II International scientific conference
„Contemporary trends and innovations in the textile industry"
16-17th May, 2019, Belgrade, Serbia

EFFECT OF WEAVE OF FABRIC AND MOLDING PRESSURE ON THE MECHANICAL PROPERTIES OF COMPOSITE LAMINATES

Ivan Zlatkov[1], Silvana Zhezhova[1], Sanja Risteski[1], Vineta Srebrenkoska[1], Svetlana Risteska[2]

[1] Faculty of Technology, "Goce Delcev" University - Shtip, North Macedonia
[2] Institute of Advanced Composites and Robotics - Prilep, North Macedonia

ABSTRACT: *The purpose of this study is to investigate the design of polymer composite plates reinforced by two different types of woven fabric structures. The prepregs for these composites have been produced by hand lay-up impregnation technique and production of laminated composites have been made by compression moulding technique. Two major factors have been taken into consideration when designing the composites: the type of weave and moulding pressure. For the purpose of this investigation, four test specimen configurations have been made. Mechanical properties i.e. flexural strength of the produced samples were determined and based on that some conclusions were made.*

Keywords: *composite laminates, glass fabrics, type of weave, pressure*

UTICAJ PREPLETAJA TKANINA I PRITISKA PRESOVANJA NA MEHANIČKE OSOBINE KOMPOZITNIH LAMINATA

APSTRAKT: *Svrha ovog rada ogleda se u analizi dizajna polimernih kompozitnih struktura ojačanih sa dva razliita tipa struktura tkanina. Prepreзi za ove kompozite proizvedeni su tehnikom ručne impregnacije, a proizvodnja laminiranih kompozita je izvršena tehnikom kompresijskog presovanja. Pri dizajniranju kompozita u razmatranje su uzeta dva osnovna faktora: tip prepletaja i pritisak presovanja. Za potrebe ovog istraživanja, izrađene su četiri konfiguracije uzoraka. Ispitivane su mehaničke osobine, poput jačine savijanja proizvedeih uzoraka, a na osnovu toga izvedeni su i određeni zaključci.*

Ključne reči: *kompozitni laminati, staklene tkanine, tip prepletaja, pritisak*

1. INTRODUCTION

Textile composites are composed of textile reinforcements combined with a binding matrix (usually polymeric). This describes a large family of materials used for load – bearing applications within a number of industrial sectors [1].
Textiles are considered to be among the most effective reinforcements for composites and the successful use of fabrics, based on carbon, glass or aramidic fibers. Textile composite materials have innovative features, due to the complex geometry of the

reinforcements. Mechanical behavior of a fabric reinforced composite material depends on the properties of each component, the proportion of the components, the shape and orientation of the yarns relative to the direction of stress, the mechanical strength of the interface matrix-yarn [2]. Properties of composites arise as a function of its constituent materials, their distribution, and the interaction among them and as a result of it an unusual combination of material properties can be obtained [3]. 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 [4]. The most popular textiles used as reinforcement are woven fabrics [5].
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 micro-structure 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. The methods for the modelling of textile structural composites are also reviewed with an emphasis on their role in the integration of design, manufacturing and structural analysis of composites [4]. The development of textile composite, their design and manufacturing technologies is one of the most important achievements in the engineering of materials. 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 [6].
Hand lay-up is a simple method for composite production. The process consists of building up or placing layers of composite fiber in a sequenced layup using a matrix of resin and hardener [7,8]. The compression molding is one of the technique that used to develop variety of composite materials. It is closed molding process with higher pressure. This process also produces high strength and complex part [9].
Experiments often involve several factors. Usually, an objective of the experimenter is to determine the influence that these factors have on the output response of the system. The general approach for planning and conducting the experiment is called the strategy of experimentation. An experimenter can use several strategies. Experimental design methods have found broad application in many disciplines. As noted previously, we may view experimentation as part of the scientific process and as one of the ways by which we learn about how systems or processes work. Generally, we learn through a series of activities in which we make conjectures about a process, perform experiments to generate data from the process, and then use the information from the experiment to establish new conjectures, which lead to new experiments, and so on. Experimental design is a critically important tool in the scientific and engineering world for improving the product realization process. Critical components of these activities are in new manufacturing process design and development, and process management [7].
The purpose of this study, was to assess the applicability of the 2^2 full factorial experimental design in predicting the flexural strength of glass fiber/epoxy resin composite plates.

2. EXPERIMENTAL

In this paper composite structure reinforced with two types of E-glass textile fabric has been analyzed. Prepregs (preimpregnated composite materials) were produced by using hand lay - up technology. Twill and basket fabrics have been used for the manufacturing of the prepregs. In Table 1 are given the specifications of the woven fabrics from E-glass fibers. For the experimental tests, a two-component thermosetting system of epoxy resin (DER 383) and a hardener (Polypox H 766) have been used as a matrix.

Table 1: Characteristics of glass fabrics

	Characteristic							
	Type of weave	Thickness (mm)	Density (g/m²)	Width (cm)	Count (ends/cm)		Strength (N/25mm)	
					Warp	Weft	Warp	Weft
Sample 1	Twill 2x2	0,32±0,05	320±20	92	8±1	6±1	≥2000	≥1400
Sample 2	Basket	0,31	320±25	100	6±1	5±1	≥1800	≥1200

Prepregs with dimensions 250mm x 200mm have been used for the manufacturing of the composite structure. The two-component resin system is applied or distributed over each piece of the fabric, in our case – the glass fabric, using a hand-roller. The resin distribution has been carried out in the following order: glass fabric, resin, glass fabric, resin etc. The final curing of preforms has been done in a press machine, using 18 and 14 kg/cm² pressure, with a predetermined temperature. The laminated samples remain in the press machine for one hour. The prepared samples are left for another couple of hours, while the mixture doesn't fully combine and dry out.

The preparation of the composites was done by application of a 2^2 full factorial experimental design. For the purposes of this research, four test specimen configurations have been made and on based on it the test results should provide material properties useful in the design stage. The type of weave was decided to be the first factor, while the second factor is the moulding pressure. As far as the first factor is concerned, basket and twill weave have been chosen respectively, while for the second factor – 14 and 18 kg/cm². The coding of the variables is conducted in accordance with Table 2.

Table 2: Full factorial experimental design -2^2

No. exp.	Matrix of full factorial experimental design				Characteristics (conditions of the experiment)	
	x_0	x_1	x_2	$x_1 x_2$	x_1 *type of fabric*	x_2 *moulding pressure* (kg/cm²)
1	+1	-1	+1	-1	basket	18
2	+1	+1	+1	+1	twill	18
3	+1	-1	-1	+1	basket	14
4	+1	+1	-1	-1	twill	14

Flexural properties of manufactured samples were determined by the three-point bending test, in accordance with the procedure described in the standard EN ISO 14125 (10). The prepared composite specimens were tested using a computer controlled universal testing machine (UTM) hydraulic press, SCHENCK- Hidrauls PSB with maximal load of 250 kN, constant crosshead speed of 5 mm/min,, illustrated in Figure 1. Load and displacement were recorded by an automatic data acquisition system for each sample.

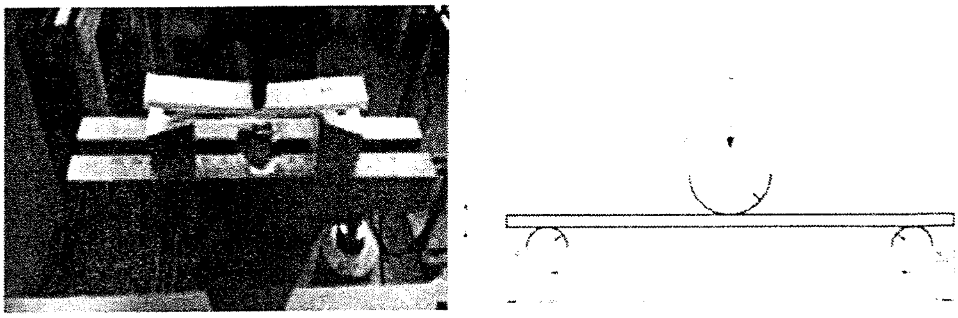

Figure 1: Flexural strength test

3. RESULT AND DISCUSSION

The results of the testing method of the laminated specimens for determination of the flexural properties are illustrated in Table 4.
The load at which the completed fracture of the specimen occurred has been accepted as breakage load. The flexural strength σ_f is illustrated by the equation (1), where , σ_f is the flexural strength 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).

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

Table 4: Results for the flexural strength of the composite plates

Sample Number		Width, **b (mm)**	Thickness, **h (mm)**	Length, **L (mm)**	Flexural strain, **σf (MPa)**	**σf** sr. (MPa)
	1-1	15,40	2,72	60,31	468,068	
1	1-2	15,31	2,76	60,29	478,467	
	1-3	15,33	2,75	60,59	465,925	470,82
	2-1	15,44	2,10	60,01	547,910	
2	2-2	15,22	2,05	60,12	550,358	548,99
	2-3	15,42	2,07	60,27	548,701	
	3-1	15,41	2,92	60,29	436,539	
3	3-2	15,30	2,91	60,29	432,456	438,35
	3-3	15,34	2,94	60,40	446,050	
	4-1	15,35	2,68	60,40	514,020	
4	4-2	15,42	2,60	60,13	519,950	512,90
	4-3	15,38	2,68	60,23	504,734	

The results obtained from tests performed on the composite samples (Table 4) show maximal flexural strength of 550,358 MPa for sample 2-2, and minimal flexural strength of 432,456 MPa for sample 3-2. The comparison of results of specimens manufactured under the same technological parameters, but from textile fabric with different weave pattern, has shown significant difference in terms of flexural strength.
By implementation of the 2^2 full factorial experimental design we have found out that the response function in coded variables, y, is:

$$y=492,765+38,18x_1+17,14x_2 \quad (2)$$

From the regression equation, it can be noted that the pressing pressure as a process parameter X_2 influences the flexural strength of the composite plates, but with lower intensity. However, this experiment has been shown that the type of weave has a greater influence on flexural strength of the composite material. If we compare the composite plates reinforced with glass fibers in a basket and twill weave, pressed at the same pressure, we will notice a big difference in the flexural strength, whereby composites reinforced with twill weave have yielded better results.

4. CONCLUSION

From the obtained results for flexural strength of laminated E-glass fabric/epoxy resin composite plates, in accordance with the experiments plan-matrix it can be concluded that highest flexural strength has been noted in the samples with the mark "2", which have been reinforced by twill fabric and molded at maximal pressure of 18 kg/cm2. Meanwhile, the samples with the mark "3", reinforced by basket fabric and moulding pressure of 14 kg/cm2 have proven to have a lowest flexural strength.

From the obtained results, it can be noted that the mechanical properties of the composite samples mostly depend on the type of reinforcing material of the composite, while the moulding pressure influences the function result, but with lower intensity. Hence, this test has confirmed the influence of geometry in the textile fabric used as reinforcing component of composite plates. Namely, the application of better type of reinforcing fiber (twill, in this case), and higher moulding pressure will result in highest flexural strength of the composite plates. The obtained regression equation implies the same conclusion is true, as well.

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