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Investigation of Mechanical Properties of Polyester, Acrylic, Polyamide Fiber Reinforced Epoxy Composites

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Abstract:

Composite materials are materials obtained by combining materials with two or more different properties that are used by people for thousands of years to solve problems without being aware of them. Polymer based composite materials have recently been developed to improve the properties of these materials, as they have many superior properties as well as insufficient strength. Depending on technological developments, different types of composites have been produced using different types of matrix and reinforcement. The purpose of this study is to produce and examine mechanical properties of polyester, acrylic and polyamide fiber reinforced epoxy composites. The composites were produced by the method of hand lay-up. Tensile, impact, flexural and interlaminar shear strength (ILSS) tests were performed on the prepared specimens. Increases in the fibre content had various effects on the above mentioned mechanical properties of the obtained composites.

Keywords: Polyester Fiber; Acrylic Fiber; Polyamide Fiber; Araldite Resin; Composite Materials.

DOI:

1. INTRODUCTION

The polymers play very important role in our daily life. They can be combined with different materials to achieve special properties according to end use applications. Polymer based composites are being used more and more intensively in space, aviation, medicine, automotive, textile, construction, building and other developing technologies. Reinforcing fibers, which are generally used in polymer composites, provide strength and other desirable properties to the composite material [1,2]. In parallel with these developments, work on fibers with better mechanical properties and higher heat-resistant, non-cracking, high impact strength and hard polymer matrices continue in the world [3-7].

Today, most of the synthetic polymer fibers in use span applications such as clothing, carpets, ropes and reinforcement materials. Some of these fibers include polyamides such as nylon, polyesters (as PET, PBT), PP, PE, vinyl polymers (as PVA, PVC), PU and acrylic fibers (e.g. PAN) [8,9].

Polyamide refers to family of polymers called linear polyamides made from petroleum. The generic name polyamide fibre has the same meaning as nylon fibre [10]. Polyamides generally are tough, strong, durable fibers useful in a wide range of textile applications. The distinguishing characteristics are high elasticity, tear and abrasion free, low humidity absorption capability, fast drying, no loss of solidity in a wet condition, crease free, and rot and seawater proof. Application areas range from underwear to outdoor sports clothing [11], from automotive to aerospace [12].

PET is the world's most widely used fiber in a variety of forms. PET is widely used in both fiber and filament forms as a strong, dimensionally stable fiber. Large quantities of PET fibers are also used for both woven and

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nonwoven fabrics used for industrial and technical applications. Polyester fibers have many excellent properties such as high strength, good stretchability, durability and easy care characteristics [13].

Acrylic fiber is named as acrylonitrile containing at least 85% of its chemical structure according to ISO (International Standards Organization) definition. Since acrylonitrile, which is predominantly homopolymerized with 100% acrylonitrile polymerization, is hard, brittle and difficult to paint, it has been converted into copolymers by the addition of a second monomer and is particularly suitably used in textiles. Acrylic fibers have a wide range of uses such as knitting, hand knitting, carpet, blankets, velvet, socks [14]. Also acrylic fibre has been extensively used in a number of industrial applications for example as a cursor for carbon fiber, as substitute for asbestos in-fibre reinforced cement, and in hot gas and wet filtration [15].

2. EXPERIMENTAL PROCEDURE

2.1. Materials

RENLAM LY113 araldite resin (Huntsman) as the resin, Ren HY97 (Huntsman) as reaction initiator and Benzyldimethylamine (BDMA-Eastman) as accelerator were used in the composite matrix formulation. Araldite is a two-part epoxy resin that, when mixed cures to produce an incredibly strong bond between many different types of materials.

Acrylic fiber (Acrylic Tow, Type Extra / Gloss Dtex 2,2 - Lotno / Apre E-4316 / RA-01 Ktex 97) supplied from Aksa Acrylic Industry Company. Polyester and aramid fiber supplied from KORDSA were used as reinforcing materials.

2.2. Mechanical Tests

All the mechanical tests given below were performed at room temperature.

2.2.1. Tensile test

Tests were performed according to ISO 527-4 standart. Composite specimens were cut to 195x25x4 and 5 specimens were used for each group. Specimens were subjected to uniaxial tension with a constant tensile speed of 5 mm/min on a Zwick Z010 universal tensile device and corresponding stress-strain values were recorded.

2.2.2. Flexural test

Flexural strength of the composite laminates were determined via 3-point bending tests with a test speed of 5 mm/min on a Zwick Z010 universal tensile device. Tests were performed according to EN ISO 14125 standart. Specimen sizes were 80x10x4 and 5 samples were used for each group. Span to depth ratio was hold as 16:1.

2.2.3. Interlaminar shear strength (ILSS) test

Specimen sizes were 24x8x4 and 5 samples were used for each group. The interlaminar shear strength test (ILSS) was performed according to ASTM D2344 standard on a Zwick Z010 universal tensile device with a test speed of 5 mm/min.

2.2.4. Impact test

Specimen sizes were 80x10x4 and 5 samples were used for each group. Unnotched specimens was tested using Zwick B5113.30 Izod Impact Device with a 5.4 J izod impact hammer according to the ISO 180 standard.

2.3. Preparation of the Composite Samples

In this study, two-piece semi-open finely ground mold made of stainless steel was produced to prepare composite sheets (Figure 1). Surfaces of the mold that are in contact with the composite were grinded to prevent adhesion. Composite specimens were obtained out of these sheets.

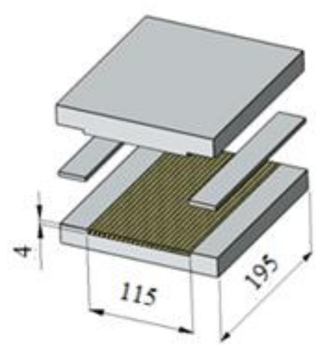

Figure 1. A schematic view of mold used for composite sheet preparation.

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Table 1. By weight ratios and weights of fibers

Materials	Weights of Fibers (gr)		
	40 %	50 %	60 %
Polyester fiber	41,262	51,577	61,893
Polyamide fiber	38,606	48,258	57,910
Acrylic fiber	44,132	55,165	66,199

The prepared composite matrix resin consists of 100 gr of araldite resin (Renlam LY113), 32 % (32 gr) of Ren HY97 and 15 drops of BDMA. Composite samples were prepared by hand lay-up method. After applying the matrix resin via brush, the fibers were placed on the open mold according to the percentage weights indicated in Table 1. The same procedures were applied to all fibers to produce composite sheets containing 40 %, 50 % and 60 % of individual polyester, acrylic and aramid fibers. Due to the difficulty of wetting the fibers with resin, it was not possible to prepare samples with more than 60 % by weight of fibers.

The upper mold was closed and compressed with the help of tacks to allow the resin to wet the fibers well and to remove air bubbles in the structure. After standing for 24 hours at room temperature, the composite sheets removed from the mold were first of all edge trimmed, then were cut according to the relevant standards and the burrs formed at the edges were sanded.

3. RESULTS and DISCUSSION

In this study, the mechanical properties of the composite materials were investigated in consideration of the weight. Figure 2 demonsrates tensile strength of composite specimens with various fiber content. Table 2 shows elongation of composite specimens with various fiber content. The fiber content is between 40 % and 60 %. In composite samples reinforced with polyamide and polyester fiber, the tensile strength increased with increasing fiber content. The maximum tensile strength was reached in the specimens having 50 % polyamide fiber. Above this content, the tensile strength reduced. The maximum elongation was observed in composite specimens having 60 % polyamide fiber. For polyester fiber reinforced composite samples, the maximum tensile strength value was observed in the sample with 60 % polyester fiber. In the acrylic fiber reinforced composite samples, the tensile strength value decreased as the fiber ratio increased. The highest tensile strength value was in the composite sample with 40 % acrylic fiber.

The tensile test results show that the highest tensile strength in all composite samples was found in composite specimens containing 60 % polyester fibers.

Figure 3 shows the flexural strength values obtained by the 3-point bending tests. Composite samples with polyamide and acrylic fiber reinforcement showed a decrease in flexural strength as the amount of fiber increased. Composite specimens with 40 % polyamide fiber reinforcement and 40 % acrylic fiber reinforcement showed maximum flexural strength. At the 60 % reinforcement, the lowest flexural strength was observed in both types of fibers. The maximum flexural strength for polyester fiber reinforced composite specimens was at the content of 50 %. 60 % polyester fiber reinforcement showed lower flexural strength but higher than 40 %.

Composite specimens reinforced with 50 % polyester fiber have the highest flexural strength.

Figure 4 shows the interlaminar shear strength (ILSS) of the composite specimens with various fiber content. It has been observed that for every 3 types of fibers used in this study, the ILSS strength reduced by increasing fiber amount. Polyamide, polyester and acrylic fiber reinforced composite samples with 40 % ratio showed the highest ILSS strength, while 60 % fiber reinforced composite samples had the lowest ILSS strength.

The composite specimens reinforced with 40 % polyester fiber showed the highest interlaminar shear strength.

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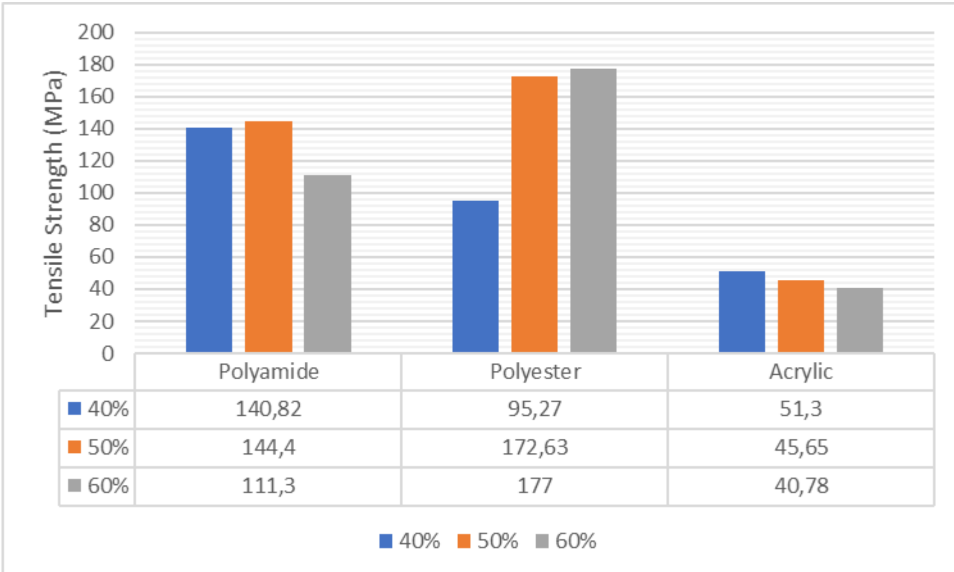

Figure 2. Variation of Tensile strength with respect to fiber type and content.

Table 2. % Variation of Elongation with respect to fiber type and content.

	Polyamide fiber	Polyester fiber	Acrylic fiber
40 %	64,4	27,6	22,3
50 %	74,9	31,6	20,3
60 %	79,6	33,3	25,8

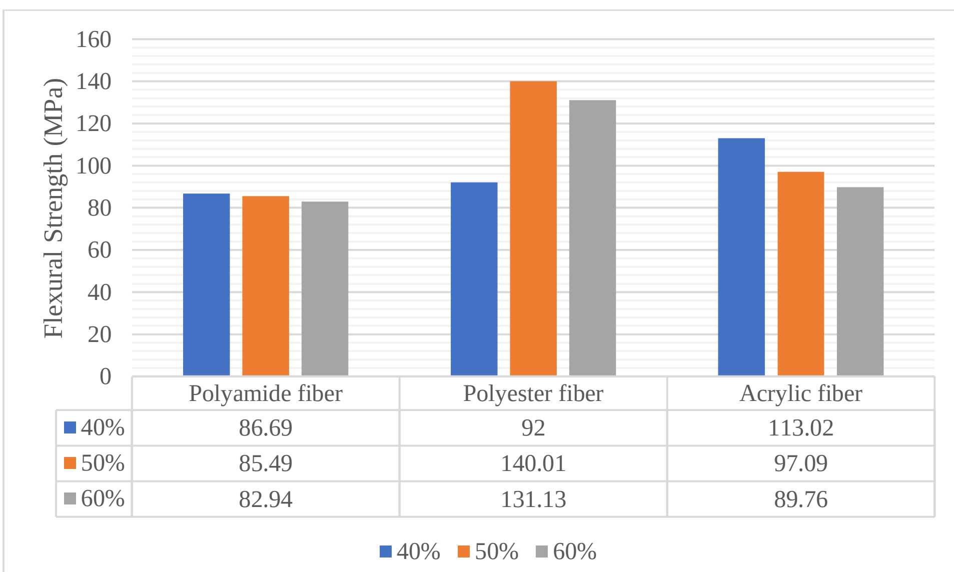

Figure 3. Variation of flexural strength with respect to fiber type and content.

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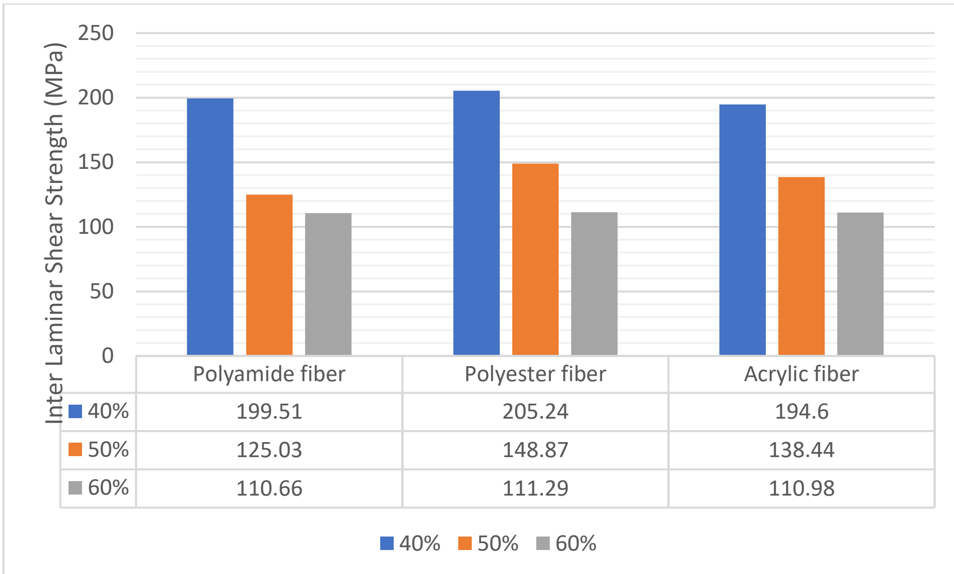

Figure 4. Variation of Inter laminar shear strength (ILSS) with respect to fiber type and content.

Figure 5 demonsrates impact strength obtained by the izod impact test of all the composite samples. It has been observed that in all 3 types of fibers used in this study, the increase in the amount of fiber also increases the impact strength. Maximum impact strength was observed in composite specimens reinforced 60 % polyamide, polyester and acrylic fiber.

In all composite specimens, the material with the highest impact resistance is composite material with 60 % polyamide fiber reinforcement.

4. CONCLUSIONS

As the ratio of polyester fiber increased in composite samples, tensile strength, elongation and impact strength increased; flexural strength decreased after the increase up to 50 %. As the polyamide fiber ratio increased, the tensile strength decreased, while the elongation increased; a decrease in flexural strength was also observed. Tensile strength and elongation of acrylic fiber increased while flexural strength decreased. All composite samples showed a decrease in ILSS values and an increase in impact strength values.

Because the polyester fiber reinforcements were more elongated than the known glass and carbon reinforcements [16], the samples subjected to impact testing exhibited a more tough behavior. Hence, the impact test samples were not divided into two parts at the end of the test and remained in one piece. In the literature, while the percent elongation values of carbon and kevlar fabric reinforced composites are around 5 % [17], the elongation values obtained from this study vary between 27-33 %. The material having the highest tensile strength, flexural strength and shear strength among the composite samples is polyester fiber reinforced composite material. Polyester fiber reinforced epoxy composites can be preferred especially in areas where high tensile strength is desired.

The material having the highest impact resistance among the composite samples is polyamide fiber reinforced composite material. The highest elongation value of this material is 64-80 %. It is clear that polyamide fiber-reinforced composite samples exhibit a significant elongation behavior without showing brittle fracture. The reason for this behavior is the presence of polyamide fibers with a high degree of elongation in the composite structure. A small portion of the strands of polyamide fiber-reinforced composite are ruptured; although the majority of them are damaged to a certain extent, they do not break, as a result of which composite test samples can maintain their integrity after testing. It can be said that such behavior has a certain degree of similarity with damage tolerant composites. In the light of the results given above, it is clear that the tensile strength and rigidity of polyamide-reinforced epoxy matrix composites are not of primary importance but will be successful in many composite applications where elongation and impact strength are important. In this

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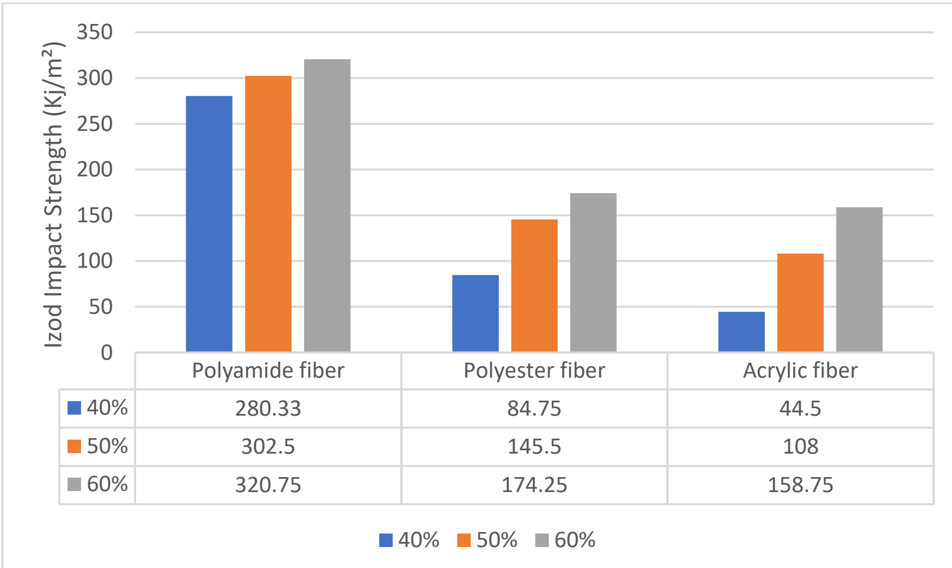

Figure 5. Variation of Izod Impact strength (ILSS) with respect to fiber type and content.

case, the rupture of the composite is not instantaneous and diffuses over time, such a composite may be included in the damage tolerant composites [17,18] group.

Acrylic fiber reinforced composites can be used successfully in composite applications subject to impact if transparency is desired in applications and especially with the increase of acrylic ratio, the impact resistance is increased significantly.

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