long lifetime beside proper design and production technology. Due to their inhomogeneous structure the peak loads or long term alternating loads do not cause fatigue break [Czvikovszky, 2000]. The strength of composites decreases slightly but continuously in function of time and load because of the micro-cracks in bedding material and the insubstantial breaking of reinforcing fibres. There is a significant difference between the tensile strength and the compressive strength of composites which can be 15-30% in case of glass or carbon fibres, but it can reach even 50% at extreme high tensile strength carbon fibres. Composite materials with aramid fibres (Kevlar) can have 60% lower compressive than tensile strength so the structures loaded with alternate normal stress have to be sized for compressive strength [Vermes, 2015].

Stress causes deflection in materials, so on the basis of their tensile strength diagram we can distinguish rigid, tough or rubbery behaviour. The fibre reinforced systems are rather rigid generally [Koncz et al., 2000]. In case of polymers the reason of the local maximum can be the too fast mechanical impact (because of their time-dependent behaviour) that the material cannot follow up without detention by changing of its structure [Mészáros, 2009]. During the tests of composites the yield stress (σ_{Yield}) is defined as the stress value belonging to the intersection of the 10% parallel shifted line of the beginning modulus with the real stress-strain curve. The yield strain (ε_{Yield}) belongs to this point as well. The tough strain ($\varepsilon_{ductile}$) starts at this point and ends at the rupture stress [Vermes, 2015]. The typical tensile stress diagrams of polymers applied in the biggest amount nowadays are represented on Figure 1. The different polymer types show really variant behaviour. Some of them break rigidly and others can sustain even several 100% strain without breaking [Gunczer, 2009].

It is featuring the polymers that the circumstances of test influence significantly the mechanical properties of the material. The main influential parameters are the followings: speed of tear, test temperature, moisture. At higher speed of tear the materials with viscoelastic features (polymers) behave more rigidly, usually their strength is higher. Only a few degree of test temperature difference can influence significantly the strength, the character of the tensile diagram. The polymers under their glass transition temperature (T_g) behave glassy, above it they behave rather tough [Sápi, 2015]. There are some polymers (e.g. polyamides, polyesters, natural polymers, some kind of fibre reinforced composites) which can absorb so many (1-4%) moisture that can influence their behavior. Moisture decreases the strength, the Young-modulus and increases the elongation break [Pék, 2000].

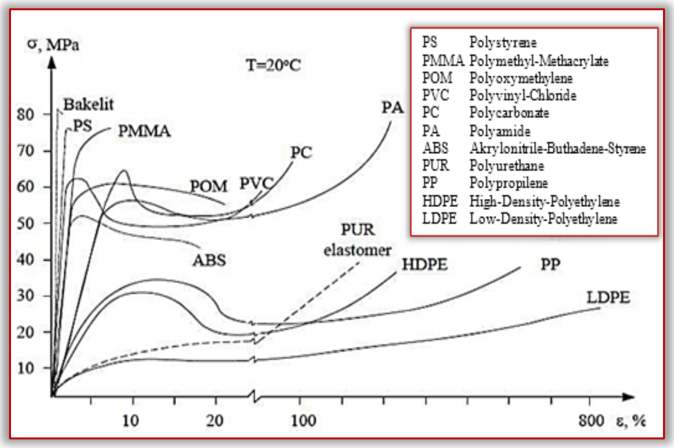

Figure 1. Tensile test diagrams of different polymers [Gunczer, 2009]

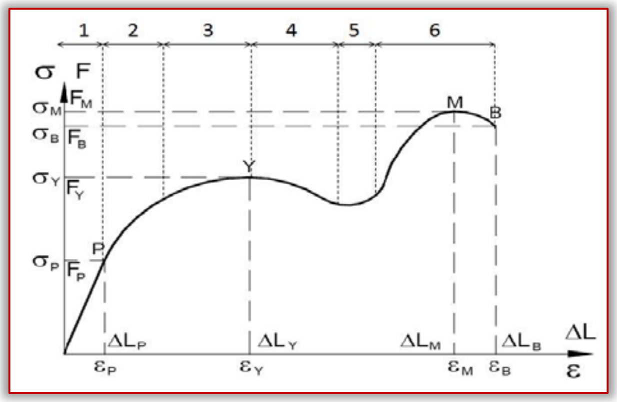

Figure 2. General plastic tensile strength diagram with six stages [Pék, 2000]

As the result of the tensile test we get the load-elongation (F-Δl) curve (valid for the given circumstances) which can be transformed to stress-strain (σ-ε) curve (Figure 2.) This tensile strength diagram can be segmented to six stages:

- small loads, linear elastic deflection;
- as the load grows, the linear viscoelastic deformation starts (it deforms back by time);
- at higher loads nonlinear viscoelastic deformation comes;
- neck-formation stage, stress decreases, local arrangement of macro-molecules starts;
- spread of neck-formation, steady flow stage;
- because of the global arrangement the tensile strength increases (deformation hardening). In this stage the arranged fibres reach their ultimate tensile strength and break one after the other.

From the tensile strength diagram the following mechanical values can be determined [Sápi et al. 2015]: plastic, yield, maximum, break values of strength and strain. Two kind of Young-modulus can be calculated:

- Chord modulus (E_{ch}): the chosen point of curve is connected with the origin and the gradient gives the modulus [Gáthi et. al., 2011].
- Tangent modulus (E_t): the tangent at the chosen point of curve gives the modulus.

As the tensile strength curve is non-linear, the tangent of it changes point by point as well. The tangent at the origin on the stress-strain curve is called initial Young modulus. In practice the Young modulus of the material is regarded as the gradient of the line going through the curve points belong to the 0,05% and 0,25% relative elongation values [Sápi et al. 2015].

RESULTS AND DISCUSSION

At choosing the right standard specimen shape for the test it was an essential consideration to be suitable for the Galdabini Quasar 100 tensile test machine (Figure 3.) available in the Technical Faculty, University of Szeged. The standard's smallest specimen was manufactured that could be tested by our tensile test machine adjusting with proper parameters. First we executed a probe test to control the accidentally emerging problems, this was the right calibration of the breaking elongation value. The specimen and its template was created by 3D solid body design software (Figure 3).

Figure 3. Tensile test machine, template of specimen, material test labour

As it was mentioned before the first set of specimens were manufactured by outer supplier. The content of the specimens: Polymer, Polyethylene PE-TIP-7700M. Composite: Sulphur, argillaceous-mineral. The signature of the basic polymer PE-K001. The specimen samples are shown on Figure 4. It is visible that the elongation at neck-formation was really high.

There were several specimens prepared from the basic compound with different weight percent argillaceous-mineral and Sulphur. The signature of the samples: PE-K002: 0,5% mineral, PE-K003: 0,5% Sulphur. The result of tests are shown on Table 1.

Figure 4. The first set of specimen before and after the tensile tests

Table 1. Test results of specimens of the first set

Specimen code	Date of test	Thickness (a)	Width (b)	Elongation at break	F_t	F_m	R_m
		(mm)	(mm)	(mm)	(N)	(N)	(N/mm²)
PE-K001-1	18-02-2019	2,18	3,89	138,2	52,5	145,5	17,16
PE-K001-2	18-02-2019	2,14	3,89	122,3	58,5	131,0	15,74
PE-K001-3	18-02-2019	2,42	3,89	144,2	13,5	159,5	16,94
PE-K001-4	18-02-2019	2,09	4,00	63,2	21,5	117,0	14,00
PE-K001-5	18-02-2019	2,28	3,95	146,2	43,0	166,0	18,43
PE-K002-1	04-03-2019	2,11	3,85	25,34	63,5	123,5	15,28
PE-K002-2	04-03-2019	2,12	3,85	126,0	56,5	131,0	16,2
PE-K002-3	04-03-2019	2,11	3,85	164,6	12,5	169,5	20,96
PE-K002-4	04-03-2019	2,18	3,89	54,5	32,5	130,5	16,4
PE-K002-5	04-03-2019	2,14	3,85	26,22	52,5	139,0	17,19
PE-K003-1	04-03-2019	2,15	3,85	211,4	38,5	127,0	15,34
PE-K003-2	04-03-2019	2,15	3,85	13,28	67,5	121,0	14,62
PE-K003-3	04-03-2019	2,14	3,86	93,13	51,5	137,0	16,61
PE-K003-4	04-03-2019	2,16	3,85	93,22	49,0	139,0	16,79
PE-K003-5	04-03-2019	2,15	3,85	178,2	38,5	137,0	16,55

The tensile strength diagrams shows the different behaviors of the different specimens as it is indicated on Figure 5-7.

After the tests of the first set of specimen manufactured by outer supplier we decided to produce composites ourselves. With the help of some suppliers we chose the production technology: the vacuum-infusion procession with epoxy resin and carbon fibres. The main advantage for us as selection criteria were the relative uniform quality and the environment-friendly technology. The first plates (with 4 and 6 reinforcing carbon-fibre fabric) were produced together with outer experts, than the second production (3 and 5 fabric) was executed without help. Only a few tensile tests were completed yet, Figure 8 shows only some introducing details of them. Number 1. specimen has 3 reinforcing layer, 2. specimen has 4 layer, 3. one has 6 fabric.

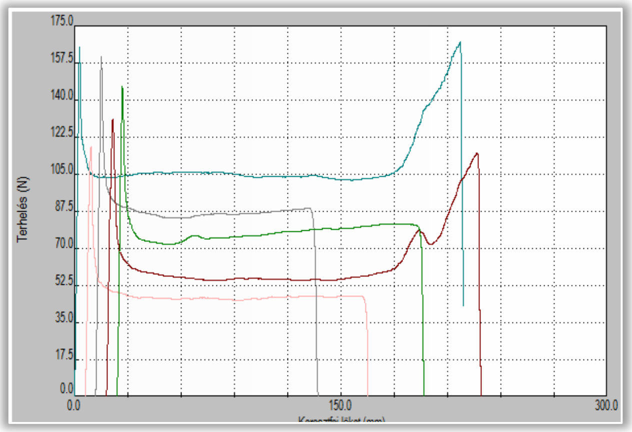

Figure 5. Tensile test result of PE-K001 (1-5) composites

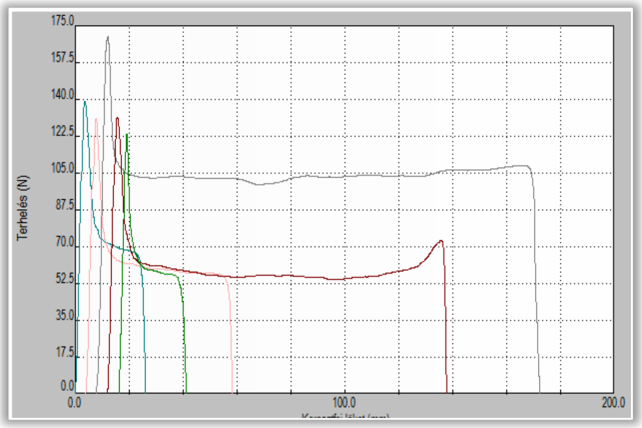

Figure 6. Tensile test result of PE-K002 (1-5) composites

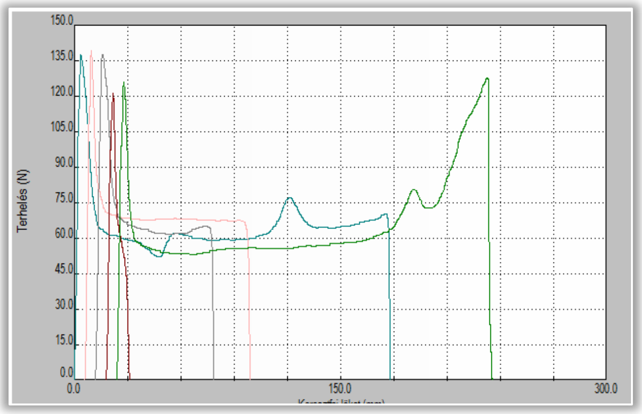

Figure 7. Tensile test result of PE-K003 (1-5) composites

We still have a lot of work on the production process and on the tensile test process to eliminate the visible problems, but the initial results are rather promising (Table 2). After the tensile tests we execute fatigue tests with our self-designed and constructed fatigue-test machine. We are searching the difference of tensile tests done before and after a 10 million fatiguing folding.

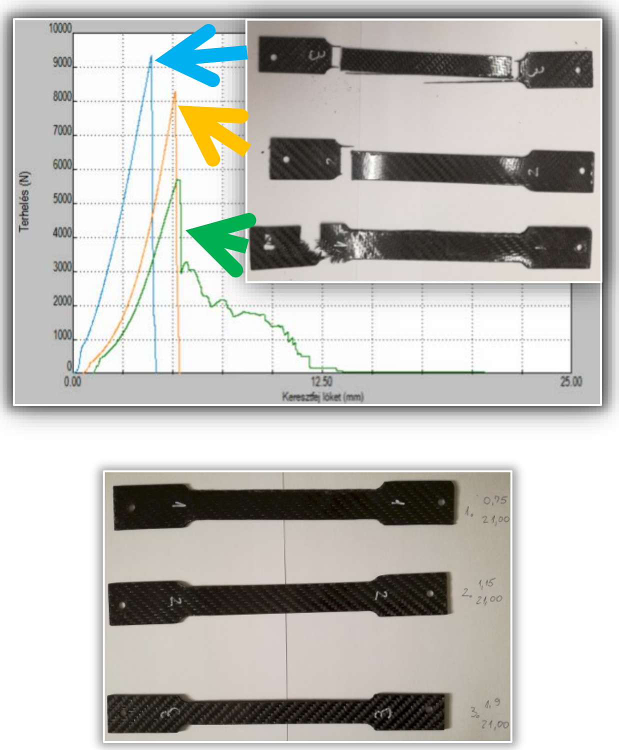

Figure 8. Tensile test results of self-made composites: **Preload:** 20mm/min, 100N; **Loading force:** 10mm/min up to break

Table 2. Test results of specimens of the self-produced second set

Specimen code	Date of test	Thickness (a) (mm)	Width (b) (mm)	Ft (N)	Fm (N)	Rm (N/mm2)
Composite 1	27-05-2019	0.75	21.00	41,5	5691,0	361,37
Composite 2	27-05-2019	1,15	21,00	40,0	8237,5	341,10
Composite 3	27-05-2019	1,9	21,00	75,5	9322,0	233,63

CONCLUSION

In the range of structural material the polymers and their composites applications are worldwide spread, because of their excellent mechanical, physical and chemical features. The small density and the light weight belongs to this with the high strength, the damping and insulating ability, the chemical and corrosion resistance, the designable anisotrophy, etc. make the synthetic polymers nowadays one of the most favourite structural material. With their application not only energy can be saved but this material group plays key role in the sustainable development as well. Nowadays the research of polymers trends towards developing such materials which are more environmentally friendly, reducing the energy supply, making our everyday life easier and comfortable.

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