International Journal of Education and Science Research Review
E-ISSN 2348-6457
Volume-10, Issue-6 Nov-Dec-2023
P-ISSN 2349-1817
www.ijesrr.org
Email- editor@ijesrr.org

TO STUDY THE MECHANICAL PROPERTIES OF NATURAL FIBER REINFORCED HYBRID POLYMER COMPOSITES

Muneesh Kashyap

Assistant professor Department of chemistry ,

M . R . P.D . Govt. College Talwara, Hoshiarpur, Punjab (India) .

Abstract:

Due to the fact that they are sustainable, kind to the environment, and possess excellent mechanical qualities, natural fiber-reinforced hybrid polymer composites are garnering a lot of attention for their versatility. In order to produce materials that have improved strength, stiffness, and durability, these composites are made up of natural fibers like jute, sisal, flax, or hemp that are blended with synthetic fibers and polymer matrices. In a hybrid construction, the mix of natural and synthetic fibers enables the optimization of a variety of mechanical qualities, including tensile strength, flexural strength, impact resistance, and hardness, among others. The purpose of this research is to investigate the mechanical characteristics of natural fiber-reinforced hybrid polymer composites. Specifically, the study will investigate how the kind of fiber, its orientation, and its volume percent influence these qualities. When it comes to selecting the final qualities of the composite, the matrix material and the processing processes both play a significant influence. Because the hybridization of fibers strikes a balance between cost-effectiveness and performance, these composites are suitable for use in a variety of industries, including the construction industry, the aerospace industry, and the automobile industry. In the course of this investigation, a variety of hybrid composites will be subjected to a series of experimental testing, including tensile, flexural, impact, and hardness procedures, in order to evaluate their mechanical performance. As a consequence of these findings, insights will be provided regarding the ideal mix of fibers and polymers for increased performance. Additionally, the potential of natural fibers as a sustainable alternative in high-performance applications will be highlighted.

Keywords: *Mechanical, Fiber, Reinforced, Polymer*

Introduction:

In recent years, research into natural fiber-reinforced hybrid polymer composites has been pushed by the growing need for materials that are both sustainable and kind to the environment. By combining the advantages of natural fibers, such as their biodegradability, low density, and availability, with the improved mechanical qualities of synthetic fibers and polymer matrices, these materials provide a combination of advantages. As a result of their renewable nature, low cost, and reduced environmental effect in comparison to standard synthetic fibers such as glass or carbon, natural fibers such as jute, flax, sisal, and hemp have gained a lot of interest. In order to achieve a unique balance between mechanical performance, weight reduction, and cost-effectiveness, hybrid composites, which are made up of a combination of natural and synthetic fibers, are introduced. Through the strategic combination of fibers, it is possible to adjust the mechanical characteristics of the composite to specific needs for a wide variety of industrial applications. These materials are finding a growing amount of application in applications such as the automobile industry, aircraft, sports, and construction, all of which require materials that are both lightweight and high-strength.

There are a number of elements that influence the performance of natural fiber-reinforced hybrid polymer composites.[1] These factors include the kind of fiber, the orientation of the fiber, the volume fraction of the fiber, and the nature of the polymer matrix. In addition, the processing procedures that are used have a significant factor in deciding the quality and performance of the composite that is ultimately produced. It is feasible to optimize the mechanical characteristics of the composite for particular applications if one has a solid grasp of the correlations that exist between these parameters.[2] The purpose of this research is to evaluate the mechanical properties of a variety of natural fiber-reinforced hybrid polymer composites. These attributes include tensile strength, flexural strength, impact resistance, and hardness. The purpose of this study is to investigate the possibilities for enhancing overall performance through the utilization of a variety of natural and synthetic fibers, as well as the ways in which natural fibers may be included into contemporary composites without compromising their mechanical integrity. This investigation will also make a contribution to the expanding field of sustainable materials, which will assist in lowering the dependency on non-renewable resources in high-performance engineering applications.

2. Influence of Filler on Mechanical Properties

Priyadarshini Tapas et al. [4] investigated the physical and mechanical characteristics of epoxy composites that were filled with Al_2O_3 and reinforced with jute fiber reinforcement. A series of experiments were carried out in order to determine the impact that filler has on the characteristics of composites. When jute and aluminum oxide were used as reinforcement, and epoxy was used as the matrix, the researchers found that filler had a substantial impact on the characteristics of the composites after being added. Additionally, they have found that the hardness, strength, flexural and tensile modulus of composites rose with an increase in the fiber and filler, and that the interlaminar shear strength of composites increased solely with an increase in the fiber and declined with the addition of filler.

A. Alavudeen et al. [5] An investigation of the mechanical characteristics of woven banana fiber, kenaf fiber, and hybrid fiber composites made of banana and kenaf was carried out. Increasing the hybridization of kenaf with banana fibers results in an increase in the mechanical strength of woven banana/kenaf fiber hybrid composites. It has been demonstrated that the woven hybrid composite of banana and kenaf fibers possesses greater tensile, flexural, and impact strengths in comparison to the separate fibers. An further increase in mechanical strength appears to be provided by treatments with sodium lauryl sulfate (SLS), which appears to be accomplished by improved interfacial bonding. In order to gain a better understanding of the de-bonding of fiber/matrix adhesion, morphological examinations of broken mechanical testing samples were carried out using scanning electron microscopy (SEM).

Table 1. This article offers information on natural fibers that may be found in nature in a variety of forms. [3].

Woodfiber	Stalkfiber	Fruitfiber	Seedfiber	Leaffiber	Bastfiber
Hard wood	Bamboo	Coconut	Cotton	Sisal	Rattan
Softwood	Wheat	Betel nut	Oilpalmseed	Manila	Hemp
Saw dust	Rice		Kapok	Banana	Jute
	Grass		Alfalfa	Palm	Ramic
	Barley			Mengkuang	Bananna
	Corn			Datepalm	Flax

				PinappileAbaka	Sugercane Kenaf Roselle

M. Ramesh et al. [6] In this study, the mechanical characteristics of sisal, jute, and glass fiber reinforced polyester composites were studied. According to their findings, the incorporation of glass fiber into jute fiber composite led to the achievement of the highest possible tensile strength. In a similar manner, they have found that the composites sample made of jute and sisal combination is capable of having maximum flexural strength, and that the sisal fiber composite was able to get highest impact strength. An instance of a composite material may be seen in Figure 1.

The variation of tensile strength, flexural strength, and compressive strength of epoxy-based sisal-glass hybrid composites was investigated by H. Ranganna et al. [5]. The researchers arrived at the conclusion that hybrid composites with a fiber length of 2 cm exhibited the highest optimal tensile, flexural, and compressive strength compared to those with fiber lengths of 1 and 3 cm of fiber length. There has also been research done on the impact that alkali treatment has on the compressive, flexural, and tensile characteristics of the material. When compared to untreated composites, it was discovered that treated hybrid composites exhibited a greater level of strength. The mechanical behavior of jute fiber in polyester and epoxy matrices was experimentally studied by Gopinath et al. [7], and the results revealed that the processing time for jute-polyester laminate is much smaller than the processing time for jute-epoxy laminate.

A. Gowthami et al. [8] Incorporating 100% biodegradable sisal fibers as reinforcement in the polyester matrix allowed for the development of sisal natural fiber composites with and without silica. When compared to composites that do not include silica, the tensile strength and tensile modulus of composites that contain silica are 1.5 and 1.08 times higher, respectively, according to the findings made by the researchers. To put that into perspective, the impact strength of composites that contain sand is 1.36 times higher than that of composites that do not contain silica and plain polyester, respectively.

Amar Patnai et al. [9] conducted research on the mechanical characteristics of particle packed glass epoxy composites as well as the abrasive wear of three different bodies. Their research was conducted with the intention of examining the abrasive wear behavior of randomly oriented glass fiber (RGF) that was reinforced with epoxy resin that contained Al_2O_3, SiC, and pine bark dust. At a test speed of one hundred revolutions per minute, dry sand and rubber wheel abrasion tests (RWAT) were carried out. The experiments were carried out with weights of 50 and 75 N, and the distance between the abrading points was varied from 200 to 600 meters. The findings of the abrasive wear tests that were conducted in the laboratory indicated that the wear of composite was sensitive to variations in the abrading distance, but it was less susceptible to variations in sliding velocity.

Hemalata Jena et al. [10] investigated the impact of a composite made of bamboo fibers that was filled with cenosphere. The inclusion of cenosphere as filler and lamina has been found to have a significant impact on the impact property of bio-fiber reinforced composites, according to the findings of the researchers. Up to a certain extent, the impact strength of a laminated composite material is improved by the addition of filler. After reaching this limit, the impact strength of the material decreases whenever further filler is added. The findings demonstrate that the impact characteristics possess a high degree of sensitivity to the concentration of the fillers. When the lamina amount is increased from three to seven, the impact strength increases; however, when the lamina amount is increased even more to nine, the strength decreases. Maximum impact strength of 18.132 KJ/m2 is achieved by a composite material consisting of seven layers and containing 1.5 weight percent cenosphere. In addition, it has been shown that the density of composites decreases, which is also a significant factor that is highly dependent on the amount of fillers and fiber present.

Girisha, C. et al. [11] investigated the mechanical characteristics of composites made from fibers derived from the fruit of tamarind and fibers derived from the husk of arecanuts that had been subjected to chemical treatment. They made the observation that treated fibers delivered superior results in comparison to fibers that had not been treated. Additionally, they observed that the strength of the hybrid composites increased in proportion to the volume fraction of fiber that was present in the hybrid composites. Composites were generated by the use of the manual hand layup technique, and the study involved the reinforcement of tamarind fruit fibers and arecanut fruit husk fibers with epoxy matrix. After conducting the experiment, it was discovered that all of the hybrid natural fiber composites exhibited the highest possible mechanical characteristics when forty percent to fifty percent of the fiber reinforcements were used.

The conclusion that can be drawn from the research that has been done on fillers is that the physical and mechanical properties of composites may be altered by including a filler phase into the matrix body during the manufacturing of the composite. In order to increase the mechanical and tribological qualities of the composite, filler is also included into the material.

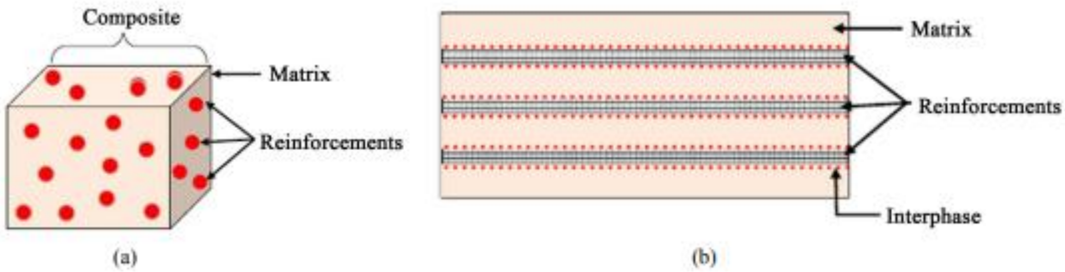

Figure 1. (a) Describes the components that make up laminate, which consist of resin as the matrix and fiber as the reinforcement, and (b) illustrates the inter-phase relationship between the matrix and the reinforcement.

Effect of Process Parameters on Mechanical Characteristics

Berhanu et al. [12] After conducting research on the impact of the weight percentage of jute fiber reinforced in polypropylene-based composites, the researchers discovered that the mechanical qualities of the composites improved as the jute weight percentage grew up to forty percent.

D. dash et al. [13] We came to the conclusion that the mechanical characteristics of composites, such as the tensile strength and compressive strength of natural fiber composites, were recorded and compared with the data for glass/epoxy composites. In the tensile test, it was observed that bamboo composite laminates exhibited better tensile strength and stiffness than jute composite laminates. However, the bamboo composite laminates did not perform at the same level as the glass fiber reinforced composite. The results of the compressive test indicate that the compressive strength and modulus of the jute composite are greater than those of the bamboo composite, but lower than those of the glass composite. The tensile behavior of the jute composite was analyzed, and the results showed that the fiber orientation angle of 0/90, 15/−75, 30/−60, and 45/−45 provided higher strength and modulus than the 45 direction of fiber orientation. There is also a relationship between the mechanical property and the specific material property. The glass fiber was made artificially in an industrial plant using a specialized instrument, but the bamboo and jute fiber was obtained from nature and manufactured using a basic tool and/or manually, which may result in inconsistencies during the production process of the product. It is for this reason that the strength of natural fibers does not reach the degree of strength that is associated with typical e-glass fiber. The natural fiber reinforced composite, on the other hand, may be utilized in locations where the application of light loads is of significant importance. Furthermore, the economics of natural fiber composite materials are more advantageous than those of e-glass fiber composite solutions.

S. Raghuraman et al. [14] The composite material that contains a mixture of sisal-glass fiber and resin at a ratio of fifty percent has a maximum tensile strength of 97.71 megapascals (MPa). The breaking load of the composite material that is reinforced with sisal and glass fiber is found to be high (10.285 KN). It has been discovered that the breaking load of sisal-glass fiber reinforced composite is 1.10 times greater than that of sisal-coir-glass fiber reinforced composite, and it is 1.33 times higher than that of coir-glass fiber reinforced composite. In comparison to other composites, the percentage of elongation of the coir-glass fiber reinforced composite was found to be greater. As a result, it is possible that this composite possesses a more ductile quality in itself. The hybrid composite material that contains 40% sisalcoir-glass fibers and 60% resin combination possesses high flexural strength (138.87 MPa) and high impact strength (1.429 KJ/m2) in comparison to other composite materials.

Zamri et al. [15] The mechanical characteristics of jute/glass reinforced polyester were investigated under conditions of water absorption. In this study, composites are exposed to a variety of water conditions. The tests were carried out by submerging composite specimens in three distinct water conditions: distilled water, sea water, and acidic water. The water was kept at room temperature for a period of three weeks. Additionally, the effects of the different water environments on the flexural and compression characteristics of the composites were investigated. It was discovered that the jute composite is not appropriate for use in applications that take place underwater.

Onal et al. [16] examines the characteristics of a glass/carbon hybrid specimen, including its tensile and flexural strengths, using a layer-by-layer sequencing both before and after the impact. In addition to improving the tensile property of hybrids, it has been discovered that carbon fire on the end surfaces not only enhances flexural strength but also improves performance.

Gujjala et al. [17] reviewed the mechanical properties of jute/glass reinforced epoxy hybrid laminate with varying hybrid sequences and pure glass, jute and epoxy composite and they were compared. Composites prepared bu using hand layup technique and laminates were prepared with a total of four piles by varying the position of glass and jute. It is found out that hybrids have better properties than pure jute and epoxy alone but less than pure glass.

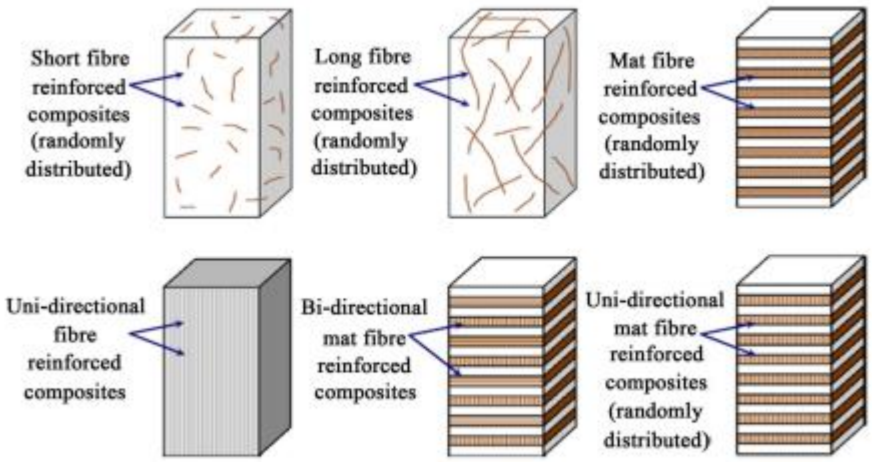

Figure 2. During the production process of laminates, many types of fiber orientations are utilized.

Motivation and Scope:

The increasing focus on sustainable development has placed significant pressure on industries to seek alternatives to traditional synthetic materials, which are often derived from non-renewable resources and contribute to environmental pollution. The shift toward natural fiber-reinforced hybrid polymer composites is driven by the need for materials that not only perform well but also have a lower environmental footprint. The use of natural fibers, when hybridized with synthetic fibers, can lead to materials that offer superior strength-to-weight ratios, lower production costs, and enhanced environmental benefits. Natural fibers are biodegradable, have low carbon emissions during production, and are often sourced from agricultural by-products, making them an attractive option for industries looking to reduce their ecological impact. However, natural fibers alone may not provide the high mechanical properties required for certain structural applications. This limitation can be addressed through hybridization—combining natural fibers with synthetic fibers such as glass or carbon fibers—which allows the composite material to achieve the desired strength and durability without completely relying on synthetic components. Hybrid composites also provide flexibility in design, enabling engineers to optimize the material composition for specific uses. For example, in automotive applications, reducing vehicle weight is critical for improving fuel efficiency and lowering emissions, while maintaining structural integrity. Similarly, in aerospace and construction sectors, materials that offer high strength-to-weight ratios are in demand. Hybrid composites allow for the customization of properties like stiffness, impact resistance, and fatigue strength, making them versatile for a wide range of applications.

EXPERIMENTAL

Fiber source

Naturally occurring fibers such as luffa cylindrica, bagasse, and coir were gathered from the surrounding area in order to provide the raw ingredients for the composite materials. When it came to the creation of the matrix, the synthetic polymer that was utilized was epoxy LY 556 and hardener HY 951. The component that is chosen is the fibrous mat that is found at the outer core of the luffa cylindrica plant after it has been matured and dried. Both the outer rind and the interior pith are components of bagasse fiber. Bagasse fiber is composed of two sections. The rind portion of the fiber is extracted for the purpose of this study and then cut into lengths that are longer than their crucial length of 3.62 millimeters [18]. These lengths are then employed as short fibers. It is necessary to collect coir dust from the outer cover of fibers that are located above the hard shell of dried coconut in order to use it as particulate reinforcement in the matrix.

Chemical Treatment

Cellulose, hemicellulose, and lignin are the three components that make up natural fibers. The very hydrophilic character of these fibers makes it difficult to construct polymer–cellulose composites. On the other hand, the polymers that are often employed for matrix production are hydrophobic, which creates compatibility concerns that lead to a loss of mechanical qualities following moisture uptake. Therefore, in order to enhance the interface contact between the fiber and the matrix, the surface of the fibers needs to be changed in order to make it less hydrophilic. This is necessary because of the poor compatibility. In order to create composite materials that have a strong link between the fiber and the resin matrix, natural fibers like jute have been subjected to a process known as mercerization, which involves treating them with an alkali (NaOH) solution. In this instance, the fibers were treated with 5% sodium hydroxide for a period of four hours, with a ratio of 15:1 between the liquor and the fibers. Following that, the fibers that had been treated were rinsed with a significant amount of distilled water until a pH level that was neutral was achieved. After that, the fibers were dried in the open air for a period of forty-eight hours, and then they were dried in an oven at a temperature of six hundred degrees Celsius for a period of six hours.

Preparation of Mould and Fabrication of composites

For the preparation of moulds with dimensions of 14 by 12 by 4 millimetres, wooden bars were placed on top of cardboard. This was followed by a thorough covering of the molds with silicon paper. The technique of hand lay-up was utilized in the fabrication of composites. Epoxy resin and hardener were mixed together in the appropriate proportions, resulting in the formation of the matrix. After that, the fibers that had been chemically treated were introduced and thoroughly combined with it. once that, silicon spray was sprayed over the mold in order to facilitate the subsequent removal of the composite once it had been fabricated. After that, the slurry was put onto the mold, silicon paper was used to cover it, and then a glass plate was placed on top of it. One kilogram of weight was placed on top of the glass plate in order to expel any air that had become trapped inside the mixture. Epoxy matrix composition is allowed to cure at room temperature for a length of time ranging from twenty-four to forty-eight hours.

After a period of forty-eight hours, the mold is broken, and the composite that has been manufactured is removed. Here is a list of the composites that were manufactured:

a. L- Single mat reinforced composite material from Luffa

b. B- Material from Luffa that is a single mat reinforced composite material

c. C(5wt%)- Coir dust (five weight percent) reinforced composite

d. CB- Coir dust 5wt% and bagasse 5wt% reinforced hybrid composite

e. LBL- Bagasse 10wt% sandwiched between two luffa fiber mat reinforced hybrid composite

f. LCL- Coir 5wt% sandwiched between two luffa fiber mat reinforced hybrid composite

g. L(CB)L- Five weight percent of coir and five weight percent of bagasse nestled between two luffa fiber mat reinforced hybrid composites

Testing of Mechanical Properties

Tensile Test

In accordance with the ASTM standard, tensile test specimens were cut into a dog-bone form with dimensions of 140 millimeters by 15 millimeters by 10 millimeters and a gauge length of 5 millimeters. A strain rate of one millimeter per minute was used to determine the tensile strength of the samples that were produced. The 3382 Floor Model Universal Testing Machine, INSRON (10 ton) was used for the test.

Flexural Strength

In accordance with the ASTM standard, the specimens for the flexural test were cut into the shape of a rectangular bar with dimensions of 120 millimeters by 10 millimeters by 10 millimeters. With a strain rate of 2 millimeters per minute and a span length of 70 millimeters, the flexural strength of the samples that were manufactured was evaluated with the 3382 Floor Model Universal Testing Machine, INSRON (10 ton).

Impact Strength

Impact test specimens were cut in accordance with the Charpy impact test standard of the American Society for Testing and Materials (ASTM) with dimensions of (7.5mmX10mmX10mm) and a notch of 2mm cut in the center of the specimen at 600. In accordance with the ASTM standard D256, the impact tester, which exhibits an accuracy of ±0.022J, was utilized.

RESULTS AND DISCUSSION

Tensile Strength

The bagasse fiber composite has the best tensile strength among the single types of reinforced fiber composites, while the L(CB)L hybrid composite has the highest tensile strength among the hybrid composites. Figure 3 presents a graph that illustrates the absolute maximum tensile strength that was achieved.

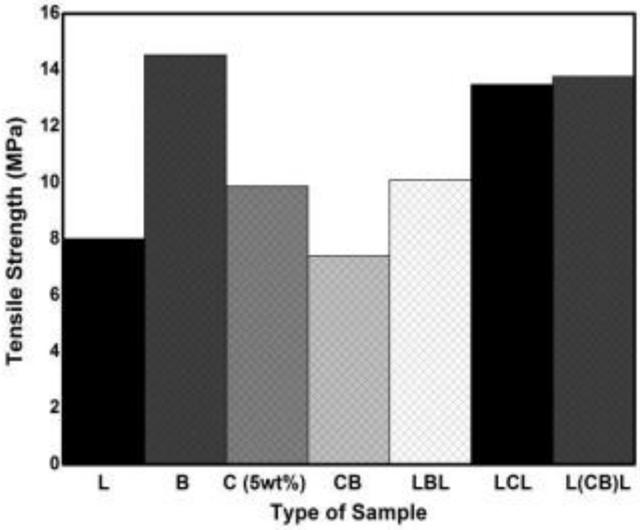

Figure 3. Tensile strength of Composites

When all of the produced composites are taken into consideration, the L(CB)L composite is able to endure an extension of 1.04153mm, while the bagasse reinforced composite is able to withstand an extension of 0.21985mm without failing.

Flexural Strength

Figure 4 illustrates the maximum flexural strength that may be achieved by working with various composites.

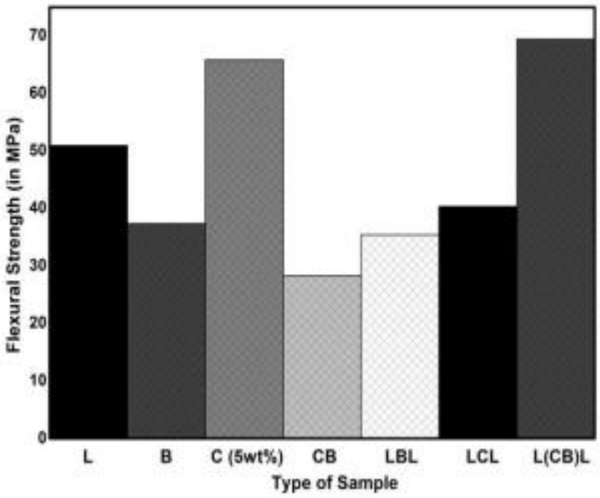

Figure 4. The tensile strength of composite materials

Whenever hybrid composites are included, the L(CB)L composite exhibits the highest possible flexural strength.

Impact Strength

As can be seen in Figure 5, the LCL composite material provides the highest possible flexural strength in hybrid composites. The following graphs illustrate the maximum impact strength that may be achieved by utilizing various composite materials:

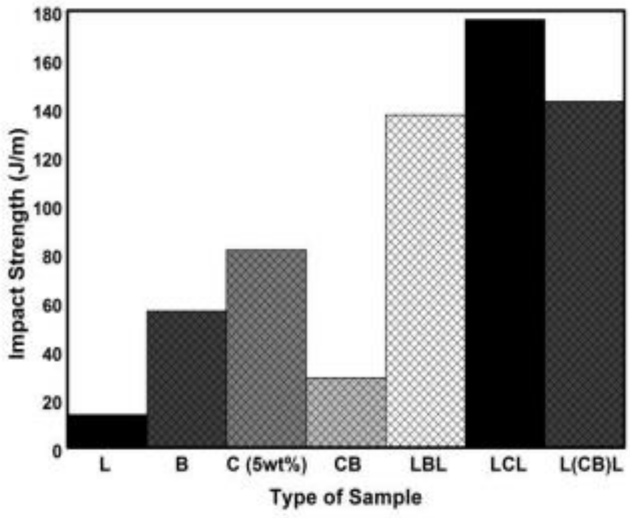

Figure 5. Impact strength of Composites

Conclusions:

The research conducted on natural fiber-reinforced hybrid polymer composites has demonstrated that these materials provide a promising balance between mechanical performance, sustainability, and cost-effectiveness. Within polymer matrices, the hybridization of natural fibers like jute, flax, hemp, and sisal with synthetic fibers like glass or carbon fibers has been demonstrated to improve the mechanical characteristics of the composites. As a result, these composites are suited for a broad variety of industrial applications. In a hybrid construction, the mix of natural and synthetic fibers results in a considerable improvement in the mechanical qualities, including tensile strength, flexural strength, impact resistance, and hardness. By bridging the gap between high performance and sustainability, hybrid composites are able to attain greater performance than composites that are constructed purely from natural fibers. A direct influence on the mechanical behavior of composites is exerted by the appropriate selection of fiber type, orientation, and volume percent. It is feasible to develop hybrid composites that are precisely customized for specific purposes by maximizing these characteristics. This will ensure that the hybrid composites have the optimal combination of strength, stiffness, and durability. When it comes to deciding the overall performance of the composite, the selection of the polymer matrix is very important. It is possible to get greater load transmission and enhanced composite strength by using matrix materials that have a good adherence to both natural and synthetic fibers. Because natural fibers are biodegradable and sourced from renewable resources, the use of natural fibers in composites helps to lessen the ecological impact that these composites leave behind. Because of this, hybrid polymer composites are an appealing choice for several businesses that are looking to lessen their impact on the environment while yet retaining high levels of material performance.

References

[1] Malhotra, N., Sheikh, K. and Rani, S. (2017) A Review on Mechanical Characterization of Natural Fiber Reinforced Polymer Composites. Journal of Engineering Research and Studies, 3, 75-80.

[2] Samuel, O.D., Agbo, S. and Adekanye, T.A. (2017) Assessing Mechanical Properties of Natural Fibre Reinforced Composites for Engineering Applications. Journal of Minerals and Materials Characterization and Engineering, 11, 780-784. http://dx.doi.org/10.4236/jmmce.2012.118066

[3] Chandramohan, D. and Marimuthu, K. (2018) A Review on Natural Fibers. IJRRAS, 8, 194-206.

[4] Swain, P.T.R. and Biswas, S. (2017) Physical and Mechanical Behavior of Al2O3 Filled Jute Fiber Reinforced Epoxy Composites. International Journal of Current Engineering and Technology, 2, 67-71. http://dx.doi.org/10.14741/ijcet/spl.2.2014.13

[5] Alavudeen, A., Rajini, N., Karthikeyan, S., Thiruchitrambalam, M. and Venkateshwaren, N. (2018) Mechanical Properties of Banana/Kenaf Fiber-Reinforced Hybrid Polyester Composites: Effect of Woven Fabric and Random Orientation. Materials and Design, 66, 246-257. http://dx.doi.org/10.1016/j.matdes.2014.10.067

[6] Ramesh, M., Palanikumar, K. and Reddy, K.H. (2019) Mechanical Property Evaluation of Sisal-Jute-Glass Fiber Reinforced Polyester Composites. Composites: Part B, 48, 1-9. http://dx.doi.org/10.1016/j.compositesb.2012.12.004

[7] Gopinath, A., Senthil Kumar, M. and Elayaperumal, A. (2019) Experimental Investigations on Mechanical Properties of Jute Fiber Reinforced Composites with Polyester and Epoxy Resin Matrices. 12th Global Congress on Manufacturing and Management, GCMM 2014, Procedia Engineering.

[8] Gowthami, A., Ramanaiah, K., Prasad, A.V.R., Reddy, K.H.C. and Rao, K.M. (2017) Effect of Silica on Thermal and Mechanical Properties If Sisal Fiber Reinforced Polyster Composites. Journal of Material Environment Science, 4, 199-204.

[9] Patnaik, A., Satapathy, A. and Biswas, S. (2020) Investigation on Three-Body Abrasive Wear and Mechanical Properties of Particulate Filled Glass Epoxy Composites. Malaysian Polymer Journal, 5, 37-40.

[10] Jena, H., Pandit, M.Ku. and Pradhan, A.Ku. (2020) Study the Impact Property of Laminated Bamboo-Fiber Composite Filled with Cenosphere. International Journal of Environmental Science and Development, 3, 456-459. http://dx.doi.org/10.7763/IJESD.2012.V3.266

[11] Sanjeevamurthy, G.C., Rangasrinivas, G. and Manu, S. (2017) Mechanical Performance of Natural Fiber-Reinforced Epoxy-Hybrid Composites. International Journal of Engineering Research and Applications (IJERA), 2, 615-619.

[12] Berhanu, T., Kumar, P. and Singh, I. (2021) Mechanical Behaviour of Jute Fibre Reinforced Polypropylene Composites. 5th International & 26th All India Manufacturing Technology, Design and Research Conference (AIMTDR 2014), Guwahati, 12-14 December 2014.

[13] Dash, D., Samanta, S., Gautam, S.S. and Murlidhar, M. (2021) Mechanical Characterizations of Natural Fiber Reinforced Composite Materials. Advanced Materials Manufacturing & Characterization, 3.

[14] Chaitanyan, C. and Raghuraman, S. (2019) A Study of Mechanical Properties of Sisal-Glass Reinforced Hybrid Composites. IJARSET, 6, 1-6.

[15] Zamri, M.H., Akil, H.M., Bakar, A.A., Ishak, Z.A.M. and Cheng, L.W. (2022) Effect of Water Absorption on Pultruded Jute/Glass Fiber-Reinforced Unsaturated Polyester Hybrid Composites. Journal of Composite Materials, 46, 51- 61. http://dx.doi.org/10.1177/0021998311410488

[16] Onal, L. and Adanur, S. (2022) Effect of Stacking Sequence on the Mechanical Properties of Glass—Carbon Hybrid Composites before and after Impact. Journal of Industrial Textiles, 31, 255-271.

[17] Gujjala, R., Ojha, S., Acharya, S.K. and Pal, S.K. (2022) Mechanical Properties of Woven Jute-Glass Hybrid-Reinforced Epoxy Composite. Journal of Composite Materials.

[18] S. Shibata, Y. Cao, And I. Fukumoto, “Press Forming Of Short Natural FiberReinforced Biodegradable Resin: Effects Of Fiber Volume And Length On Flexural Properties,” Polym. Test., Vol. 24, No. 8, Pp. 1005–1011, 2018.