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Research Article

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Fabrication and Characterization of Hybrid Composite Fibers

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Abstract

Fiber reinforced polymer (FRP) composite materials were heterogeneous without plastic deformation. They are currently used in a range of contemporary applications, including manufacturing sports equipment, transportation, and maritime industries. Carbon FRP and glass FRP composites, together with additional fiber reinforced materials, have been gradually replacing conventional materials due to their exceptional durability and low specific weight characteristics. Their ability to be manufactured in a variety of combinations with customized strength qualities, as well as their high fatigue, toughness, in addition to high temperature wear as well as oxidation resistance, make these materials an enormous choice for industrial applications. A Carbon FRP composite outperforms Glass FRP composites in terms of mechanical qualities. However, catastrophic failure has been recorded in carbon fiber composites due to limited carbon fiber elongation. To accomplish both design adaptability and cost savings, both carbon/glass hybrid composite with its mechanical properties must be developed. Glass/carbon fiber reinforced polymer composites are increasingly being used in industry. As a result, careful design selection for a particular use of these kinds of hybrid composites is essential. Hand lay-up was expected to be used to create the hybrid laminates. The preparation and testing of glass/carbon fiber hybrid composites with various combinations is envisaged. Tensile and flexural strength tests were recommended to evaluate their performance capability.

Keywords

Carbon fiber, Glass fiber, Epoxy, Tensile, Compression, Flexural, Impact strength

Introduction

Materials are the cornerstone of improving living and productivity conditions for people. They signify important milestones in human development. Humans have utilized and had access to materials for thousands of years. It is seen from the development of human evolution with the intention of its progress is depended on individual access to and utilize of materials through social creative forces, skill, and knowledge. It exemplifies humanity's ability to comprehend and modify nature. When novel epoch-making material is developed, productivity increases dramatically, and human society advances. As a result, materials are now a symbol of human civilization's growth, as well as thresholds for dividing eras in human history. Materially, human civilization has gone through the Stone Age, the Bronze Age, and Iron Age. Since their invention in the 20th century, high-performance plastics and composites have invaded numerous industries and people's lives at a previously unheard-of rate of development. They have replaced traditional materials and demonstrated enhanced performance. Materials now play an important part in the national economy and defence due to the rapid advancement of science and technology. New materials provide the foundation of emerging technologies, and materials science, energy science, as well as data science have emerged as the three foundations of today's science and technology. The integrated discipline is materials science. It is very close to many other disciplines. It provides a set of recommendations for developing, producing, and utilizing new materials with specific features after outlining the requirements of macroscopic attributes of substances depending on chemical composition along with internal structural principles. Three content sections make up the majority of it. According to a chemical perspective, how they interact with the chemical natures of substances is explored, along with the connection among their properties and the processes used to make materials [1-3].

The physical performance of materials is researched, as is the interaction among the internal framework of materials (the mixture of molecules and atoms, their dispersal in space, and the condition of aggregation). The technological challenges connected to the synthesis and use of materials are being investigated within the supervision of physical and chemical theory [3-5]. There are numerous types of materials. Based on the primary combination bonds that connect their atoms or molecules, they can be roughly divided into three types of materials: Metallic materials along with metal elements are connected by metal bonds, and macromolecular complexes are covalently joined by organic polymer materials as well as non-metallic parts. Covalent links, ion bonds, or a combination of the two bonds are used to join ceramic materials, nonmetallic components, and metal elements.

There are two major sorts of materials in terms of service performance: structural materials and functional materials. Mechanical qualities like strength, stiffness, deformation, and so on are important in structural materials, whereas the qualities of light, sound, heat, electricity, along with magnetic materials are significant. In this scenario, it can be recognized how materials behave in terms of sound, light, electricity, heat, and magnetic fields. As current science and technology advances, the unique criteria for materials become more stringent. Material research is rapidly moving left in the path of investigating through experiences and other methodologies. On the basis of the designed qualities, it advances along the journey of material design. The composite material can retain the advantages of its initial components while additionally overcoming some disadvantages and displaying some new traits. It is made by specific techniques utilizing metallic in nature, nonmetallic in nature and polymeric materials. Such composites' development is a prime example of material design. A composite substance consists of a matrix and reinforcing material and is a multi-phase mechanism. Matrix material is a permanent segment consisting of matrix-based metal composite substances, natural non-metallic matrix composite materials, and polymer matrix composites. Reinforcing substance is a dispersed form that is usually fibrous in nature, such as glass fiber or organic fiber. In this book, we solely cover polymer matrix composites. Polymer matrix composite materials use organic polymer as the matrix and fiber as reinforcement. Fibers outperform matrix materials in terms of strength and modulus. As a result, the main load-bearing element is made up of fibers. It needs a matrix material with excellent adhesive properties to firmly bind fibers together. By the identical a period of moment the matrix material may operate by distributing the applied load uniformly and transmit the loads in the direction of fiber. Additionally, the characteristics of the matrix material heavily influence a number of elements of composite materials. As a result, the effectiveness of composite materials is directly impacted by the characteristics of each fiber, the matrix, as well as interface among them.

The development of composite materials has supplanted the majority of conventional building materials in the automobile, aviation, and other industries. Fiber reinforced composites have proven mostly effective in many situations at high strength materials wherever required. There are dozens of bespoke formulations available that provide FRPs with several ranges of tension and flexural loads. FRP is a very popular option for enhancing the appearance and functionality of a product as compared to traditional resources, such as metals, due to its exceptional strength as well as its low weight.

Most often used in the aerospace sector, composites made of polymer matrix are now also found in the automotive, marine, sports, medicinal, construction, and other sectors due to the declining cost of carbon fibers. Beginning to be used in automobiles are carbon fiber matrix polymer composites, mostly to reduce weight and increase fuel efficiency. Carbon fiber epoxy-matrix composites are used in body sheets, supports, bumpers as well as tires, drive shaft, engine components, and suspension systems in the graphite automobile. This vehicle weighs 570 kg less than a comparable steel vehicle. It weights only 1250 kg, as opposed to the typical American car's 1800 kg. PEEK and polycarbonate thermoplastic composites are being used as spring elements in automobile suspension systems.

A laminated composite consisting of a pair of sections, the first of being reinforced by glass fiber and the second with Kevlar fiber, was studied by He and Gao [1] to determine how the fiber volume proportion affected the flexural features of the material. The findings demonstrate that whereas tension stress increases as the volume percentage of Kevlar grows, it decreases as the volume fraction of lower layer fibers increases. Hu et al. [2] investigated the breakdown of fiber-reinforced laminates made of composites subjected to biaxial tensile loading. A composite failure criterion comprising of maximum stress criteria determines the beginning of failure for particular lamina. Following the first damage, the lamina's response was studied and seen to exist brittle or deteriorating phases through a breakdown of the whole laminate.

Al-Naimi and Abbas [3] investigated the structural responses of a hybrid FRP-concrete bridge superstructure design under adverse moment flexural forces using experimental techniques. The found results revealed that under a negative flexural moment, the structure of the composite FRP-concrete bridge superstructure is stiffness-driven rather than strength-driven. Lightweight FRP poles' flexural behavior was investigated by Metiche and Masmoudi [4]. According to experimental findings, using lower linear density glass fibers could boost some FRP poles' maximum load carrying capacity by up to 38%. The final load carrying capacity of 5.4 m (18") FRP poles increases by up to 22% when the hole is positioned on the compression side as different to the tension side, while the 12 m (40 feet) FRP pole's show no discernible effect (3, 5%). The stacking order plus the stress states created around the hole are primarily to blame for this.

Maleic-anhydride-modified polypropylene (m-PP) was examined by Rijsdijk et al. [5] to see how it affected the monotonic mechanical characteristics of continuous-glass-fiber reinforced PP composites. This investigation demonstrated that adding PP that has been treated with maleic anhydride to continuous PP composites reinforced with glass fiber increased the strength of the composite. For polymers constructed using a PP aggregate with 10 wt.% m-PP, an optimal level of longitudinally and longitudinal flexural strength was attained.

Saleh Mousavi-Bafrouyi et al. [6] looked at the effects of layering sequence on the bending features, flexural attributes, and flexural failure processes of aramid-UHMPE composites. Flexural strength is influenced by the kind of fibers at the crushed face as well as the level of fiber dispersion. The unidirectional metallic wire tapes were used in glass fiber composites and carbon fiber composites, according to Matteson and Crane [7], who also reported an increase in flexural strength. They demonstrated that a switch between compressive buckling to almost ductile tensile failure caused the rise in flexural strength.

Bradley and Harris [8] used omnidirectional high-carbon metal wires to improve the impact properties of an epoxy resin reinforced utilizing omnidirectional carbon fiber reinforcement laminate. Steel wire on the specimen's compression side improved the laminate's strength, which in turn raised the fracture's energy by 200% of getting rid of the compressive collapse mode. Specifically, since the wires were positioned in the specimen's compression side and as the volume percentage of the wires grew, the hybrid laminate's flexural strength improved.

An examination on types of failure and indicators for the development of them in composites columns and beams was done by Daniel et al. [9]. They discovered that the origin of the different failure modes depended on the characteristics of the material, the geometrical parameters, and the kind of force. They claimed that the location and the mechanism of failure are controlled by the loads type or condition, which also defines the level of stress across the composite structure. The bi-axiality or tri-axiality of the condition of stress is taken into consideration by the proper criteria for failure at any point in the structure.

Natural fibers have a significant role in the production of polymers that are highly valued in nanoform. New perspectives in the domains of science and engineering have been opened up by the production of nanofibers from polymers that are natural or synthetic, metallic substances, semiconductors, composite materials, and carbon-based materials. Nanofibers have also been the subject of extensive study [10, 11].

After a thorough review of the literature as well as discussion, it is clear which the application of polymer composite laminates is becoming increasingly important across all business sectors, but particularly in the automotive sector due to the advantages of their high strength-to-weight ratio for improving vehicle performance. Since most components are exposed to twisting and shear loads, assessing the flexural and shear characteristics of laminated composites is recognized to be relevant [12-14]. The flexural test and the brief beam shear test are also regarded as real-time tests. The prior research placed less emphasis on the torsional and brief beam shear capabilities of simple bi-woven laminates for various fiber orientations. The preceding research did not analyze the flexural properties for specimens with different thicknesses, particularly for fiber reinforcement volumes between 56% and 60%. There is no discussion of the impact of delamination on the boundary among the matrix as well as fiber reinforcement under flexural pressures. Correlation between experimental and finite element analysis results for various fiber fractions and fiber orientations has not received significant attention. Therefore, the investigation in the current work will concentrate on the flexural because shear behavior of laminated materials, that is very beneficial for the sector and aids design engineers in selecting the best materials for particular applications.

Experimentation

Preparation of mold

The glass plate with the dimensions 200 x 200 x 3 mm is chosen as the mold's basis. The dimensions for one set of pieces are 200 x 200 x 3 mm. Glass fragments are joined together using arnaldite. It is important to take care that the attachment's corners have no gaps. These glass molds remain open for one day to ensure a solid connection.

Preparation of composite specimen

In this instance, we mix 12 ml of Hardener (HY 951) with 120 ml of epoxy resin. Afterwards pour the contents of a glass beaker then stir in a glass rod to prevent bubble formation. A glass mold is set up on a level surface, after which the consistently poured solution is covered with layers of carbon and glass fiber that have been properly mixed in. Insert OHP sheet upon the mold after it has been finished, then add weight. This mould is kept for 24 h. We remove the mold and retain it in the boiler for the post-curing process after 24 h. This facilitates the specimen's removal out of the mold and improves the specimen's characteristics. The preparation and process for creating a composite specimen for test samples are shown in figure 1, figure 2, figure 3, figure 4, and figure 5.

Results and Discussion

Here are the findings of the numerous characterization tests. It has been examined and discussed how tensile strength and flexural strength have evolved. Various composite samples' interpretations of the data are offered. Figure 6 depicts the tensile test apparatus, whereas figure 7 depicts the flexural test apparatus in use. Figure 8 depicts the compression testing process, while figure 9 depicts an impact testing machine in use.

The traditional coupon test geometry is used for tensile testing and consists of two areas: the gauge length, which is the centre region where failure is anticipated to happen, and the two end portions, that are clamped into a grasp mechanism attached to a test machine. The composite material's ten-

Figure 1: Tensile test specimen.

Figure 2: Composite preparation.

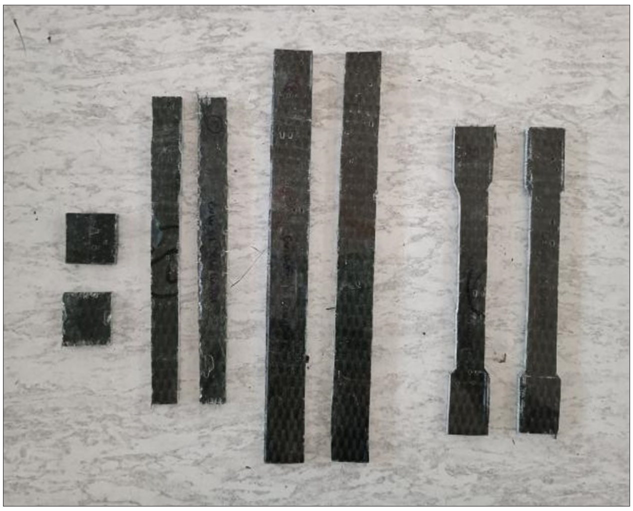

Figure 3: Specimen preparation.

Figure 4: Composites preparation.

Figure 5: Test Specimen sample.

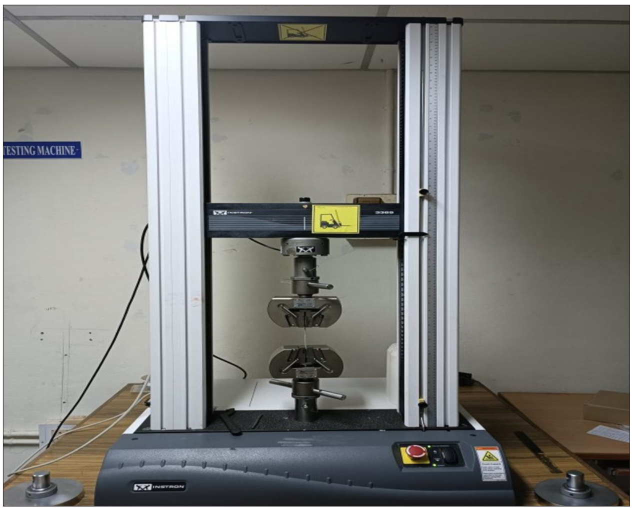

Figure 6: Tensile test.

sile strength is demonstrated in figure 10 during a tensile test. The two layers of glass fiber (mat) are separated by a single layer of carbon fiber. The composite material's tensile strength is demonstrated in figure 11 during a tensile test. Between the two layers of carbon fiber, there is one layer of glass fiber (mat).

A lot of reasonably flexible materials, including polymers, wood, and composites, are tested for flexure. The 3-point flex

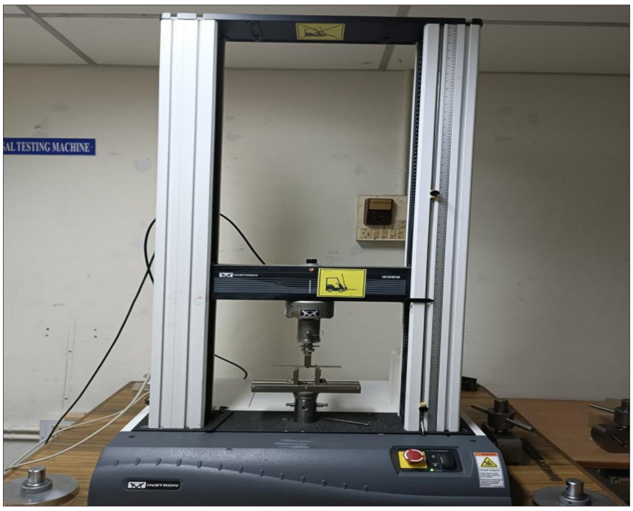

Figure 7: Flexural test.

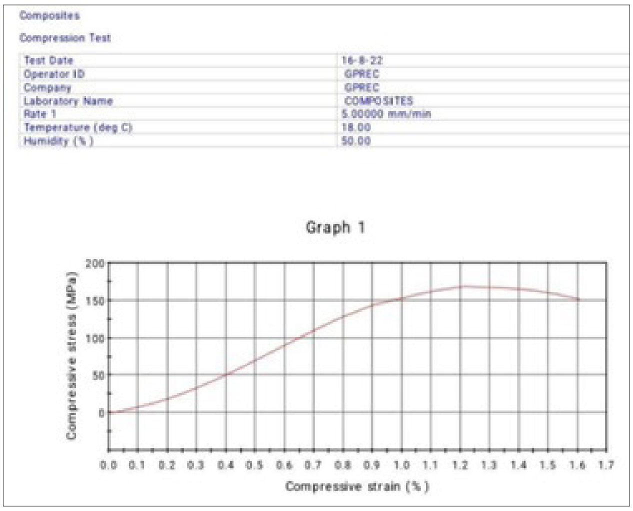

Figure 10: Compression strain results for sample 1.

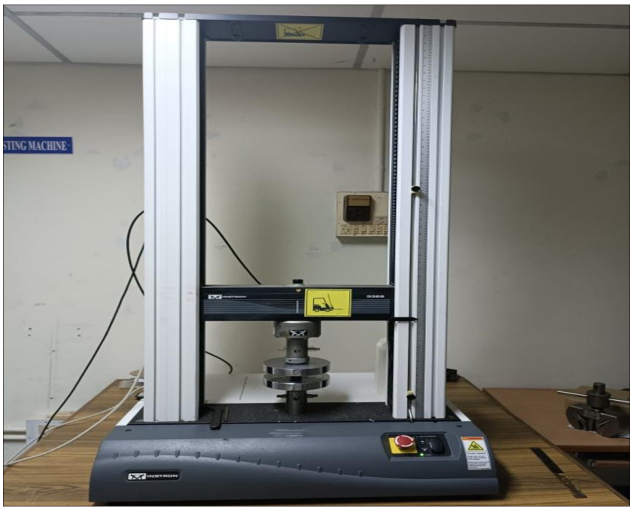

Figure 8: Compression test.

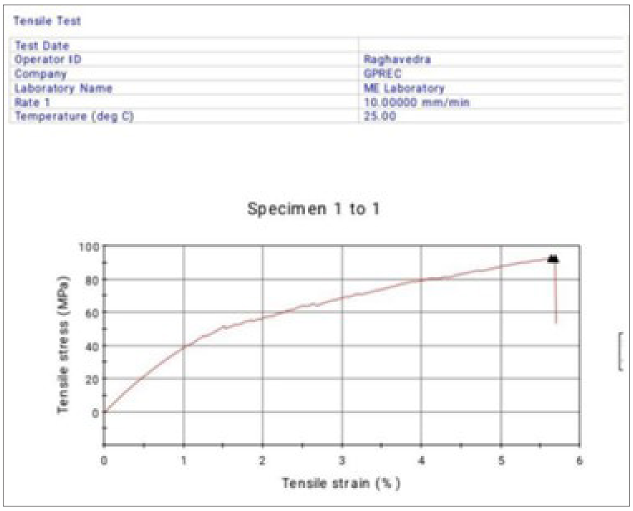

Figure 11: Tensile test results.

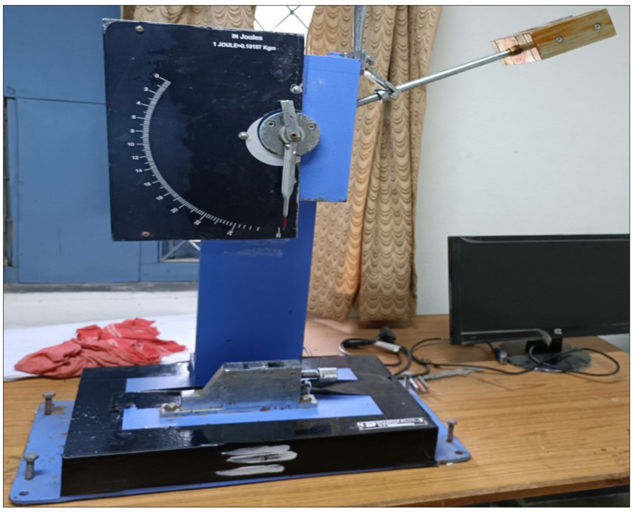

Figure 9: Impact testing.

as well as 4-point flex tests are the two available varieties. The region of uniform stress in a 3-point test is relatively small and focused beneath the center's loading point. The 4-point test's area of uniform stress, which is typically half the length of the outer span, is located within the inner span overloading points. Figure 12 displays the composite material's flexural strength during a flexural test. Between the two layers of glass fiber (mat) is preserved one layer of carbon fiber. Figure 13 displays the composite material's flexural strength during a flexural test. Between the two layers of glass fiber (chopped), one layer of carbon fiber is preserved. Figure 14 displays the composite material's flexural strength during a flexural test. Between the two layers of carbon fiber, there is one layer of glass fiber (mat). The composite material's bonding is readily seen when its greatest tensile strength is attained at two layers of carbon and 1 layer of glass fiber (mat). It has been found that the flexural characteristics improve as the proportion of carbon fiber decreases as that of glass fiber (mat) increases.

Conclusions

The results of this experimental analysis of mechanical behavior by epoxy composites reinforced along with carbon as well as glass fiber are as follows.

- This work demonstrates that the straightforward hand lay-up procedure is responsible for the efficient production of

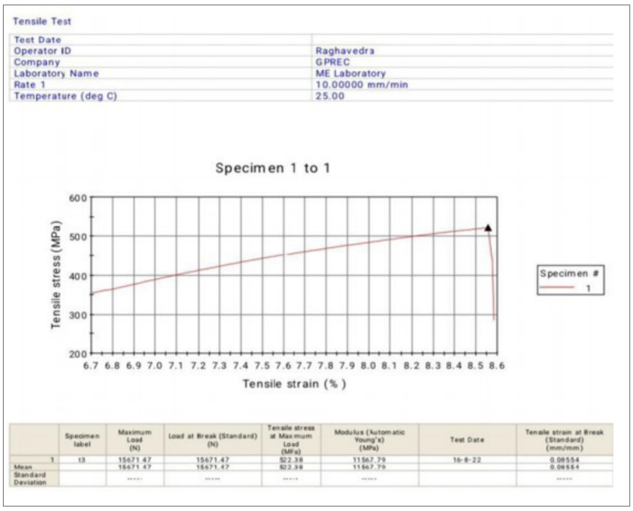

Figure 12: The composite material tensile strength under tensile test.

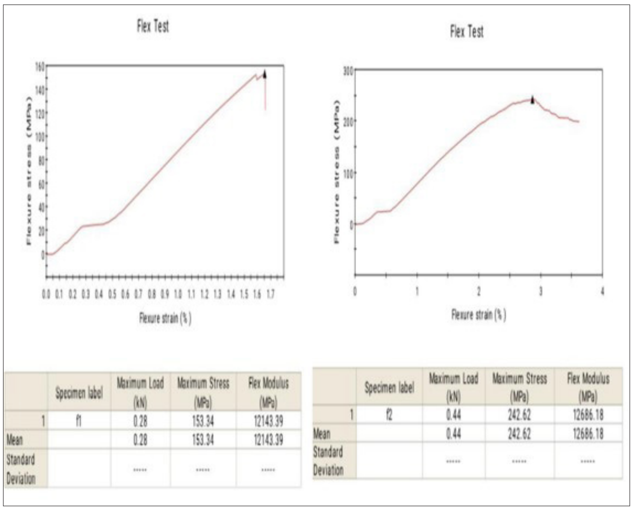

Figure 13: The composite material flexural strength of sample 1 under flexural test.

carbon and glass fiber reinforced epoxy composites using different fiber layers.

- It has been noted that the fiber layers have a significant impact on the mechanical characteristics of composites, like tensile strength and flexural strength.
- Around a total of two layers of carbon fiber and 1 layer of glass fiber, the mechanical characteristics of carbon fiber reinforcement matrices reach their peak value.
- A mat with two layers of carbon plus a single layer of glass fiber has the maximum tensile strength.
- The value for maximum flexural strength is. One layer of glass fiber (mat) and two layers of carbon.
- It has been found that the tensile qualities of a material (mat) increase when the fraction of carbon fiber decreases and vice versa.
- It has been found that the flexural characteristics improve as the proportion of carbon fiber decreases as that of glass fiber (mat) increases.

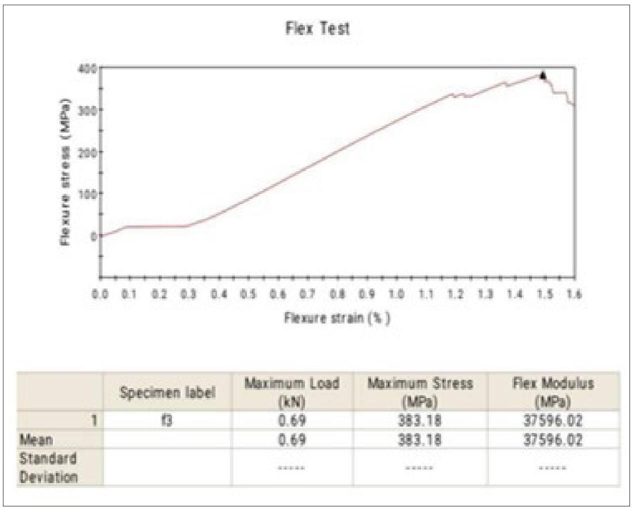

Figure 14: The composite material flexural strength of sample 2 under flexural test

Acknowledgements

None.

Conflict of Interest

None.

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