MECHANICAL PROPERTIES RESEARCH OF CARBON FIBRE COMPOSITES INCORPORATING NANOCLAY AND GRAPHENE

by

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Study purpose is to determine the interactions between the widely-used graphene and nanoclay on carbon fiber composite materials. They are produced using the vacuum infusion method by reinforcing the nanoclay and graphene, which have a montmorillonite structure organized at various ratios via homogenizer, into the resin that is to be applied to carbon fiber layers. Eczacıbaşı EsanNANO 1-140 was used as nanoclay, and GRAFEN NG5 of the Nanografi Co. Ltd. was used as graphene. The graphene ratio was kept constant by taking reference from antecedent studies. Tensile test was applied to the produced samples. Graphene in the resin is expected to increase the saturation in the layers and improve mechanical properties. After nanoclay ratio exceeds a certain limit, it acts negatively rather than positively in the tensile test, their cracked roads are then rendered easier to traverse by them combining. This is why there is a certain bell-shaped curve in the strain values measured in samples. The result that gives the optimum values is sought after. Additionally, there are studies previously conducted with polymer matrix composite, from which samples that could reach to certain strains or to higher yield stress values in certain intervals are obtained. By increasing the strength and toughness of the graphene and nanoclay resin, they gain more rigidity, which raises an expectation of increment to be observed in the yield and tensile strengths.

Key words: *graphene, nanoclay, carbon fiber, low velocity impact test, tensile test*

Introduction

Nanotechnology is an interdisciplinary field that includes physics, chemistry, engineering and biology. In addition to this, according to the nature of the work done, for example, by the entrance of the medical research area is expanding research. Research on materials made with nanotechnology it continues to increase today. We will also describe it as the work done at the atomic scale nanotechnology is the study of atoms at the atomic level in the building blocks of materials with the development, the increase in interest in this area with the addition of superior features to the material and technology to develop.

Because of the lightness of the carbon fiber, the high strength and the high cost, used in aerospace, defense and defense fields. In light of recent studies work together to provide more strength, stiffness or flexibility. Due to the high mechanical properties of carbon nano-

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tubes, nanostructures have gained importance in the scientific world and research. Since the production of carbon nanotubes is costly, the production methods are improved day by day, and the costs are reduced. In addition, in the sectors of advanced material technologies; necessary criteria and high performance are key factors, while costs are insignificant [1].

Nanoclays can make the materials that they are used in gain properties based on that specific material. To wit: strength, heat resistance, fire retardancy, friction resistance, ultraviolet protective effect, *etc.* Carbon fiber reinforced polymer (CFRP) composites are used widely in military planes [2, 3]. For example, CFRP composites are used in the manufacture of A400M, F-22, F-35, Eurofighter [4], Eurocopter Tiger [5]. Fiber composite materials generally make up 40% of the structural mass and 70% of the surface area [6]. Other usage areas of CFRP composites are the pieces that require high heat resistance such motor bearings, mounts, air ducts, *etc.* [7]. The electrochemical properties of the nanotube and nanoclay, determining the electrical resistance and prospective studies have been made to improve the electrical and thermal properties [8-11].

Previous studies have added nanoclay to the resin of CFRP matrix composites. They performed low speed pulse and CAI tests to investigate the impact damage relationships. They added nanoclay at 1.5%, 3%, and 5% of resin weight to the samples they prepared for the tests and performed the tests. Optimum values were obtained with 3% nanoclay-reinforced samples [1]. In another study, nanoclay was incorporated into the epoxy at 1%, 3%, and 5% by weight. Epoxy resin and hardener ratio is 10:4 by weight and composite layers are produced by hand laying method. They have done tests on these samples. The results are as follows: 3% added samples in their conclusions; found that they gave the best values with an increase of 57% in flexural strength, and 8% in tensile strength [2].

In one study, it was researched mechanical properties of graphene and nanotube reinforced carbon fiber composites. They have worked to improve the fiber-matrix interfacial behavior of reinforcing elements added at different rates and to increase the tensile strength of composite sheets. As a result of the study, improvement in mechanical properties and improvement in impact behavior due to increased torsion were observed [3]. This study was carried out with the aim of using tensile strength properties of nanoclay and graphite on selected specimens, to catch appropriate design values and to keep light on the works to be done afterwards. Tensile tests were carried out with determination of the mechanical properties of layered composite materials.

As a result of the literature survey, it was determined that the ratio of graphene added to epoxy by vacuum infusion method gives 0.1% optimal numerical and mechanical properties. However, no information was found in the literature about the properties of composites with the graphene and nanoclay additives.

For this reason, in this study, matrix materials containing nanoclay were prepared at different ratios, composite sheets were produced, and mechanical properties were examined. In addition to this, simple specimens without reinforcement and only graphene reinforced specimens were produced to try to observe the difference of nanoclay reinforcements.

Experimental work

Carbon fiber Tenax-E HTA 40 3k, resin Laminating Resin MGS L160, resin hardener Hardener MGS H160, and nanoclay EsanNANO 1-140 were used in the construction phase of the layered composites. Graphene and nanoclay rates added to the prepared samples are given in tab. 1.

Table 1. Produced samples

	Graphene [%]	Nanoclay [%]
GP0.1NC0	0.1	0
GP0.1NC1	0.1	1
GP0.1NC3	0.1	3

As the sample names are easy to understand; graphene-GP is shown as nanoclay-NC and the numbers on the side indicate the weight percentages according to the resin in the samples. Composite sheets were produced 8 layer carbon fiber.

Epoxy added graphene and NC were first mechanically mixed and then dispersed in ultrasonic homogenizers at nano size. Properties of carbon fiber, epoxy and hardener used in the study are shown in tab. 2 [4].

Table 2. Technical specifications of used materials

	Carbon Fibre	Epoxy	Epoxy Hardener
Trade name	Tenax– E HTA 40 3k	Laminating resin MGS L160	Hardener MGS H160
Fiber density [piece per cm]	5		
Filament diameter [μm]	7		
Density [gcm^{-3}]	1.76	1.18-1.20	0.96-1
Yield strength [MPa]	3950	70-80	
Modulus of elasticity [GPa]	238	3.2-3.5	
Breaking extension [%]	1.7	5-6.5	
Vizcosity [mPas]		700-900	10-50
Impact resistance [KJm^{-2}]		40-50	

As a nanoclay, Esan NANO 1-140 coded shaft of Eczacıbaşı with montmorillonite structure was used. The clay, which has an ultra-white and pure structure, improves the fire resistance, strength, moisture and gas permeability properties of the material it is joined to. The distance between montmorillonite clay layers is approximately 15 Å as shown in fig. 1. When the same nanoclay organic modification is made, these values reach 38-40 Å. During the production of EsanNANO 1-140 montmorillonite is purified and organic modification is carried out. With this modification, homogeneous distribution of the matrix material is achieved [5].

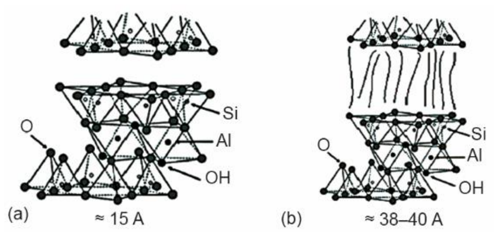

Figure 1. (a) Montmorillonite structure and (b) naturalized montmorillonite structure

The chemical properties and grain size analysis of EsanNano clay are given in tabs. 3 and 4 [6, 7]. Plates were presented in fig. 3 connectedly with the vacuum. The processing machine is a special manufacture containing the property of injection double vacuum-assisted resin transfer moulding, whose heat and vacuum values can be adjusted according to the time.

Table 3. The EsanNANO clay chemical properties

	Al_2O_3	SiO_3	Na_2O	Fe_2O_3	K_2O	CaO	MgO	TiO_2	LOI
%	6 ±1	44 ±1	0.6 ±0.2	0.4 ±0.2	0.3 ±0.1	0.4 ±0.1	1.4 ±0.2	0.05 ±0.02	45 ±2

Table 4. The EsanNANO clay grain size analysis

Size [μm]	0-0.5	0.5-1	1-2	2-2.7	2.7-5	5-7.5	7.5-10	10-15
Ratio [%]	2.27	8.66	23.8	15.84	32.25	12.6	3.94	0.64

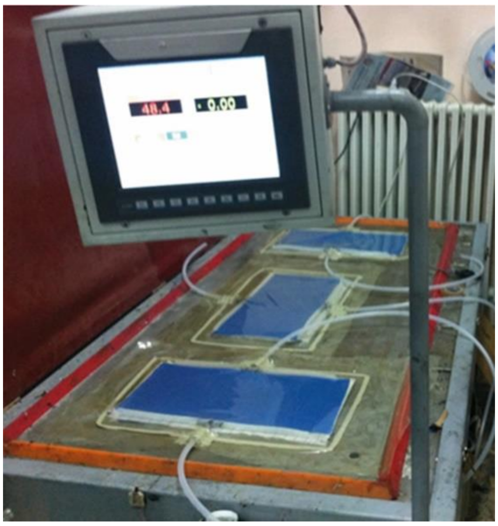

Figure 2. Vacuum infusion method – processing machine

In order for the nanoclay and graphene to be dispersed homogeneously in the resin, they were dispersed by keeping the resin in an ultrasonic homogenizer after adding additives and mechanical mixing. Tensile tests were carried out at a draw speed of 2 mm per minute depending on the D3039/D3039M – 14 standard no. Standard Test Method for Tensile Properties of Polymer Matrix Composite Materials standard. In the calibrated Zwick Z250 tensile tester shown in fig. 3, tests were performed. The obtained results are shown in fig. 4. and the maximum values are shown in fig. 5.

As can be seen in the stress-strain curve, the maximum elongation was found to be 3% with nanoclay-reinforced specimen. As the nanoclay ratio increased, the unit strain rate increased. It is seen that the maximum stress value is reached in the sample with 1% nanoclay.

The low velocity impact tests were performed on a specially manufactured test device. Test device has a probe to record damping and splash energies in tests at different energy levels and seen in fig. 6.

(a) (b)

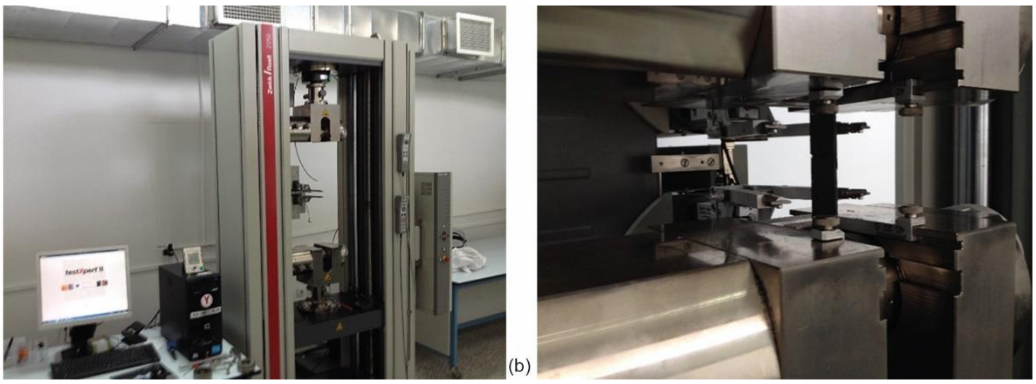

Figure 3. Zwick tensile test machine

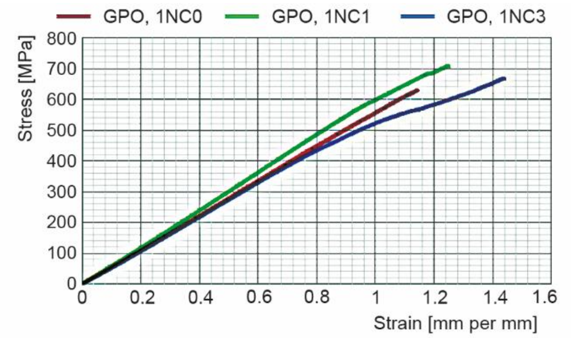

Figure 4. Stress-strain graph

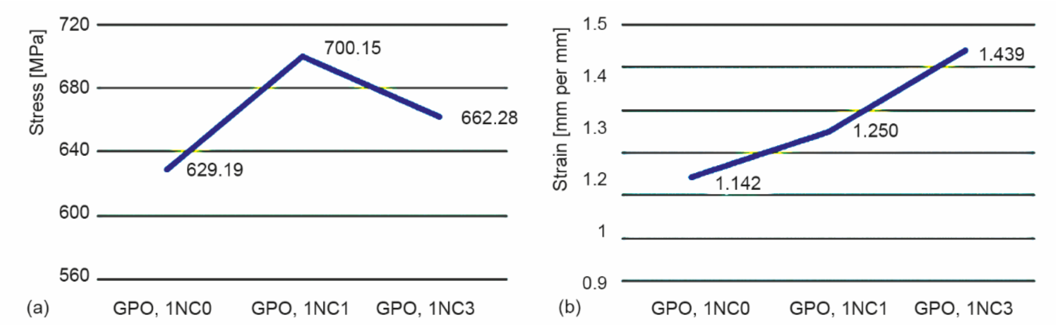

Figure 5. (a) Maximum stress values and (b) maximum strain values

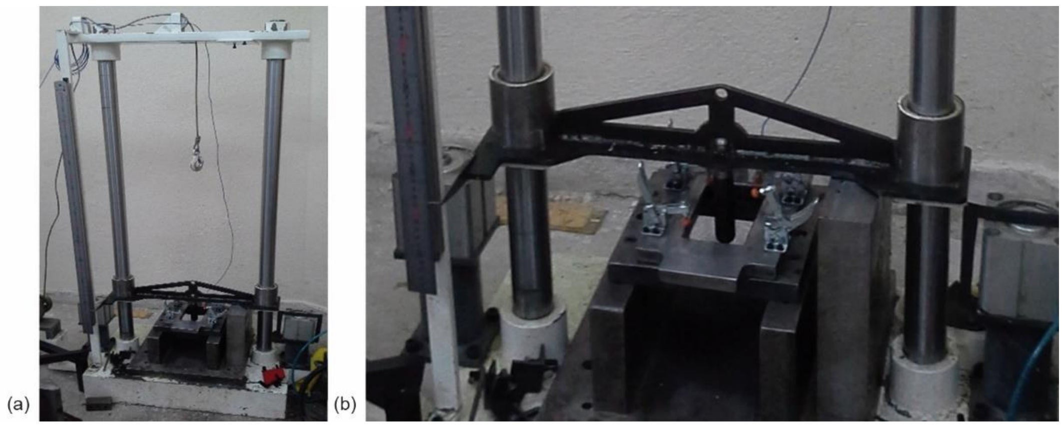

Figure 6. Low speed impact testing machine

The energy-time graph measured from low speed impact tests is shown in fig. 7. Low velocity impact tests were performed on the samples as 25 joules. The amount of energy they absorb and splash is shown in detail in fig. 8. Depending on the applied energy, the GP0.1NC0 sample absorbed the most energy. However, it is seen as the GP0.1NC3 sample, which is the sample with the highest amount of nanoclay that reflects the most energy. In the low velocity impact test, it is seen that the non-nanoclay sample absorbs the most energy

(24.03J), and it is clearly seen that as the nanoclay ratio increases, the energy absorbed decreases and the splash energy increases.

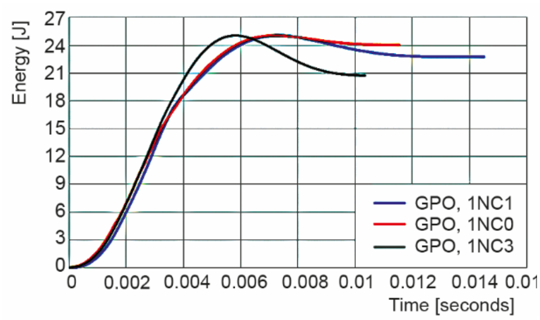

Figure 7. Measured energy – time charts

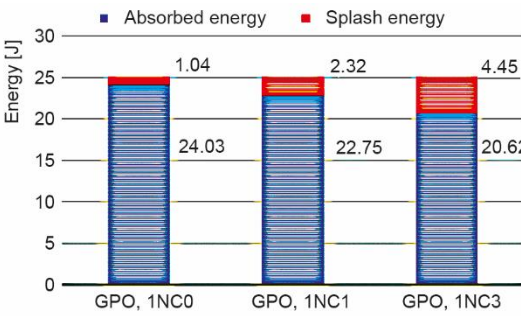

Figure 8. Applied energy (25 J) and absorbed energy

Conclusion

When the tensile strengths are examined, it is seen that 1% of nanoclay added together with graphene gives the highest values. Nano as the clay ratio increases, the strength decreases. Macro size clay granules combine to form bridge cracks and less resistance to stretching. When nanoclay ratio was added 1%, a significant increase of unit shape change 9% compared to non-added sample and 26% in 3% form sample was observed. It was observed that the nanoclay sample (GP0.1NC3) splashs more energy. It splashed approximately 4.5 times more energy than the nanoclay-free sample (GP0.1NC3). Nanoclay is planned to respond more to incoming strains, as it makes the resin in the composite plate more rigid. As a result of the increase, the nanoclay can be seen as increasing its ductility by better bonding the epoxy. In addition, as the nanoclay increases, the material becomes more rigid, so it can be said that it will withstand more external impacts without being damaged.

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