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Investigation of Flexural Response of Kevlar Composite

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Abstract

Objectives: This work investigates the flexural behaviour of Kevlar composite that are prepared by hand layup method. **Methods/Analysis:** Hand lay-up is a simple method for composite production. The epoxy resin of LY556 grade and an Araldite HY951 hardener is mixed with correct ratio. Then the Kevlar fiber is placed over the plate and an epoxy resin with a hardener is rolled over the fiber, by continuing which forms the layer by layer as per the requirement. Then after fabrication flexural test is carried out and then SEM analysis has been done to analyze the tested specimen. **Findings:** When tested under flexural load the composite breaks at 226 kN. It strains to maximum displacement of 6.7mm with ultimate stress of 5.56N/mm^2, that is it can withstand the maximum load of 226 kN with ultimate stress of 5.56N/mm^2. As we know that in the flexural test a uniform load is applied on the middle of the specimen, which tends a tensile stress is developed on the convex side and a compression stress is developed on the concave side of the specimen. This will create an area of shear stress along the middle line of the specimen resulting in its breakage. The Kevlar fibre having excellent strength survives even very high flexural loads and the result shows some unbroken Kevlar fibres in the middle even after the flexural load. **Novelty/Improvement:** While changing the orientation of the fibers from 0^0, 30^0, 45^0 and 90^0 the ultimate stress withstand by the specimen may also change. From this experiment we came to know that specimen may withstand the maximum of ultimate stress 5.56 N/mm^2 at 45^0 fibre orientation.

Keywords: Flexural Testing, Hand Lay-Up Method, Kevlar, Scanning Electron Microscope (SEM)

1. Introduction

The major development in organic fibres over the last three decades has been the production by DuPont of aromatic polyamide fibres, collectively known as aramids, of which the best known for many years in the composites industry has been Kevlar-49. Highly-oriented Kevlar fibres can be produced by wet-spinning process that has strength of the order of 2.6GPa and module up to 130GPa, depending on the degree of alignment of the polymer chains. Having properties intermediate between those of carbons and glass Kevlar offer an extra degree of flexibility in composite design. One important characteristic of the fibre is that it is extremely difficult to cut on account of its fibrillary structure. In[1] evaluated tensile tests on single Kevlar-29 filaments, to characterize their intrinsic behavior under quasi-static loading, and nanoindentation tests, to investigate their cross-section mechanical properties. In[2] Investigated the mechanical behaviour of Jute+Flax+GFRP composite and also the comparison of it with the Jute+GFRP based composite. The arrangement of hybrid composite is such that a layer of vertically laid flax fiber was flanked between layers of horizontally laid jute fiber. Test results showed that the hybrid natural composite has excellent properties under tensile, flexural loading. In[3] noticed a positive hybrid effect for a segregated hybrid in which one layer of carbon fibres was sandwiched between two layers of Kevlar. Hybrids with a greater degree of

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hybridization showed a negative hybrid effect, irrespective of whether the outer layers were carbon or Kevlar. In[4] arranged the fibres in alternative layers of abaca in horizontal and vertical orientation. The mechanical properties of the composite were determined by testing the samples for tensile and flexural strength. He observed that the tensile strength of the composite material is dependent on the strength of the natural fiber and also on the interfacial adhesion between the reinforcement and the matrix. In[5] developed procedure to study the performance of effects under quasi-static compressive and tensile load using a servo-hydraulic testing machine. The work involved investigation on the variety of orientation angles of Kevlar-29 fiber. In[6] determined the variation in the stress value depending on the resin material as well as the influence of GFRP in the strength of SiC polymer composite. Results from the tests were analyzed to show that the polyester resin is better for shear strength, in both Sic/GFRP reinforced and SiC composite material. In[7] investigated the stress–strain response in warp and fill directions, the apparent Poisson's ratio, and the in-plane shear response of Kevlar 49 fabric including the possible effects of specimen size and pre-loading on the mechanical responses of the fabric. In[8] developed a material model suitable for simulating the behavior of dry fabrics subjected to ballistic impact. The developed material model is implemented in a commercial explicit Finite Element (FE) software LS-DYNA through a user defined material subroutine (UMAT). In[9] dealt with the fabrication and mechanical investigation of aluminium alloy, alumina (Al_2O_3) and boron carbide metal matrix composites. He fabricated by stir casting process which involves mixing the required quantities of additives into stirred molten aluminium. After solidification, the samples are prepared and tested to find the various mechanical properties like tensile, flexural, impact and hardness. In[10] investigated a few works about the effects of nanoclays on the impact strength of Kevlar/epoxy laminates. Therefore, his paper intends to study the ideal amount of nanoclays to obtain the best impact performance. explored the possibility of using the natural fibre to reinforce polyester and thus opens a new way to implement locally available inexpensive fibres and produce a new candidate tribo-material for bearing applications. In[11] Fabricated a epoxy and polyester resin composites using aluminium oxide, silicon carbide with different proportion of Al2O3 and SiC along with GFRP. Mechanical testing like tensile, impact hardness shear biaxial were conducted in order to know the properties of fabricated composites. The result showed that composites with epoxy resin shows higher strength as compared to composites with polyester resin. In[12] investigated the mechanical properties of a Kevlar composite. In his work, Kevlar composites were prepared by using hand lay method. Four layers of Kevlar composite were prepared and hardness and impact test were conducted. The result shows that Kevlar has good strength and hence can be a good alternative material for automobile and other applications. In[13] introduced a new concept of fibre twisting and investigated the effect of twisting and the fibre orientation on the mechanical properties of bio degradable green composites. The composites were fabricated by vacuum assisted compression moulding technique. Here, two fibers namely twisted neem and twisted kenaf are sandwiched between layers of glass fibres to enhance the stiffness and strength of the laminates. Initially, the fibers were alkalized to increase the mechanical properties. The result showed that there is a significant improvement in mechanical properties of composites due to the presence of twisted fibers. It also showed the influence of fiber orientation on mechanical properties. In[14] determined tensile behaviour of GFRP/SiC polymer reinforced composites and found that adding reinforcement increases strength. In[15] the interest of using the Fiber Reinforced Composites (FRCs) has increased due to its potential for replacing the traditional materials in various applications. Kevlar fiber, due to its unique properties such as higher strength to mass ratio and modulus, has become very popular as reinforcement in composite materials and its application has growth considerably. However, for enhancing its properties in various applications, a proper characterization is very important. Many researchers have been conducted in recent years, for characterization of Kevlar fiber and its composites. In this paper, a state-of-the art review of these characterizations is presented. In[16] manufactured composite plates by hand lay-up process with epoxy matrix (DGEBA) reinforced with Kevlar fiber plain fabric and Kevlar/glass hybrid fabric. Results of the mechanical properties of composites were obtained by tensile, bending and impact tests. The tests were performed in the parallel direction or fill directions of the warp and in a 90^o direction. Composites with Kevlar/glass hybrid structure in the reinforcing fabric showed the better results with respect to specific mechanical strength, as well as bending and impact energy. In[17] evaluated the failure modes and energy absorption capabilities of different kinds of circular tubes made of carbon, Kevlar, and carbon Kevlar hybrid fibers composites with epoxy resin. In[18] evaluated tensile and impact behaviour of abaca-raffia hybrid composite. In[19] used Kevlar Fibers (KFs) as reinforcement for Wood-Flour/High-Density-Polyethylene Composites (WF/HDPE) to improve the mechanical properties of the resulting composites. Addition of a small amount (2–3%) of KF caused an improvement in the tensile, flexural, and impact properties of WF/HDPE. In[20] concluded that chemical treatments are very effective in modifying the fiber surface, reducing the hydrophilic nature of fiber, improving fiber matrix adhesion there by increasing the mechanical performance of composites. Presented the finding of an experimental study on kenaf fibre hybrid composite plates for potential application in shear strengthening of RC beam. In the experimental programme, hybrid composite plates had been fabricated using kenaf and carbon fibres with five different mixes i.e., 47% kenaf with 0% carbon; 45% kenaf with 2.5% carbon; 47% kenaf with 5% carbon; 45% kenaf with 7.5% carbon and 45% kenaf with 10% carbon. The physical and mechanical properties of the fabricated hybrid composite plates were then experimentally investigated.

2. Materials and Methods

2.1 Kevlar Fibers

Kevlar is a polyaromatic amide formed by combining para-phenylenediamine and terephthaloyl chloride. The crystallinity of the Kevlar polymer strands contributes significantly to Kevlar's unique strength and rigidity. They also have high strength to weight ratio.

2.2 Resin and Hardener

Epoxy resins are low molecular weight pre-polymers or high molecular weight polymers that contain at least two epoxies groups. The having high boiling point. For epoxy resin the hardener HY 951 is employed in order to improve the interfacial adhesion and to impart strength to the composite. They are mixed in the ratio 9:1.

2.3 Glass Polymer

Fiber-Reinforced Plastic (FRP) (also –reinforced polymer) is a composite material made of a polymer matrix reinforced with fibers. They are composed of two parts fibers and polymers. The fibers used are glass, aramid and carbon. The polymers are epoxy, vinyl ester, polyester thermosetting plastic and phenol formaldehyde resins. They are used to protect to composite from moisture.

2.4 Composite Fabrication Process

Hand lay-up is a simple method for composite production. The Kevlar composite which is available as a sheet of required dimensions is spread out dried to remove the moisture content. The flat surface used for fabrication is cleaned thoroughly to remove any dust particles which might create some defects in the specimen like void and air-bubbles. The epoxy resin of LY556 grade and an Araldite HY951 hardener is mixed with correct ratio. Now the Kevlar fiber is placed over the plate and an epoxy resin with a hardener is rolled over the fiber, which forms the first layer. The structural arrangement is such that the composite specimen consists of four layers of Kevlar with an epoxy resin matrix between each layer such that each layer are arranged in different orientation as 0^0, 30^0, 45^0, 90^0.A proper resin-hardener mixture is applied between these layers for perfect adhesion. The resin and hardener is mixed at ratio of 9:1. The material is dried out under sunlight for 24 hours to form a Kevlar fiber reinforced composite with an epoxy resin matrix. A suitable weight say 300 N is placed over the fiber arrangement for better adhesion. Figure 1- 3 shows the procedure for hand layup method for mixing resin and hardener.

Figure 1. Application of resin on the surface.

Figure 2. Resin and hardener.

Figure 3. Mixing of resin and hardener.

2.5 Flexural Test

The flexural test measures the force required to bend a beam under three-point loading conditions. The data is often used to select materials for parts that will support loads without flexing. Flexural modulus is used as an indication of a material's stiffness when flexed. Since the physical properties of many materials (especially thermoplastics) can vary depending on ambient temperature, it is sometimes appropriate to test materials at temperatures that simulate the intended end uses environment.

2.6 Test Procedure

Most commonly, the specimen lies on a support span and the load is applied to the centre by the loading nose producing three points bending at a specified rate. The parameters for this test are the support span, the speed of the loading, and the maximum deflection for the test. These parameters are based on the test specimen thickness and are defined differently by ASTM and ISO. For ASTM D790, the test is stopped when the specimen reaches 5% deflection or the specimen breaks before 5%. For ISO 178, the test is stopped when the specimen breaks. A variety of specimen shapes can be used for this test, but the most commonly used specimen size for ASTM is 3.2mm x 12.7mm x 125mm as shown (Figure 4).

3. Result and Discussion

3.1 Flexural Result

When tested under flexural load the composite breaks at 226 kN. It strains to maximum displacement of 6.7mm with ultimate stress of 5.56N/mm². The Flexural response of Kevlar Composites under different orientation (Table 1).

$$\sigma_f = 3PL / 2bd^2 \text{ N/mm}^2$$

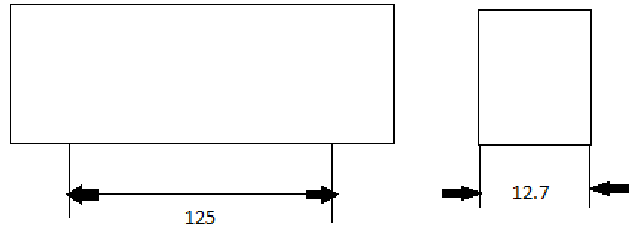

Figure 4. ASTM D790 standard.

Table 1. Flexural response of kevlar composite

S. No	Samples	Orientation (Deg.)	Flexural stress (N/mm²)	Ultimate stress N/mm²
1	Composite 1	0o	204	5.01
2	Composite 2	30o	212	5.21
3	Composite 3	45o	226	5.56
4	Composite 4	90o	205	5

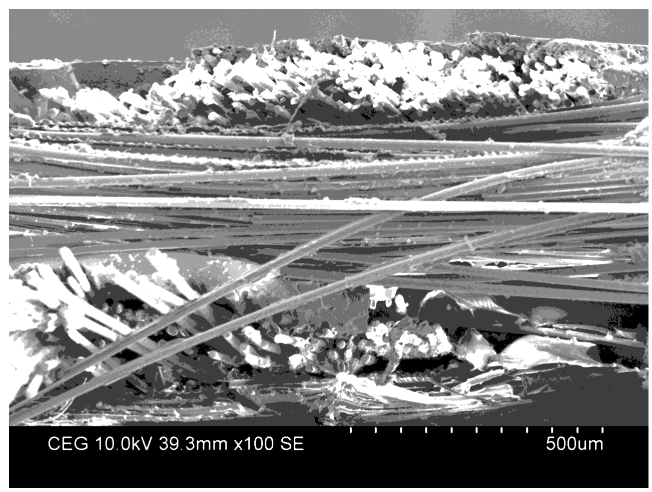

Figure 5. SEM image after flexural test.

3.2 SEM Image after Flexural Test

Figure 5 shows the Scanning Electron Microscope (SEM) micrograph of the specimen after flexural test. As we know that in the flexural test a uniform load is applied on the middle of the specimen, a tensile stress is developed on the convex side and a compression stress is developed on the concave side of the specimen. This will create an area of shear stress along the middle line of the specimen resulting in its breakage. The Kevlar fibre having excellent strength survives even very high flexural loads and the image shows some unbroken Kevlar fibres in the middle even after the flexural load.

4. Conclusion

Finally, from this work we found out the flexural response of the fabricated Kevlar composite material. When we compare this results with the plain Kevlar fibres the result obtained by our composites are quite higher as per the guided values. Then the ultimate stress are also been found to determine the specimen flexural response.

5. References

1. Cisneros JA, Tejeda-Ochoa A, García-Estrada JA, Herrera-Ramírez CA, Hurtado-Macías A, Martínez-Sánchez R, Herrera-Ramírez JM. Characterization of Kevlar-29 Fibers by Tensile Tests and Nano Indentation, Journal of Alloys and Compounds. 2012 Sep 25; 536(1):S456–S59.
2. Ramnath BV, Elanchezhian C, Nirmal PV, Kumar GP, Kumar SV, Karthick S, Rajesh S, Suresh K. Experimental Investigation of Mechanical behavior of Jute-Flax Based Glass Fiber Reinforced Composite, Fibers and Polymers. 2014; 15(6):1251–62.
3. Marom G, Drukker E, Weinberg A, Banbaj J. Impact behaviour of Carbon/Kevlar Hybrid Composites, Composites.1986 Apr; 17(2):150–53.
4. Raja RN, Kokan SJ, Narayanan RS, Rajesh S, Manickavasagam VM, Ramnath BV. Fabrication and Testing of Abaca Fibre Reinforced Epoxy Composites for Automotive Applications, Advanced Materials Research. 2013; 718–20:63–68.
5. Abu Talib AR, Ramadhan AA, MohdRafie AS, Zahari R. Influence of Cut-Out Hole on Multi-Layer Kevlar-29/ Epoxy Composite Laminated Plates, Materials and Design. 2013 Jan; 43:89–98.
6. Ramnath B, Rajesh S, Elanchezhian C, Vignesh C, Vijai Rahul V, Tamilselvan V, Narayanan SUS. Investigation of Mechanical behaviour of Glass fibre based SiC Polymer Composites, Applied Mechanics and Materials. 2014; 591:142–45.
7. Zhu D, Mobasher B, Vaidya A, Rajan SD. Mechanical behaviours of Kevlar 49 Fabric Subjected to Uniaxial, Biaxial Tension and In-Plane Large Shear Deformation, Composites Science and Technology. 2013; 74:121–30.
8. Zhu D, Vaidya A, Mobasher B, Rajan SD. Finite Element Modelling of Ballistic Impact on Multi-Layer Kevlar 49 Fabrics, Composites Part B: Engineering. 2014 Jan; 56:254–62.
9. Ramnath BV, Elanchezhian C, Jaivignesh M, Rajesh S, Parswajinan C, Ghias SA. Evaluation of Mechanical Properties of Aluminium Alloy–Alumina–Boron Carbide Metal Matrix Composites, Materials and Design. 2014; 58:332–38.
10. Reis PNB, Ferreira JAM, Zhang ZY, Benameur T, Richardson MOW. Impact Response of Kevlar Composites with Nanoclay Enhanced Epoxy Matrix Composites, Part B: Engineering. 2013 Mar; 46:7–14.
11. Rajesh S, Ramnath BV, Elanchezhian C, Aravind N, VijaiRahul V, Sathish S. Analysis of Mechanical Behavior of Glass Fibre/ Al2O3- SiC Reinforced Polymer composites, Procedia Engineering. 2014; 97:598–06.
12. Rajesh S, Ramnath BV. Investigation of Hardness and Impact Property of a Kevlar Composite, International Journal of Applied Engineering Research. 2015; 10(8):6215–18.
13. Ramnath BV, Rajesh S, Elanchezhian C, Shankar AS, Pandian SP, Vickneshwaran S, Rajan RS. Investigation on Mechanical Behaviour of Twisted Natural Fiber Hybrid Composite Fabricated by Vacuum Assisted Compression Molding Technique, Fibers and Polymers. 2015; 17(1):80–87.
14. Rajesh S, Ramnath BV. Evaluation of Tensile Behaviour of GFRP/SiC Polymer Reinforced Composites, International Journal Applied Mechanics and Materials. 2015; 766-767:70–72.
15. Singh TJ, Samanta S. Characterization of Kevlar Fiber and Its Composites: A Review, International Journal of Advanced Engineering and Technology. 2015; 3(1):108–12.
16. Raja RN, Kokan SJ, Narayanan RS, Rajesh S, Elanchezhian C, Ramnath BV. Properties and Performance Analysis of Woven Roving Composite Laminates for Automotive Panel Board Applications, Advanced Materials Research. 2013; 683:21–24.
17. Valenca SL, Griza S, Oliveira VGD, Sussuchi EM, Cunha FGCD. Evaluation of the Mechanical Behavior of Epoxy Composite Reinforced with Kevlar Plain Fabric and Glass/ Kevlar Hybrid Fabric, Composites: Part B. 2015; 70:1–8.
18. Ramnath BV, Manickavasagam VM , Elanchezhia C, Karthick R, Bharath U, Kishore RA M, Rahul R. Investigation of Tensile and Impact Behaviour of Abaca-Raffia Hybrid Composite, ARPN Journal of Engineering and Applied Sciences. 2015; 10(13):5577–80.
19. Punyamurthy R, Sampathkumar D, Bennehalli B, Patel GR. Gouda R, Srinivasa CV. Pre-Treatments on Mechanical Characterization of Natural Abaca Epoxy Composites, Indian Journal of Science and Technology. 2015; 8(11):1–11.
20. Alam MA, Alriyami K, CheMuda Z, Jumaat MZ , Kenaf H. Fibre Composite Plates for Potential Application in Shear Strengthening of Reinforced Concrete Structure, Indian Journal of Science and Technology. 2016; 9(6):1–7.