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THE DESIGNING OF COMPOSITE LAMINATES FOR APLICATION IN AUTOMPOTIVE INDUSTIES

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ABSTRACT: *The purpose of this study is to investigate the design of polymer composite plates for application in automobile industries reinforced by thermoplastic unidirectional prepreg material based on carbon fibers. The production of laminated composites have been made by compression moulding technique. Two major factors have been taken into consideration when designing the composites: processing temperature 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 PREPLET TKANINA I PRITISAK PRESOVANJA NA MEHANIČKE OSOBINE KOMPOZITNIH LAMINATA

APSTRAKT: *Cilj ove studije je istražiti dizajn polimernih kompozitnih struktura za primenu u automobilskoj industriji ojačanih termoplasticnim jednosmetnim prepreg trakama na bazi ugljeničnih vlakana. Proizvodnja laminiranih kompozita izvedena je tehnikom kompresijskog presovanja. Pri projektiranju kompozita uzeta su u obzir dva osnovna faktora: temperatura procesiranja i pritisak presovanja. Za potrebe ovog istraživanja, napravljene su četiri konfiguracije uzoraka. Ispitivane su mehaničke osobine, odnosno jačina svijanja, proizvedenih uzoraka i na osnovu tome su izvedeni određeni zaključci.*

Ključne reči: *kompozitni laminati, staklena tkanina, tip preplet, 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. Composites are ideal materials for aerospace, automotive and other mechanical industries where the use of high performance advanced materials directly enhances their capability. The structures made of advanced composites have been majorly manufactured by hand layup of prepreg tapes to produce composite parts that are finalized by a consolidation and a curing process in an autoclave [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 unidirectional prepreg [5].

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].

Thermoplastic composites have several advantages [7,8]: good damage tolerance properties; superior chemical resistance; non-limited storage time; recyclability. These advantages make thermoplastic composites a very interesting material for structures parts manufacturing, not only from the cost perspective but also from structural strength capability standpoint. These composites are attractive for application in the automotive and aerospace industry due to the high stiffness, fracture toughness, compressible strength, good impact, fatigue. Another advantage of thermoplast composites is their ability to re-melt, which widens the possibilities in product and production process designs [9–11].

The compression moulding is one of the manufacturing process that produce the thermoplastic and thermoset product in industries. This 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 [10-12].

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 to 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 [12,13]
The purpose of this study, was to assess the applicability of the 2^2 full factorial experimental design in predicting the flexural strength of thermoplastic composite plates.

2. EXPERIMENTAL

The materials used in this paper was thermoplastic unidirectional (UD) prepreg tape. Prepreg is a semiproduct consisting of reinforcing fibers and thermosetting or thermoplastic polymer matrix. This material can be further processed at a certain temperature depending on the polymer matrix and the appropriate pressure for forming a composite structure with certain strength characteristics. In this study for the production of the thermoplastic composite laminates, unidirectional prepreg material based on carbon fibres (AS4 carbon fibres) and thermoplastic matrices polyphenylene sulfide - PPS (Ticona 0214 PPS), supplied by Suprem, Switzerland. was used (table 1). Eight layers of prepreg with dimensions 200mm x 200mm have been used for the manufacturing of composite laminates. The final curing of preforms has been done in a press machine, using 385N and 530 N pressure, with a predetermined temperature (figure 1).

Table 1: Description of UD prepregs (used in this study)

Materials	Suprem™ T 60% AS4/PPS-214
Prepreg areal weight	305 g/m²
Fibre areal weight	200 g/m²
Matrix content	34 wt.%
Nominal thickness	0.19 mm
Matrix glass transition temperature (*Tg*)	80 – 90 °C
Matrix melting temperature (*Tm*)	285 °C

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 temperature was decided to be the first factor, while the second factor is the moulding pressure. As far as the first factor is concerned, 330°C and 380°C have been chosen to be low and high levels respectively, while for the second factor – 270 N and 380 N. The coding of the variables is conducted in accordance with Table 1.

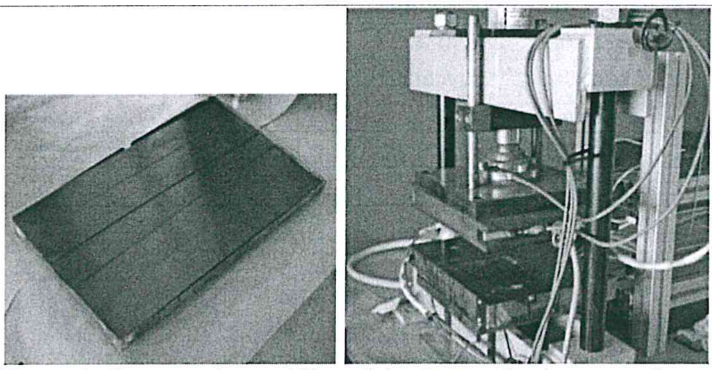

Figure 1: Compression molding of the thermoplastic prepreg layers

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 (14). Therefore, computer controlled universal testing machine (UTM) hydraulic press, SCHENCK- Hidrauls PSB with maximal load of 250 kN, constant crosshead speed of 5 mm/min, was used. The prepared composite specimens were tested for flexural strength using a universal testing machine - (UTM), illustrated in Figure 1. Load and displacement were recorded by an automatic data acquisition system for each sample.

Table 2: Processing parameters used in the current study

Materials	**Suprem™ T 60% AS4/PPS-214**
Target temperature	330 °C and 380 °C
Tool temperature	Unheated/no cooling
Tool material	Stainless steel
Pressure	270 N and 380 N
Numbers of layers	8

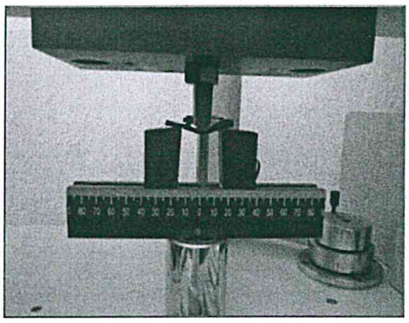

Figure 2: Flexural strength test

Table 3: 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 *temperature* (°C)	x_2 *moulding pressure* (N)
1	+1	+1	+1	+1	380	380
2	+1	-1	+1	-1	330	380
3	+1	+1	-1	-1	380	270
4	+1	-1	-1	+1	330	270

	x_1 *temperature* (°C)	x_2 *moulding pressure* (N)
zero level, $x_i = 0$	355	325
interval of variation	25	55
high level, $x_i = +1$	380	380
lower level, $x_i = -1$	330	270

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).

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

The results obtained from tests performed on the composite laminated (Table 4) show maximal flexural strength of 884,11 MPa for sample 2 produced on the lower level of temperature and higher level of molding pressure, and minimal flexural strength of 617,74 MPa for sample 1 produced on high level of both factors. The comparison of results of specimens manufactured under the different temperature and molding pressure, has shown differences in terms of flexural strength.

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

Sample Number		Width, b (mm)	Thickness, h (mm)	Loading force (N)	Flexural strain, σ_f. (MPa)	$\sigma_{f\ sr.}$ (MPa)
1	1-1	15,31	1,95	697	628,56	**617,74**
	1-2	15,2	2,16	736	544,86	
	1-3	15,3	2,05	781	637,69	
	1-4	15,28	1,86	671	666,40	
	1-5	15,19	1,77	554	611,17	
2	2-1	15,13	1,87	954	946,64	**884,11**
	2-2	15,07	1,96	875	793,49	
	2-3	15,17	1,96	971	874,74	
	2-4	15,03	1,84	927	956,41	
	2-5	15,11	1,96	939	849,27	
3	3-1	15,17	1,94	1410	730,47	**746,71**
	3-2	15,1	1,89	1624	821,19	
	3-3	15,19	1,95	1251	607,75	
	3-4	15,14	1,92	1611	846,06	
	3-5	15,16	1,85	1332	728,11	
4	4-1	15,08	1,9	1628	660,10	**712,75**
	4-2	15,07	1,85	1483	617,43	
	4-3	15,07	1,87	1745	799,53	
	4-4	15,15	1,92	1689	791,19	
	4-5	15,07	1,79	1568	695,50	

By implementation of the 2^2 full factorial experimental design we have found out that the response function in coded variables, y, is:

$$y = 740{,}25 - 58{,}19X_1 + 10{,}51X_2 - 75{,}17X_{12} \quad (2)$$

From the regression equation, it can be noted that the most influent factor on the mechanical characteristics of the composite laminates has the interaction between the two factors. The temperature as a process parameter has a higher influence then molding pressure as a process parameter x_2 on the flexural strength of the composite plates. But, temperature has a negative input into the process than molding pressure which has a positive effect. However, these experiments have been shown that the interaction between the factors has the significant influence on the flexural strength. Namely, the higher temperature and higher molding pressure led to production of the laminates with lower flexural strength.

4. CONCLUSION

From the obtained results for flexural strength of laminated 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 produced at minimal temperature of 330°C and maximal pressure of 380 N. Meanwhile, the samples with the mark “4”, produced at high level of temperature and moulding pressure (380 °C and 380 N respectively) 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 process parameters. Namely, the application of lower processing temperature 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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