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Strength tests of sandwich composite materials connected by means of screw joints

S. Żółkiewski*
Division of Mechatronics and Designing of Technical Systems, Institute of Engineering Processes Automation and Integrated Manufacturing Systems, Silesian University of Technology, ul. Konarskiego 18a, 44-100 Gliwice, Poland
* Corresponding author: E-mail address: slawomir.zolkiewski@polsl.pl

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Properties

ABSTRACT

Purpose: of this thesis is to present the exemplary results of strength tests of sandwich composite materials consisted of the laminate plate and the metal sheet plate.

Design/methodology/approach: The strength tests were carried out in the laboratory stand by means of the electric resistance wire strain gauge. The laboratory stand was specially designed for the purpose of testing composite materials.

Findings: The results are presented in the form of graphs. In graphs the maximal and minimal strains in the time function are presented.

Research limitations/implications: The tests were carried out for different configurations of the samples. The specimens were prepared as the samples with the external steel plate or with the steel plate arranged among the laminate layers.

Practical implications: The experimental tests are still necessary in analysis of the composite materials. The real parameters of the samples should be determined in an experimental way. However, the numerical computer simulation of the composite materials is possible e.g. in Unigraphics software, but modelled in the computer environment composites have very often some errors and results of simulation is not proper.

Originality/value: The sandwich composite materials were tested in the laboratory stand by means of extensometers. The results could be used in designing of mechanical parts and mechanisms made of the laminate connection in the steel plate by means of screws. The fundamental mechanical properties of such a type materials were derived.

Keywords: Working properties of materials and products; Mechanical properties; Composites; Deformations

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1. Introduction

In this work the fundamental information on the composite materials connected by means of the screw joints. The most popular methods of strength testing of composite materials are used to determine fundamental mechanical properties of the considered composites. The tests were carried out using the strain gauges measurements. Findings of the strain gauges measurements done on the composite structure samples are presented. Mechanical and physical properties of fibrous

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composite materials are very good and much better than in case of traditional construction materials. The advantages of such a type materials are connected with low weight and high strength [1-5]. A lot of mechanisms made up of composite materials have less weight than traditional constructions e.g. steel constructions. Big problem in applying composite materials is the way of connecting them with other materials such as steel. The ways used to connect composites to steel and composite-to-alloy are unreliable. Adhesive joints, screw joints and integrated joints are most popular ways of connecting composite materials with other materials. The first two ones are very frequently used in all kinds of technical applications [1-5].

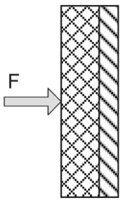
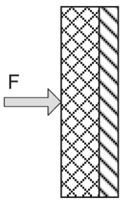
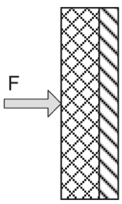
The most proper way of determining parameters and strength properties of composite materials is still the experimental test. Of course it is also possible to carry out some computer simulation. There are many computer applications for dynamic analysis of mechanical systems e.g. [6-15] but many of them does not allow to model the composite structure properly. For example a computer simulation in Unigraphics software. Modelling of the composites in Unigraphics software makes it possible to set the parameters for each layer of the laminate [3]. In Unigraphics app. one can set parameters such as: ply material, thickness or angle of ply and nesting consecutive ply in every layer, making different structure from each layer. It is also possible to define parameters such as: reinforcements layer, matrix volume fraction, warp fibre material, weft fibre angle and material etc.

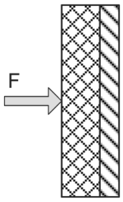
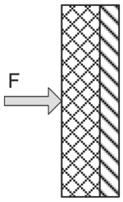
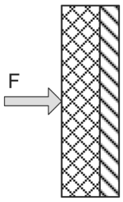
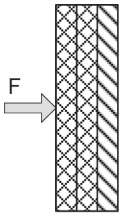
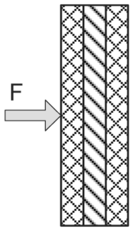
2. Exemplary results of experimental tests

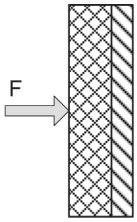
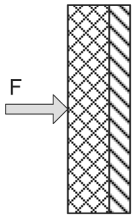
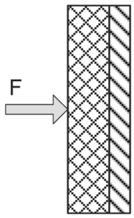
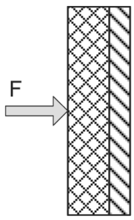
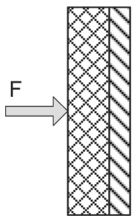
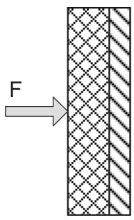
In Table 1 the parameters and properties of tested specimens are presented. The tested samples are made up of composite materials reinforced with fibreglass, carbon fibres and Kevlar fibres. To fabricate the specimens Epidian 6 and Polimal 1094 resins were used. Polimal 1094 is construction resin, on average the flexible, accelerating agent with low vinyl benzene emission [1-2]. The considered composites are both the hybrid ones and sandwitch ones, because of a connection between laminates and metal sheet plate.

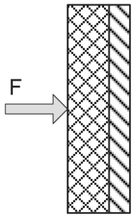
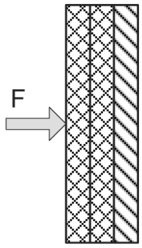
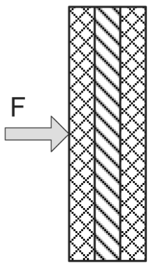
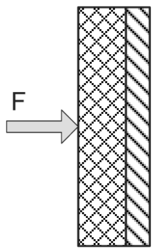
First chart presents the measured strains from three extensometers one at a time. The strain ε_0 is marked by a red color line, the strain ε_{90} by a blue line and the strain ε_{45} by a green line. Second chart presents the measured force in the time function and the last one is the non-dilatation stress angle in the time function. The charts were generated in Catman software from the HBM company.

Table 1.
Parameters of the samples

No.	Designation	The way of loading	Parameters of the specimens	
1	R400_5		G.S.M.	400 g/m^2
			Number of layers	5
			Type of connection	Adhesive
			Body mass	1440 g
			Thickness	3.5 mm
2	R400_5_8_M4		G.S.M.	400 g/m^2
			Number of layer	5
			Number of screws	8
			Nominal diameter	M4
			Body mass	1440 g
			Thickness	3.5 mm
3	R400_5_8_M6		G.S.M.	400 g/m^2
			Number of layer	5
			Number of screws	8
			Nominal diameter	M6
			Body mass	1440 g
			Thickness	3.5 mm

4	R400_5_16_M4		G.S.M.	400 g/m^2
			Number of layer	5
			Number of screws	16
			Nominal diameter	M4
			Body mass	1440 g
			Thickness	3.5 mm
5	R400_5_16_M6		G.S.M.	400 g/m^2
			Number of layer	5
			Number of screws	16
			Nominal diameter	M6
			Body mass	1440 g
			Thickness	3.5 mm
6	R400_5_16_M6(A)		G.S.M.	400 g/m^2
			Number of layer	5
			Number of screws	16
			Nominal diameter	M6
			Body mass	1440 g
			Thickness	3.5 mm
			Remarks	The sheet covered with anticorrosive
7	R400_5x2_16_M6 KKB		G.S.M.	400 g/m^2
			Number of layer	5x2
			Number of screws	16
			Nominal diameter	M6
			Body mass	1900 g
			Thickness	6 mm
			Remarks	The sheet is outside
8	R400_5x2_16_M6 KBK		G.S.M.	400 g/m^2
			Number of layer	5x2
			Number of screws	16
			Nominal diameter	M6
			Body mass	1900 g
			Thickness	6 mm
			Remarks	The sheet is in the center

9	R400_10_16_M6		G.S.M.	400 g/m^2
			Number of layer	10
			Number of screws	16
			Nominal diameter	M6
			Body mass	1940 g
			Thickness	6 mm
10	R1000_2		G.S.M.	1000 g/m^2
			Number of layer	2
			Type of connection	Adhesive
			Body mass	1435 g
			Thickness	3.2 mm
11	R1000_2_8_M4		G.S.M.	1000 g/m^2
			Number of layer	2
			Number of screws	8
			Nominal diameter	M6
			Body mass	1435 g
			Thickness	3.2 mm
			Remarks	-
12	R1000_2_8_M6		G.S.M.	1000 g/m^2
			Number of layer	2
			Number of screws	8
			Nominal diameter	M6
			Body mass	1435 g
			Thickness	3.2 mm
13	R1000_2_16_M4		G.S.M.	1000 g/m^2
			Number of layer	2
			Number of screws	16
			Nominal diameter	M4
			Body mass	1435 g
			Thickness	3.2 mm
14	R1000_2_16_M6		G.S.M.	1000 g/m^2
			Number of layer	2
			Number of screws	16
			Nominal diameter	M6
			Body mass	1435 g
			Thickness	3,2 mm

15	R1000_2_16_M6(A)		G.S.M.	1000 g/m2
			Number of layer	2
			Number of screws	16
			Nominal diameter	M6
			Body mass	1435 g
			Thickness	3.2 mm
			Remarks	The sheet covered with anticorrosive
16	R1000_2x2_16_M6 KKB		G.S.M.	1000 g/m^2
			Number of layer	2x2
			Number of screws	16
			Nominal diameter	M6
			Body mass	1890 g
			Thickness	5.4 mm
			Remarks	The sheet outside
17	R1000_2x2_16_M6 KBK		G.S.M.	1000 g/m^2
			Number of layer	2x2
			Number of screws	16
			Nominal diameter	M6
			Body mass	1890 g
			Thickness	5.4 mm
			Remarks	The steel sheet among laminate layers
18	R1000_4_16_M6		G.S.M.	1000 g/m^2
			Number of layer	4
			Number of screws	16
			Nominal diameter	M6
			Body mass	1850 g
			Thickness	5.4 mm

The readout strains from three extensometers of the strain rosette and calculated average strains are presented. In Figure 1 the characteristics of the strains in the time function for specimen with five layers of roving fabric made with g.s.m. 400g/m^2 connected by means of eight screws joints (Metric thread 4) are presented. In this case as in the adhesive connection case the minimal and maximal strains are similar in absolute one another.

In Figure 2 the results for the sample with five layers of roving fabric with g.s.m. 400g/m^2 connected by means of eight screws joints (Metric thread 6) are presented. In this case (Fig. 2) in absolute values, the minimal strains are twice smaller than the maximal one. In Figure 3 in absolute values, the minimal strains are twice larger than the maximal one. This situation is connected with not sufficient fixation of the specimen and some translation in the fixing frame when the loading force was greater than 0,3kN. In this case the specimen was made of five layer roving fabric with g.s.m. 400g/m^2 connected by means of 16 M4 screws. In Figure 4 the results for the five layer sample made of roving with g.s.m. 400g/m^2 connected by means of 16 M6 screws are shown. In the presented case (Fig. 4) the results are similar to the case with the smaller screws number one and the situation is also the same as previous.

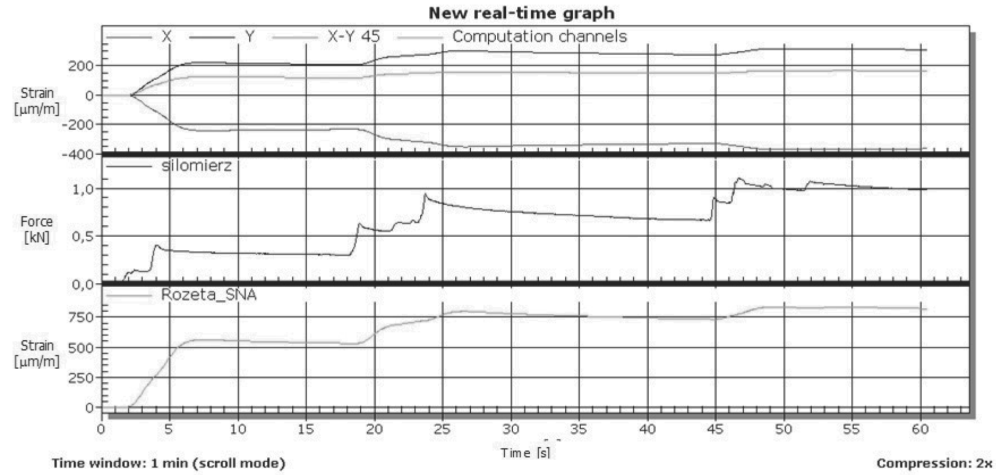


Fig. 1. Characteristic of the strains and the force in function of the time for five roving layers connected by means of 8 M4 screws

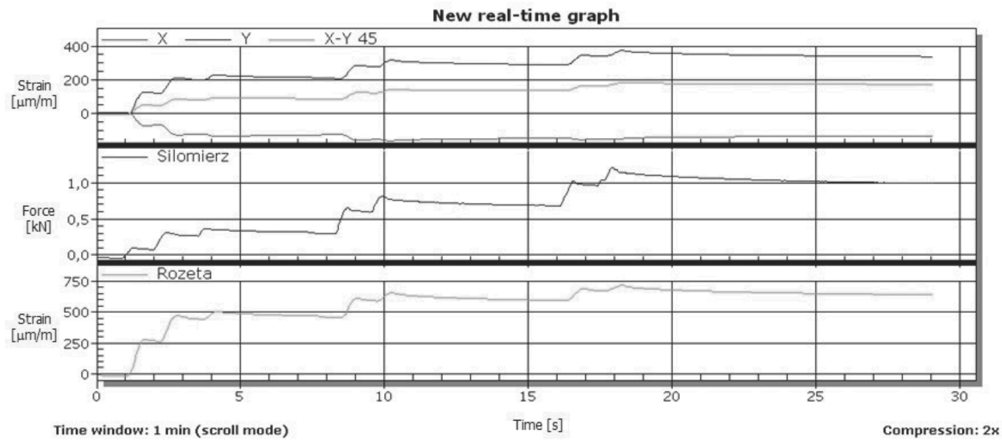


Fig. 2. Characteristic of the strains and the force in function of the time for five roving layers connected by means of 8 M6 screws

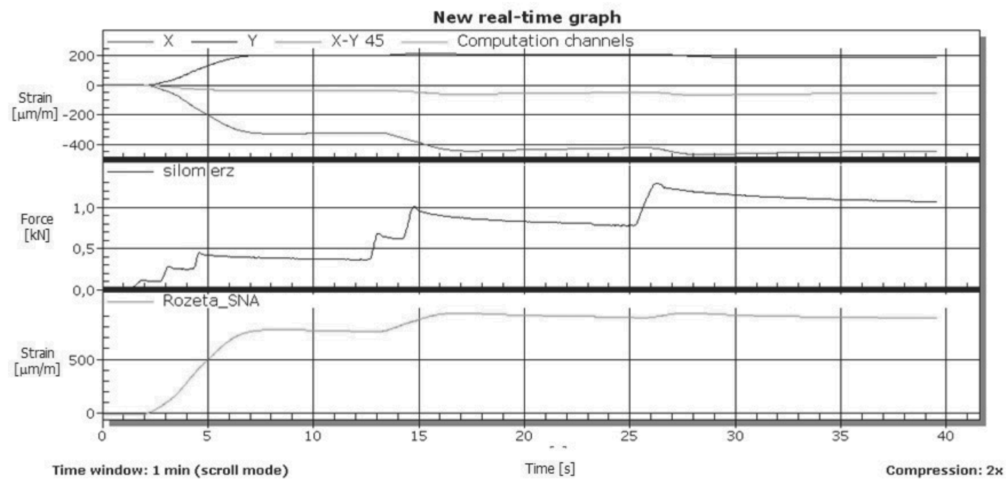


Fig. 3. Characteristic of the strains and the force in function of the time for five roving layers connected by means of 16 M4 screws

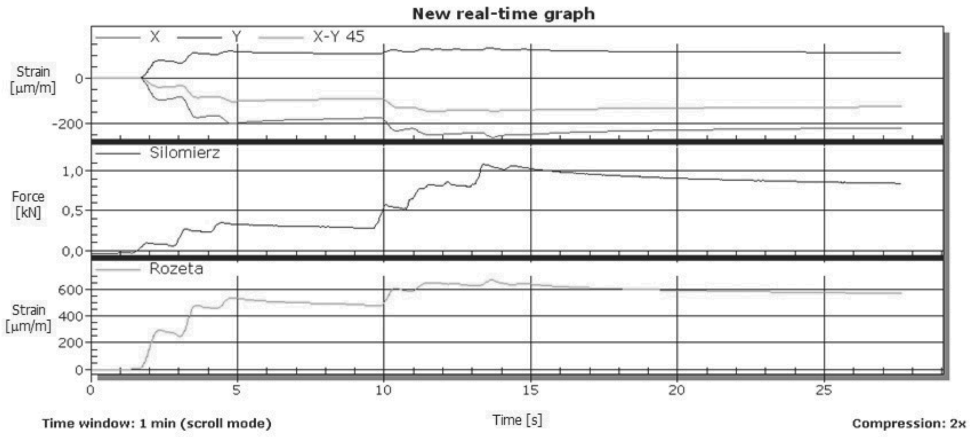


Fig. 4. Characteristic of the strains and the force in function of the time for five roving layers connected by means of 16 M6 screws

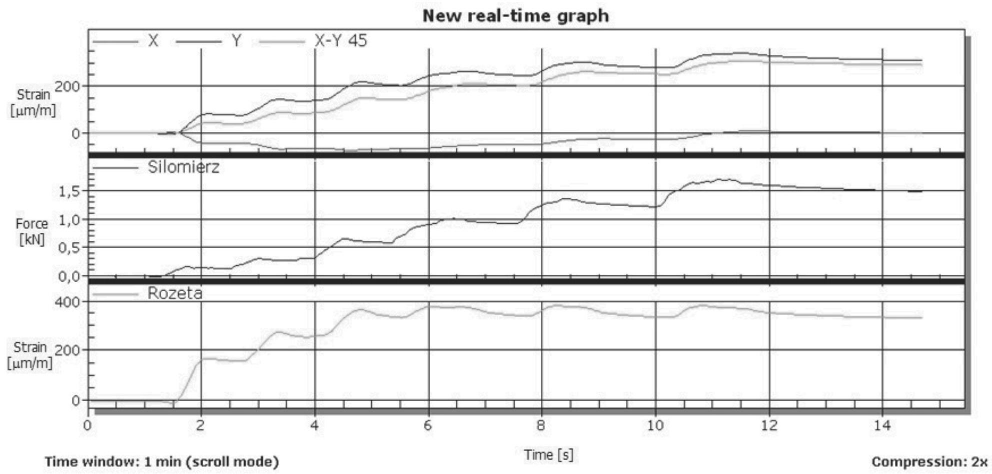


Fig. 5. Characteristic of the strains and the force in function of the time for five roving layers connected by means of 16 M6 screws protected by anticorrosive

In Figure 5 the five layer roving sample connected by means of 16 M6 screws protected by anticorrosive is shown. In the presented case (Fig. 5) decreasing of the values of the principal stress can be observed. This situation can be connected with some faults in the laminate sheet or in the connection. Repetition of the measuring gave the same results. The real reason of this situation is uncertain.

3. Conclusions

In this paper the experimental results of the samples made up of the laminate plates and the steel plates are presented. The laminates were handmade fabricated in an adhesive way. The considered composites are the steel-laminate sandwich connected with each other by means of the screws. In this work there are the chosen results of strength testing fibrous composite materials connected in screw joints, shape joints and glue joints presented. Composite materials reinforced with fibreglass, carbon and Kevlar fibres are considered in connection with the metal sheet plate.

The specimens were fabricated using the Polimal 1094 and the Epidian 6 resins. The Polimal 1094 resin in comparison with the Epidian 6 resin has better processing features. The Polimal resin is a very infiltrating one and efficiently cuts down the time of infiltrating reinforcements fibres. It is very important to prepare the surface of the sample adequately. The screw joint of the laminate and the metal sheet plate may provide some discrepancy between displacements of the connected elements. This fact is the reason why the strength properties are not so strong as they could be. The samples joint with the higher number of the applied screws has lower displacements and better overall strength properties. The difference between Young's modulus of the connected laminates and metal sheet plates may cause the damage of elements.

In accordance to the obtained results, the lowest displacement was for composites with carbon fibres. This reinforcement is characterized by high strength properties and low mass density. The presented results for combination of laminates and metal sheet plates can be used for many different applications such as: containers, freight and goods wagons.

The tested handmade samples have some heterogeneities in laminate layers that can provide some result errors and distinctions between the results obtained in computer simulation and experimental test. A fundamental problem of modelling and computer simulating the composites in numerical environments is assuming proper physical and material parameters of the analyzed parts. The producers of woven fabrics do not provide any important values and parameters or mechanical properties. Numerical simulations permit testing of impact on strength properties. In such a case the most important is to define the boundary conditions and properly define finite elements (FEM) providing an appropriate reflection of warp and fibers. Handmade composites have different participation of warp and reinforcement fibres. The results of experimental testing on resin impact show no impact in this aspect.

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