SAKARYA ÜNİVERSİTESİ
FEN BİLİMLERİ ENSTİTÜSÜ DERGİSİ

Sakarya University Journal of Science
SAUJS

ISSN 1301-4048 e-ISSN 2147-835X Period Bimonthly Founded 1997 Publisher Sakarya University
http://www.saujs.sakarya.edu.tr/

Title: Characterization Of Jute/Aramid Hybrid Composite Materials with Using Different Resins

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Recieved: 2022-02-28 00:00:00

Accepted: 2022-08-15 00:00:00

Article Type: Research Article

Volume: 26
Issue: 5
Month: October
Year: 2022
Pages: 1915-1930

How to cite
Berkay KARACOR, Mustafa ÖZCANLI; (2022), Characterization Of Jute/Aramid Hybrid Composite Materials with Using Different Resins. Sakarya University Journal of Science, 26(5), 1915-1930, DOI: 10.16984/saufenbilder.1080172
Access link
http://www.saujs.sakarya.edu.tr/en/pub/issue/73051/1080172

Sakarya University Journal of Science 26(5), 1915-1930, 2022

Characterization Of Jute/Aramid Hybrid Composite Materials with Using Different Resins

Berkay KARACOR*[1], Mustafa ÖZCANLI[1]

Abstract

For the last twenty to thirty years, interest in the use of hybrid fiber-reinforced composites has gradually increased due to their potential for various applications. The balanced strength and stiffness properties of hybrid composites, along with the advantages of lighter weight and lower cost, have made them an important step toward replacing traditional materials. In this study, a hybrid composite was made from a combination of Jute fabric from natural fibers, Aramid fabric from synthetic fibers, and two different resins (polyester and vinylester). This type of study was proposed because there is little research in the literature on how the use of polyester and vinyl ester resins affects the mechanical properties of homogeneous composites and hybrid composites. The vacuum assisted resin transfer molding process was used for the fabrication. The mechanical properties of the manufactured products were determined by tensile and hardness tests, and their morphological structures were examined by taking scanning electron microscope images. The results indicate that the value of tensile strength and elastic modulus of the Jute/Aramid hybrid samples in the productions prepared with polyester resin is 37.6% and %12.28, respectively, higher than in those made with vinyl ester resin. When comparing the values for microhardness, the results of the Jute/Aramid hybrid specimens produced with polyester resin were 1.20 times higher than those produced with vinyl ester resin. Scanning electron microscope images of the samples also clearly show that the bonding between matrix and fiber is better in polyester resin samples.

Keywords: Hybrid composites, jute fiber, aramid fiber, polyester resin, vinylester resin

1. INTRODUCTION

Hybrid composites are materials in which two or more materials form a combination, where the advantages and disadvantages of their components become a balance element. The hybridization process provides possibilities to obtain and develop customized material properties based on the unique properties of its constituent components. For a suitable hybridization process, the fiber and design must be compatible, and the performance-price balance of the composite materials would be well taken into account [1, 2]. Hybridization is indicated in many studies as a solution to reduce the disadvantageous properties of natural fibers and the applications of sustainable, non-environmental synthetic fibers. As a modern material, hybrid composites formed by synthetic-natural fibers have directed the attention of the

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manufacturing sector to the use of hybrid composites and these materials have found various application areas such as marine, aviation and automotive sector, making hybridization an increasingly effective solution [3, 4]. In this context, natural fiber reinforced composites, which are expected to be used more in hybrid composites, come to the fore as an alternative and environmentally friendly option to synthetic fiber composites. Jute, flax, kenaf, hemp, ramie, and banana can be counted as the main stem type natural fibers. Among these fibers, jute is one of the strongest bast fibers grown in tropical countries and at low cost [5]. Jute is a widely used natural plant fiber with its easy availability and good insulating properties. In addition to being one of the most common agricultural fibers exhibiting moderately higher mechanical properties, jute has seen a significant increase in use as reinforcing materials in composites, along with flax fiber, over the past decade. This increased use can be attributed to the specific mechanical properties of the fiber obtained from the natural jute plant and its very good compatibility with polymers [6, 7]. In the search for alternatives to traditional materials, synthetic fiber-reinforced composite materials from fiber-reinforced composites have become the focus of attention due to the potential to replace these materials in various applications. Compared to traditional metallic materials, synthetic fibers are preferred due to their low weight, high mechanical properties, flexible structure, convenience in manufacturing, and corrosion resistance. Among these fibers, poly aramid fiber, called Kevlar fiber, stands out with its distinctive features [8]. Choosing Kevlar as a reinforcing element in composites has become popular due to its unique properties such as good strength, high impact and high energy absorption capacity, higher modulus, and higher strength per mass rate. In addition to its current use in helmets, bulletproof waistcoats, badminton and tennis rackets, airplanes, helicopter rotor blades, Kevlar fiber has a high potential for use in high-value applications, including vehicles, both for commercial purposes and as an innovative material in the future [9]. Polymer matrix composites are formed from polymer resin as matrix and fibers as reinforcement element. The matrix material generally determines the maximum service temperature because it normally softens, melts, or decomposes at a temperature much lower than the fiber reinforcement. The matrix materials commonly used in composite materials are thermosets and thermoplastics. Thermoset composite matrices include epoxies, phenolics, cyanate esters, bismaleimides, polyesters, polyimides, and vinyl esters [10]. Polyester resin is heat resistant, high strength, and tough. Polyester is a reactive solid and unsaturated in a polymerizable monomer. They are produced by a growth reaction between a glycol and an unsaturated (malic or fumaric) dibasic destructor [11]. Polyester resins are known for their fast curing, versatility, and long life at room temperature, but they also have disadvantages such as self-polymerization at higher temperatures compared to epoxy [12]. Vinyl esters, which are very similar to polyesters in molecular structure, differ from polyesters by having merely reactive groups at the ends of the molecular bond. The fact that vinyl esters have fewer ester groups than polyesters, and that the ester group is more sensitive to hydrolysis by water, increases their resistance to deterioration from water and moisture [13]. Vinylester materials are less sensitive at ambient temperature, with significant interfacial adhesion of natural fibers to the polymer matrix, but have a greater curing effect than polyester [14]. Little research has been done in the field of composite materials created using different resins reinforced with Kevlar and Jute fibers. Bhanupratap and Chittappa [15] investigated the effect of Kevlar fabric on the mechanical properties of hybrid composites they created by adding Kevlar fabric to homogeneous Jute fabric reinforced composites. As the Kevlar fiber ingredient increased in the hybrid composites, it was observed that the tensile strength and load carrying capacity of the jute reinforced epoxy composites increased. In another Jute/Kevlar fiber reinforced epoxy composite investigation [16], the effect of reinforcement elements on the thermal properties of the material designed using dynamic mechanical features was investigated. By adding increasing numbers of Kevlar and converting them to hybrid composites, it increased the storage modulus and loss modulus, glass transition temperature (T_g) compared to pure Jute composites. Maharana et al. [17] created Jute/Kevlar hybrid composites using a hand layup process and investigated how fiber orientation would affect mechanical features. While 20% Kevlar as a weight percent remained constant in the produced composites, the amount of jute changed with epoxy. The maximal tensile endurance value was determined at 30° orientation in the fiber orientation, and the bending strength value was determined the highest at 45° fiber orientation. In a different study [18], the impact absorption energy of hybrid composites formed with Jute fiber and Kevlar fiber was tested. A low velocity impact test was applied to the composites at heights between 50 mm and 250 mm, and energies were observed to vary between 0.4 J and 2.3 J. As the amount of Kevlar fiber increases in the hybrid composites formed, the impact energy of the composites and the absorbed energy increase with the increase in height and speed, and penetration is either absent or partial. Maharana et al. [19] created several hybrid array combinations of bidirectional woven Jute and Kevlar fabric, in which nanoscale fumed silica was used as the filler reinforcement. Double cantilever beam and end notch bending tests were applied to 13 different hybrid composite material combinations they produced. They determined the effect of layering sequence and nanofiller content on interlayer fracture toughness. In other examination [20], in which fumed silica was used as nanofiller and Jute fiber and Kevlar fiber were used as reinforcement elements, it was desired to observe the moisture absorption capacity of the hybrid materials produced. In the results, it was found that when the nanofiller reinforcement was increased up to 3%, the moisture absorption capacity of the hybrid composites decreased, the amount of more than 3% had an adverse effect on moisture absorption, the surface exposure of the jute fibers decreased and the moisture absorption decreased as the proximity of the Kevlar fiber to the surface in the composites increased. In a search in which Kevlar fiber and sisal fiber formed a hybrid composite, it was found that maximum mechanical properties were obtained when the nano silica additive to the polyester resin was 4%, and it was understood that increasing the nano silica ratio more than 4% had a negative effect on the mechanical properties [21]. In the study of Dogan et al. [22], they found that the absorbed energy and deformation amounts of graphene nanoplatelets added at different rates to the hybrid structure consisting of Aramid fiber and carbon fiber also had a significant effect. It was stated that 0.1% and 0.25% by weight nanoparticles added to the resin created the best effect on the structures. In the study of Cetin et al. [23], they analyzed the energy absorbed, deformation and damage in the composites they formed by reinforcing carbon and aramid fibers with halloysite nanotubes. In these analyzes carried out at different temperatures, they stated that the damage increased as the temperature decreased, and the nanoparticle additive had a positive effect on the mechanical properties of the material at the same temperatures. In another study where Cetin et al. [24] examined the effect of nanoparticles on wear in carbon-aramid fiber hybrid composites, they stated that as the percentage of halloysite nanotubes added to the composite material increased, the wear rate and friction coefficient decreased from 9% to 11%. In his study, Cetin [25] examined how the addition of multi-walled carbon nanotube filler (0.1% and 0.2% by weight) to sandwich composite materials affects low velocity impact energy, it was observed that 0.1% nanomaterials improved low velocity impact energy properties. In researches where glass fiber and Kevlar fiber are used as hybrid yarns and polyester resin is preferred as resin, the presence of Kevlar fiber in hybrid yarns significantly increases the mechanical properties, while the effects of fiber orientation and aging test applied on the results are seen [26, 27]. Kennedy and Inigo Raja [28] chose Jute fiber and glass fiber reinforcement material, polyester resin as matrix material in their studies. It has been observed that hybrid Jute/Glass fibers improve their mechanical properties compared to pure Jute fibers in tensile, bending, impact, and hardness tests, and even in some tests, hybrid material properties exceed those of pure glass fiber composite material. Hybrid composites formed by Kevlar fibers and natural fibers are used not only where mechanical properties are important but also where physical properties such as sound insulation are important. When the good mechanical strength properties of synthetic fibers are combined with the acoustic properties of natural fibers, these materials become a remarkable alternative in sound transmission loss performance [29]. Swami and Dabade [30] investigated the optimum fiber-resin combination in the study where different resin types (epoxy, polyester, vinylester) were reinforced with glass fiber. Inter-laminar shear stress and bending test results, it is stated that the highest mechanical properties were obtained in the sample with 60% fiber and 40% vinyl ester resin, while the polyester resin fiber combination showed the lowest mechanical properties. Khare et al. [31] produced composites using different percentages of jute and glass fibers by hand lay-up three different resins as epoxy, vinylester, and polyester. The highest tensile, flexural strengths, and impact energy were obtained with grewiaoptiva at 7.5 wt% in epoxy-based hybrid composites, while the value was found to be better when using grewiaoptiva at 5% wt for hardness compared to other resins. Bozkurt et al. [32] and Bulut et al. [33] performed impact behavior, damping and vibration analysis of hybrid structures formed by aramid fibers with basalt fibers. They showed that the volumetric percentage of aramid fibers in the hybrid structure and the variation of the sequence order with basalt fibers significantly affect the mechanical properties of the hybrid composites. The objective of this research is to examine the mechanical properties of hybrid composites produced in the combination of Jute and Kevlar fibers, rarely used in studies, with two different resins (vinylester and polyester). The mechanical properties of pure Jute and pure Aramid reinforced composites will be compared with the use of two different resins in the results of the study with the hybridization of natural Jute fibers and synthetic Kevlar fibers. The results of the analysis will shed light on the emergence of a low-cost material that can be used in the automotive industry, both in terms of the resin used and the use of natural fibers.

2. MATERIAL AND METHOD

2.1. Material

The reinforcing materials used were plain weave Jute fabric and Aramid twill fabric. Both fabrics were supplied by a company in Istanbul, Turkey. For this research, Table 1 contains the texture characteristics. Figure 1 indicates the texture specimens.

Table 1 Fabric features [34, 35]

Fabric	**Weight (g/m^2)**	**Thickness of fabric(mm)**	**Warp**	**Weft**
Jute fabric	250	0.4	-	-
Aramid fabric	170	0.25	1270	1270

Figure 1 Texture samples: a) Jute texture b) Aramid texture

In the work, polyester resin with related additives and vinyl ester resin with related ingredients were benefitted for matrix materials. They were procured from the Poliya company. Technical specifications of the resins are demonstrated in Table 2 and Table 3. Mixing was carried out for both polyester and vinyl ester resins in a weight ratio of resin: cobalt nephthalate (as an accelerator): methyl ethyl ketone peroxide (MEKP) of 1:0.002:0.02.

Table 2 Polyester properties [36]

Maximum temperature (°C)	170
Flexural strength (MPa)	134
Elongation at break (%)	2.6
Viscosity (cps)	500-600
Tensile strength (MPa)	71
Barcol Hardness	40

Table 3 Vinylester properties [37]

Flexural strength (MPa)	155
Elongation at break (%)	5
Viscosity (cps)	200-250
Tensile strength (MPa)	76
Barcol Hardness	36

Twelve composite specimens were produced using two different resins and with different fabric stacking orders. Table 4 displays the pattern names for the texture laminas in the composite specimens.

Table 4 Naming pattern specimens

Pattern Names	Texture kinds
J	Jute fabric
A	Aramid fabric
JA	Jute/Aramid fiber hybrid composite
JP	Jute fiber reinforced polyester hybrid composite
AP	Aramid fiber reinforced polyester hybrid composite
JAP	Jute/Aramid fiber reinforced polyester hybrid composite
JV	Jute Fiber reinforced vinylester hybrid composite
AV	Aramid fiber reinforced vinylester hybrid composite
JAV	Jute/Aramid fiber reinforced vinylester hybrid composite

After curing at 60 °C for 1 hour, the composite specimens were cut off with a water jet machine in accordance with the test sizes determined in the norms, such as 250 mm length, 25 mm width, and 2.5 mm thickness. As the state of the produced samples before the tensile test is given in Figure 2, the stacking sequences of the fabrics are given in Figure 3 and Figure 4.

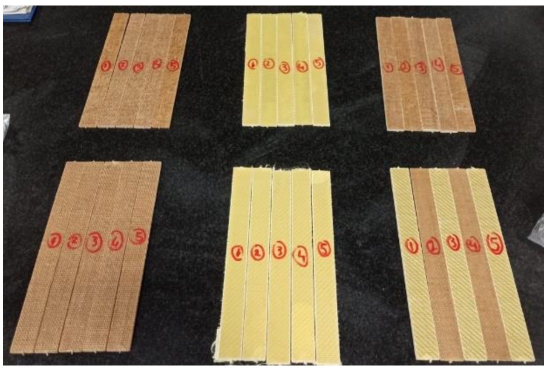

Figure 2 Composite samples after water jet machine application

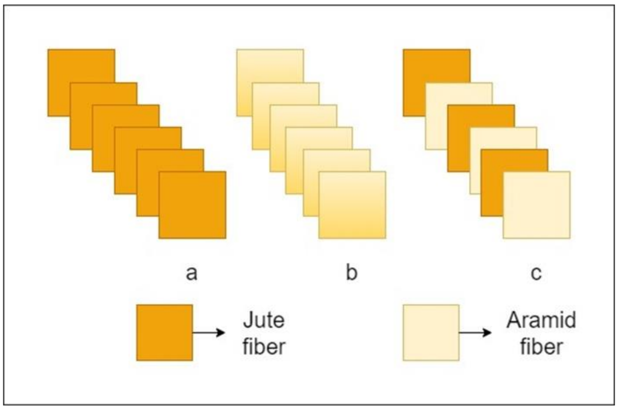

Figure 3 Fabric stacking sequences of a) JP b) AP c) JAP

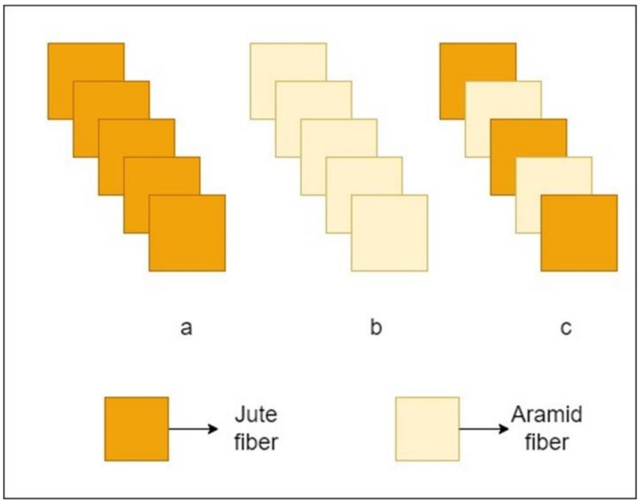

Figure 4 Fabric stacking sequences of a) JV b) AV c) JAV

2.2. Method

The vacuum-assisted resin transfer process was used to produce composite laminates reinforced with jute and aramid fibers. The composites were prepared at ambient temperature (20°C±2°C). This method uses a vacuum to remove the air from the reinforcing material so that the resin can penetrate the preform. The production area was created by using tempered glass for the composite production process. Firstly, the surface was sanitized and the area to be produced was determined with a vacuum sealing tape. Mold release wax was applied twice at specified times to the specified surface. Then the fabrics were laid in the predetermined sequence, and the peeling fabric and infusion net were set on top. The system was sealed with a vacuum bag, in an airtight manner, only two small holes were made for the resin inlet and outlet. During these procedures, the mixing ratio of resin and additional additives was specified, considering the values from prior manufacturing, and the blend was put together thence. Lastly, the vacuum pump was started to absorb the resin (Figure 5). The vacuum pump was operated for an average of 2 hours at a pressure of about 1 bar and was switched off as soon as the additional resin flow on the sample was interrupted. The products prepared to complete the curing process were left in this position for 24 hours. At the end of this period, the test samples were put into the oven and kept at 60°C for 1 hour.

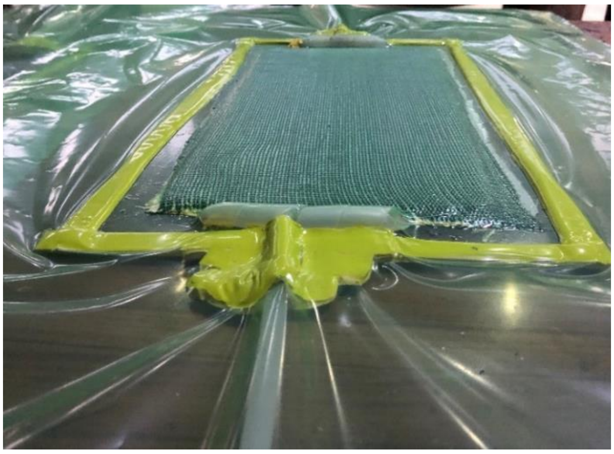

Figure 5 Vacuum assisted resin transfer molding process

2.3. Tensile Testing

The tensile experiment was performed to decide the mechanical properties of the produced composite specimens. Average tensile strength values were calculated by testing 5 samples from each configuration were tested, resulting in a total of 6 configurations. The tensile test was performed following the ASTM D 3039 standard [38]. The test was carried out with ALŞA hydraulic testing device (KOLUMAN Automotive Industry Laboratory) and 2 mm/min was adjusted as the cross-head speed on the machine with a 98000 kN load cell. Figure 6 displays the universal tensile tester. The tests were carried out at room temperature, and the sample sizes were recorded in the computer program before starting the tests. In addition to the automatic drawing of the engineering stress-strain diagram by a computer connected to the machine, the tensile strength, elastic modulus, and elongation ratios are calculated by the device.

Figure 6 Tensile testing machine

2.4. Hardness Testing

The definition of hardness in materials is known as resistance to local plastic deformation. In order to determine the hardness of the samples produced in this study, Vickers hardness tests, also called 136-degree diamond pyramid hardness tests, were performed. In hardness samples, the sample thickness was produced to be 1.5 mm. The Vickers hardness value was determined by measuring 15 hardness measurements from different areas of the surface of each sample, and the average of these values was found as the hardness value. While the hardness test of the samples was carried out with respect to the ASTM E92-17 standard [39], the AOB Lab hardness test measuring device was used. Figure 7 demonstrates the Vickers hardness test device.

Figure 7 Hardness testing machine

2.5. Morphological Analysis

The most suitable method for analyzing fiber surface morphology of materials is scanning electron microscopy (SEM). Owing to this method, fracture surfaces, fiber-matrix interactions, and fiber structures formed in composites can be observed as a result of tests. A Scanning Electron Microscope FEI Quanta 650 Field Emission instrument at an acceleration voltage of 100V-30kV was used for SEM analysis. In order to increase the superficies conductibility of the specimens, a gold overlay was done by spraying method. The machine seen in Figure 8 has a magnification capacity of 6-1,000,000 x. In order to see the hybridization effects, in addition to analyzing the quantitative data, the effects of mechanical fracture in a macroscopic way can be examined by SEM.

Figure 8 SEM analysis machine

3. RESULT AND DISCUSSION

3.1. Tensile Test Results

Figure 9 highlights that composite products prepared with polyester resin has higher tensile strength than those prepared with vinylester resin. It is understood from Figure 10 that this trend continues in the same way in the tensile modulus results. In the tensile strength results, it was found that the tensile strength value of the samples prepared with polyester resin was 1.37 times superior to the samples prepared with vinylester resin. In the tensile modulus outcomes, the samples using polyester resin were 1.12 times higher than the samples using vinylester resin. As seen in Figures 9 and 10, the highest tensile strength and tensile modulus values were obtained in pure aramid composite products. Pure jute composites, on the other hand, had the lowest values among the products produced in terms of both tensile strength and tensile modulus. The tensile strength results are also close in the studies where jute fibers and polyester resin are used together. The tensile strength values of the samples in the study are not far from each other. While the woven topology in the samples reduces the shrinkage in the fibers while the samples are breaking, it is stated that the progression of the crack formation is caused by the pulling of the fibers from the hollow structures in the matrix [40, 41]. When evaluated in terms of hybridization effect among the produced products, the tensile strength of JAP products was 3.89 times higher than that of JP products, and the tensile strength of JAV products was 3.09 times higher than JV products. This resulted in the value of the JAV product being 1.87 times higher than the value of the JV product, and the value of the JAP product being 1.88 times higher than the value of the JP product in the tensile modulus comparison. The low mechanical properties of jute fibers due to their nature are tried to be eliminated by using different fiber structures and by hybridization. In another study in which jute fibers were hybridized, an increase in tensile strengths of 4.79% and 6.14% were found depending on the warp and weft directions. In addition, it has been stated that the core-centered array creates an advantage in mechanical properties compared to the axial surface array in fiber fabric arrays [42]. In this study, the hybridization process with Aramid fibers provides improved tensile strength and tensile modulus values in the produced composites, but also provides a significant change in character. The use of polyester resin with jute fibers improved the tensile strength of the composite structure by 1.09 times compared to the use of vinylester resin with jute fibers, while the composite structures of aramid fibers prepared with polyester resin allowed an improvement in tensile strength by 1.32 times compared to structures prepared with vinylester resin. In the comparison of pure jute composites in the tensile modulus results, it was determined that the modulus value of JP was 1.12 times higher than that of JV, and the modulus value of AV was 1.55 times higher than that of AP. Considering the elongation rates in Figure 11, the elongation rates of the samples prepared with vinylester resin were higher than the samples prepared with polyester resin. The elongation rate values indicate the ductility of the sample. Since the factors that increase the yield and tensile strengths of material mostly decrease the ductility, it is seen that the samples prepared with polyester resin with high strength value results have less elongation rate. While the JAV structure showed 1.28 times higher elongation rate than the JAP structure, this difference was found to be 1.93 times in favor of AV between AV and AP and 1.11 times in favor of JV between JV and JP. Pure jute fiber polyester resin structures showed 1.81 times less elongation than hybrid jute/aramid fiber polyester resin structures. Structures formed with pure jute fiber polyester resin showed 1.57 times less elongation than structures formed with hybrid jute/aramid fiber polyester resin.

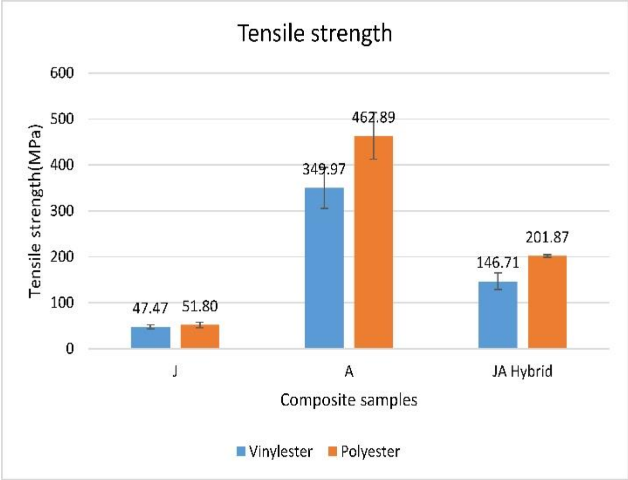

Figure 9 Tensile strength test results

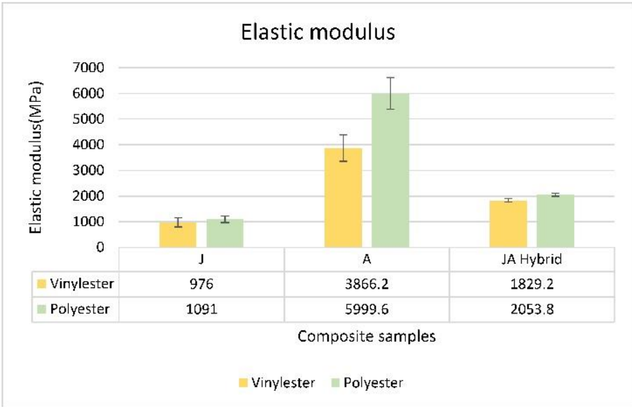

Figure 10 Elastic modulus results

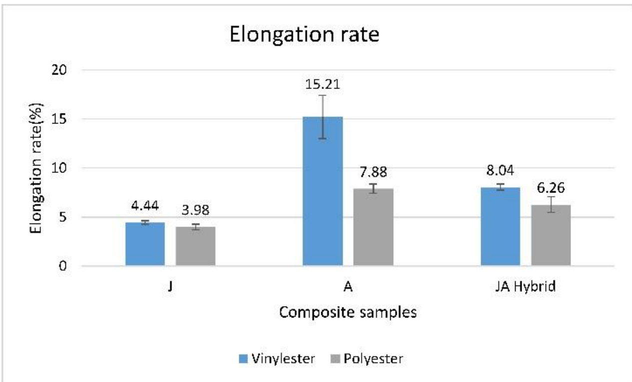

Figure 11 Elongation rate results

Figures 12- 17 indicate one of the stress-strain curves closest to the mean value from each configuration of the samples tested. As seen in Figures 12 and 13, rupture was observed at the maximum force of 4.2-4.63 kN with the brittle structure of the jute fiber. The fracture forces with the high elongation amount of aramid fibers were also determined at the values of 15.12-20.65 kN, as can be seen from Figures 14 and 15. As stated in Figures 16 and 17, in hybrid composites, on the other hand, a breaking force was determined between pure jute and pure aramid composites with a maximum breaking force of 11.35-16.02 kN, almost without departing from a linear curve.

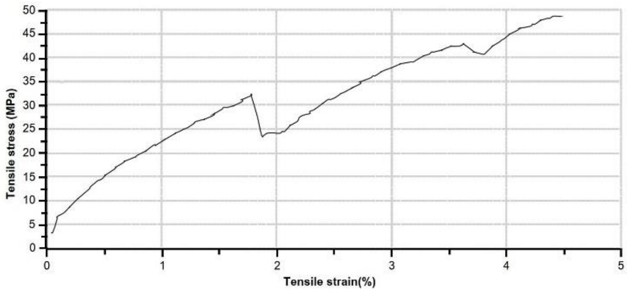

Figure 12 Stress-strain curve of JV sample

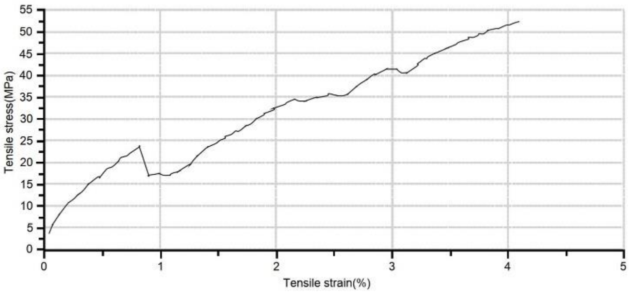

Figure 13 Stress-strain curve of JP sample

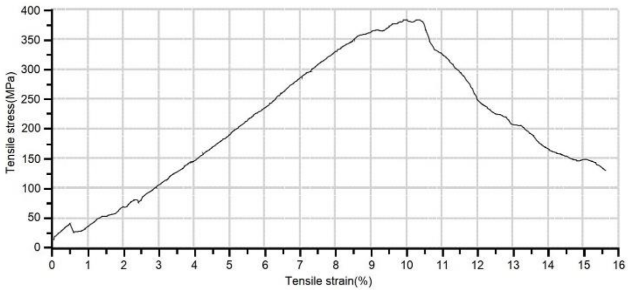

Figure 14 Stress-strain curve of AV sample

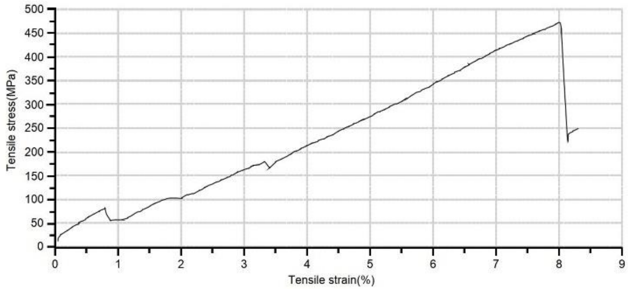

Figure 15 Stress-strain curve of AP sample

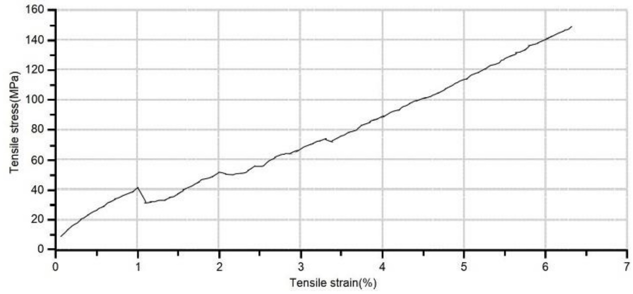

Figure 16 Stress-strain curve of JAV sample

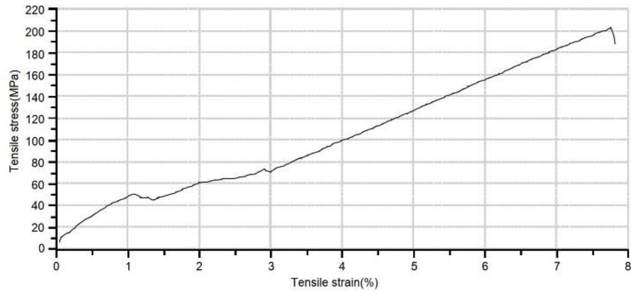

Figure 17 Stress-strain curve of JAP sample

Figure 18 and Figure 19 indicates the photographs of broken surfaces after the tensile test. From the sample images in Figure 18, it is understood that the ductile structure of aramid fibers manifests itself in the form of elongation of the fibers, while the jute fibers have a more fragile structure and break from the axial center. In hybrid jute/aramid structures, fiber tearing occurred on the outer surfaces, and unlike the breakage in pure jute fibers, aramid fibers tried to make breaking difficult. In the study examining the impact force applied to aramid and basalt, it was determined that the fibers showed slight ruptures and cracks occurred in the central region. High stresses where the impact force is applied have been the areas where the deformations are concentrated [3, 32].

Figure 18 Back side view(a) of JP, AP and JAP and front side view(b) of JP, AP and JAP

When the breaks in the vinylester resin samples in Figure 19 were examined, it was observed that there was no complete break in the aramid fibers. This explains why the percent elongation in tensile results is greater in samples prepared with vinylester resin. It was determined that the JV structures were completely broken, as in the JP structures in Figure 18. In the JAV structure, it was understood that the elongation of the fibers was less than that of the JAP structure, and it showed sharper breakage. In the study [2], in which aramid fiber and glass fiber were used as reinforcement elements, it was stated that the sequence types of the samples determined the tearing in the fabrics. Therefore, in the hybrid structures, the fibers in the outer layers of the fabrics were broken.

Figure 19 Back side view (a) of JV, AV and JAV and front side view (b) of JV, AV and JAV

3.2. Hardness Test Results

In view of Vickers hardness test outcomes as seen in Figure 20, products using polyester resin in composite production have higher Vickers hardness than products using vinylester resin. The use of aramid fabric as a reinforcement element in the use of both polyester and vinylester resin gave the highest Vickers hardness value. The use of jute fiber fabric as a reinforcing element showed the lowest Vickers hardness values in both resins. Hybridization of jute fabric with aramid fabric increased the hardness value in both resins compared to homogeneous composites using Jute fabric from the natural fiber fabric category. In this study [43], where the hybridization of Aramid fabric to natural fiber fabrics was investigated, it was observed that the addition of 5% Aramid fabric increased the hardness value by 14% compared to the pure vinylester resin composite.

While the Vickers hardness value of the JAP sample increased by 49.28% compared to the homogeneous JP sample, the hardness value of the JAV sample increased by 89.71% compared to the homogeneous JV sample. There is a difference of 20.2% between the JAP hybrid sample and the JAV hybrid sample in terms of hardness in favor of the composite sample using polyester resin. When the product specification values are also examined, the hardness value of pure polyester resin is higher than that of vinylester resin, as given in Tables 2 and 3. This difference is 52.75% on behalf of JP structure for JP and JV samples, while 10.24% is on behalf of AP structure for AP and AV samples. These results indicate that the highest hardness value difference is in the samples using Jute reinforced polyester resin and vinylester resin. In the study of Khare et al. [31], the hardness value in the samples produced by using polyester resin together with jute fiber was higher than the samples using vinylester resin, even though jute fiber was used in varying ratios such as 2.5% and 7.5%.

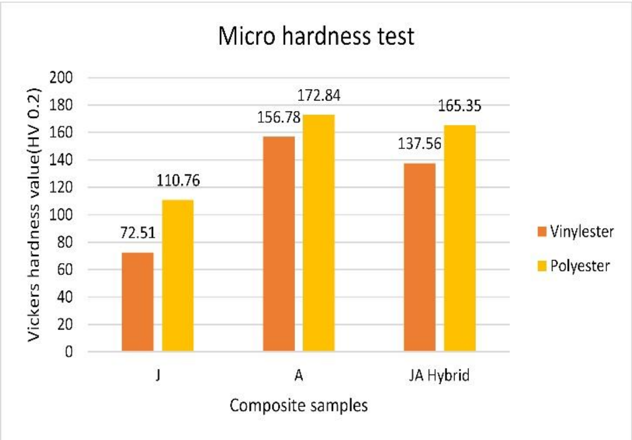

Figure 20 Micro hardness test results

3.3. SEM Analysis Results

The SEM images of Figures 21 displays the morphological structure of the JV after the tensile test, and also Figure 22 and 23 demonstrate morphologies the AV and JAV hybrid composite structures after the tensile test. In the JV composite structure as seen in Figure 21, fiber breaks are observed due to the brittle structure of the jute fibers, while in the AV composite structure in Figure 22, it is understood that the aramid fibers are broken homogeneously and there is no rupture. In the JAV composite structure in Figure 23, it has been determined that the Kevlar fiber provides a higher mechanical property by reducing the shrinkage effect on the jute fiber, with the effect of the hybrid structure, compared to the JV structure. It has also been noted in previous studies that hybridization of Kevlar fiber with jute provides a significant matrix fiber interaction [44, 45].

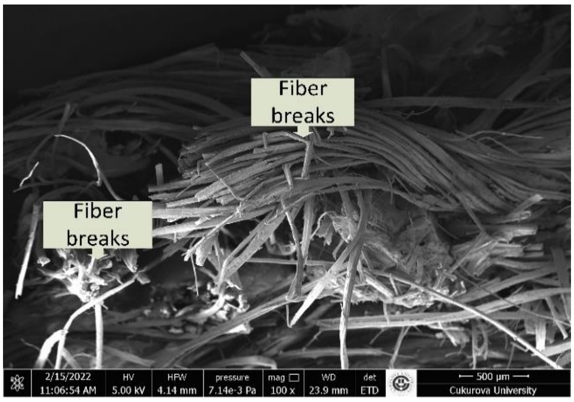

Figure 21 JV composites SEM micrograph

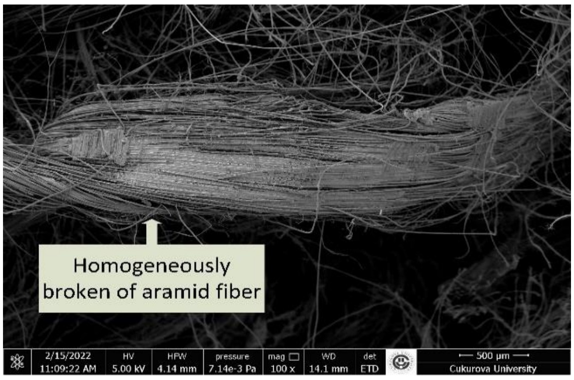

Figure 22 AV composites SEM micrograph

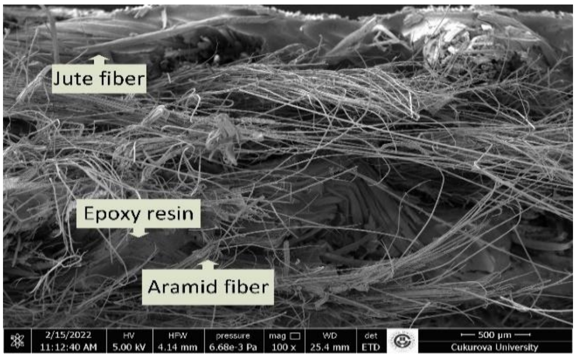

Figure 23 JAV hybrid composites SEM micrograph

Figures 24 shows the morphological forms of JP composite structures after the tensile test. Figures 25 and 26 indicate the morphological examination of AP and JAP composite structures after the tensile test prepared with polyester resin. Compared with the SEM images in Figures 21, 22, and 23, it is seen that JP, AP, and JAP hybrid composite structures have fewer voids, fewer air bubbles, and high toughness structure. In the tensile test results, better tensile strength values are obtained in the use of polyester resin compared to the use of vinylester resin, which is supported by these morphological analysis images. The absence of gaps around the fiber in the AP composite structure as in Figure 25 compared to the JP composite structures as in Figure 24 indicates that it provides a better adhesion with the resin. In structures where aramid fibers are used as reinforcing elements, fiber abrasion and fiber breakage occur as frequently encountered situations. Significant cases of rupture and micro buckling in Kevlar fibers have also been found in other studies [46]. In the JP composite structure, the fibers are not broken evenly, while a more homogeneous breakage is detected in the JAP composite structure in Figure 26.

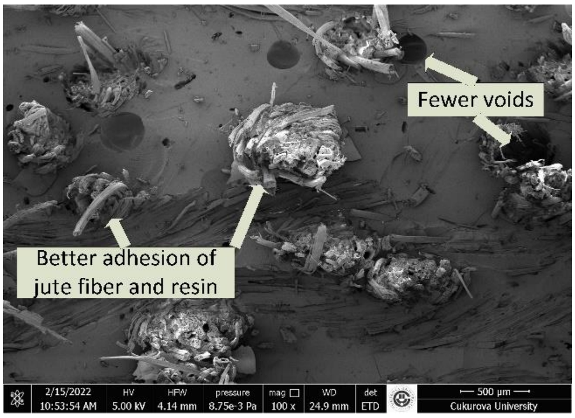

Figure 24 JP composites SEM micrograph

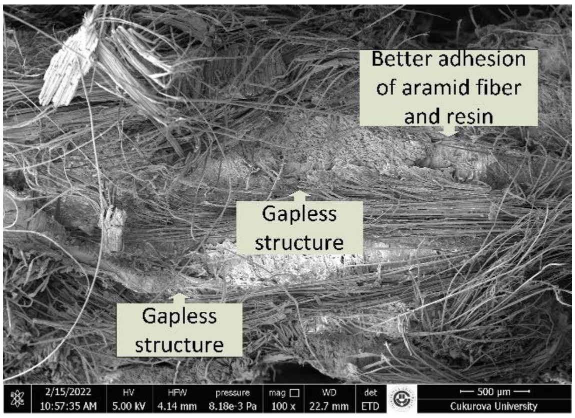

Figure 25 AP composites SEM micrograph

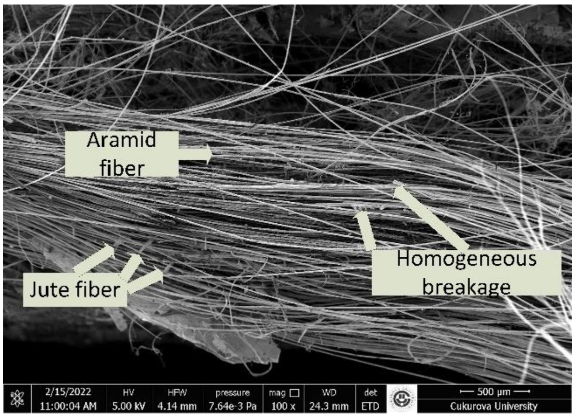

Figure 26 JAP hybrid composites SEM micrograph

4. CONCLUSION

In this work, jute fabric made of natural fibers and Kevlar fabric made of synthetic fibers were preferred as reinforcement elements, vinylester and polyester resins were preferred as matrix elements. The effects of using two different resins on the mechanical properties of the pure and hybrid composites were investigated. It has been determined that the use of polyester resin in hybrid jute/aramid composites improves the tensile strength, tensile modulus and microhardness value compared to the use of vinylester resin. The use of polyester resin, as understood from the SEM analysis results, provided better delamination resistance and structural integrity of the structures by creating better interfacial bonds between the fiber and the matrix and allowing less air gaps. In addition, it can be deduced from the results of this study that the mechanical properties of jute fibers in hybrid structures are improved by the hybridization process of jute fibers with aramid fibers in both resins. The results of this paper show that the use of polyester resin for reinforcement with jute and aramid fabrics results in better mechanical properties than vinylester resin. The use of polyester resin, which is more economical in terms of cost, instead of the commonly used epoxy resin, together with jute fibers, which are cheaper than Kevlar fibers and belong to natural fibers, points to an important point in terms of less harm to the environment and sustainability. In the light of the results of this study, these materials offer designers new ideas in terms of cost and weight without any loss in performance in the areas of the interior of the vehicle.

Funding
The authors have no received any financial support for the research, authorship or publication of this study.

The Declaration of Conflict of Interest/ Common Interest
No conflict of interest or common interest has been declared by the authors.

Authors' Contribution
The first author contributed 60%, the second author 40% to the study. BK: Literature research, conducting experiments, writing the article, MO: Literature research, writing the article.

The Declaration of Ethics Committee Approval
This study does not require ethics committee permission or any special permission.

The Declaration of Research and Publication Ethics
The authors of the paper declare that they comply with the scientific, ethical and quotation rules of SAUJS in all processes of the paper and that they do not make any falsification on the data collected. In addition, they declare that Sakarya University Journal of Science and its editorial board have no responsibility for any ethical violations that may be encountered, and that this study has not been evaluated in any academic publication environment other than Sakarya University Journal of Science.

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