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MODIFICATION OF PHYSICAL AND MECHANICAL PROPERTIES OF COMPOSITE MATERIALS AFTER SHORT TIME EXPOSURE TO UV RADIATION

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Abstract: *During life conditions, the composite structures are subjected to environmental factors: variations in humidity, temperature, UV radiations, chemical and biological agents which lead to mechanical properties modification of them. From a mechanical point of view, the exposure to UV radiation can produce, on the one hand, the change in elastic characteristics, and on the other hand the appearance of stress concentrators on the surface of the polymeric material (which can lead to its premature failure). The aim of this paper is to evaluate the physical and mechanical features of ageing glass fibres chopped strands reinforced polymeric composite, denoted MAT300. The coefficients of color change were determined with chroma meter before and after UV exposure. Then, the control samples were subjected to tensile and three points bending since the other samples were tested after exposure to ultraviolet radiation UV-A radiation for 216 hours .*
Keywords: *glass fibers reinforced plastic (GFRP); color change, UV exposure, 3 points bending*

1. INTRODUCTION

The advantage of glass fiber reinforced plastic in comparison with other materials, are the specific strength (the strength to weight ratio σ/ρ), specific stiffness or specific modulus (the stiffness to weight ratio E/ρ) and tailored material [1]. But, during life conditions, the composite structures are subjected to environmental factors: variations in humidity, temperature, UV radiations, chemical and biological agents which lead to mechanical properties modification of them. Exposure to ultraviolet radiations triggers changes in the chemical structure on the surface of the composite, a phenomenon known as photolysis. Similarly, free radicals are formed in the polymer by the dissociation of the C-H ties in the polymer chains [2, 3]. These chemical reactions lead to a material fragility and micro-cracking of its matrix at the interface with the fibers [4]. From a mechanical point of view, the exposure to UV radiation can produce, on the one hand, the change in elastic characteristics, and on the other hand the appearance of stress concentrators on the surface of the polymeric material (which can lead to its premature failure) [5]. Concomitant exposure to UV radiation and to temperature changes accelerates the degradation processes which occur in GFRP, such as oxidation, chemical attack, degradation of the morphological characteristics of the surface, cutting down on mechanical properties and reducing the occurrence of the creep [6, 7]. In previous studies, the authors investigated the mechanical properties of glass fibres chopped strand mat composites subjected to tensile and bending [8, 9]. This study deals with evaluation of mechanical and physical properties of glass fibres chopped strand mat subjected to UVA radiation (365 nm), for 216 hours.

2. MATERIALS AND METHODS

2.1. Materials

The composite material analysed in this study consists of six layers of glass fibres chopped strands Mat 300 g/m2 reiforcement and polyester resin of the APROPOL M 105 TA. The mechanical properties of resin are presented in Table 1. For bending test, the samples were performed according to ISO 178: 2003. The geometrical characteristics of tested samples are shown in Tables 2. The samples were obtained from the same plate of glass fibres chopped strands mat composite, being devided in two sets: one of them is for control, being subjected to tensile and bending tests, the other, was exposed to ultraviolet radiation and after 216 hours, the color change and the mechanical properties were measured (Fig. 1, a). Tensile test specimens were made according to EN ISO

527-2-SR and for bending test, the samples were performed according to ISO 178: 2003. The control samples were denoted with MAT_C and the samples exposed to UV radiation were denoted with MAT_UV.

Table 1. The mechanical properties of poliester resin as matrix of E-fiber glass chopped strand Mat composites

Properties	Values
Density [kg/dm^3]	1.1
Cure temperature[°C]	66
Bending strength [MPa]	90
Shear modulus [MPa]	4100
Tensile strength [MPa]	55
Longitudinal elasticity modulus [MPa]	3600
Strain	2 %
Water absorbtion in 24 h (sample of 50x50x4 [mm^3]) [mg/sample]	19
Water absorbtion in 28 days (samples of 50x50x4 [mm^3]) [mg/sample]	92

Table 2. The physical features of samples for bending test

Bending test	MAT01-B	MAT02-B	MAT03-B	MAT04_B	Media	STDEV
Length [*mm*]	80	80	80	80	80	0
Width [*mm*]	9.89	9.92	9.97	9.93	9.928	0.033
Thickness [*mm*]	4.19	4.06	4.49	4.15	4.223	0.186
Mass [*g*]	4.436	4.346	4.855	4.455	4.523	0.226
Sample before UV	MAT1B-UV	MAT2B-UV	MAT3B-UV	MAT4B-UV	Media	STDEV
Length [*mm*]	80	80	80	80	80	0
Width [*mm*]	9.89	9.92	9.97	9.93	9.928	0.033
Thickness [*mm*]	4.19	4.06	4.49	4.15	4.223	0.186
Mass [*g*]	4.436	4.346	4.855	4.455	4.523	0.226

2.2. Methods

2.2.1. Color changes

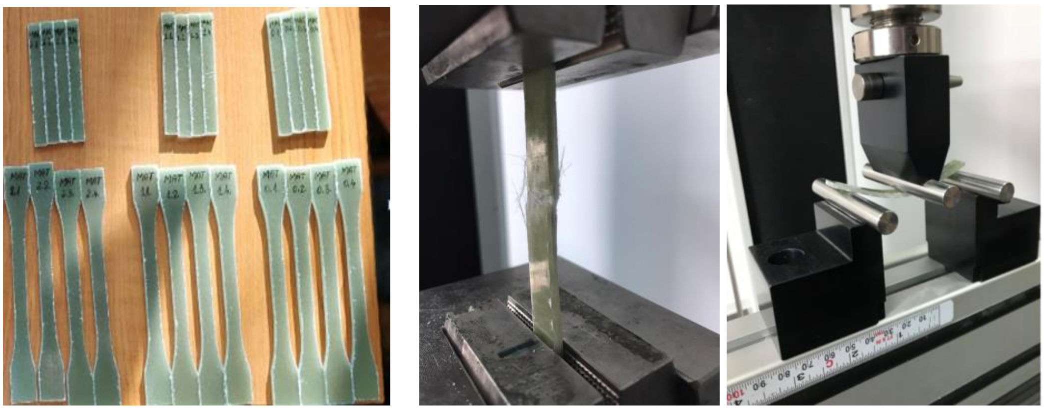
The experimental investigation consists of tensile and bending tests of samples before and after UV exposed samples. The mechanical tests were performed on universal testing machine LS100 Lloyd's Instrument belonging to the Mechanical Engineering Department of Transylvania University of Brasov. The specimens were loading with a constant speed of 1 mm/min until breaking. For data aquisition, the Nexygen Plus software was used.

A part of samples were used as control samples and the other part were used for ageing by UV-A radiation (wavelength λ = 365 nm) exposed for 216 hours. Also, the color changes (in terms of ligthness L; redness a* and yelowness b*) was measured before and after ageing, and also before and after mechanical tests with aim to emphasize the surface modification of composites in different stage of degradation (physical/mechanical). The used device for color changes was Chroma Meter CR-400. The CIE L*a*b* colour scale (Commission Internation de l'Eclairage, 1976) was used to quantify the changes on colour produced by UV radiation of glass fibres chopped strand mat composite. The overall colour change of composite surface was calculated using the relation (1), where E* represent the overall colour change; index 0 – the values of control samples; UV – the values after ageing [9]:

$$\Delta E^* = \sqrt{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2} \quad (1)$$

2.2.2. Mechanical test

The specimens were loading with a constant tensile speed of 5 mm/min until breaking, being used the equipment by LS100 Lloyd's Instrument belonging to the Mechanical Engineering Department of Transylvania University of Brasov (Fig. 1, b and c).



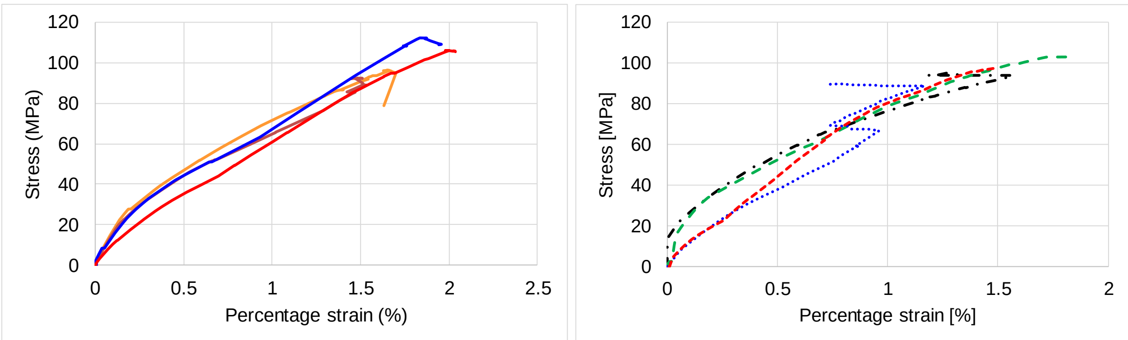
a) b) c)

Figure 1. The glass fibres chopped strand MAT samples: a) the samples for tensile (bottom) and bending (upper); b) tensile test; c) bending test.

3. RESULTS AND DISCUSSIONS

3.1. Tensile test

In Figure 2 can be seen the characteristic curves to tensile test in case of MAT composite befor (Fig 2, a) and after exposure to UV radiation for short time (Fig. 2, b). It can be noticed that after UV radiation, even for short time, some structural changes of matrix appear: the curves (in Fig 2, b) recorded different variation laws, some of them expressing the micro-cracks of materials. In Table 3 are summarized the statistics of main mechanical properties determined by tensile tests. Generally, the mechanical properties decrease after UV exposure even for short time.



(a) (b)

Figure 2. a) Load vs deflection graph; b) Stress vs strain graph

Table 3. The statistics of mechanical properties of MAT samples subjected to tensile

Mechanical properties	Mean Values *		Coefficient of Variance (%)		Standard Deviation *	
	MAT_C	MAT_UV	MAT_C	MAT_UV	MAT_C	MAT_UV
Stiffness (N/m)*	86364000	34394000	127.6	48.74	110280000	16765000
Young's Modulus (MPa)*	98745	41655	126.3	49.93	124810	20798.0
Load at Maximum Load (kN)*	4.3233	4.0077	7.5	5.59	0.3264	0.22384
Stress at Maximum Load (MPa)*	101.80	96.445	7.69	4.93	7.8329	4.7569
Percentage Strain at Maximum Extension (%)*	2.659	2.0519	34.76	35.24	0.9242	0.72309
Load at Break (kN)*	4.2706	3.9964	6.53	5.69	0.2788	0.22752
Stress at Break (MPa)*	100.57	96.171	6.97	5.00	7.0090	4.8112
Strain at Break (-)	0.0178	0.0133	12.92	30.13	0.0023	0.00402
Percentage Strain at Break (%)*	1.7851	2.0519	12.92	35.24	0.2306	0.72309
Tensile Strength (MPa)*	101.80	96.445	7.69	4.93	7.8329	4.7569

3.2. Bending test

The mechanical behavior of MAT samples is presented in Fig. 3, were can be noticed the characteristic curves load – deflection (Fig. 3, a) and stress – strain (Fig. 3, b). From both figures, it can be observed that samples have similar behavior during bending test. But, analyzing the values of Young modulus to bending, the MAT samples subjected to UV radiation recorded an increasing of modulus with almost 95% (Fig. 4, b) and an increasing of bending stress with almost 80% (Fig. 4, d). The stiffness decreases after UV radiation with 72% and the maximum load also decreased with 90%.

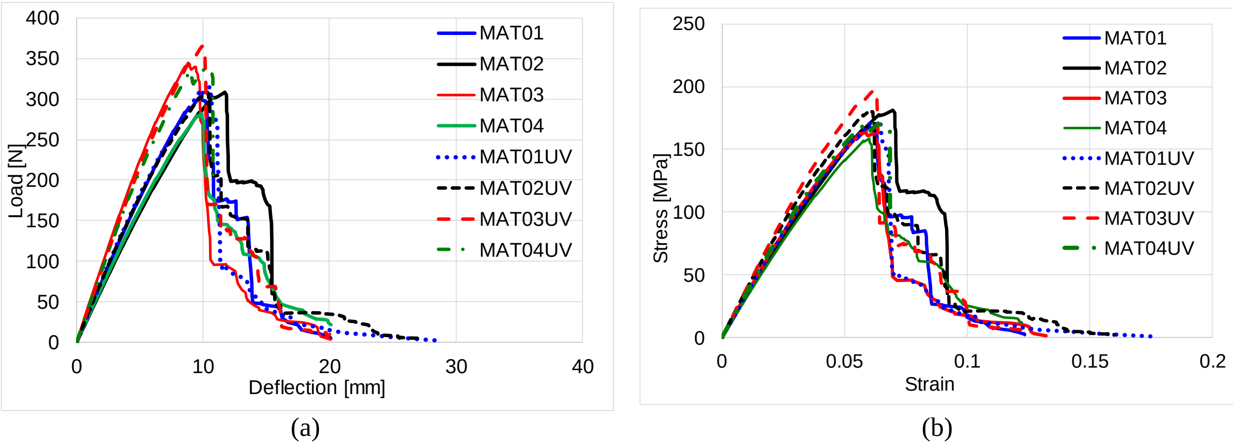


Figure 3. a) Load vs deflection graph; b) Stress vs strain graph

So, it can be concluded that the exposure at UV radiation affects the mechanical characteristics of composite structure. The increasing of some mechanical features of glass fibres chopped strands MAT composite it can be due the acceleration process of polymerization-condensation of matrix by means of ultraviolet radiation. For a long period of exposure to UV, at the matrix surface some reticular process will appear which will lead to decreasing the mechanical properties of composite as [10 – 12].

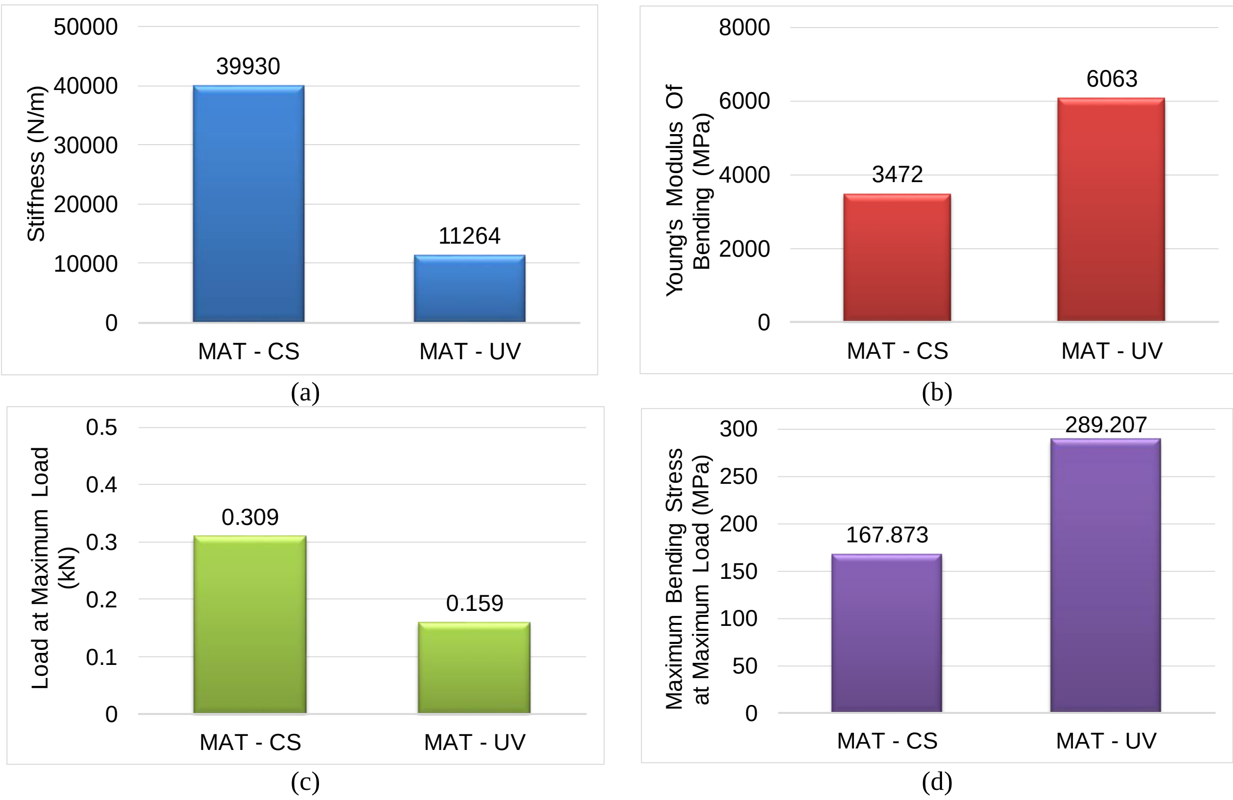


Figure 4. Comparison of average values of different features of MAT control samples (MAT-CS) and MAT samples exposed to UV radiation (MAT-UV): (a) stiffness; (b) Young modulus; (c) Maximum Load; Maximum Stress

3.3. Color change

The novelty of this study consists of evaluation of color changes in case of UV radiation. So, the chroma test was applied on control sample before and after bending test and on samples exposed to UV radiation. Both mechanical bending test and UV exposure, the lightness (L*) increases: with 3.5% in case of UV exposure and with almost 30% in case of breaking to bending, in comparison with control samples lightness (Fig. 5, a). Because of composite structure, the samples recorded a green scale (negative values of a* coefficient, according to CIE) which decreasing with 14% for MAT-UV (Fig. 4, b). The scale of yellow increased with 4.25% after ageing and decreased with 18% when the samples broken (Fig. 5, c). Applying the relation (1), the overall change color represented in Fig. 5, d, is more obviously in case of mechanical stressed samples and UV exposure.

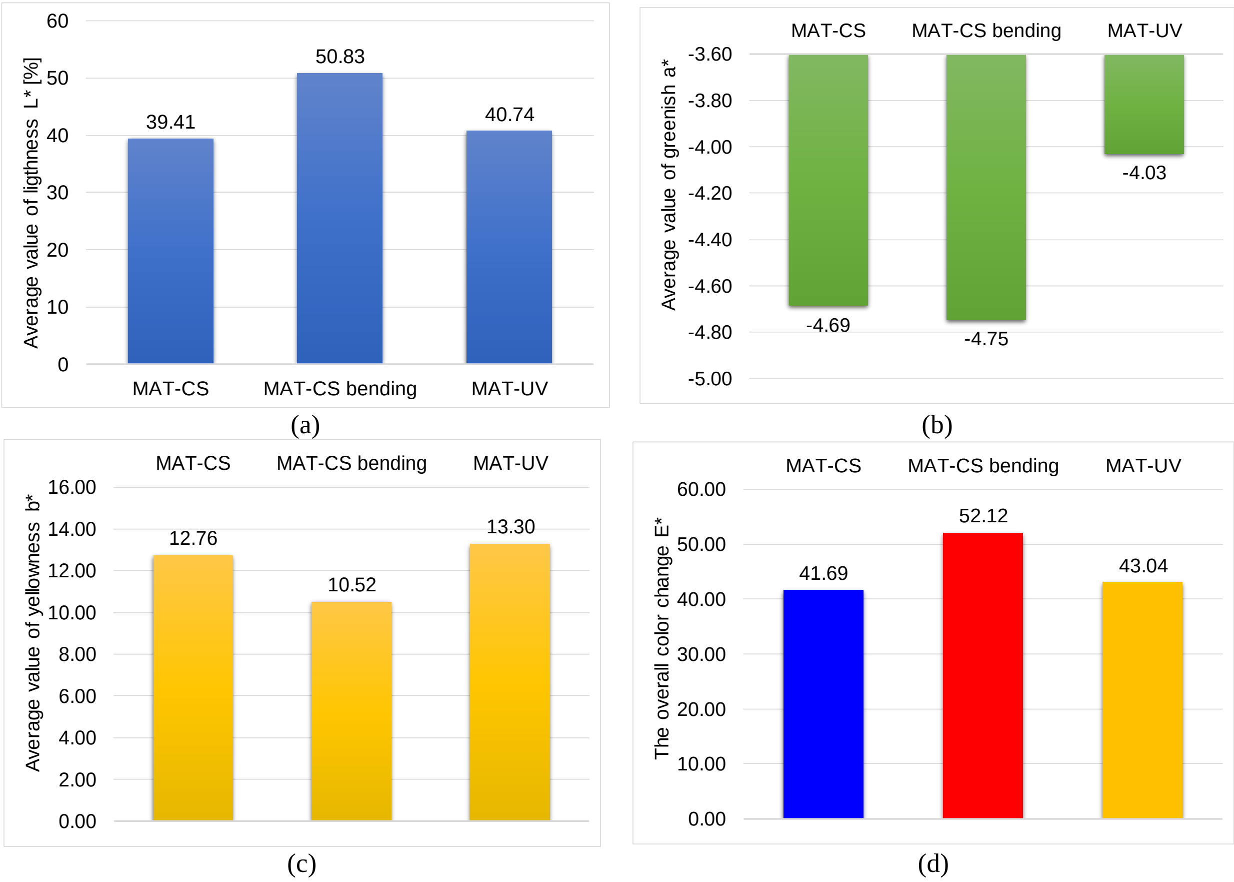


Figure 5. The average values of color changes parameters: (a) the lightness L*; (b) the greenish a*; (c) the yellowness b*; (d) the overall color change E*

3. CONCLUSION

The paper presents the experimental study on ageing of fibres glass chopped strands materials for short time exposure. The following remarks can be mentioned:

- The elasticity modulus determined by tensile test recorded a decreases with almost 57% after UV exposure;
- Tensile strength decreases with 5% after UV exposure;
- For short time exposure to UV-A radiation, the Young modulus of bending recording an increases with 95%, which is explained by accelerating chemical reaction of matrix (polymerisation) and matrix curing;
- The bending strength increases after UV radiation with almost 80%;
- The lightness of MAT samples exposed to UV increased with 3.5% in comparison with control sample, the greenish decreased with 14% and the yellowness increased with 4.25%.

As future research, the authors will continue to analyse the ageing and weathering of glass fibres chopped strands mat composite, exposing the samples for a longer period.

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