UNION OF ENGINEERS AND TEXTILE TECHNICIANS OF SERBIA

UNION OF ENGINEERS AND TECHNICIANS OF SERBIA
FACULTY OF TECHNOLOGY AND METALLURGY IN BELGRADE
FACULTY OF TECHNOLOGY IN LESKOVAC

INTERNATIONAL SCIENTIFIC CONFERENCE

CONTEMPORARY TRENDS AND INNOVATIONS IN THE TEXTILE INDUSTRY

NAUČNA KONFERENCIJA SA MEĐUNARODNIM UČEŠĆEM

SAVREMENI TRENDOVI I INOVACIJE U TEKSTILNOJ INDUSTRIJI

PROCEEDINGS

ZBORNIK RADOVA

Editor:
Snežana Urošević

Belgrade, 18 th May, 2018
Union of Enginering and Techicans of Serbia
Dom inženjera "Nikola Tesla"

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On the occasion of celebrating
150 years of the Union of Engineers and Technicians of Serbia
65 years of the Union of Engineers and Textile Technicians of Serbia
65 years of continual publishing of the *Tekstilna industrija* journal

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UNION OF ENGINEERS AND TEXTILE TECHNICIANS OF SERBIA

SCIENTIFIC COMMITTEE

Conference Contemporary Trends and Innovations in the Textile Industry

ORGANIZING COMMITTEE

Conference Contemporary Trends and Innovations in the Textile Industry

Confrerence is financially supported by The Ministry of Education, Science and Technological Development of the Republic of Serbia

UNION OF ENGINEERS AND TEXTILE TECHNICIANS OF SERBIA

PREFACE

The international conference Contemporary Trends and Innovations in the Textile Industry is coorganized by the Union of Engineers and Textile Technicians of Serbia, the Union of Engineers and Technicians of Serbia, the Faculty of Technology and Metallurgy in Belgrade, the University of Belgrade and the Faculty of Technology in Leskovac, University of Niš. The Conference is being organized on the occasion of celebrating 150 years of the Union of Engineers and Technicians of Serbia, 65 years of the Union of Engineers and Textile Technicians of Serbia and 65 years of continual publishing of the Textile Industry journal.

The Ministry of Education, Science and Technological Development of the Republic of Serbia recognized the importance of this Conference, and thus, supported it.

The aim of this Conference is to consider current technical, technological, economic, ecological, R&D, legal and other issues related to the textile industry, then the application of contemporary achievements and the introduction of technical and technological innovations in the production process of fiber, textile, clothing and technical textile by applying scientific solutions in order to improve the business and increase the competitive advantages of the textile industry on the domestic and global market.

Leading scientists and experts from the Balkans and other countries, working at faculties, textile colleges and institutes, but also individuals who professionally deal with the issues at hand are taking part in this Conference.

The Conference program involves papers dedicated to the scientific and practical aspects of the following topics: Textile and Textile Technology, Textile Design, Management and Marketing in the Textile Industry and Ecology and Sustainable Development in the Textile Industry. The Conference program includes 45 papers, and a total of 105 participants from 13 countries: Bosnia and Herzegovina, Bulgaria, Croatia, India, Italy, Macedonia, Portugal, Romania, Serbia, Slovenia, Turkey, Ukraine and Spain. Therefore, this Conference is an opportunity for establishing scientific, educational and economic cooperation of our country with other countries. Certain number of papers by domestic authors present the project results dealing with fundamental research and technological development, financed by the Ministry of Education, Science and Technological Development of the Republic of Serbia.

I would like to thank all those who have made it possible to organize the conference Contemporary Trends and Innovations in the Textile Industry and make it a success. First, I would like to thank the Scientific and Organizing Committee for working hard, spending countless hours and finding the best solutions for numerous organizational aspects of our Conference. Also, I would like to express my gratitude to all sponsors who believed in the importance of this Conference and cofinanced it. I also thank all the other institutions that supported the Conference in various ways, because without their support, the Conference could not have been organized. Last but not least, I would like to thank plenary lecturers, all authors and co-authors and guests for their participation in the Conference.

On behalf of the Organizing Committee
Prof. dr Snežana Urošević, president

Confrerence is financially supported by The Ministry of Education, Science and Technological Development of the Republic of Serbia

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TABLE OF CONTENTS

PLENARY LECTURES

CONFERENCE PAPERS

SESSION I

Confrerence is financially supported by The Ministry of Education, Science and Technological Development of the Republic of Serbia

CONFERENCE PAPERS
SESSION II

Confrerence is financially supported by The Ministry of Education, Science and Technological Development of the Republic of Serbia

CONFERENCE PAPERS
SESSION III

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MECHANICAL CHARACTERIZATION OF GLASS FABRIC/EPOXY COMPOSITES

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ABSTRACT: *Textile composite materials present a class of advanced materials reinforced with textile preforms used for primary structural applications. Using the unique combination of light weight, elasticity, strength and toughness, the textile structures have long been recognized as an attractive reinforcement component for production of different types of composite materials for various applications. The aim of this study is to investigate the influence of different types of two - dimensional textile structure as a reinforcing component on mechanical properties of composite materials. For that purpose, E-glass fabric/epoxy resin prepress have been fabricated by using the hand lay-up technique and used in the production of laminated composite samples with help of compression technology. Flexural properties of manufactured samples were determined with help of three-point bending test in accordance with the procedure described in the standard EN ISO 14125. Comparison between results of specimens manufactured at same technological parameters, but from textile fabric with different weave pattern shown that all samples tested at MD direction had performed better flexural properties in comparison to the samples tested at CD direction.*

Keywords: *E- glass fabric, epoxy resin, prepreg, flexural properties*

MEHANIČKA KARAKTERIZACIJA KOMPOZITA NA BAZI STAKLENIH TKANINA/EPOKSIDNIH SMOLA

APSTRAKT:*Tekstilni kompozitni materijali predstavljaju klasu naprednih materijala ojačani tekstilnim predformama namenjeni za primarnu strukturnu primenu. Koristeći jedinstvenu kombinaciju male težine, elastičnosti, čvrstoće i žilavosti, tekstilne strukture odavno su prepoznate kao atraktivna komponenta za ojačanje priikom proizvodnju različitih vrsta kompozitnih materijala. Cilj ove studije je istraživanje uticaja različitih tipova dvodimenzionalne tekstilne strukture kao ojačivač mehaničkih osobina kompozitnih materijala. U tu svrhu proizvedeni su preimpregnirani materijali, E-staklena tkanina/epoksidna smola tehnikom ručnog polaganja i dalje su korišteni u proizvodnji laminiranih kompozitnih uzoraka uz pomoć tehnologije kompresije. Fleksibilna svojstva proizvedenih uzoraka određena su pomoću testa savijanja u tri tačke u skladu s postupkom opisanom u standardu EN ISO 14125. Upoređivanje rezultata ispitivanja uzoraka proizvedenih prema istim tehnološkim parametrima, ali od* *tkanina različitih prepletaja pokazaloje da svi uzorci koji su testirani u smeru MD imaju bolje osobine savitljivosti u poređenju sa uzorcima koji su testirani u pravcu CD-a.*

Ključne reči: *E-staklena tkanina, epoksidna smola, prepreg, fleksibilna svojstva*

1. INTRODUCTION

Composite materials reinforced with textile preforms are called textile composites [1]. Textile composites proved to be competitive materials because they possess outstanding physical, mechanical and thermal properties, particularly light weight, high strength and stiffness, good fatigue resistance, excellent corrosion resistance and dimensional stability [2].

Textile preforms are fibrous structures with a predetermined fiber orientation, preshaped and often pre-impregnated with matrix intended for the production of composite materials. The microstructure of the fibers within the preform or the structural characteristics of the fibers determine the geometry and distribution of the pore within the composite material. Textile preforms do not only play a key role in the transformation of fiber properties into complex composite performance, but also affect the easy or difficult infiltration of matrix and consolidation [3]. The primary functions of the textile preforms in the composite are to improve its mechanical properties while the matrix transfers the stresses between the fibers and protects them from mechanical and environmental damage. The types of textile preforms are subject of interest to a large number of authors.

In general, the classification of textile structural preforms should reflect the macro geometry, the method of manufacture of textile structure and structural micro geometry. The micro geometry includes the direction of the reinforcement, the linearity of the reinforcement in each direction, the continuity of the reinforcement component, the linear density of the fiber, the number of yarns in each direction (warp and weft) [4, 5]. From the aspect of the structure of the textile materials and their specific geometry [3], textile preforms can be classified into 3 levels: one-dimensional (non-axial – roving yarns), two-dimensional (one-axial – chopped strand mats; non-axial – sheets; biaxial – plain weave; three-axial – three-axial weave; multi-axial) and three-dimensional (linear element – 3D solid braiding, multiple weave, three-axial and multi-axial 3D weave; plane element – laminates, honeycombs and beams) [2, 6]. The structural characteristics of textile material have a significant impact on the physical and mechanical properties of the fabrics and their performance in the final composite. Often they are determined from the yarns of which they are made, as well as from the process parameters of the weaving machines. The basic structural characteristics of the fabrics include: the material composition of the fabric, the linear density of yarns used for warp and weft, the density of the fabric in warp and weft direction, the way of interlacing the weft and warp yarns (style or weave pattern), etc.. The most commonly used types of weave patterns are: plain, basket, twill, and satin [7].

The development of textile composite, their design and manufacturing technologies is one of the most important achievements in the engineering of materials [8]. When combined with high performance fibers, matrices and properly fitted fiber / matrix interfaces, the creative use of textile preforms significantly expand the options for designing advanced composite materials for different applications. The outstanding achievements in the field of computer-aided design and manufacturing have facilitated the adaptation of many traditional textile processes to create 2-D and 3-D textile structures at relatively low production costs. Considering the critical role which the textile preform have in the production and performances of the composite materials, the interest in the subject of textile composites has been greatly increased.

Textile composites are widely used in the aerospace industry, automotive industry railway, marine, commercial mechanical engineering applications, like machine components, mechanical components, civil buildings, protective and sport equipment etc.

2. EXPERIMENTAL TEST

In this study are used (prepregs) pre-impregnated composite materials, which were produced by using the hand lay-up technique. For the production of prepreg materials two different types of two- dimensional E - glass fabric were used. In these experimental test as a matrix, a two-component thermosetting system of epoxy resin (DER 3821) and a hardener ((Polypox H 766) was used. In table 1 and table 2 are presented the characteristics of used E-glass fabrics and epoxy resin.

For production of composite laminates ten piles of manufactured E glass fabric/ epoxy resin prepreg with dimensions 250 mm x 200 mm were used. The plies were stacked in press machine where final curing of the preforms was performed at compressive pressure of 30 bar and temperature of 70-80° C. The laminated samples stay in the press machine for one hour. For the first half hour of the process, the sample is at temperature of 70 °C, and the rest of the time the temperature rises to 80 °C. The prepared samples are left to stand for a few hours, while the mixture does not fully combine and dry out.

Flexural properties of manufactured samples were determined with help of three-point bending test in accordance with the procedure described in the standard EN ISO 14125 [9]. For that purpose computer controlled universal testing machine (UTM) Hydraulic press, SCHENCK- Hidrauls PSB with maximal load of 250 kN, constant crosshead speed of 5 mm/min and span-to-depth ratio of 16:1 was used. The standard dimensions of the tested samples according to EN ISO 14125 are 15 x 60 x the sample thickness (mm). With help of machine five rectangular forms in a machine direction MD and five rectangular forms in CD direction (contrary to the direction of the machine) were cut from finished composite laminates. Dimensions and thickness of each specimens were measured with a help of micrometer instrument. In this way prepared composite specimens were tested for flexural strength using a universal testing machine (UTM), which is illustrated in Figure 1. Load and displacement were recorded by an automatic data acquisition system for each sample. Minimum five reproducible tests were conducted for each sample at room temperature.

3. RESULTS AND DISSCUSSION

The results of the testing method of the laminated specimens for determination of the flexural properties are presented in Table 3. The load at which completed fracture of the specimen occurred has been accepted as breakage load. Load-displacement curves were plotted for every tested sample and values for stress, strain and module of elasticity were calculated as an average value. The flexural stress σ_f was determined by the equation (1), where, σ_f is the flexural stress in Megapascals (MPa); F is the load in Newtons (N), L is the span, in millimeters (mm), b is the width of the specimen, in millimeters (mm), and h is the thickness of the specimen in millimeters (mm).

The flexural modulus of elasticity describes the dependence between stress, $\sigma_f$and deformation, ε_f. Flexural modulus of elasticity (E_f) and flexural strain (ε_f) of the composite specimens were determinate using equations (2) and (3). Where, E_f is the flexural modulus of elasticity, expressed in Megapascals (MPa), Δs is the difference in deflection between S`` and s`, $\Delta F$ is the difference in the load F`` and load F` at s`` and s` respectively, and s is maximum deflection of the center of the specimen (mm).

Obtained results from performed tests on laminated composite samples (Table 3) shown maximal flexural strength of 492,813 MPa for sample II-1 and minimal flexural strength of 370,128 MPa for sample I-2. Comparison between results of specimens manufactured at same technological parameters, but from textile fabric with different weave pattern shown that all samples tested at MD direction had performed better flexural properties in comparison to the samples tested at CD direction. The laminated samples manufactured from the second E-glass fabric with twill weave structure shown bigger values for flexural strength in both direction in relation to laminated samples produced from E-glass fabric with plain weave structure.

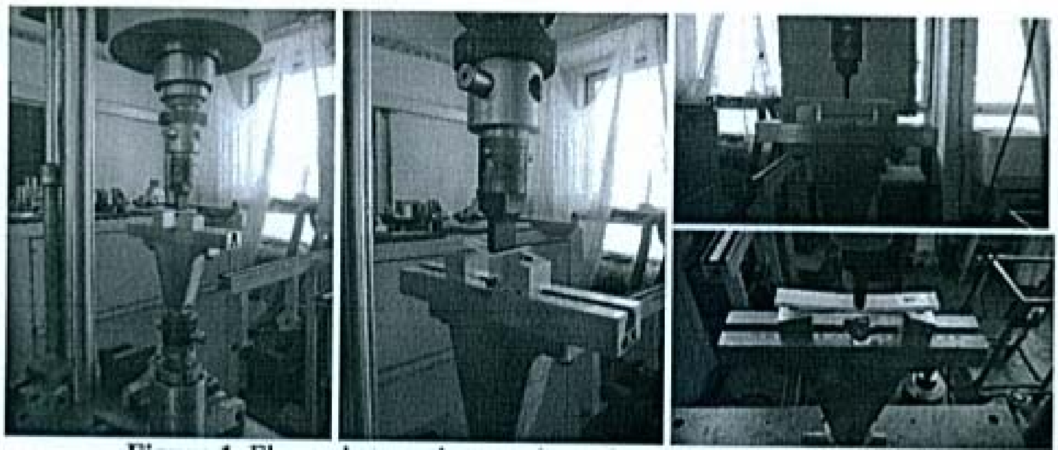

Figure 1. Flexural strength test using a three-point flexural method

Table 1. Characteristics of E- glass fabrics (sample 1 and 2)

Characteristic	Sample 1	Sample 2
Type of weave	Plain	Twill 2x2
Density (g/m²)	300	325±15
Thickness (mm)	0,3	0,32±0,05
Width (cm)	2000	92
Count warp (ends/cm)	8±1	90±1
Count weft (ends/cm)	7±1	50±1
Strength warp (N/25mm)	≥2000	3920
Strength weft (N/25mm)	≥1800	980

Table 2. Characteristics of the components of the resin system

Epoxy resin (D.E.R 3821)/		Polypox H 766	
Epoxide Equiv. Weight (g/eq)	176 – 183	Density at 25°C, [g/cm³]	0,94±0,05
Epoxide Percentage (%)	23,5 – 24,4	Viscosity at 25°C, [mPa s]	14
Epoxide Group Content (mmol/kg)	5460 – 5680	Amine number [mg KOH/g]	540±15
Color (Platinum Cobalt)	125 Max.	H – equivalent weight [g/Equiv.]	55
Viscosity @ 25°C (mPa•s)	9000 – 10500	Colour (Gardner)	blue
Hydrolyzable Chlorine Cont. (ppm)	500 Max.		
Water Content (ppm)	700 Max.		
Density @ 25°C (g/ml)	1,16		
Epichlorohydrin Content (ppm)	5 Max.		
Shelf Life (Months)	24		

Table 3. Results from flexural testing of the laminated specimens

Sample Number		b (mm)	h (mm)	L (mm)	Fmax (N)	S (mm)	σ_f (MPa)	E_f (GPa)	ε_f (%)
I-1 MD	1-1	15,33	2,25	5,66	636,29	5,66	491,925	23,035	4,776
	1-2	15,20	2,27	4,31	625,61	4,31	479,247	24,266	3,669
	1-3	15,40	2,25	3,78	659,18	3,78	507,305	21,741	3,189
	1-4	15,39	2,25	4,43	600,43	4,43	462,394	18,617	3,738
	1-5	15,00	2,25	2,89	592,04	2,89	467,785	19,052	2,438
					622,71		**481,731**	**21,342**	**3,562**
I-2 CD	2-1	15,27	2,34	4,70	508,12	4,70	364,625	15,944	4,124
	2-2	15,30	2,32	4,06	490,57	4,06	357,425	15,226	3,532
	2-3	15,27	2,33	3,80	485,23	3,80	351,195	16,287	3,320
	2-4	15,29	2,35	3,43	570,67	3,43	405,502	17,948	3,023
	2-5	15,34	2,37	4,55	534,06	4,55	371,894	16,653	4,044
					517,73		**370,128**	**16,412**	**3,609**
II-1 MD	1-1	15,46	2,63	60,43	887,29	3,41	497,847	19,454	3,363
	1-2	15,35	2,68	60,40	944,51	2,96	514,020	18,744	2,975
	1-3	15,42	2,60	60,13	903,32	3,41	519,950	19,899	3,325
	1-4	15,38	2,68	60,23	929,26	3,48	504,734	18,026	3,497
	1-5	15,45	2,85	60,48	894,16	3,27	427,512	16,408	3,495
					911,708		**492,813**	**18,506**	**3,331**
II-2 CD	2-1	15,44	2,55	60,11	704,95	4,42	421,291	18,302	4,227
	2-2	15,33	2,58	60,09	729,37	4,06	428,862	20,143	3,928
	2-3	15,16	2,54	60,06	658,41	4,26	403,907	18,287	4,058
	2-4	15,28	2,58	60,47	779,72	4,44	459,968	19,505	4,296
	2-5	15,15	2,59	60,21	740,05	4,79	436,918	18,551	4,652
					722,50		**430,189**	**18,958**	**4,232**

$$\sigma_f = \frac{3FL}{2bh^2} \quad (1)$$

$$E_f = \frac{L^3}{4bh^3}\left(\frac{\Delta F}{\Delta s}\right) \quad (2)$$

$$\varepsilon_f = \frac{6sh}{L^2} \quad (3)$$

4. CONCLUSION

From the obtained result for flexural properties of laminated E- glass fabric/ epoxy resin composite samples can be concluded, that flexural strength and flexural modulus of elasticity increase in MD direction in comparison to CD direction. This is because in MD direction (warp) the textile structure usually have bigger number of yarns than in CD direction (weft). Also, yarns used for warp have better mechanical properties than yarns used for weft. The way of interlacing of warp and weft yarns (style of weave pattern) also has a direct influence on the mechanical properties of laminated composite samples. Depending on the requirements of the laminate, many weave configurations can be used. Wide choice of matrices and textile preforms give good opportunities to choose an appropriate combination for a given application.

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