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MECHANICAL PROPERTIES OF NATURAL FIBRE‑REINFORCED SUSTAINABLE EPOXY COMPOSITES

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ABSTRACT

The use of composites in various fields has increased rapidly due to their advantages such as convenience, stability, tensile, flexural and impact resistance. Mechanical properties in textile composites are closely linked to fiber reinforcement. Flax fibers are used with various polymer materials. The most common matrix material used in flax fibers is epoxy polypropylene, as it is easy to process and has good mechanical properties. Flax fiber reinforced composites have high tensile, flexural and impact strength. Compared to other natural fibers, composites made with flax fibers are costly. In this study, a composite surface was obtained by applying epoxy polymer to the surface of flax fiber reinforced fabric of different lengths and the mechanical properties of the resulting composite samples were examined. As a result of the testing of composites made of flax fibers, tensile strength measured between 17.76 and 26.62 MPa, flexural strength between 28.82 and 46.92 MPa and impact strength of 2.39-5.25 J were measured. The results obtained show that improvements were achieved in the mechanical properties of epoxy resin and flax fiber reinforced polymeric composite materials.

Keywords: Composite, Epoxy resin, Mechanical properties, Flax.

DOĞAL ELYAF TAKVİYELİ SÜRDÜRÜLEBİLİR EPOKSİ KOMPOZİTLERİN MEKANİK ÖZELLİKLERİ

ÖZ

Kompozitlerin çeşitli alanlarda kullanımı, vermiş olduğu kolaylık, stabilite, çekme, eğilme ve darbe direnci gibi üstünlüklerde dolayı hızla artmıştır. Tekstil kompozitlerindeki mekanik özellikler lif takviyesi ile yakından bağlantılıdır. Keten lifleri çeşitli polimerler malzemeler ile birlikte kullanılmaktadır. Keten liflerinde kullanılan en yaygın matris malzemesi işlenmesi kolay olduğundan ve iyi mekanik özelliklere sahip olduğundan, epoksi polipropilendir. Keten elyaf takviyeli kompozitler yüksek çekme eğilme ve darbe mukavemetine sahiptir. Diğer doğal liflerle karşılaştırıldığında, keten liflerle yapılan kompozitler maliyetlidir. Bu çalışmada farklı uzunluklarda keten elyaf takviyeli kumaş yüzeyine epoksi polimer uygulanarak kompozit yüzey elde edilmiş ve elde edilen kompozit numunelerin mekanik özellikleri incelenmiştir. Keten liflerinden yapılan kompozitlerin test sonucunda 17,76 ile 26,62 MPa arasında ölçülen çekme mukavemeti, 28,82 ile 46,92 MPa arasında eğilme dayanımı ve 2,39-5,25 J darbe dayanımı ölçülmüştür. Elde edilen sonuçlar epoksi reçine ile keten elyaf takviyeli polimerik kompozit malzemelerin mekanik özelliklerinde iyileşmeler sağlandığını göstermektedir.

Anahtar kelimeler: Kompozit, Epoksi reçine, Mekanik özellikler, Keten.

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1. Introduction

Composite materials, which combine more than one material with different techniques and have suitable properties, have replaced traditional materials in many industrial areas [1-3]. Especially in recent years, thanks to the developments in the field of engineering, research and development activities on the production of higher quality composite materials and their performance properties continue to increase, resulting in high strength and elastic modulus [4, 5]. However, developing the properties of a composite material in itself is one of the options that can prevent loss of material and time by avoiding various difficulties that the production of a new composite material may bring. With the developing fiber technology in recent years, the use of technical fibers with superior properties such as flax fiber as reinforcement material in various forms in composite materials has become widespread in order to improve the weak aspects of brittle materials, eliminate brittleness and increase their strength.

In recent years, studies on fiber-reinforced polymer composite materials have used epoxy resin as a polymer matrix material due to its advantages such as chemical resistance, hardness, toughness and wear resistance. In addition to these properties, epoxy resin has a brittle structure.

Although flax fiber stood out with its superior quality compared to most plant fibers, it has constantly declined since it cannot compete economically with other fibers, especially cotton, and its share among natural fibers has constantly narrowed [6]. Flax stalk provides around 16 to 24% fiber, and in some varieties 34 to 37%, and this rate varies depending on the variety. Flax fiber has been widely used in products such as canvas fabric, rope, sails, rope, sacks, tent cloth, fire hose, rugs, floor mats such as mats, which have been widely used in both clothing and various home textile products for many years. The use of flax fiber in weaving and making clothes from these textiles arose out of necessity, depending on geographical conditions. As a matter of fact, linen fabrics provide great comfort, especially for people in hot regions, as they absorb sweat and at the same time allow the body to breathe. When linen fibers get wet, they swell and gain a tighter structure, increasing their durability [7].

Most of the notable studies on fiber/epoxy composites in the literature are related to the mechanical properties of composite materials. Muniandy et al. [8] they found that sugar palm fiber-reinforced polymer composite provided good mechanical properties. Ng et al. [9] found that composites from pineapple leaf fibers provided good mechanical properties. Yan et al. [10] investigated the impact resistance. The mechanism of multilayer aramid/epoxy composites increased the low impact resistance. Atas et al. [11] they tested woven fabric composite plates made of glass fiber using epoxy resin as reinforcement material. The impact energies ranged between approximately 4–45 J. Mariatti et al. [12] banana plain weave reinforced polyester fabrics exhibited high performance in flexural and impact properties. Barkoula et al. [13] led to improvements in tensile strength of flax fiber-reinforced polypropylene composites through dimensional changes in fiber length. Li et al. [14] due to the different structural properties of flax fibers, relationships between the voids and mechanical properties of the composites have been established. Sawi et al. [15] a similar behavior was observed in the flexural properties of flax fiber reinforced epoxy composites produced under pressure and curing cycle temperatures. Gning et al. [16] showed the strong influence of the fiber volume fraction and ply thickness parameter of flax/epoxy composites on the mechanical properties of the material and the fracture of the samples, followed by the compression pressure and ply number parameters. Yukseloglu et al. [17] showed that hand-laid composite materials with flax fibers are an alternative source of natural fibers in the development of reinforced composites for industries. George et al. [18] flax fiber reinforced epoxy composites Lignin content, pectin content and degree of polymerization were found to have a significant impact on the mechanical properties of the composites. Charlet et al. [19] Since the properties of flax fibers unidirectional composites are linearly related to the fiber volume fraction, these properties are used for the properties of flax bundles.

As a result of the literature research, it is noteworthy that fibers with different properties were used in the modification of fiber reinforced epoxy composite materials produced by different methods and improvements were achieved in the performance properties of the composite material after application. When the literature is examined, the lack of effect on the mechanical properties of flax-reinforced composite materials draws attention. Therefore, in this study, unlike the literature, the effect of flax/epoxy added composite material on the mechanical performance properties of the epoxy matrix element was examined. In this article, naturally obtained flax fiber was combined with high-performance

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epoxy and resin compression machine to the fabric surface to produce composite plates with different fiber percentages.

2. Material and Method

Within the scope of the study, flax fiber reinforced composite material with plain fabric construction was used as a sample. A composite surface was obtained by applying epoxy polymer to the flax fiber reinforced fabric surface of different lengths. Flax fiber reinforced epoxy composite test samples are given in Figure 1.

Figure 1. Flax fiber reinforced epoxy composite.

Test samples were obtained in accordance with ASTM D3039 standards for flax fiber composite tensile test, ASTM D790 standards for flexural test, and ASTM D6110 standards for impact resistance test. The results obtained from the analysis and tests carried out to determine the properties of the produced composite materials and the parameters affecting the results were evaluated by taking into account the findings available in the literature. Firstly, fiber/epoxy percentage ratio values, which determine the performance properties of the composite plates produced in the study, were calculated [20].

Within the scope of the study, a composite material sample was produced from a combination of woven fabric with plain fabric construction and pure epoxy resin matrix using the hand lay-up method. Pure liquid epoxy resin was used in the production of composite materials [21]. The prepared mixture was directly absorbed into the fabric by hand-laying method [22].

Mechanical characterization of composite materials produced with pure liquid epoxy resin flax fiber reinforcement material was carried out [23]. Tensile, flexural and impact tests were performed during the mechanical characterization phase of the produced composite plates [24-26].

2.1. Tensile test

Static tests are performed by entering information such as sample dimensions, pulling speed of the moving jaw, and extensometer measurement range. At the end of the test, the tensile strength is calculated by the program and a stress-strain change graph is drawn. Tensile tests; According to the ASTM D 3039 standard, it was carried out using a Charpy brand tensile test device, at room temperature and at a tensile speed of 1 mm/min, in a tensile device with a capacity of 50 kN [20].

2.2. Flexural test

The flexural properties of composite plates were determined by the three-point flexural test based on the principle of applying a load at a certain speed to the sample from three points, according to the ASTM D790 standard. A flexural test was carried out to determine the changes in flexural strength values due to structural changes in the samples produced with different fiber percentages and the damages that would occur in the samples as a result of this test [20].

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2.3. Impact test

Impact resistance test was performed in accordance with ASTM D6110 standard. The samples were cut in three pieces in the 0º, 90º and 45º directions, with dimensions of 12.7 mm x 127 mm, and notches of 2.25 radius and 45º were cut on each sample. Charpy impact tester and a hammer with a capacity of 6 joules were used for the test [20].

3. Research Findings

3.1. Tensile test result

Relationship between length and fiber percentage and tensile strength is given in Figure 2.

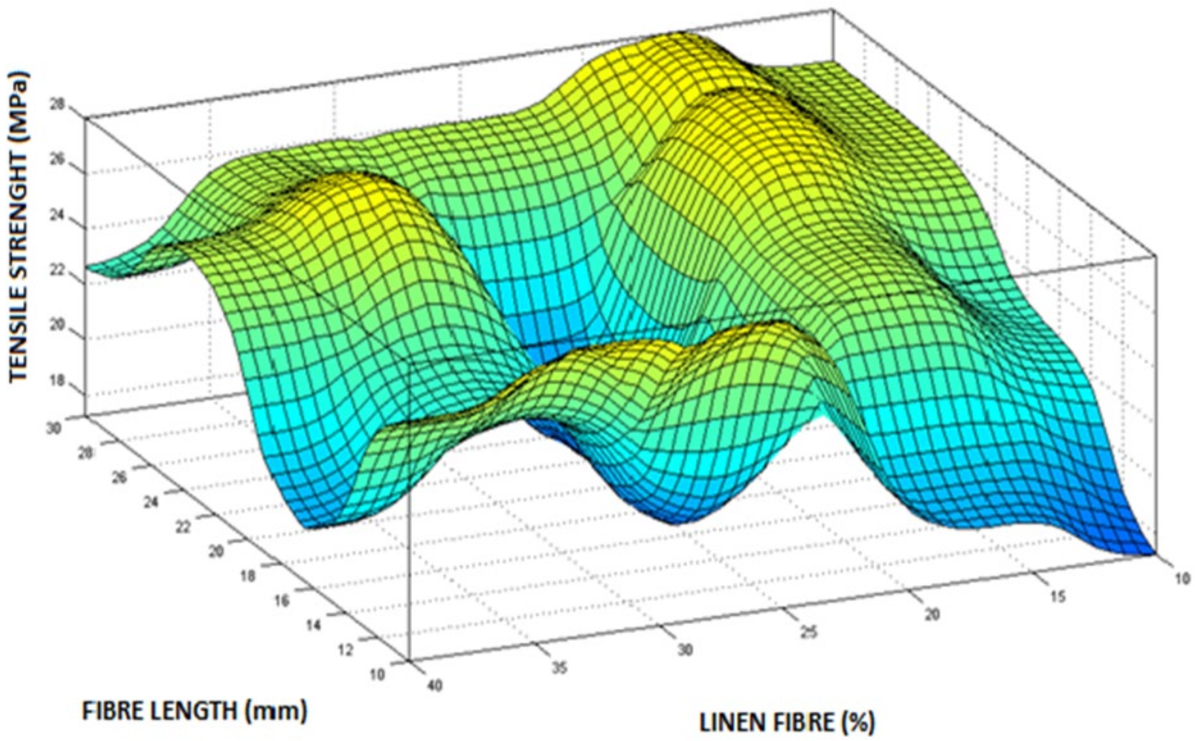

Figure 2. Relationship between length and fiber percentage and tensile strength.

When the fiber percentage was 15% and the fiber length was 30 mm, the tensile strength reached 27.89 MPa. The mechanical stability of flax fiber reinforced epoxy composite plates was determined using tensile test data. Three samples were used for each force application direction in the test, and as a result of the analysis, tensile stress values of the composite material samples were obtained. When the tensile test results performed in the direction of flax fiber reinforced epoxy fiber were examined, it was observed that the average maximum tensile stress properties for this sample were high.

Each tensile test was repeated at least 3 times depending on the sample type, and the average value was taken as the tensile strength. We tested the tensile strength of flax fiber reinforced composite samples at different lengths and percentages. Relationship between fiber percentage and tensile strength is given in Figure 3.

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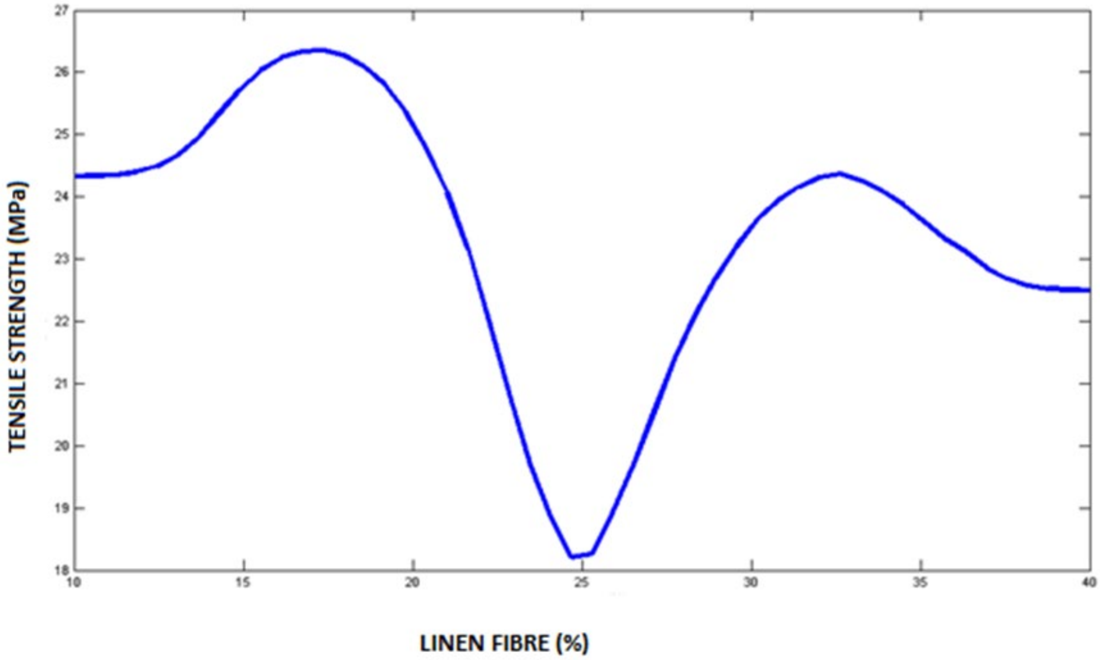

Figure 3. Relationship between fiber percentage and tensile strength.

Among samples with different percentages, tensile strength reached the highest values with 17% compared to others. It is seen that it reaches the lowest value at 25%. Composite reached 26.70 MPa at 15% fiber content, composite reached 25.86 MPa at 20%, composite reached 18.34 MPa at 25%, composite reached 22.86 MPa at 30% and 35% In the tensile strength of the composite reached 23.57 MPa. When the tensile strength values of samples with 17% and 33% fiber length are compared, it is seen that the tensile strength values increase depending on the fiber length. Relationship between fiber length and tensile strength is given in Figure 4.

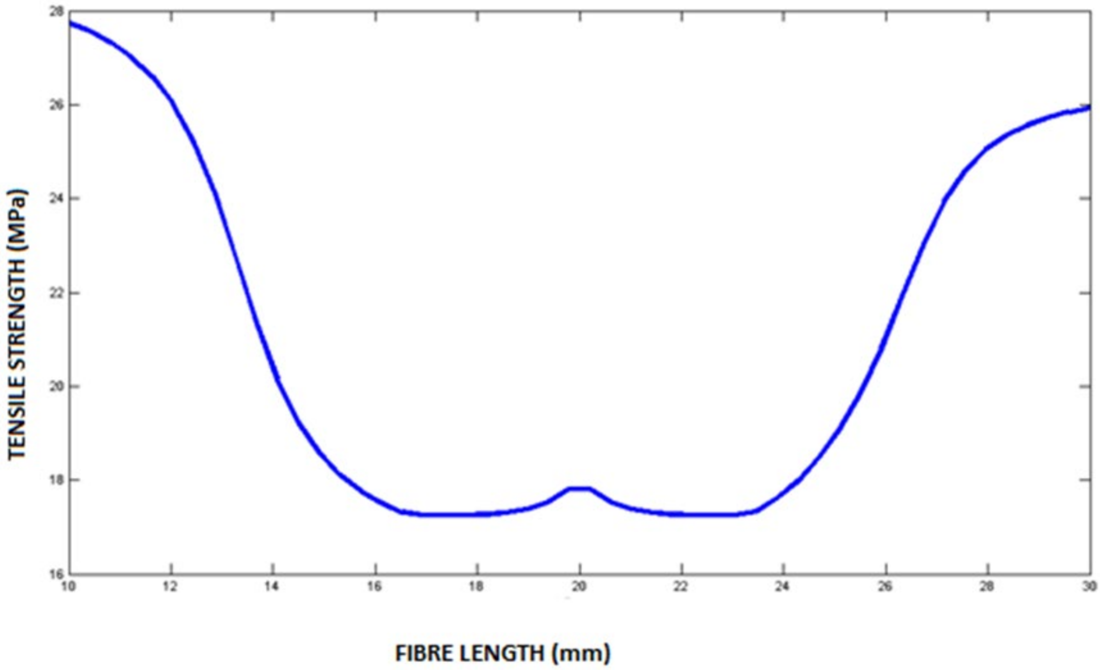

Figure 4. Relationship between fiber length and tensile strength.

In our research, we tested fibers of different lengths. When comparing composite samples in the 16-24 mm length range, depending on the length, it is seen that lower results are obtained compared to other length levels. The 10 mm flax fiber reinforced composite reached a tensile strength of 27.72 MPa, the 20 mm composite samples reached a tensile strength of 17.76 MPa, the 25 mm composite sample reached a tensile strength of 22.54 MPa and the 30 mm length reached a tensile strength of 25.92 MPa.

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3.2. Flexural test result

Relationship between length and fiber percentage and flexural strength is given in Figure 5.

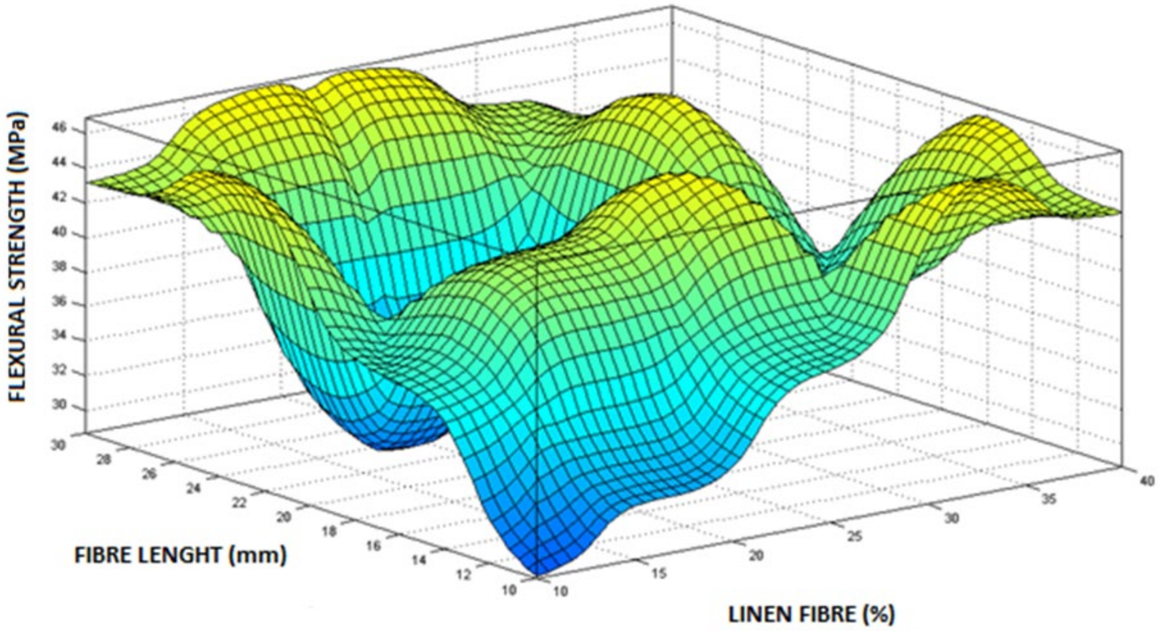

Figure 5. Relationship between length and fiber percentage and flexural strength.

Within the scope of the study, the flexural properties of flax fiber reinforced epoxy composite plates were determined by a three-point flexural test based on the principle of applying a load at a certain speed to the sample from three points, according to the ASTM D790 standard. As a result of the test, flexural stress (strength) and flexural modulus values of the composite plate samples produced within the scope of the study were determined.

Flexural tests of the prepared samples were carried out on the Charpy test device, with the inter-support spacing at the value specified in the ASTM D790 standard and the machine pressing speed of 1 mm/minute. In Figure 6, Relationship between fiber percentage and flexural strength.

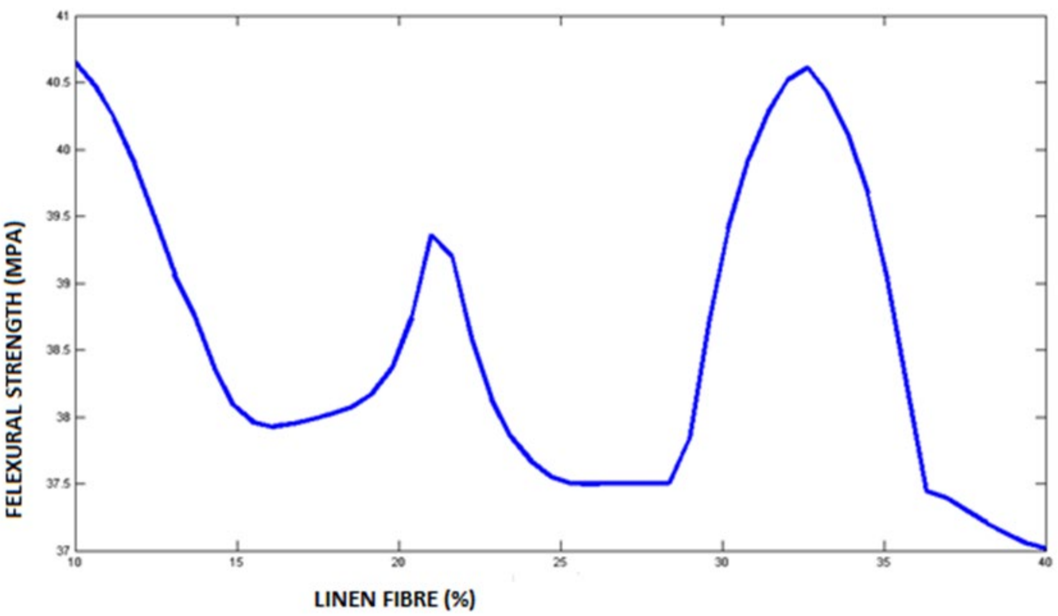

Figure 6. Relationship between fiber percentage and flexural strength.

Among the samples with different percentages, the flexural strength reached the highest values with 34% compared to the others. It is seen that it reaches the lowest value at 25%. At 15% fiber content, the

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composite reached 38.20 MPa, at 20% the composite reached 38.46 MPa, at 30% the composite reached 38.86 MPa and at 35% the flexural strength of the composite reached 38.97 MPa reached. When the tensile strength values of samples with 21% and 32.5% fiber length are compared, it is seen that the tensile strength values increase depending on the fiber length. Relationship between fiber length and flexural strength in Figure 7.

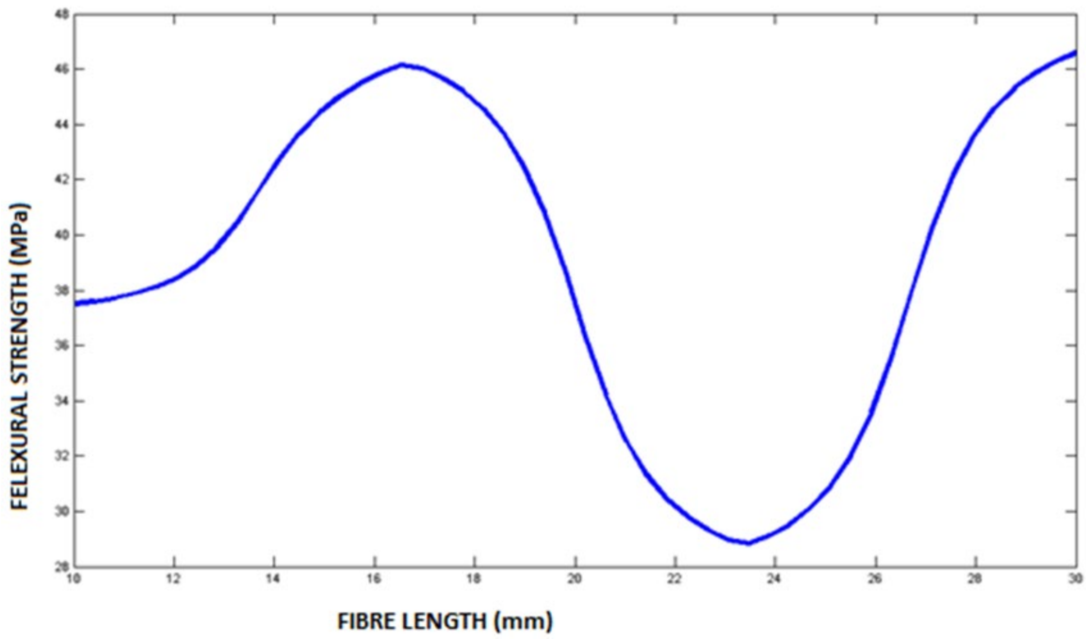

Figure 7. Relationship between fiber length and flexural strength.

For the flexural experiment, we tested fibers of different lengths. When comparing composite samples in the 22-26 mm length range, depending on the length, it is seen that lower results are obtained compared to other length levels. The 10 mm flax fiber reinforced composite reached a flexural strength of 37.72 MPa, the 18 mm composite samples reached 45.76 MPa, the 25 mm composite sample reached 30.54 MPa, and the 30 mm length reached 46.92 MPa.

3.3. Impact test result

Relationship between length and fiber percentage and impact strength is given in Figure 8.

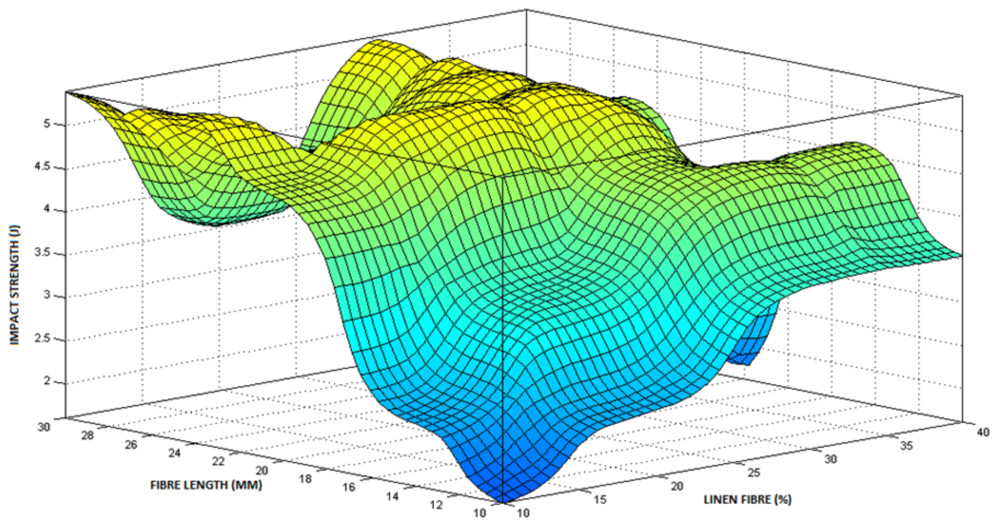

Figure 8. Relationship between length and fiber percentage and impact strength.

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The effects of flax fiber reinforced fabric on impact properties were examined. Charts have ascending and descending sections. The graph shows that increasing fiber length increases impact resistance. In Figure 9, relationship between fiber percentage and impact strength.

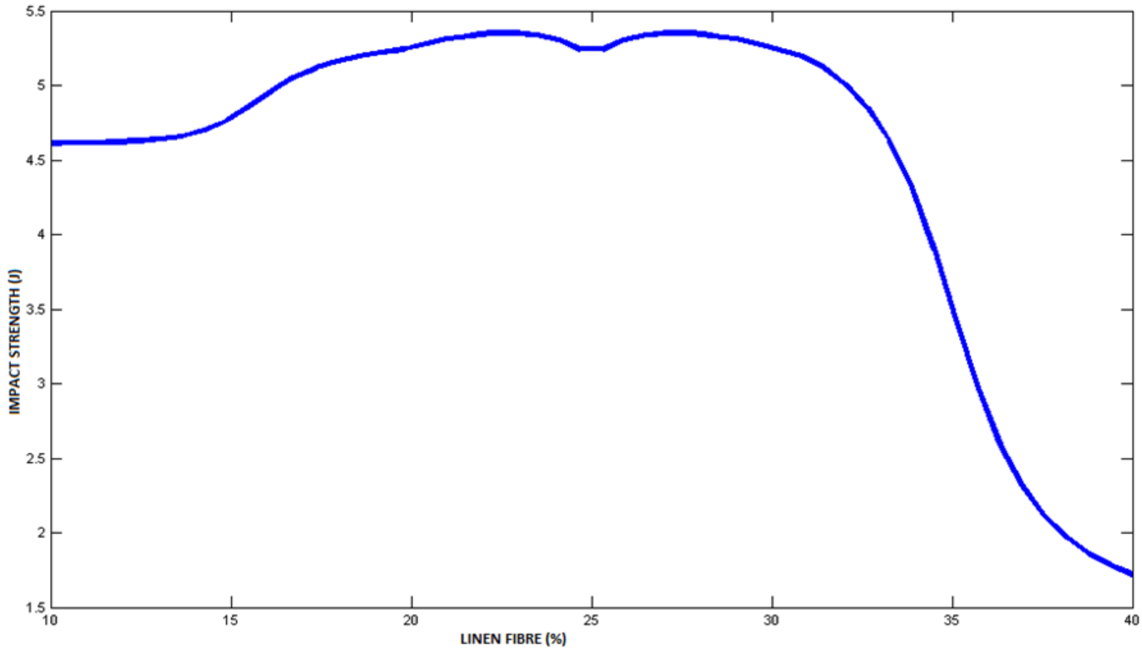

Figure 9. Relationship between fiber percentage and impact strength.

Among the samples with different percentages, the impact strength reached the highest values at 25% compared to the others. It is seen that it reaches the lowest value at 40%. At 15% fiber ratio, the composite reached 4.78 J, at 20% the composite reached 5.25 J, at 30% the composite reached 5.25 J, and at 35% the flexural strength of the composite reached 3.51 J. Relationship between fiber length and impact strength in Figure 10.

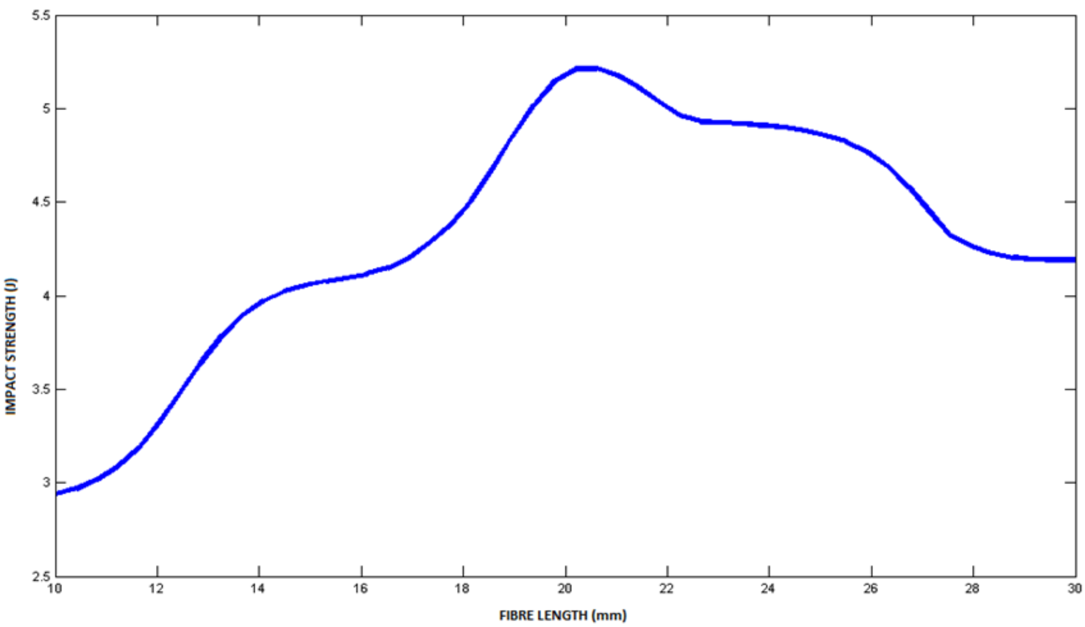

Figure 10. Relationship between fiber length and impact strength.

For the impact experiment, we tested fibers of different lengths. When comparing composite samples in the 10-15 mm length range, depending on the length, it is seen that lower results are obtained compared to other length levels. The 10 mm flax fiber reinforced composite reached an impact strength of 2.39 J,

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the 20 mm composite samples reached an impact strength of 5.25 J, the 25 mm composite sample reached an impact strength of 4.68 J and the 30 mm length reached an impact strength of 3.54 J.

4. Results And Discussion

The strength of natural fibers may vary depending on the type. The mechanical strength of flax fiber reinforced composite samples is higher than other natural fiber reinforced samples. Flax has low tensile strength, but high flexural and impact strength. This is due to the mechanical compatibility of the bond between fibers and epoxy resin.

Composite samples with different lengths and different percentages of flax fibers were produced. When evaluated according to fiber percentage, tensile strength reaches the highest values of 26.62 MPa at 17% and when evaluated according to fiber length, 10 mm long flax fiber reinforced composite reaches the highest values of 27.72 MPa. When evaluated according to the fiber percentage, the flexural strength reached the highest values at 34% with 40.67 MPa. When evaluated according to the fiber length, the 30 mm long flax fiber reinforced composite reached the highest values with a flexural strength of 46.92 MPa. When impact resistance is evaluated according to fiber percentage, it reaches the highest values of 5.25 J at 30% and when evaluated according to fiber length, 20 mm long flax fiber reinforced composite reaches the highest values of 5.25 J.

5. Conclusions

Within the scope of this study, the production of flax fiber reinforced epoxy composite materials was aimed by the hand lay-up method. Mechanical characterization was carried out to determine its effect on composite material performance properties. It shows that it improves the composite performance properties during the mechanical characterization stage. Unlike the literature, in various mechanical properties evaluation methods, epoxy polymer was applied to the surface of flax fiber reinforced fabric of different lengths to obtain a composite surface and the mechanical properties of the obtained composite samples were examined.

The usage areas of flax and other trunk fibers are increasing day by day in technical textiles and composites. Especially in recent years, many countries have lost their ability to compete in conventional textile production, and studies on the production of technical textiles and more special products have intensified. Flax and other trunk fibers are important in these areas. In this study, the mechanical properties of flax/epoxy applied composite material were examined.

In addition to the development of techniques such as different production methods in the production of composite materials, different mixing methods in the preparation of flax/epoxy, functionalization with different chemical groups through chemical processes can contribute to the improvement of the properties of the produced materials. Research in this field will enable the production of new generation composite materials.

As a result, the improvements obtained in the mechanical properties of epoxy resin, which is frequently used as a matrix material in fiber-reinforced polymeric composite materials, will contribute to the expansion of the usage area of fiber-reinforced polymeric composite materials. The composite structures produced within the scope of the study can be recommended for use in industrial applications requiring flexibility and as technical textiles.

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