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The Effect of Layers on the Unidirectional Carbon Fibers of the Reinforced Polyester Resin Matrix Composite Material

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Abstract

In this study, composite materials are produced, placing unidirectional carbon fiber reinforcements with 12 filament numbers in a polyester matrix to form one, two, and three layers at room temperature through the hand lay-up method. The samples are prepared from composite plates with the help of a mold in line with the fiber direction angle by the standards. Tensile, bending, and falling weight low-speed impact tests are conducted to determine the mechanical properties of the samples. As a result of the tensile test, the highest tensile strength value among layers is obtained in the two-layer unidirectional fiber-reinforced composite materials. In bending tests, the highest elasticity values of unidirectional carbon fiber reinforcements are observed in three-layer composite materials with a fiber direction angle of 0^0. 0^0 unidirectional fiber-reinforced one-layer composite materials are observed in composite materials with the highest deformation values in the falling weight low-velocity impact tests.

Güçlendirilmiş Polyester Reçine Matrisli Kompozit Malzemelerin Tek Yönlü Karbon Fiberler Üzerinde Katmanların Etkisi

Anahtar Kelimeler

Karbon lifler
Kompozit Malzemeler
Mekanik Özellikler
Polyester Reçine

Öz

Bu çalışmada, 12 filament numaralı tek yönlü karbon fiber takviyelerin polyester matris içerisine bir, iki ve üç katman oluşturacak şekilde oda sıcaklığında elle yatırma yöntemiyle yerleştirilmesiyle kompozit malzemeler üretilmiştir. Numuneler, standartlara uygun olarak elyaf yön açısı doğrultusunda bir kalıp yardımıyla kompozit plakalardan hazırlanır. Numunelerin mekanik özelliklerini belirlemek için çekme, eğilme ve düşen ağırlık düşük hızlı darbe testleri yapılır. Çekme testi sonucunda katmanlar arasında en yüksek çekme dayanımı değeri iki katmanlı tek yönlü elyaf takviyeli kompozit malzemelerde elde edilmiştir. Eğilme testlerinde tek yönlü karbon elyaf takviyelerin en yüksek elastisite değerleri 0^0 dogrultusunda üç katmanlı kompozit malzemelerde gözlenmektedir. 0^0 tek yönlü güçlendirilmiş kompozit malzemelerin düşen ağırlıkta düşük hız darbe testlerinin en yüksek deformasyon değerlerine sahip kompozit malzemelerde görülmektedir.

1. INTRODUCTION

Materials formed by combining two or more materials with several methods are called composite materials. Composite materials exhibit different properties from the materials that make them up. The most important purpose of using composite materials is to improve the properties of composite materials such as strength, flexibility, and lightness, which are insufficient when used alone [1-3]. In this context, with the developing technologies, especially in the defense industry, automotive, space, and aviation sectors, composite are frequently used [4]. In addition, recent research on biomedical applications (bone plate, external fixtures, etc.) continues. Hence, composite materials with different reinforcements and matrices are used in today's industry.

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The most commonly used reinforcement materials among fiber-reinforced polymer composites are glass, carbon, and (aramid) Kevlar-type fibers [5]. Carbon fiber reinforced polymer composites are widely preferred because of the superior mechanical, environmental stability and a lightness of carbon fibers [6].

The compressive, tensile, and interlayer shear properties of different carbon-reinforced/polyamide composite materials obtained by interface polymerization and hot compression molding techniques are compared. With the increase of carbon fiber content, a slight increase in the composite material's elastic modulus, tensile and compressive strengths are detected [7]. The tensile strengths of composite materials consisting of carbon fiber, hybrid carbon/glass fiber, and hybrid carbon/basalt layers are investigated at different temperatures. The tensile strength values of hybrid composites decreased with increasing temperature values [8]. Composite materials were reinforced with glass fiber in different fiber ratios and their mechanical properties were investigated. Tensile, impact and three-point bending tests were carried out by cutting samples from the obtained plate composite materials in accordance with ASTM standards. Consequence of all these studies, it was observed that the maximum stress, tensile elongation, elastic modulus and impact resistance properties of the composite material increased with the increase in the glass fiber ratio [9]. Higher-strength is determined in the glass fiber layers of carbon fiber layers with a high modulus of epoxy-based glass/carbon fiber layered hybrid composites [10]. Impact tests have been carried out by producing layered composites using carbon and glass fiber. Epoxy and unsaturated polyester are used as the resin. As a result of impact tests, it has been revealed that if the resin is epoxy, its energy absorption is lower than that of unsaturated polyester resin [11]. In another study, it is observed that the impact and strength resistance of composites increased with the addition of nano reinforcement to epoxy matrix [12]. Consequently the tensile tests of biaxial fiber direction $-+45^0$ composite samples, the best ductility, and the best impact strength value are obtained in the low-speed impact tests of the falling weight [13]. Unidirectional basalt fiberglass fiber-reinforced composites and hybrid composite materials are produced by vacuum bagging technique, then tensile and three-point bending tests are performed to evaluate samples mechanical properties. It has been concluded that the mechanical properties of composites with basalt fiber out layer are better [14]. Buckling and tensile test are performed on carbon fiber reinforced epoxy resin composites, revealing that the mechanical properties mainly depend on the fiber orientation of the laminated composites [15]. In the study conducted by Kösedağ and Ekici [16], aramid reinforced polymer matrix composite materials were produced in equal thicknesses by hot press method. Impact tests were carried out at 15, 30, 45J energy values. The energy absorption capabilities of these materials were examined. As a result, they observed that as the impact energy increased, there was an increase in the maximum contact forces of the composite samples and a decrease in the contact times. Subası et al. investigated the ın the deep drawing of thermoplastic composite laminates the effects of different holding pressure, punch speed, specimen temperature and piece depth parameters on the molding force. Bidirectional woven glass fiber reinforced 3 mm polypropylene composite materials were used in the experiments. As a result of the experiments, as the specimen temperature increased the molding force decreased. The molding force increased as the holding pressure increased. Increasing punch speed caused an increase in required molding force [17].

As mentioned so far, the mechanical properties of composite materials with different layers and reinforcement materials have been investigated. In this study, the mechanical properties of the composites produced by hand lay-up method using polyester resin matrix and reinforcement materials consisting of unidirectional 0^0 carbon fiber with different layers types have been investigated. Tensile, three-point bending, and impact tests are performed on the composite specimens. The mechanical properties obtained from the experimental results are explained in detail.

2. MATERIALS AND METHODS

2.1. Materials

In the studies, the composite material is produced at room temperature using the hand lay-up method in the Atelier of Bandırma Onyedi Eylül University. Carbon fiber fabric with two different weaves is used as a reinforcement element, polyester as matrix material. The carbon fiber fabrics we are used supplied ready-to-use, unidirectional woven CW400 B-Carbon 12K plain weave fabric from Teletext Company. The matrix materials we are used supplied by the company Yücel Kompozit A.Ş. (Turkey). Camelyaf brand

92 N8 general purpose polyester resin is used as one of the most preferred polyester types in matrix material hand lay-up methods. Additives Methyl ethyl ketone peroxide (MEK-P) is used to freeze the matrix material, and cobalt is used for fast freezing. Also, two separators are used to remove the product from the mold easily. First, the solid separator Polivaks SV-6 is used, then the liquid separator Polivaks PVA is used.

Tensile and three-point compression tests are carried out in the test training laboratory of Zwick Avrasya company. The falling weight low-speed impact test is carried out in Dumlupınar University Mechanical Engineering Department Laboratory. Drop height of 1 meter, impact energy of 30.41 J, and velocity of 4.43 is accepted as experiment parameters. For the tensile test, the Zwick/Roell brand Allround Line Z250 SrR test device is used to test the samples produced according to the ISO 527-1 standard. Four samples are tested for each sample group. The Zwick/Roell brand ProLine table-top testing machines Z005 up to Z100 testing devices are used to test the samples produced following the ISO 178 standard for the three-point compression test.

3. RESULTS

Samples are produced from unidirectional carbon fiber with 0^0 fiber directions. According to the experiments, T for the tensile test, B for the bending test, D for the drop test, and 1, 2, 3 for the number of layers, respectively. For this reason, composite samples are prepared and named differently. In total, 12 samples were tested for the tensile and bending test, and 15 samples were tested for the drop test.

3.1. Tensile Tests

Fig. 1. shows the tensile strength and elasticity values of one, two, and three-layer composite materials. The values of the tensile test results of the samples formed from one layer with a unidirectional carbon 0^0 fiber orientation angle are close to each other. It is seen that a difference of 10,31% between the highest and lowest values in elasticity value and 23.51% difference in breaking strength value is obtained. After the experiment, the carbon fibers of samples occur a large deformation. From the tensile test results of the samples consisting of two layers with unidirectional carbon 0^0 fiber orientation angle, it is seen that there is a 12.98% difference between the highest and lowest values in elasticity value and a 7.82% difference in breaking strength value. When comparing the one-layered and two-layered specimens, it was determined that the difference between the elasticity values was greater, and the difference between the breaking strength values was less. After the tensile test, it was observed that the carbon fibers in the samples broke in the direction of orientation.

On the other hand, it was observed that there is no fragmentation in the two-layered specimens as in the one-layered specimens. When the tensile test results of the unidirectional carbon 0^0 fiber orientation angle three-layer composite group are examined, it is seen that there is a 3.77% difference between the highest and lowest values in elasticity value and a 13.99% difference in breaking strength value. It has been determined that the ratio between the ductility of the three-layered samples is lower than that of one and two layers, and the ratio between the breaking strength values is less than one layer and higher than two layers. When the samples were examined after the test, it was seen that there was little deformation in the three layers; also, parts were broken from some samples. The images of unidirectional carbon 0^0 fiber-oriented one-layer, two-layer, and three-layer samples before and after the tensile test are shown in Fig 2.

When the results of the tensile tests of the samples are compared, It was determined that the composite material with the best elasticity according to the average and highest values belongs to the unidirectional 0^0 three-layer Materials. It was observed that the highest breaking strength value is the two-layer composite material with a unidirectional 0^0 fiber orientation angle. The tensile test results showed that the best composite material in the tensile direction belonged to the three-layer composite materials produced according to the unidirectional 0^0 fiber orientation angle.

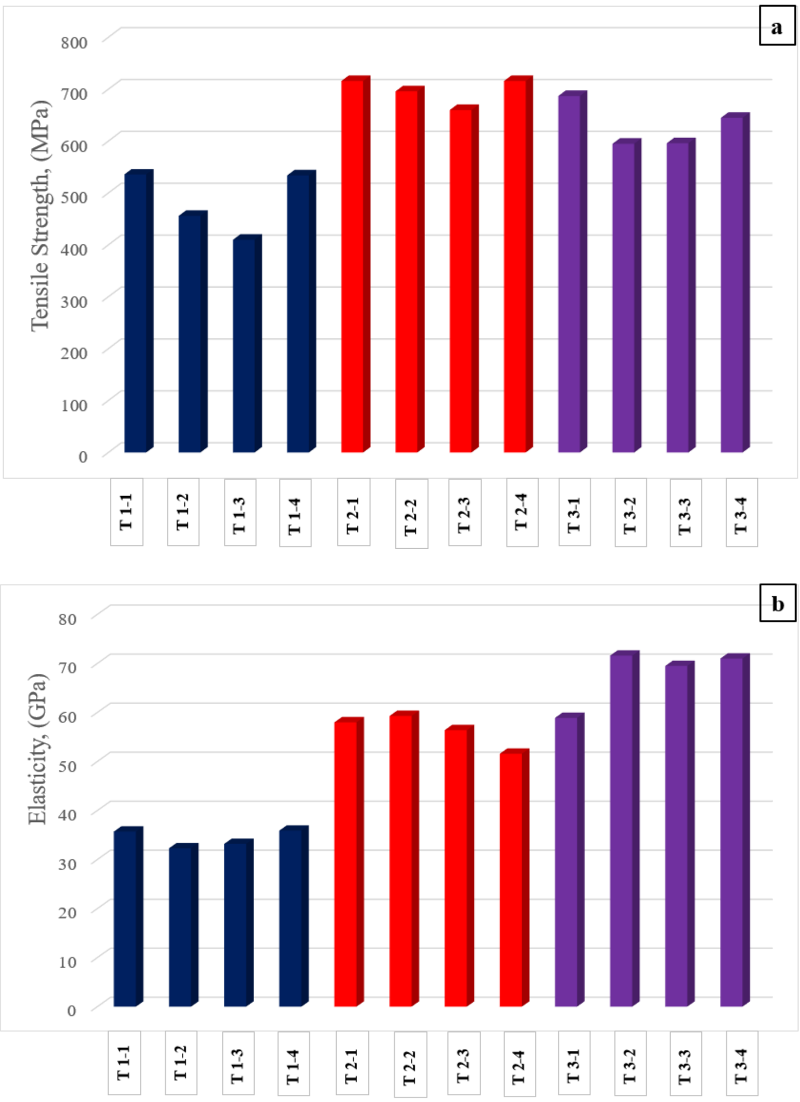
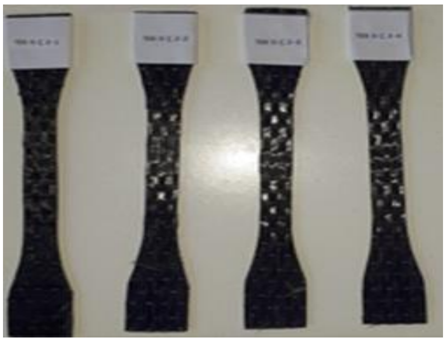
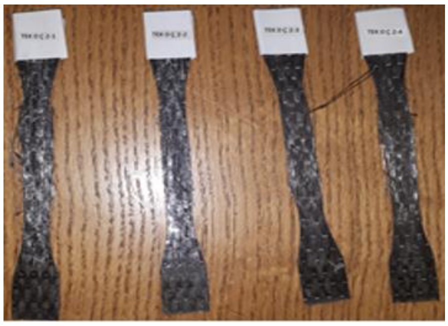


Figure 1. *The change in the (a) tensile strength* ***(****b) elasticity modulus of the samples according to one, two and three layers changes*

(a) *(b)*



(c)



(d)

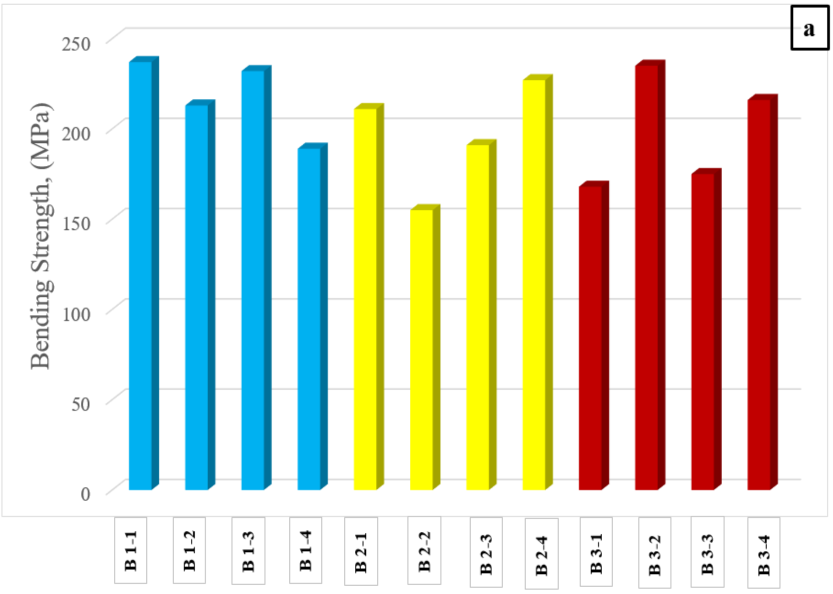
(e)

(f)

Figure 2. *Tensile test images of unidirectional 0^0 carbon fiber samples; (a) T1 group's status before the test, (b) T1 group's status after the test, (c) T2 group's status before the test, (d) T2 group's status before the test, **(**e) T3 group's status before the test, (f) T3 group's status after the test*

3.2. Three Point Bend Test

Three point bending test results of the samples are given in Fig 3. The bending test results of the unidirectional carbon 0^0 fiber orientation angle one layer composite group differ. After the test, it was observed that there were fractures in the orientation of the carbon fibers in the samples, but there was no complete rupture. When the three bending test results of the two-layer composite group with unidirectional carbon 0^0 fiber orientation angle are examined, the values of the samples are different from each other. It was concluded that the ratio between flexural strength values of two-layered specimens increased more when compared to one-layered specimens. The three-point bending test results of the three-layer composite group with a unidirectional carbon 0^0 fiber orientation angle showed that the sample values are closer to each other than the other layers. A continuous increase in elasticity and flexural strength values are detected. When the three-point bending test values of the samples consisting of one layer are examined, the best elasticity and flexural strength values are obtained in the one layer composite group samples with unidirectional carbon 0^0 fiber orientation angle. At the same time, with the increase in elasticity and breaking strength values, it was observed that the most brittle material belonged to the same group, unidirectional carbon 0^0 one-layer composite material. The B3-3 samples have 427.32% higher elasticity value, while 330.30% higher values for flexural strength have been obtained. When the average three-point bending test values of the samples consisting of two layers are examined, it is seen that the best elasticity values belong to the two-layer composite group (B2-3) with a unidirectional carbon 0^0 fiber orientation angle, showing similar properties to the samples consisting of one layer. It has been determined that the best average result belongs to the one layer (B1) composite group due to the difference in bending strength values compared to the samples consisting of one layer. Higher elasticity values have been determined in the (B3) group. Likewise, higher values of three-layer composite material with unidirectional 0^0 fiber orientation angle have been obtained in bending strengths.



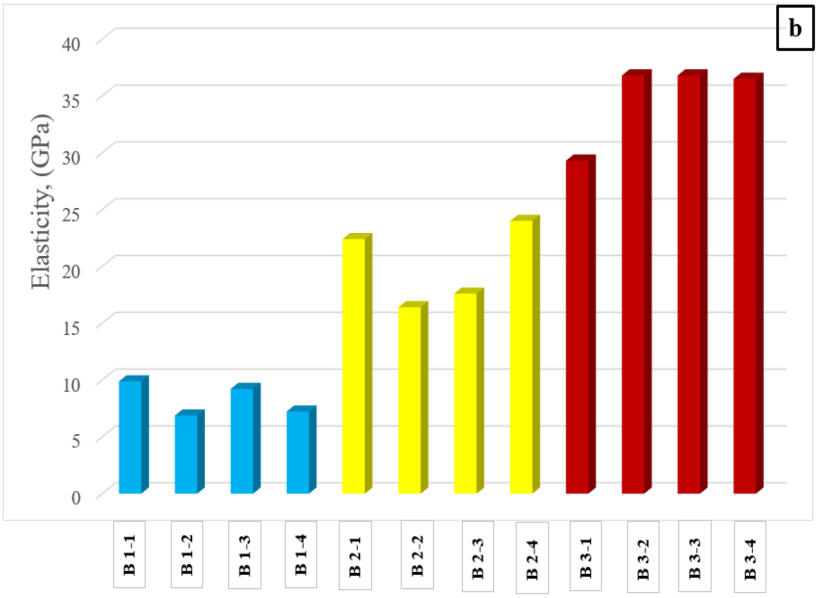


Figure 3. *The change in (a) bending strength (b) elasticity modulus of the samples according to one, two and three layers changes*

3.3. Dropped Weight Impact Test at Low Speed

The experiments are carried out as one, two, and three layers. The low-weight, low-speed impact test images of one, two, and three-layer composite materials with unidirectional 0^0 fiber orientation angles are shown in Fig 4.

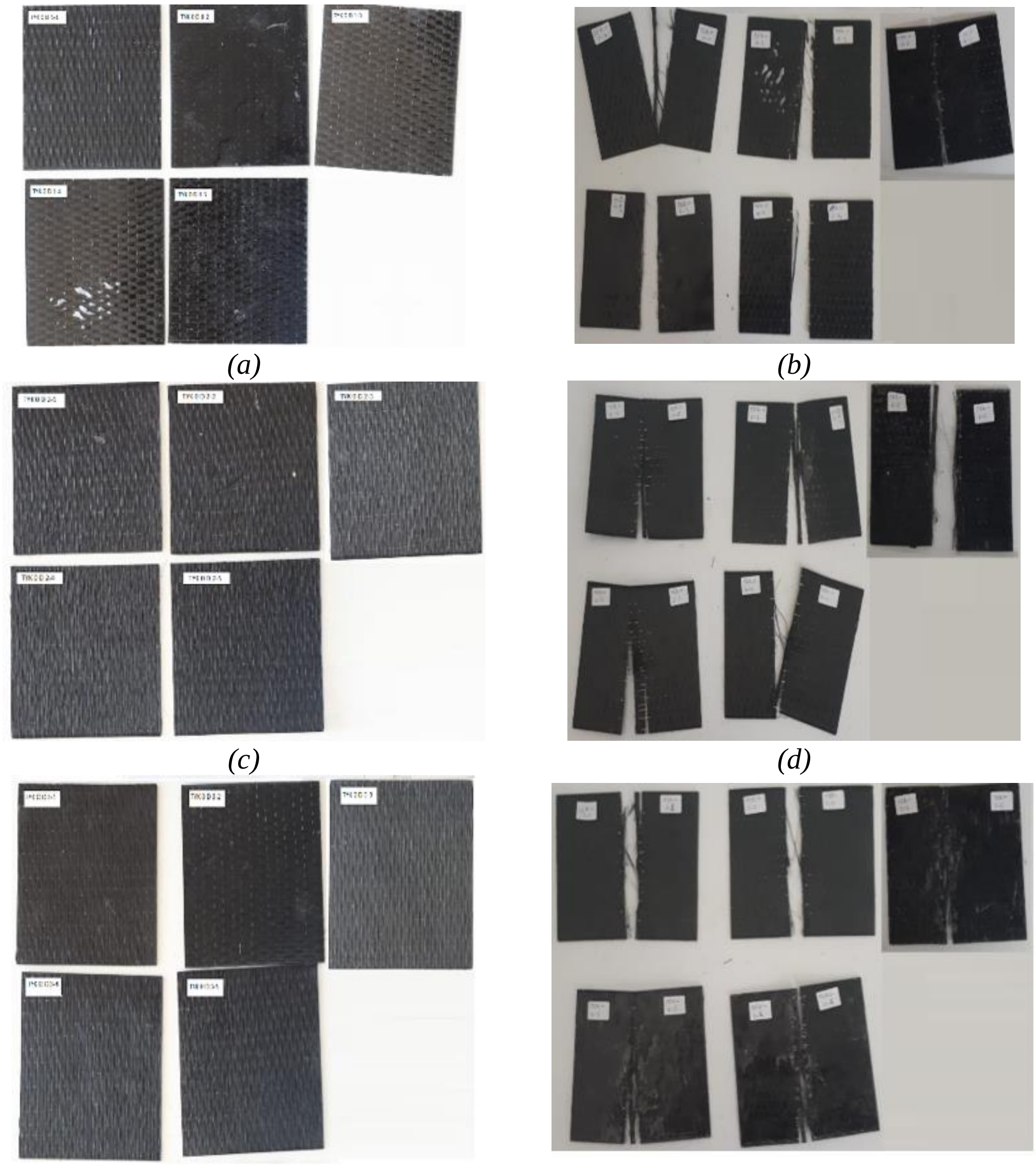


Figure 4. *Drop weight low-velocity impact images of unidirectional 0^0 carbon fiber samples; (a) D1 sample condition before the test, (b) D1 sample condition after the test, (c) D2 sample condition before the test, (d) D2 sample condition before the test, (e) D3 sample condition before the test, (f) D3 sample condition after the test*

Herewith the weight applied to all samples, a break occurred at the contact point parallel to the orientation angles of the fibers. For this reason, two fragmentation occurred in the samples. When we examine the results of the falling weight low-velocity impact test, all sample groups have been deformed, and values are tabulated in Table 1. All samples showed good strength resistance to impact energy of 30.41J. It has been determined that the deformation on the bottom surface of the sample is caused by the fiber orientation and due to the separation of the fibers.

Table 1. *Drop weight low speed impact test results of all samples with unidirectional carbon 0^0 fiber orientation angle*

Samples	Average Thickness (mm)	Dimension (mm-mm)
D 1-1	0,82	100,32×99,87
D 1-2	0,87	100,48×100,23
D 1-3	0,88	100,16×100,23
D 1-4	0,77	100,49×99,87
D 1-5	0,83	100,12×99,75
D 2-1	1,33	99,63×99,53
D 2-2	1,37	99,65×99,58
D 2-3	1,32	100,09×99,76
D 2-4	1,28	99,95×99,98
D 2-5	1,26	100,28×99,68
D 3-1	1,68	99,38×99,82
D 3-2	1,84	100,29×99,79
D 3-3	1,75	99,72×99,98
D 3-4	1,64	99,68×99,82
D 3-5	1,73	99,54×99,72

4. CONCLUSIONS

The mechanical test results have shown that the reinforcement element, number of layers, fiber orientation direction, angle, matrix material, and production method of the composite materials are greatly important according to their use and purpose. In the production of carbon fiber composites, the expensiveness of carbon fiber materials has generally led to the selection of matrices with higher mechanical values and the use of more technological methods. However, in this study, we reported that composites with high mechanical values would be produced with polyester resin, the most widely used matrix material of carbon fibers, and the hand lay-up method, which is the simplest method in terms of workmanships. While increasing the number of layers, the most dangerous situation in composite products obtained by the hand lay-up method should be done very carefully. According to the results obtained;

- As a result of the tensile test of unidirectional carbon fiber reinforcements, the tensile strength and modulus of elasticity values increased depending on the number of glass fiber layers. The highest tensile strength value among layers is obtained in the two-layer unidirectional fiber-reinforced composite materials.

- As a result of three-point bending tests of unidirectional carbon fiber reinforcements, flexural strength and breaking force values also increased depending on the number of fiber layers. The highest elasticity values of unidirectional carbon fiber reinforcements are observed in three-layer composite materials with a fiber direction angle of 0^0.

- It was observed that the mechanical properties of composite materials improved as the number of fiber layers increased. Since the region between the layers causes the composite strength to be lower than it should be, the desired increase cannot be achieved after a certain number of fiber layers depending on the increase in the number of fiber layers.

- It was observed that the composites with unidirectional carbon fiber reinforced 0^0 fiber orientation, which had the best elasticity values in the tensile and bending tests, were the composite materials that underwent the most deformation in the falling weight low velocity impact test.

REFERENCES

[1] Clyne, Trevor William, and Derek Hull. An introduction to composite materials. Cambridge university press, 2019.

[2] Jones, Robert M. Mechanics of composite materials. CRC press, 2018.

[3] Kollar, Laszlo P., and George S. Springer. Mechanics of composite structures. Cambridge university press, 2003.

[4] Mallick, P. K. "Fiber Reinforced Composites, Materials, Manufacturing, and Design, Marcel Decker." Inc., New York (1993).

[5] Zhang, Xiaoqing, et al. "Interfacial microstructure and properties of carbon fiber composites modified with graphene oxide." ACS applied materials & interfaces 4.3 (2012): 1543-1552.

[6] Karnati, Sidharth Reddy, Philip Agbo, and Lifeng Zhang. "Applications of silica nanoparticles in glass/carbon fiber-reinforced epoxy nanocomposite." Composites Communications 17 (2020): 32-41.

[7] Botelho, E. C., M. C. Rezende, and B. Lauke. "Mechanical behavior of carbon fiber reinforced polyamide composites." Composites Science and Technology 63.13 (2003): 1843-1855.

[8] Cao, Shenghu, W. U. Zhis, and Xin Wang. "Tensile properties of CFRP and hybrid FRP composites at elevated temperatures." Journal of composite materials 43.4 (2009): 315-330.

[9] Çakır, Mustafa, and Boran Berberoğlu. "E-cam elyaf takviyeli epoksi matrisli kompozit malzemelerin elyaf oranındaki artış ile mekanik özelliklerindeki değişimlerin incelenmesi." El-Cezeri Journal of Science and Engineering 5.3 (2018): 734-740.

[10] Murugan, Ramasamy, R. Ramesh, and Krishan Padmanabhan. "Investigation on static and dynamic mechanical properties of epoxy based woven fabric glass/carbon hybrid composite laminates." Procedia Engineering 97 (2014): 459-468.

[11] Sugie, Tomohiko, Asami Nakai, and Hiroyuki Hamada. "Effect of CF/GF fibre hybrid on impact properties of multi-axial warp knitted fabric composite materials." Composites Part A: Applied Science and Manufacturing 40.12 (2009): 1982-1990.

[12] Boumbimba, R. Matadi, et al. "Preparation and mechanical characterisation of laminate composites made of glass fibre/epoxy resin filled with tri bloc copolymers." Composite structures 116 (2014): 414-422.

[13] Güneş, D., Çanlı, M, and Urtekin, L. "Investigation of Mechanical Properties of Carbon Fibre Reinforced Polyester Matrix Composite." Journal of Scientific Reports-A 047: 68-78.

[14] Fiore, V. I. N. C. E. N. Z. O., G. Di Bella, and A. Valenza. "Glass–basalt/epoxy hybrid composites for marine applications." Materials & Design 32.4 (2011): 2091-2099.

[15] Banakar, Prashanth, and H. K. Shivananda. "Preparation and characterization of the carbon fiber reinforced epoxy resin composites." Department of Mechanical Engineering, Atria Institute of Technology, Visvesvaraya University, Bangalore-24, India. Department Of Mechanical Engineering, University Visvesvaraya College of Engineering, Bangalore University Bangalore-01, India ISSN (2012): 2278-1684.

[16] Kösedağ, Ertan, and Recep Ekici. "Impact Behavior of Aramid Reinforced Polymer Matrix Composites Produced By Hot Press-Prepreg Method." Avrupa Bilim ve Teknoloji Dergisi 28 (2021): 84-90.

[17] Özdemir, Abdullah Onur, Mehmet Subaşı, and Çetin Karataş. "Investigating the Effects of Forming Parameters on Molding Force and Springback in Deep Drawing Process of Thermoplastic Composite Laminates." Gazi University Journal of Science (2021): 1-1.