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Material Characterization Analysis of Fiber Reinforced Composites

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Abstract

The study investigates the physical characteristics of PAN carbon fabric/epoxy composite which is a material commonly utilized in aerospace, defense, and automotive sectors. The material has exceptional mechanical properties like high specific strength and hardness. The materials utilized in this experiment are T-300 PAN carbon fabric, LY556 Epoxy resin, and HY5200 hardener to create pre-preg materials. Then the laminate was pre- pregged in a die mold of identical shape matched, and then pressed with the use of a hydraulic press. The specimens were precisely taken the readings in adherence to ASTM guidelines and they are analyzed for mechanical characteristics using a universal testing machine (UTM). Then the findings were evaluated against previous literature sources to confirm the reliability and consistency of the composite materials. This research study offers important information regarding the mechanical behavior of PAN carbon fabric/epoxy composites, and evaluation of their characteristics. Using the standardized testing techniques and literature standards, it improves the dependability and credibility of the results. The results of the research help in the development of compound which meets specific mechanical requirements and enhancing its suitability for use in different industries. This research aims to help advance composite material science and technology, guaranteeing their ongoing importance and usefulness in tackling the changing challenges encountered by different industries.

Keywords: Semi-rigid materials, vinyl ester resins, polyesters, epoxy resins, ceramic matrix composites, fibre reinforced composites, American society for testing and materials.

INTRODUCTION

Composite materials weave themselves into the fabric of human history, contributing greatly to technological progress and innovation. The assembly of different materials into composites has proven to be a transformational endeavor, offering benefits such as corrosion resistance, durability, and strength. This two-part study goes deeper into the comparative analysis are made in the case of high-strength fiberglass epoxy blends and rayon carbon blends It serves as a guiding principle for evaluating the quality of composites, opening up a close relationship between raw materials and resulting composite functions between them.

Throughout history, composite materials have emerged as indispensable materials, finding applications in various industries such as construction, medicine, aerospace, transportation etc. From corrosion resistance to structural flexibility, the benefits of its availability on composite materials has led to its ubiquitous use in a variety of industries -which has shed light on composites, their unique properties and potential applications.

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The development of hybrid products depends heavily on the interplay between science, design and manufacturing. Especially fiber blends offer distinct advantages in terms of material properties, flexibility, and manufacturing efficiency. The use of crystal types, shown by classifications D, E, R, and S, adds micro-dimension to composite engineering, and allows matching materials to be suited to specific applications as we begin this review the comparative study of high- strength fiberglass epoxy composite rayon. Exploring the mechanical prowess of carbon composites is promising.

The central role of composites in human history, emphasizing its multifaceted benefits and general applicability. From construction to spaceflight, hybrids have left an indelible mark on technological development. Fiber composites in particular are distinguished by their material properties, design, manufacture, and practicality. The research results and findings highlight the enduring importance of the composite materials, providing corrosion resistance, durability, design flexibility and durability in a variety of industries.

As we move towards a more detailed analysis of vitreous epoxy composite and high-strength rayon-carbon composites, the method used in this study incorporates the rules of hybridization. This method is instrumental a powerful tool for estimating the properties of composites.

In the sections that follow we will explore the historical trajectories of composite materials from their emergence during World War II to the development of the FRP industry Mid-20th century manufacturing processes, with the patenting of carbon fiber in 1961, set new boundaries in composite materials the overall content has been consistently refined.

Tri-Dung Ngo's [1]. investigation of the technical challenges of glass coating epoxy blends and rayon carbon blends goes beyond the immediate reach, providing a comprehensive approach to composite materials science and technical. Construction techniques, identifying architectural limitations, and analyzing practical implications, our research provided comprehensive insights. Beyond the specific perspective, Tri-Dung Ngo emphasized the broader contribution of hybridization across sectors, introduce alternative design approaches and highlight the practical implications, urging the importance of doing research in the dynamic development of composites is intensified and takes up the challenges of specific composites to contribute to a deeper understanding of their properties and at the same time gives a broader narrative of the central role of all technologies in shaping the industrial environment develops.

Rahul Reddy Nagavalli [2]. provided a comprehensive analysis of composite materials, including historical trends, manufacturing processes and applications. The study highlights the potential of composite material transformation, and emphasizes the advantages of robustness, lightness and cost-effectiveness. The combination of technical and communication capabilities puts composite materials science at the forefront, requiring continuous R&D efforts for their further refinement and innovation Nagvalli's work is a significant, attention-grabbing contribution emphasize the special characteristics and important role of composite materials in shaping the industrial environment.

C.S. Sharada Prabhakar et al., [3]. The Mechanical and thermal properties of the high strength glass epoxy and rayon carbon phenolic composites were carefully characterized. In Prabhakar study, laminated specimens were tested for mechanical, physical and thermal properties. Notably, the synthesis of a cylindrical pressure component with these materials exhibited commendable performance. The lamination process, and the results of the mechanical and thermal properties analysis were presented. Extensive research on epoxy and phenolic composites, especially in aerospace and thermal protection applications, highlighted the importance of this research Furthermore, the study highlights important considerations in laminate fabrication and property testing in properties, emphasizing the importance of care to obtain accurate test results and thermal properties were tested at 150°C.

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Autar K. Kaw's [4] work on the mechanics of composite materials, illustrated by diagrams of fiber geometries and crack propagation paths, provides detailed insights. The results section examines Tsai's comparison of failure coefficients about the strain, providing experimental insights into angle lamina failure stresses. The introduction emphasizes the importance of lamina laminate structures and emphasizes their specific mechanical behavior and the effects of temperature and moisture changes on Kaw processes, including low-pressure carbonization and resins types to be loaded, average properties of laminates Despite limitations such as low operating temperatures that help to understand failure and prediction, the analysis is particularly helpful, providing insight into temperature impact, failure prediction, and beam analysis for laminated composite structures.

Richa Sunil Patel [5]. Non-Destructive Testing (NDT) techniques aimed at evaluating material properties and detecting defects while preserving product integrity. This emphasizes the importance of NDT in detecting abnormalities and defects in materials and materials without causing damage. By reviewing and comparing various NDT methods such as visual inspection, radiographic methods, optical methods and wave based methods, the research highlighted the widespread applications in industry especially NDT methods play an important role in areas like oil and gas aircraft manufacturing and nuclear power plants. This critical important assurance study helps to understand the versatility of NDT techniques and their importance for quality control and safety assurance in industrial environments.

Mridul Gupta’s [6] detailed overview of non-destructive inspection (NDT) techniques including visual inspection, magnetic particle inspection, penetrator inspection, ultrasonic inspection, radiographic inspection, acoustic emission, and eddy current inspection, a focusing primarily on improvements in their applications and the research concluded that NDT techniques are universally effective and recommend the combination of several techniques to increase overall effectiveness. The method section lists the methods discussed in the study, while the practical implications highlight the effectiveness of NDT in identifying and removing defects, with technical improvements in reliability and cost creation is effective and reinforced.

T. J. Eisenreich [7]. challenges encountered in implementing the ASTM D 3039 test procedure for graphite/epoxy tape laminate at cryogenic temperatures, focusing on issues such as strain rate, peel, etc. Although the ASTM D 3039 standard was originally designed to provide resin matrix composite (RMC) tensile properties at ambient conditions That's it generated, which necessitated the development of alternative specimen designs by GDSS The proposed designs, mainly with 1 or 7 panels modeled, exhibited improved mean strength, reduced standard deviation, and a higher percentage of normal failures. The main methodology considered included careful selection of the adhesive to ensure smooth load transfer from the tab to the specimen. The practical implications of the paper highlight the importance of developing these new models for cryogenic testing and emphasize the important role of adhesive choice. In addition, the research contributed to the literature by identifying factors affecting cryogenic stress testing of RMC materials, such as the effect of tab design and geometry on failure patterns and ultimate strength, and the effect of taper angle obtain on the stress distribution in the sample.

R.A. Ilyas [8] examined the mechanical properties and applications of fiber-reinforced polymer composites, focusing on the reinforcing effects of different synthetic and natural fibers on biopolymer composite performance. In summary, the abstract conveys the intention of the book to present the latest developments in materials applications in composites, mechanical properties, and applicability, with the main objective and to enhance the current and future literature on this topic. Methodologically, the paper examines various aspects including composite processing, mechanical characterization, and potential uses, as well as fiber design, surface interface characterization, economic benefits, and challenges.

Junxian Zhao [9] investigated the mechanical, thermal, and corrosion resistance properties of unsaturated polyester resin (UPR) blends, focusing on those of surface-modified titanium dioxide (TiO2) nanoparticles and reinforced-spun glass fibers TiO2 nanoparticles and glass fibers incorporation in particular significantly improves the mechanical properties of UPR composites, and exhibits adequate corrosion resistance in acidic media. The aim of the study is to expand the range of UPR composites used in the construction industry, thereby demonstrating the potential of these modified materials for various construction applications notably; the research focused on glass fibers of TiO2 nanoparticles on the mechanical and thermal properties of UPR composites. The findings suggest that it shows the potential benefits for companies seeking to increase the productivity and distribution of UPR-based products.

Jimmie L. William's [10] work on monolith substrates, focusing on their widespread use in automotive static emission control reactors, especially selective catalytic reduction (SCR) units Notably, the authors' new reactors a beyond conventional vehicles -Emphasizes the increasing adoption, development and evaluation of monolith substrates as catalyst supports in a range of applications. This application covers a variety of industries, including chemical synthesis, catalytic combustion, plus ozone reduction. Through a discussion of monolithic architecture, its characteristics and specific applications, the paper highlights the versatility and importance of monolithic reactors in a variety of industrial environments and also explores the use of commercial applications established and evolving and the important role of single substrates in emission control and catalyst contribution in various applications, highlighting their practical implications for environmental sustainability regularity and efficiency.

Basingala Praveen Kumar [11] investigated in detail the design of Poly-Acrylic-Nitrile (PAN)- based carbon composite pieces for high-temperature environments, especially thermal protection systems (TPS) by experimental investigation of PAN-based carbon fiber fabrics and phenolic resin combinations (Cf PR).The research results confirmed the high strength and good thermal properties of PAN-based carbon composite laminates, making them well suited for applications in thermal protection systems. Where high temperature exposure is common Investigation off-side -Incorporated a range of properties such as shear stress, bending strength, compressive strength, thermal conductivity, and density, which clarified the performance of materials under different conditions in Hand layup method of preparing laminate with hydraulic hot- for curing. Using a press, the research provided important insights into how PAN-based carbon composite laminates can perform for high temperatures, where strength and thermal stability are the most important drivers which are useful for its use in thermal protection systems.

Our work mainly focused on upcoming research seeks to further investigate the mechanical characteristics of PAN-based carbon composite laminates and how they can be utilized in multiple sectors. Our main goal is to improve the strength and stability of composite materials, especially in aerospace thermal protection systems, by continuing to perfect the fabrication process. Furthermore, we intend to explore how environmental factors like exposure to seawater and high temperatures affect the mechanical properties of these composites. Through thorough testing and analysis, our goal is to offer important information that can guide the creation of stronger and longer-lasting composite materials for critical purposes. This research aims to help advance composite material science and technology, guaranteeing their ongoing importance and usefulness in tackling the changing challenges encountered by different industries.

METHODOLOGY

Throughout the literature review, significant attempts were made to collect data on the mechanical characteristics of PAN carbon fabric/epoxy composite materials, commonly used in aerospace, missile, and commercial industries. While there is a huge information about glass/epoxy and rayon carbon/phenolic composites. There is a clear shortage of data on PAN carbon fabric/epoxy composites.

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Our study is focused on systematically evaluating the mechanical properties of these materials before integrating them into structural components, and recognizing the crucial need for a comprehensive understanding. To help with this investigation, BD laminates were carefully created on both sides with ASTM standards to meet testing requirements. After conducting a few mechanical tests on these samples, the data of the samples was gathered on characteristics of material such as tensile strength, flexural modulus, and impact resistance. Precautions were taken to reduce the factors that could lead to defects in BD laminate production in order to preserve the mechanical properties of the composite materials. Efforts were made to carefully address issues like air entrapment in fabric prepreg lay-up, uneven resin flow from temperature differences during curing, and errors from cutting specimens to reduce variation in experimental results. The research methodology is depicted in a detailed flow chart in Figure 1, outlining the mechanical characterization process for PAN carbon/epoxy composites designed for high-strength uses. Through detailed documentation of the manufacturing process and analysis of mechanical testing results, our study seeks to offer valuable knowledge on the performance traits of these composite materials, ultimately aiding in the development of structural composite design and manufacturing methods.

EXPERIMENTAL PROCEDURE

Raw Materials

Details of raw materials used, manufacturing of laminates, testing of mechanical properties of high strength PAN carbon epoxy bidirectional laminates are as per the following.

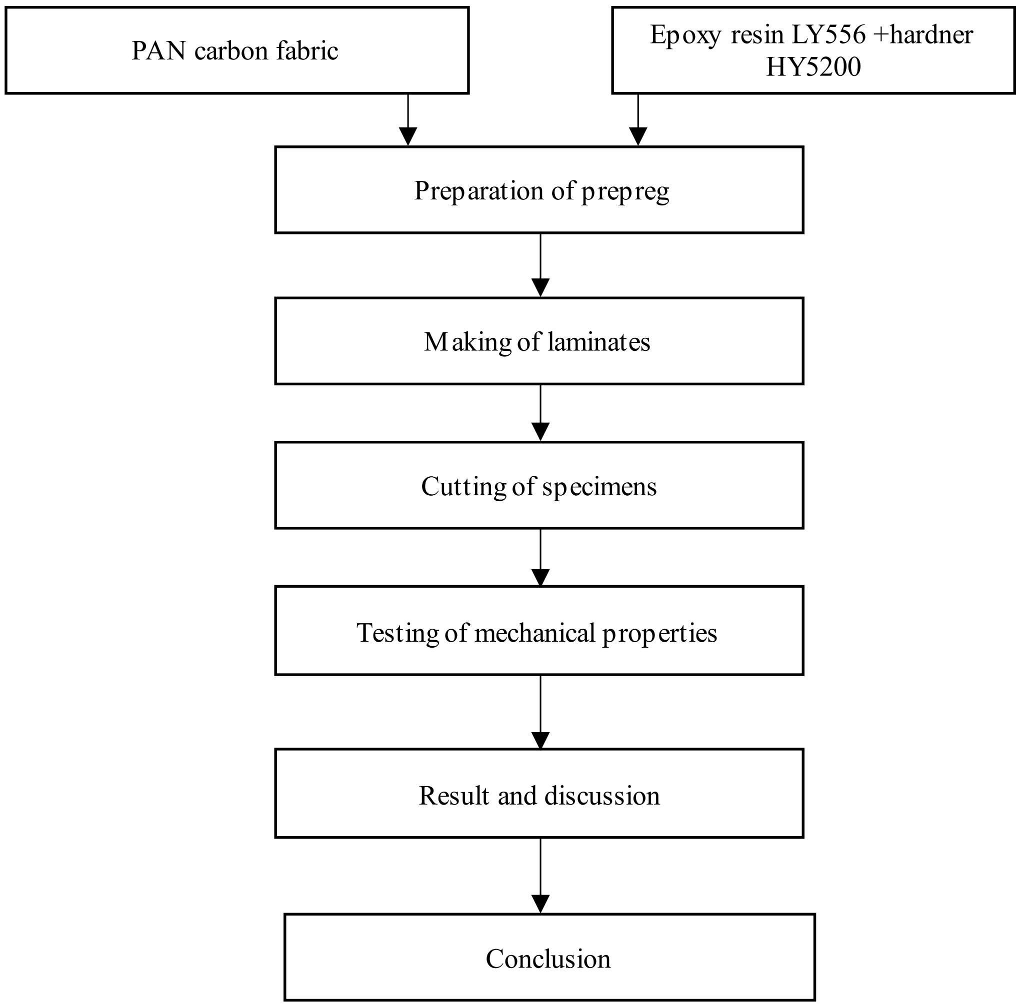

Figure 1. Flow chart for mechanical characterization for PAN carbon/ Epoxy composite.

PAN Carbon Fabric

PAN carbon fabric, essential for making composite materials, is commonly produced by weaving carbon rovings. Out of the many weaving patterns, satin-weave fabric is highly beneficial, especially the eight-harness satin variation which is commonly used. This particular weaving technique successfully maintains the distinct features of the carbon fibers in the composite structure and provides outstanding flexibility, allowing easy shaping around complex shapes. The specifications of PAN carbon fabric was ensured consistency and excellence throughout the manufacturing process. Table 1 provides a detailed overview about specifications and important information such as the pattern of the weave, quantity of the fibers, weight of the fabric, and the dimensions. The specifications are crucial in maintaining the quality and effectiveness of the PAN carbon fabric, allowing it to be easily merged into composite materials for different applications. Using the PAN carbon fabric in satin-weave designs like the eight-harness satin style is essential for the creating composites. The recommendations which are outlined in Table 1 serve as a blueprint for assuring the fabric's dependability and efficiency, which laying the foundation for creating composite structures of superior performance that meets the engineering criteria.

The PAN carbon fabric material must be stored in original containers and at room temperature with under controlled conditions. It is important to shield/protect the fabric from sunlight, radiation, dust, and corrosive atmospheres. It is needed to maintain the integrity and performance of the PAN carbon fabric in order to maintain its suitability for future manufacturing processes and applications. By following the proper storage procedures and protecting materials from harmful environmental factors, it helps the manufacturers to maintain the quality and consistency of their materials.

Epoxy Resin- LY556

Epoxy resins is important for creating the composite materials which are composed of epoxy groups containing one oxygen atom and two carbon atoms. Hardeners are also added to resins in order to make them into strong materials suitable for structural purposes. Generally, these curing agents consist of organic amines or anhydrous compounds. LY 556 resin, available for purchases and also it consists of DGEBA. This resin contains of two reactive groups and they are unable to cure by themselves, so a curing agent is required for the curing process. It is important to include the aromatic amine curing agents in the resins for composite structural components which needs have high temperature resistance. When the material is heated, a unique blend of resin and hardener both reacts to form cross-links and which completes the curing process within 5-6 hours. The Table 2 have appropriates for scenarios in which composite structural components needed to withstand the temperatures between 150 and 180 degrees Celsius. By choosing the right resin and hardener combination, manufacturers can ensure the performance of composite materials in tough work environments.

Table 1. Specifications of pan carbon fabric.

S N.	Parameter	Specification
1	Reinforcement	PAN based High strength Carbon fabric-3K
2	Areal density	380±20 g/m^2
3	Ends/inch	24±1
4	Picks/inch	24±1
5	Type of weave	8Harness Satin
6	Fabric Thickness	0.38±0.05 mm
7	Fabric width	1000±50mm
8	Fabric Breaking strength	200 Kg/inch (minimum) Both warp &weft direction
9	Carbon content	91% (minimum)
10	Sizing	Epoxy compatible

Table 2. Specifications of epoxy resin LY556.

S N.	Parameter	Specification
1.	Grade	LY556
2	Colour	Pale yellow, clear liquid
3.	Specific gravity	1.10 to 1.20
4.	Viscosity at 25ºC	8000-12000 CPS
5.	Epoxy content	5.0 to 5.9 Eq/Kg
6.	Volatile content	0.75% by weight (maximum)
7.	Shelf life	Two years from the date of manufacture

In order to maintain its quality and effectiveness of epoxy resin LY556 it needs the special care in storing. It is important to store the epoxy resin Ly558 in a controlled environment, with air conditioning, where the temperatures stay below 30°C. Also, maintain the relative humidity (RH) within a precise range of 55±5% (maximum). It is important to follow these designated storage conditions for the durability and life span of the resin. It is necessary for manufacturers to give importance to regularly rotating their inventory to make sure that the products maintain their optimal quality for a minimum of two years after they have been produced. It is essential to seal opened containers of LY 556 resin after it is used. This protect the resin from the outside factors that may impact its effectiveness in the long run. Manufacturers can maintain the quality and performance of the LY 556 epoxy resin for different applications by following these storage guidelines, guaranteeing its reliability.

Hardener –HY5200

Hardener HY 5200 is the major improvement in the field of composite materials. It is described as a liquid aromatic diamine without MDA with very low viscosity. Hardener HY5200 when paired with Epoxy Resin LY 556, it prolongs the pot life at process temperature, allowing manufacturers in increased flexibility and easy to handle during fabrication processes.

The LY 556 resin and HY 5200 hardener creates a cured resin system with a glass transition temperature which is higher than that of conventional DDM hardeners. This characteristic is especially significant because it boosts the effectiveness and longevity of composite structures. Furthermore, the use of HY 5200 is also addresses worries regarding the use of DDM hardeners, because they are slowly being eliminated for of their suspected in cancer-causing characteristics.

Table-3 offers the detailed technical specifications for hardener HY 5200, which are acting as a useful resource for manufacturers who are looking to improve their composite formulations. By utilizing the special characteristics of HY 5200, the producers of composites can get a better outcomes in performance and safety, leading to progress and growth in the composite materials industry.

For keep the effectiveness and stability of Hardener HY 5200, it requires specific storage conditions. It is recommended to keep it in a likely to be in controlled environment, preferably in a cool place with temperatures below 30°C. Also, the relative humidity (RH) should not be more than 60%. It is also crucial to close the seal of the containers after they are opened for usage. This method of storage protects the hardener from outside elements that might affect its properties in the future and ensure that it will perform well in later uses.

Table 3. Specifications of hardener HY5200.

S N.	Parameter	Specified value
1.	Grade	HY 5200
2.	Colour	Brown, clear liquid
3.	Viscosity at 25ºC , cPs	150-180
4.	Specific gravity at RT	1.0 to 1.1
5	Shelf life	Two years from the date of manufacture

HY 5200 when combined with epoxy resin LY 556, a mixture of 100 grams of resin and 24 grams of hardener has a gel time of at least 120 minutes at 100°C. This longer gel time at higher temperatures will provide sufficient the time for working on the composite fabrication, improving handling and ensuring the composite material cures properly. By following these storage and usage recommendations, manufacturers can enhance the effectiveness of hardener HY 5200 when used with epoxy resin LY 556, making it easier to create top-notch composite materials for a range of uses.

Fabrication methodology of PAN Carbon/Epoxy Laminate

Steps involved for fabrication of laminate are:

i. Prepregging
ii. Mould Preparation
iii. Prepreg cutting
iv. Lay-up
v. Curing & Extraction
vi. NDT

Prepregging

Measure and cut a 1m piece of PAN carbon fabric, then determine and document its weight. Make a mixture of epoxy resin (LY556 and HY5200 in a 100:24 ratio by weight) with an additional 10% for potential waste. Ensure resin is spread uniformly over fabric on polythene sheets, making sure there are no areas without coverage. Cure the pre-preg in a sterile environment until reaching the appropriate stickiness for lay- up, with resin content ranging from 40% to 50%.

Mould Preparation

The mold for the laminate consists of a top plate and a bottom plate, with spacers attached to all four sides of the bottom plate in order to reach the required thickness for the laminate which is depicted in Figure 2. Wax is spread on the contact areas of the top and bottom plates, as well as on all spacers, to aid in easy removal and promote proper adhesion. Afterwards, the spaces are firmly attached to the bottom plate, finishing the preparation of the laminate mold for future manufacturing procedures.

Prepreg Cutting

Six prepreg plies, each 300mm x 300mm in size, are carefully sliced from PAN carbon/epoxy prepreg with a surgical blade to create a 2mm laminate. Going further, a twelve prepreg plies with same dimensions are chosen and trimmed to create a 4mm laminate. These exact cutting methods are crucial in maintaining the consistency and precision in making composite laminates for later production steps.

Figure 2. Laminate mould bottom plate and top plate.

Lay Up

Before starting the lay-up process, the wax should be applied thoroughly to the top surface of the bottom plate and the bottom surface of the top plate. Afterwards, to peel off the polythene covering from one side of the first ply and place it gently on the top of the bottom plate. Then carefully roll to remove any air pockets between the layer and the surface of the bottom plate. Afterwards, take off the polythene wrap from the initial layer, and has to make sure no residue remains on the layer when taking it off. Continue this same procedure for the next following layers, making sure there are no leftover polythene materials on the plate and rolling them carefully for maximum adhesion. This process is repeated for each of the six plies for creating a laminate that is 2mm thick, and for each of the twelve plies to create a laminate that is 4mm thick. In the end, place the top plate of the laminate onto the bottom plate to finish the assembly.

Curing & Extraction

Position the laminate mold in the center of the lower platen of the hydraulic press. Adjust the top platen of the press to meet the top of the mold, guaranteeing a tight connection between the top platen and the mold's top plate. Place a J-type thermocouple into the specified opening on the lower plate of the mold for temperature monitoring. Turn on the platen heaters of the press and follow the recommended curing cycle as described in Table 4.

Remove the mold from the heat when it is under 50°C, then take out and trim the laminate. The laminate can be seen in Figure 3. Record the thickness and weight, then cut 6 samples each measuring 10x10x4mm and 10x10x2mm for analyzing resin content and density

NDT

Grid marking in Figure 4 for every 20x20 mm helped with ultrasonic testing using Sona test Dry scan 410D with STP 10 probe (10mm diameter, 0.5MHz, 180KHz frequency, 100mm range, and probe to probe dB of 45). After receiving approval in UT, samples are trimmed as necessary

Table 4. Curing cycle.

S N.	Temperature		Ramp rate	Hold time	Load
	From	To			
1	Room temp	80 C	1 C/min	---	15Ton
2	Hold at 80 C		---	1 hour	15Ton
3	80 C	120 C	1 C/min	---	15Ton
4	Hold at 120 C		---	1 hour	15Ton
5	120 C	180 C	1 C/min	---	15Ton
6	Hold at 180 C		---	4 hours	15Ton
Heaters switched off					

Figure 3. PAN carbon fabric/ epoxy laminate.

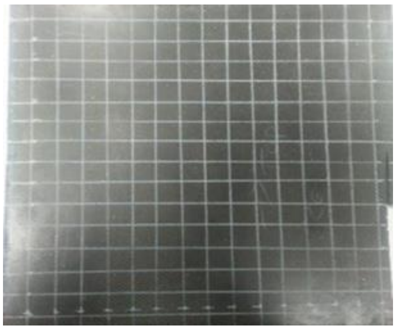

Figure 4. PAN carbon fabric/ epoxy laminate after UT.

Table 5. Specimens details for mechanical testing.

S N.	Test	Dimension	Quantity	Standard
1	Tensile test	250 x 25 x2 mm	6	ASTM D3039
2	Compression test	140 x 15 x 2mm	6	ASTM D3410
3	Flexure test	90 x 15 x 4mm	6	ASTM D790
4	ILSS	60 x10 x 4 mm	6	ASTM D 2344

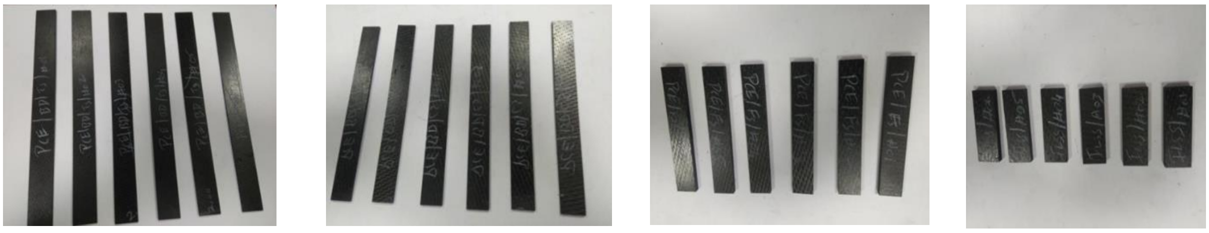

Figure 5. Tensile, compression, flexural, ILSS test specimens.

Resin Content & Density

Resin content and density of the Carbon/epoxy laminate are determined according to ASTM D792 standards, yielding a resin content of 39.25% and a density of 1.42 g/cc, respectively.

Specimen Cutting

The specimens are cut from the laminate for mechanical testing as per the table 5. And slitted specimens are shown in Figure 5.

Instruments used for polymer characterization include -

- *Universal testing machine (UTM):* This instrument measures mechanical properties such as tensile, compressive, flexural and Interlaminar shear strength.
- *Ultrasonic testing equipment*: This instrument used in the NDT to detect internal defects of the specimens.
- *Thermocouples*: Used to monitor and control temperature during curing processes

Laminates are made in to pieces according to required dimensions and shown in Figure 5.

Mechanical Testing

Tensile test

Tensile testing is an important procedure, though it is destructive, that provides information about the tensile strength and ductility of materials. It involves determining the amount of force needed to break a composite or plastic sample, as well as its stretching capacity until it breaks. Following standards such as ASTM D 3039 which is shown in Figure 6, experiments usually use simple tension or flat-sandwich tension setups to produce stress-strain curves that are crucial for calculating tensile modulus. Proper alignment of samples is crucial because composites are both anisotropic and naturally brittle.

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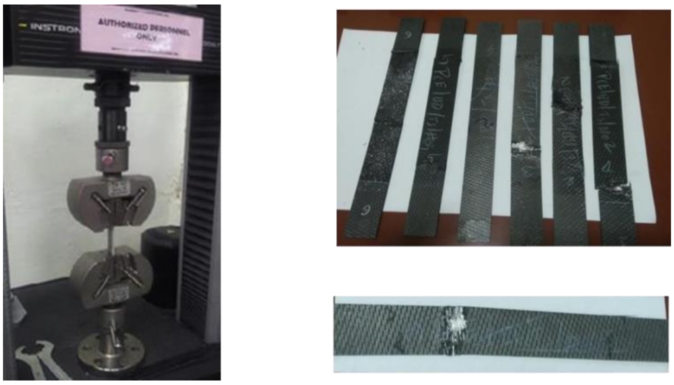

Figure 6. Tensile testing & Specimens after testing.

Figure 7. Compression testing & compression tested specimens.

Compression Test

Composite compression testing techniques aid in applying compressive loads to thin, flat rectangular specimens like laminate panels in a controlled manner to avoid buckling. These tests evaluate how materials behave when subjected to heavy loads, measuring compression and deformation to determine compressive stress and strain. (The fixtures are specially created to accommodate the specific requirements of composite materials, which is essential for the success. Tests are regulated by standards such as ASTM D 3410 shown in Figure 7, which provides the stress-strain diagrams to explain features like elastic limit, proportional limit, and compressive strength and guidance to prevent buckling.

Flexural Test

The flexural test measures the amount of force is needed to bend a beam when it is subjected to three-point loading, and determining if materials are suitable for bearing loads. The testing procedures follows the standards of ASTM D 790 and ISO 178, which are frequently include in three-point or four-point bend testing. The test parameters such as support span, loading speed, and maximum deflection change depends on specimen thickness and are defined differently by ASTM and ISO. In the ASTM D790 shown in Figure 8, testing stops at 5% deflection or at specimen failure, whereas in ISO 178 it continues until failure. The flexural testing provides an information on various parameters such as flexural stress at break, strain at break, stress at specific deflection levels (3.5% for ISO and 5.0% for ASTM), modulus, and stress-strain curves, by giving valuable insights into stiffness of materials and interfacial strength between the fibers and matrix in composites.

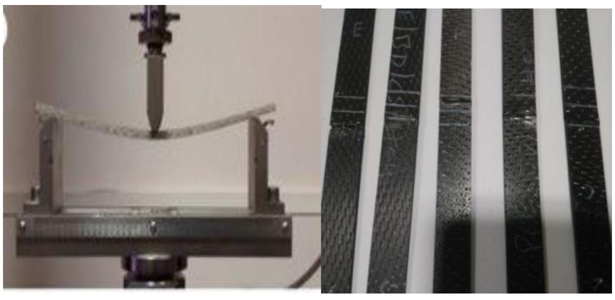

Figure 8. Flexural testing and specimens

Figure 9. ILSS testing and specimens.

Interlaminar Shear Strength Test

Testing ILSS is essential to evaluate the resin-fiber bond quality in CFRP. Normally done through a three-point bending test, ILSS evaluates the material's ability to withstand interlaminar shear stress in line with ASTM D2344 Shown in Figure 9 guidelines. This test offers important information about the strength and longevity of the composite material's resin-fiber connection.

- *The methods used to characterize polymer composites include: Mechanical testing:* Tensile, compression, flexural, and interlaminar shear strength (ILSS) tests. These are common methods for evaluating mechanical properties of composites like PAN carbon fabric/epoxy laminates.
- *Non-destructive testing (NDT):* Techniques like ultrasonic testing are used to detect defects in composites without damaging the material.
- *Thermal testing*: Used to assess thermal properties such as heat resistance.
- *Resin content and density tests:* These tests will to help determine the composition and quality of the composite materials.

RESULTS AND DISCUSSION

The results of Tensile test, Compression test, Flexure test and ILSS of PAN carbon fabric/ epoxy composite laminates are given in Table-6, Table-7, Table-8 and Table-9 respectively and minimum, maximum and average of all the above test results are shown in Table-10.

Table 6. Tensile Test Results.

S N.	Sample	Specimen area width x thick (mm)	Maximum load (kN)	Tensile stress (MPa)	Tensile modulus (GPa)	Poission's ratio
1	Specimen 1	25.47 x 1.99	37.60	742	78.45	0.047
2	Specimen 2	25.48 x 1.97	43.08	857	68.48	0.050
3	Specimen 3	25.49 x 1.98	43.76	867	59.73	0.050
4	Specimen 4	25.49 x 1.95	28.58	575	68.15	0.045
5	Specimen 5	25.48 x 1.97	40.64	810	67.84	0.049
6	Specimen 6	25.55 x 1.99	38.67	761	68.55	0.048

The reaction of composites to ductile loads is exceptionally subordinate on the pliable solidness and quality properties of the support strands, since these are distant higher than the tar framework on its claim.

Table 7. Compressive test results of Carbon Fabric, Anamide 1947 & Epofine 1333/01.

S N.	Tested temp	Sample dimension (mm)	Max load (KN)	Stress (MPa)	Remarks
1	Room Temp	12.99 x 4.42	19.430	338	Gauge Failure
2	Room Temp	12.80 x 3.38	18.369	425	Gauge Failure
3	Room Temp	12.91 x 3.43	19.482	440	Gauge Failure
4	250° C	12.93 x 3.37	4.404	101	Gauge Failure
5	250° C	12.76 x 3.35	2.963	69	Gauge Failure
6	250° C	12.95 x 3.39	2.703	62	Gauge Failure

Table 8. Compressive test results of Carbon Fabric, Cyanate Ester /02.

S N.	Tested temp	Sample dimension (mm)	Max load (KN)	Stress (MPa)	Remarks
1	Room Temp	12.99 x 3.09	12.116	302	Gauge Failure
2	Room Temp	12.85 x 3.10	12.778	321	Gauge Failure
3	Room Temp	12.84 x 3.05	10.615	268	Gauge Failure
4	250° C	12.79 x 3.05	4.793	123	Gauge Failure
5	250° C	12.77 x 3.05	7.926	204	Gauge Failure
6	250° C	12.92 x 3.05	8.014	203	Gauge Failure

Table 9. LSS test results.

S N.	Sample	Specimen area width x thick (mm)	Maximum Load (kN)	ILSS (MPa)
1	Specimen1	10.44 x 4.00	5.83	47.78
2	Specimen 2	10.43 x 4.08	6.12	48.63
3	Specimen 3	10.40 x 3.98	5.53	45.12
4	Specimen 4	10.55 x 4.05	6.18	48.03
5	Specimen 5	10.44 x 3.92	5.40	44.56
6	Specimen 6	10.43 x 4.09	5.92	47.00

Table 10. PAN carbon fabric/epoxy composite mechanical properties.

S N.	Property	No. of samples tested	Average	Minimum	Maximum
1	Tensile Strength, MPa	6	768	565	867
2	Tensile Modulus, GPa		68.50	59.73	78.45
3	Poisson’s ratio		0.048	0.045	0.050
4	Comp. strength, MPa	6	404	344	443
5	Flexural strength, MPa	6	829	738	900
6	Flexural modulus, GPa		67.35	64.87	69.51
7	ILSS, MPa	6	46.85	44.56	48.63

Here, the adhesive and stiffness properties of the resin system are crucial, as it is the role of the resin to maintain the fibres as straight columns and to prevent them from bulking.

Flexural loads are really a combination of tensile compression and shear loads. When loaded as shown, the upper face is put into compression, the lower face into tension and the central portion of the laminate experiences shear.

CONCLUSION

PAN carbon fabric/epoxy composite materials are carefully tested for mechanical properties before being manufactured to ensure they meet established standards in the existing literature. Bi- directional laminates are carefully made, with mechanical properties thoroughly assessed in accordance with ASTM standards. Although there may be slight variations between experimental results and literature values, careful attention to detail is necessary during the laminate fabrication, specimen cutting, and testing processes. In the process of designing actual components, it is crucial to consider these experimental properties as they can cause deviations from expected values due to differences in fabric quality, orientation, and manufacturing limitations. Therefore, depending on experimental data guarantees precise evaluation and following performance criteria while making components.

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