RESEARCH OF THE MECHANICAL PROPERTIES AND IMPACT TOUGHNESS OF CARBON-KEVLAR HYBRID COMPOSITES WITH NANOALUMINA IN DIFFERENT LAYERS

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SUMMARY

In this study, hybrid composites with 3, 5 and 7 layers of carbon-kevlar layered with nano aluminminas are produced using vacuum infusion method. Subsequently, burning, tensile, charpy impact experiments were carried out to determine the mechanical properties of these samples. Calculations were made using tha data obtained as a result of these experiments. After these procedures, damage analysis was performed using notch impact samples. Finally, SEM images were taken and whether the nano aluminminas were homogeneusly distributed and damage determinations were made.

As a result of the experiments and SEM images taken, the number of layers has been shown to have a positive effect on mechanical properties. In other words, the number of layers increases as well as mechanical properties. When sem images were examined, it was seen that the nanoaluminminas used were homogeneously distributed in the resin.

Keywords, Hybrid composite, Kevlar fiber, Vacuum infusion method

1. INTRODUCTION

It is an inescapable fact that composites have an important place when the materials used today are evaluated. A composite is a material formed by combining the superior properties of two or more materials in a single material or by combining them at the macro level to produce new properties.The formation of different components gives composites superior properties. These include: high rigidity, wear resistance, corrosion resistance, fatigue resistance, low density and high resistance. Considering these properties, composite materials are used in almost all fields of technology such as aerospace industry, automotive, defense, energy, construction and sports. Composite materials have different types according to matrix phase and reinforcement phase. In this study, hybrid composite materials, which are one of the reinforcement phase types, were produced and the mechanical properties of these samples were investigated. Hybrid composite is called new materials obtained by combining two or more reinforcement phases with a single matrix. The main purpose of this composite is to minimize the effect of unwanted properties and to increase the effect of the required properties.

When selecting the reinforcing phases forming the hybrid composite material, they are selected to complement each other's missing aspects. For example, S-glass and E-glass have high tensile strength and resistance to chemicals while their thermal resistance is low. Kevlar has high strength, low density, low modulus of elasticity. They have high strength and good modulus of elasticity in carbon fibers. By considering these general properties of fibers, composites with the desired properties or closest to the desired properties can be produced as a result of hybrid production.

In this study, the preferred reinforcing phase materials for hybrid composite production were carbon and kevlar fibers. For the matrix phase, epoxy resin and nanoalumina with a size of 40 nm will be added to this resin.

2. HYBRID COMPOSITE PRODUCTION AND EXPERIMENTS

2.1. Hybrid Composite Production

In this study, hybrid composite production was performed by vacuum infusion method. The reasons for the selection of this method are high surface quality, homogeneous dispersion of the nanoalumina incorporated in the epoxy, high interfacial bonding is desired and most importantly, the reinforcing phase ratio is greater than the matrix phase ratio.

In the production of hybrid composite plates, kevlar fabric having a 45˚ angle (75g / m2) and a density of 1.8 g / cm3 carbon fiber and tiwil weave (207g / m2) and a density of 1.13g / cm3 were used. The aluminum plate, placed on a flat table, was formed by a double-sided tape to match the size of the cut fibers. Mold release agent was applied into this frame. This procedure was repeated 3 times with 5 minute intervals. Subsequently, the cut fibers of 320 * 320 mm were placed in this frame. Peel - fly and flow net were placed on the fabrics respectively.

Table 1: Stacking order and angles of the fibers used

Sample Code	Stacking Sequence	Stacking Angles	Thickness
S1	K /A /K	45˚ 0˚ -45˚	1.01 mm
S2	K/ A/ K/ A/ K	45˚ 0˚ -45˚ 0˚ 45˚	1,57 mm
S3	K/ A/ K/ A/ K/ A/ K	45˚ 0˚ -45˚ 0˚ 45˚ 0˚ -45˚	1.69 mm

In order to provide the inlet and outlet of the resin, the cut spiral hoses were mutually fixed in parallel to each other and vacuum hoses were connected to them to transfer the resin. As a final step, the vacuum bag was cut to cover the whole system. It was bonded with the help of double-sided tapes that were previously glued and made ready for vacuuming. The vacuum pump was operated at a pressure of -1 atm and all air in it was vented out of the system.

The epoxy used as the matrix material consists of two parts: hardener and resin. In order to determine the amount required for hybrid composite production, epoxy calculation was used. In this calculation, the fibers to be used (carbon and aramid) were weighed one by one on the precision tailor and the resulting values were collected. Epoxy was prepared to be 2 times the result obtained. 79% of this value consisted of resin and 21% consisted of hardener. Into the prepared mixture, 2% nanoalumina powder of 40 nanometers was added.

It was immersed in the epoxy beaker in the vacuum hose at the entrance of the system which was prepared for production. The flow valves of the vacuum hoses at the inlet and outlet were opened at the same time and taken into the epoxy system with the help of -1 atm pressure provided by the vacuum pump. The flow was monitored and the flow was continued until the fibers were wetted. The excess epoxy was flowed from the outlet hose into the container in the flow tank.

2.2. Applied Experiments

2.2.1. Resin burn off method

One of the most important values of fiber reinforced composite materials is the ratio of fiber and resin. There are two methods for determining these ratios. These are the determination of the density of the composite and the combustion test. When the matrix material is selected from polymer resins, the gas void ratio is considered to be non-void since it is less than 1%. It is calculated from the following formula [51].

$$Vf = (Wf/pf) / (Wk/\rho k)$$

Respectively, Wf refers to fiber weight, pf fiber density, Wk composite weight and Pk composite density.

Incineration samples of dimensions 25 * 25 mm were prepared from each plate (3, 5 and 7 plies) for use in the combustion test. These samples were weighed on a precision balance of 0.01 mg and then placed in the oven at 300˚C and the resin was completely burned in the oven for half an hour. At the end of this period, the remaining kevlar and carbon fibers were re-weighed and the matrix amount was calculated.

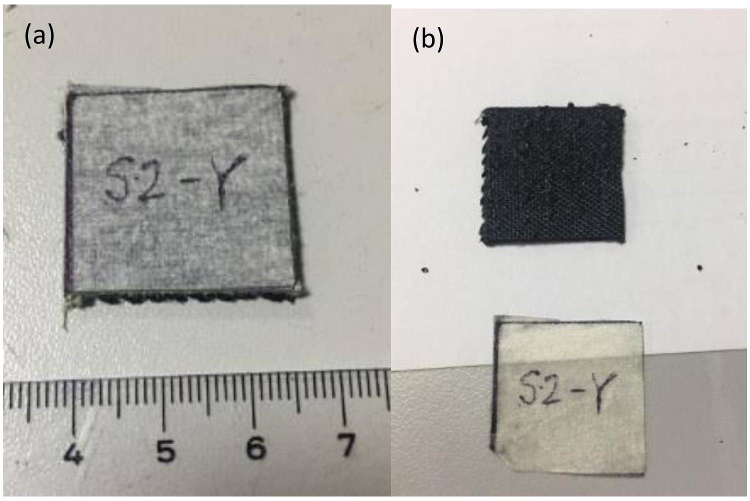


Figure 1: (a) burning sample (b) view of the sample after the burning test

Table 2: The results obtained from the burning test are given.

Numune / Ağırlıklar(g)	Composite Weight	Fiber Weight	Removed Matris
3L (S1)	0,829	0,709	0,12
5L (S2)	1,274	1,085	0,189
7L (S3)	1,367	1,191	0,176

Using the data in Table 2 and the above correlation, the fiber volume ratios of the composite plates were calculated. The 3-ply composite was calculated as an example and the other values are given in table 3.

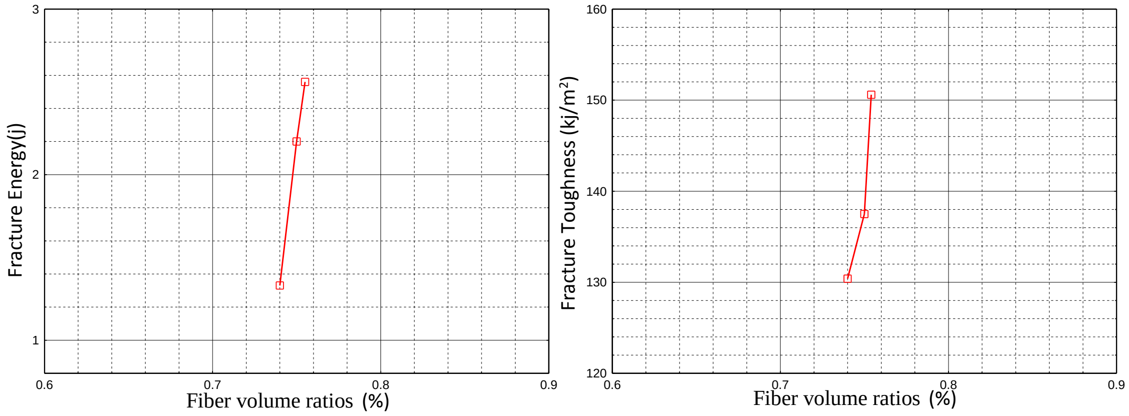
$Vf = (Wf/pf) / (Wk/\rho k)$

$Vf=(0{,}709⁄(1{,}57)/(0{,}829⁄(1{,}36)))$

$Vf=0{,}74$

Table 3: Fiber volume ratios of samples

Sample	Fiber Volume Ratios(%)
3L (S1)	%74
5L (S2)	%75
7L (S3)	%75.4



2.2.2. Tensile Test

Tensile test samples, according to ASTM A-320 standards as 20*250 mm ,a total of 9 pieces were prepared, 3 of each plate. These samples were further processed before being connected to the drawing device. This process is called notification. Notification is the process of cutting copper circuit boards to a certain extent by gluing the two ends of the samples with the help of a strong adhesive. The purpose of this process is to prevent slippage when the specimens are pulled by the jaws and to protect the composite material from the pressure of the jaws. It is also to prevent faulty breakages.

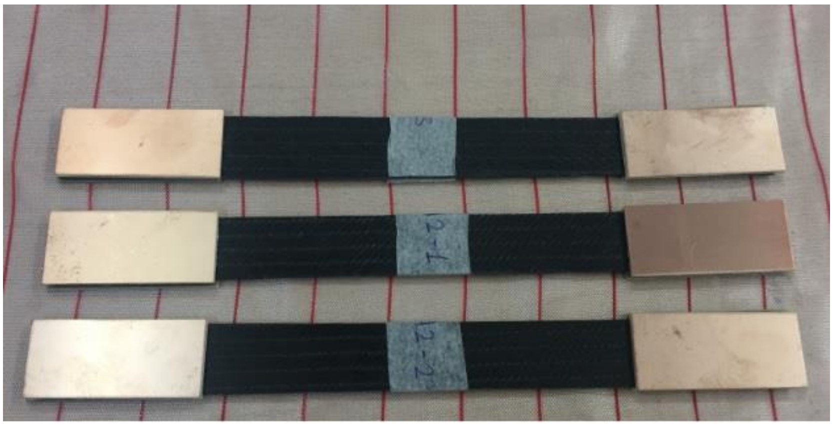


Figure 2: Tensile samples

The shrinkage was performed at room temperature and at a shrinkage rate of 3 mm / min. This process was continued until the samples were broken or completely deformed. The results of the experiment are given in Table 4.

Table 4: Data obtained from tensile test

Hibrit Kompozit Malzemeler						
	σ_{max} (MPa)	**ε %**	**E (GPa)**	**ρ_c (g/cm^3)**	**V_f %**	**H_c (mm)**
3L	2973	7,2	3,150	1,31	%74	1,01
5L	6944	5,97	3,970	1,48	%75	1,57
7L	10056	7,3	2,999	1,29	%75.4	1,69

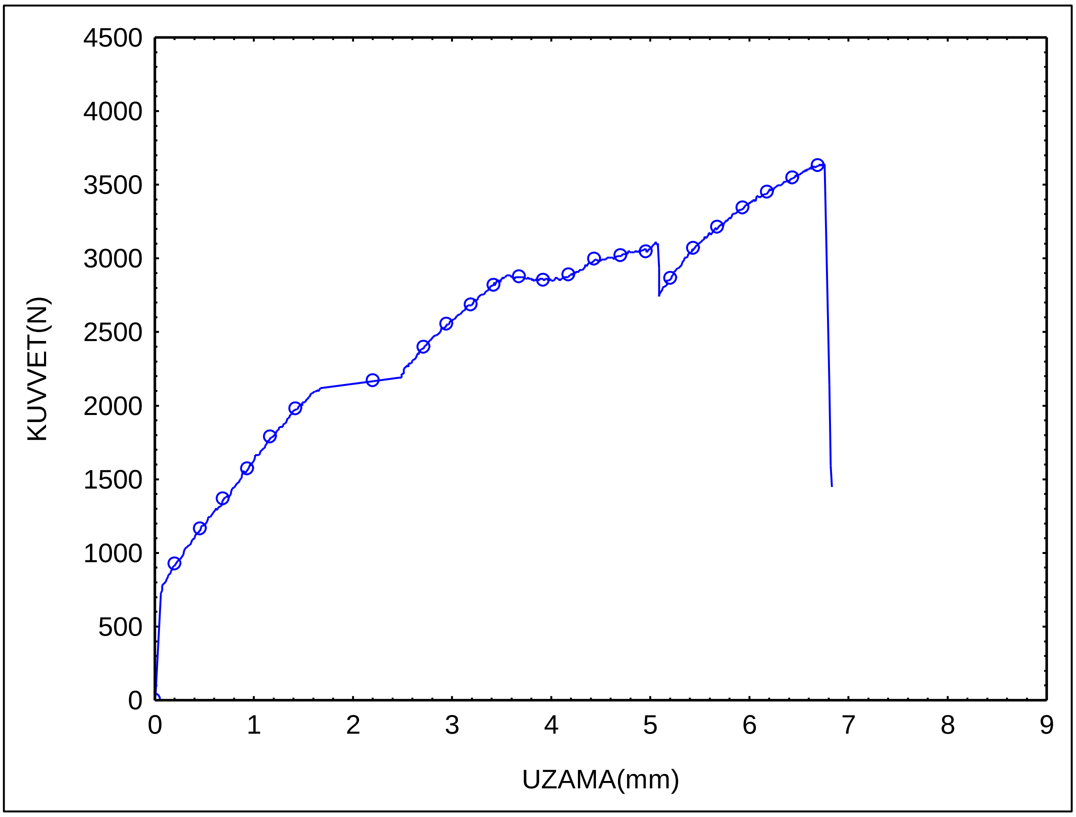


Figure 3: 3-fold sample force-elongation graph

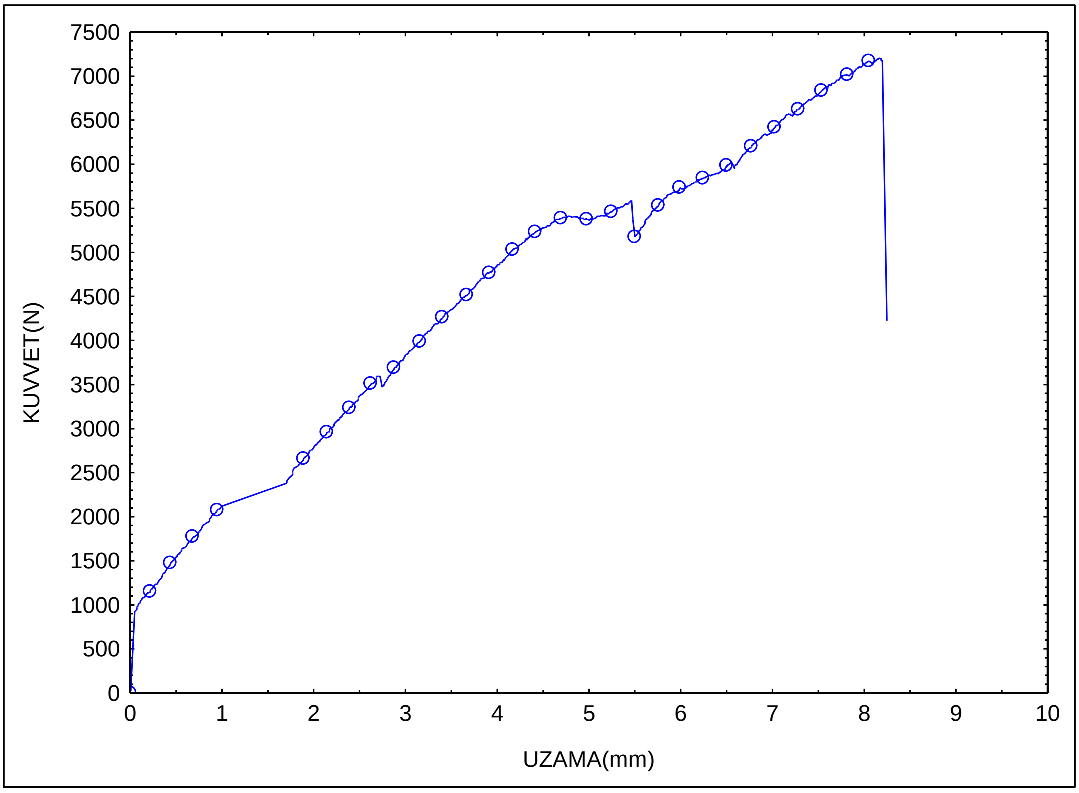


Figure 4: Force-elongation plot for 5L sample

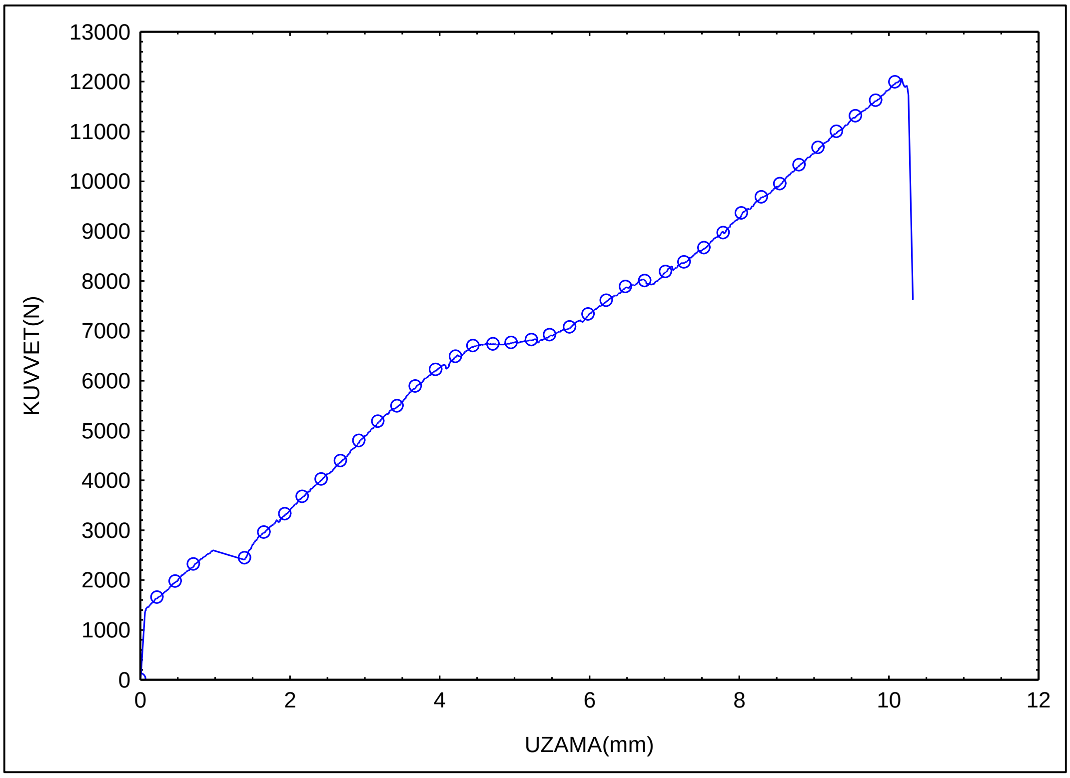


Figure 5: Force-elongation plot for 7L sample

2.2.3. Charpy Impact Test

For the notch impact test, 10 * 80mm samples were cut from pre-produced laminated hybrid composite sheets in accordance with ASTM D-2584 standards. They were then cut with 45 mm notches at a depth of 2 millimeters.

Figure 6: Notch impact samples

Fracture energies of the samples were obtained as a result of impact test and fracture tolerances were calculated by using these values.

Table 5: Fracture energies

Number of stacks / sample	**1. Sample**	**2. Sample**	**3. Sample**	**Average**
3L (S1)	1.4	1.2	1.4	1.33
5L (S2)	2.4	2.3	1.9	2.2
7L (S3)	2.3	2.5	2.9	2.56

Fracture toughness is calculated from the following correlation.

$$Kc=Ke/((bh))$$

From the above correlation Kc fracture toughness (kj / m2), Ke fracture energy (j), b and h are respectively sample height and thickness.

Table 6: Fracture toughness

Sample Code	**Number of Layers**	**Fracture Energy (E, J)**	**Fracture Toughness (K_c, kJ/m^2)**
S1	3	1,33	130,4
S2	5	2,2	137,5
S3	7	2,56	150,6

3. DAMAGE ANALYSIS AND SEM IMAGES

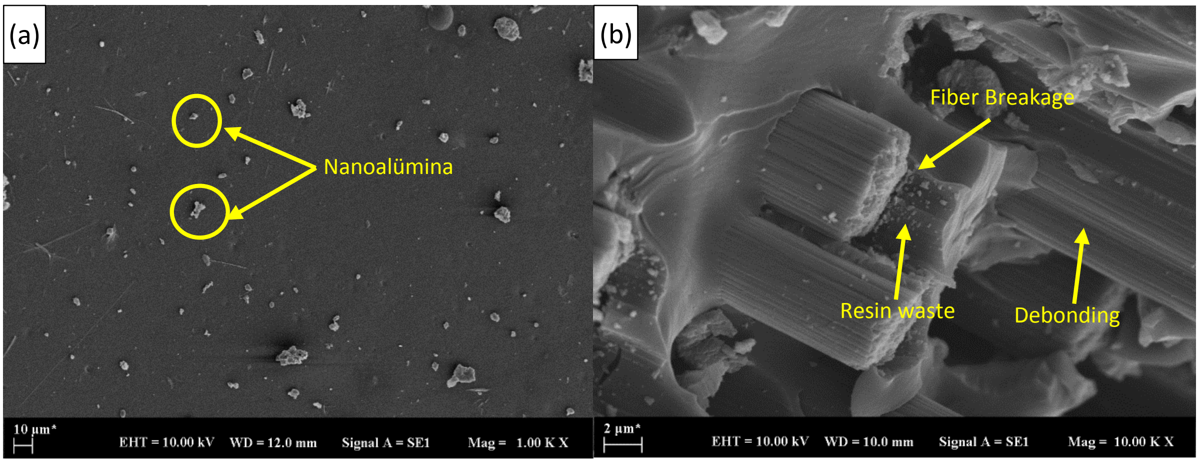


Figure 7: SEM images of a 3-ply sample

In the images given in Figure 7, the (a) picture shows the homogeneous distribution of the nanoalumina, and (b) the damage on the fracture surface.

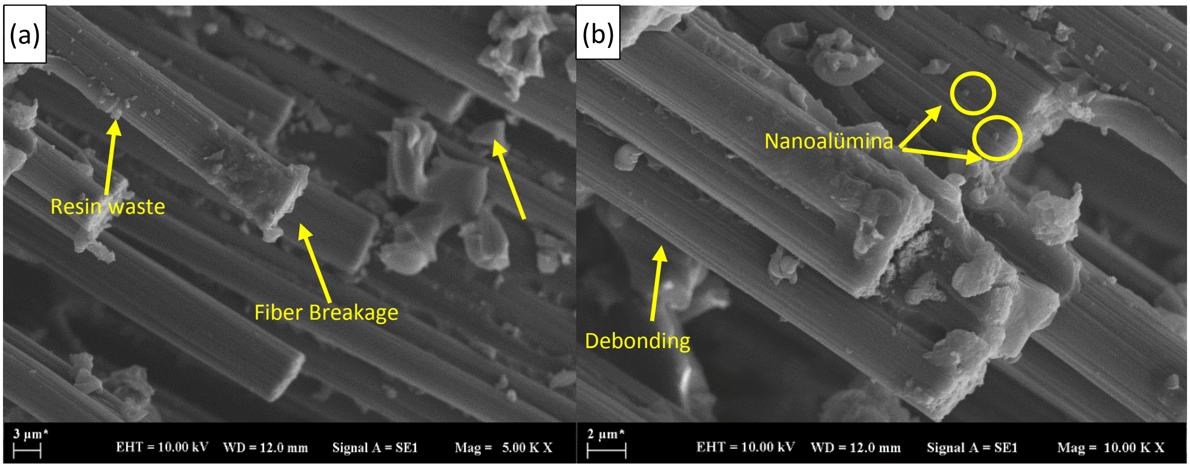


Figure 8: SEM images of a 5-ply sample

In the images given in Figure 8, both (a) and (b) images show the damage on the fracture surface.

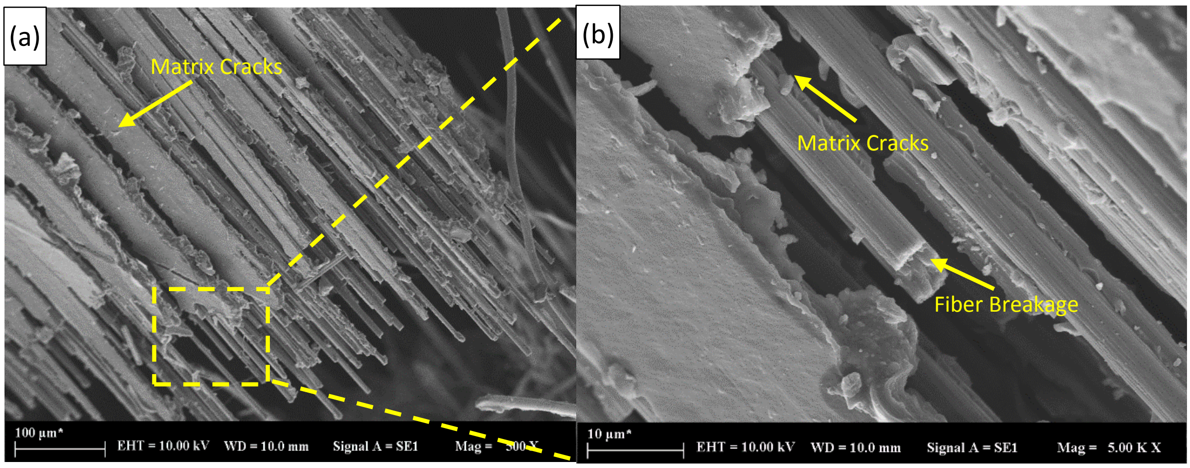


Figure 9: SEM images of a 7-ply sample

Figure (a) shows the matrix crack, and (b) is a closer view of the same region.

4. CONCLUSION

Fiber volume ratios of 3, 5 and 7 ply samples were calculated as 74%, 75% and 75.4%, respectively, based on the values obtained from the burning test data.

As a result of tensile test, tensile strength of 3, 5 and 7 ply samples were measured as 2973 MPa, 6944MPa and 10056MPa, respectively. Based on these data, tensile strength increases as the number of layers increases.

The fracture energies of the samples were measured by the charpy impact test. These values were measured as 1.33J for 3-ply sample, 2.2J for 5-ply sample and 2.56J for 7-ply sample.

The fracture toughness values of the samples were calculated using fracture energies. These values were calculated as 130.4 kJ / m2 for 3-layer sample, 137.5 kJ / m2 for 5-layer sample and 150.6kJ / m2 for 7-layer sample. When the fracture energy and fracture toughness values obtained as a result of the notch impact test are taken into consideration, these values increase as the fiber volume ratio increases.

When the SEM images were examined, it was observed that the nano alumina added to the epoxy resin was homogeneously dispersed.

Based on the results of the damage analysis and the obtained SEM images, the damage types seen in the samples were determined as fiber break, fiber peel, fiber gap and matrix crack. In addition to these damages, matrix wastes are seen on the fracture surfaces.