Research article Available online www.ijsrr.org ISSN: 2279–0543

International Journal of Scientific Research and Reviews

Evaluation of Tensile Strength of Carbon - Kevlar Fiber Reinforced Epoxy Hybrid Composites by Experimentation

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ABSTRACT

The varied high strength fibers are now being explored for high performance application in automotive and aerospace sectors in larger scale. Carbon and Kevlar fibers are classified as a high strength and toughness reinforcing materials and yield better mechanical properties. To escalate the benefits presented by the newly established composites constituting a Carbon/Kevlar as a reinforcing materials along with epoxy resin under Tensile and Compressive loading scenario, tests are conducted to investigate the influence of inter-ply hybridization on static properties and the results were reported. Wet layup with vacuum bagging approach was used for fabrication of laminated samples with a total of eight layers by varying the carbon/Kevlar layers sequence and orientation for obtaining of ten configured laminates. A volume fraction of fiber of 36 ± 2% *is* kept for all ten laminates. Results indicated that highest tensile strength provided by carbon reinforced epoxy composites. The Lowest tensile strength by hybrid sample having Kevlar fibers on the middle part sandwiched between carbon on the outer part with orientation of $\pm 45^0$ to second and seventh layer of Kevlar. Tensile strength of carbon reinforced epoxy composites is 2.23 times the value of Kevlar reinforced epoxy composite. The decrease of Kevlar weight fraction and the increase of carbon fiber content, results gave a higher tensile strength to the hybrid composites.

KEYWORDS: Tensile Strength, Carbon Fabric, Kevlar Fabric, Wet Layup, Hybridization

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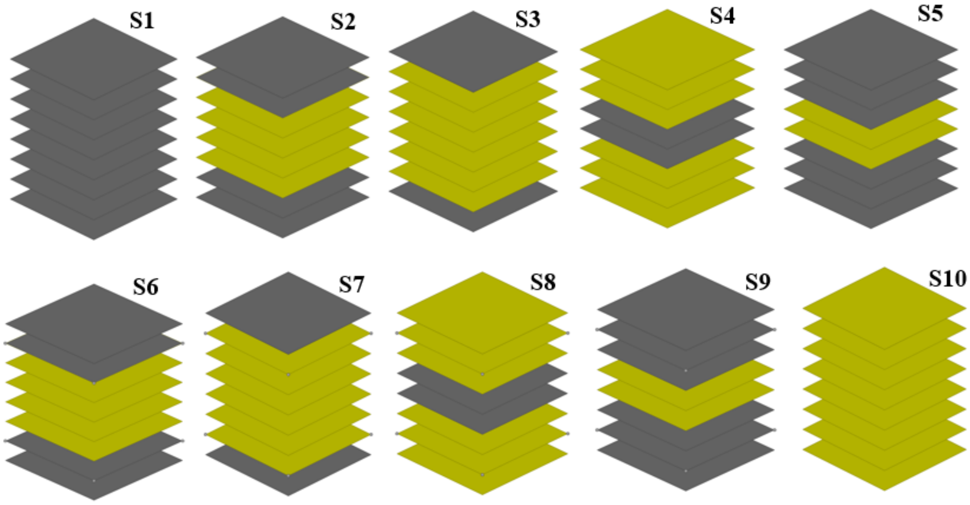
INTRODUCTION

The synthetic fibers such as Carbon and Kevlar are widely used in many applications due to their benefits of high strength, high stiffness, long fatigue life, environmental stability and corrosion resistance. Recently, the research has gained a wide interest on hybrid composites formed between synthetic-synthetic fibers. Different mechanical properties are obtained by hybridization with two or more synthetic fibers in the single matrix. Superior strength and stiffness yield by carbon fibers but often have poor damage tolerance while Kevlar fibers have better toughness degree and damage tolerance, but lower strength. Hybridization could be a suitable solution to overcome the limitations of an individual fibers[1]. The tensile test on Kevlar-glass epoxy composites with three orientations $0^0/90^0$,$45^0/45^0$ and $30^0/60^0$ for determination of mechanical properties mainly tensile strength, tensile modulus and peak load. The study indicated that better tensile properties were obtained for ply orientation at $0^0/90^0$[2]. An addition of carbon fiber to the kenaf epoxy composites, there was improvement in the tensile properties of kenaf-carbon hybrid composites[3]. The theoretical predications using rule of mixtures, inverse rule of mixtures, Halpin-Tsai and Xu-Reifsnider and an experiemation for determination of tensile, compressive, flexural strength and modulus of K-49 thermoplastic based composite, result of tensile strengths predicted by rule of mixture, inverse rule of mixture and Halpin-Tsai were higher than the experimented values. Rosen model predicted higher compressive strengths compared to experimented values. The inverse rule of mixture model calculated the flexural properties which are 15% higher than experimentally obtained values[4]. In this work, the benefits of varying stacking sequence and orientation of carbon and Kevlar fibers by establishing hybrid composites andits effect on tensile and compressive properties were investigated using experimental methods as per ASTM standards[5].

FABRICATION OF TEST LAMINATES

Twill bidirectional Carbon fabric, plain bidirectional K-29 Kevlar fabric and epoxy are the materials used for laminates preparations[6]. The composite laminates were fabricated in wet layup using vacuum bagging with a total of eight layers by changing the location and orientation of carbon and Kevlar fabrics in an epoxy matrix. With a total of ten sample configuration is obtained including carbon and Kevlar based epoxy composites. The laminates were kept under 645 mm of Hg pressure during vacuum process and cured for four hours at room temperature. Post curing was carried out for all the laminates in the oven for mechanical properties improvement. In a ten sample configurations as illustrated in fig. 1, all eight layers of sample configuration S1, S2, S3, S4, S5 and S10 having a normal orientations i.e. $0^0/90^0$, only second and seventh layers of sample configuration of S6, S7, S8 and S9 having an orientation of $\pm 45^0$ and remaining layers are orientated in normal directions. The volume fraction of fiber for all ten laminates is maintained at 36 ± 2%



Color code of lamina: Carbon – black and Kevlar - yellow

Figure1. Stacking Sequences of Carbon and Kevlar Fabrics

EXPERIMENTATION

The tensile and compressive test was conducted using Universal Testing Machine, Model TFU – C 1000KN, serial No. 2012/169 at laboratory conditions at room temperature. The tensile test was conducted as per the guidelines of ASTM D3039. Knowing the properties of material due to tensile loading is important in engineering designing. The tensile strengths of the composites are useful for qualitative characterization, research and development purposes. The flat strip specimen size is 250 mm x 25 mm x thicknessas shown in fig. 2 was loaded into the grips of the testing machine and loaded in tensile at loading rate (speed of cross head) is 2 mm/min. All data output is collected through a data acquisition system.

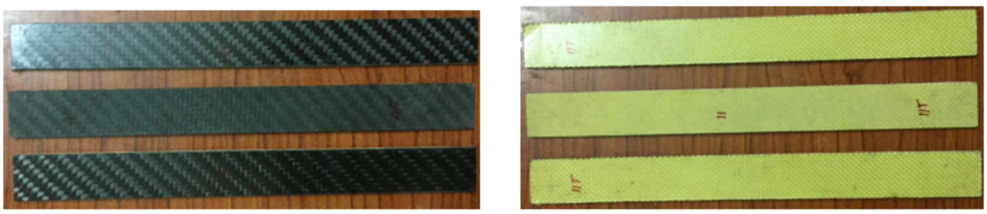
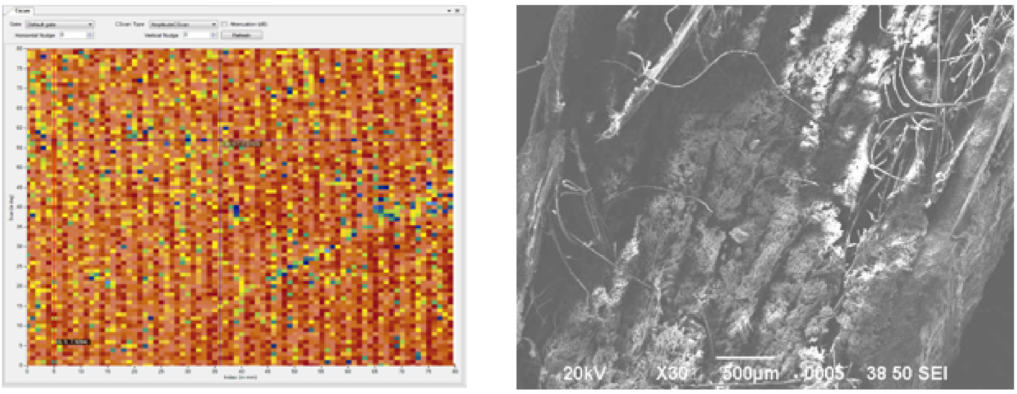


Figure2. Specimen Used for Tensile Test

RESULTS AND DISCUSSIONS

The stacking of fibers plays important role in the hybrid composite to achieve desired results of tensile strength. At most care is taken during wet layup process to keep the percentage volume of voids by below 6% for all the laminates and percentage of volume of voids was calculated by knowing a theoretical and measured density. Air trapped between the plies during manufacturing leads to formation of voids which was observed through C Scan devices and typical image of C scan for S5 configuration is shown in fig. 3(a). fig. 3(b) indicates an unreasonable formation of resin due to occurrence of micro-voids which are the points for of crack invitation. At certain areas where the resin did not bond with the reinforcement due to poor supply of resin or faster curing. Typical load–deflection curves and effect of loading on tensile strength for carbon-reinforced epoxy composites, carbon-Kevlar/epoxy hybrid composites and Kevlar reinforced epoxy composites are shown in fig.2 and fig. 3 respectively. The tensile strength of all the considered samples is depicted in Table: 1. It is observed that highest tensile strength provided by sample S1 and lowest by sample S10. Tensile strength of sample S1 is almost 2.23 times more than that of sample S10. Whereas in hybrid configuration, Tensile strength of sample S5 is 1.23 times more than that of sample S2. When comparing sample S1 and S5, tensile strength of sample S1 is 1.24 times than that of sample S5.



(a) (b)

Figure3.(a) Typical C-scan Image of S5 Sample (b) SEM Image of Sample S10

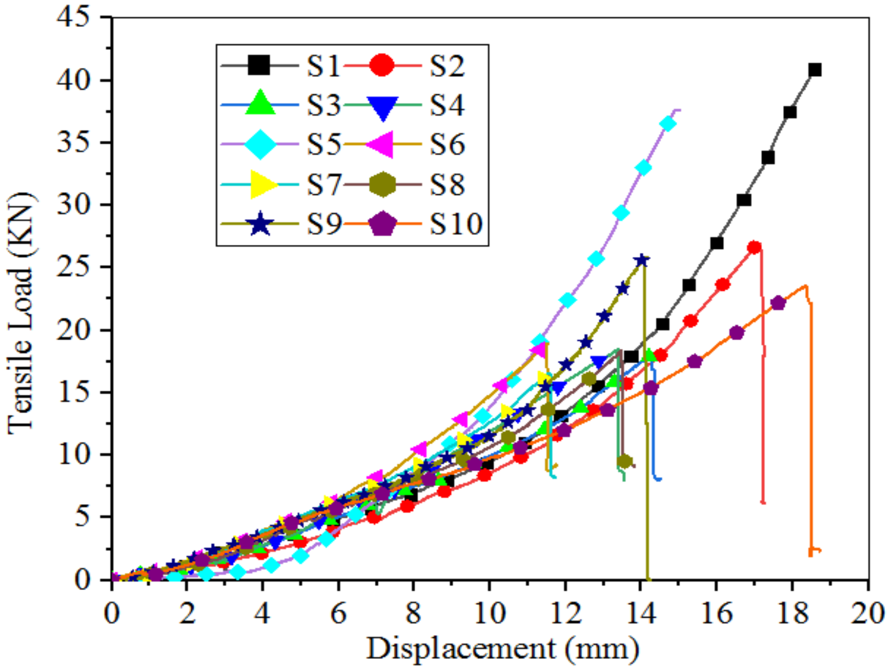


Figure4. Typical Load Displacement Curves for Tensile Test Carried out on Samples

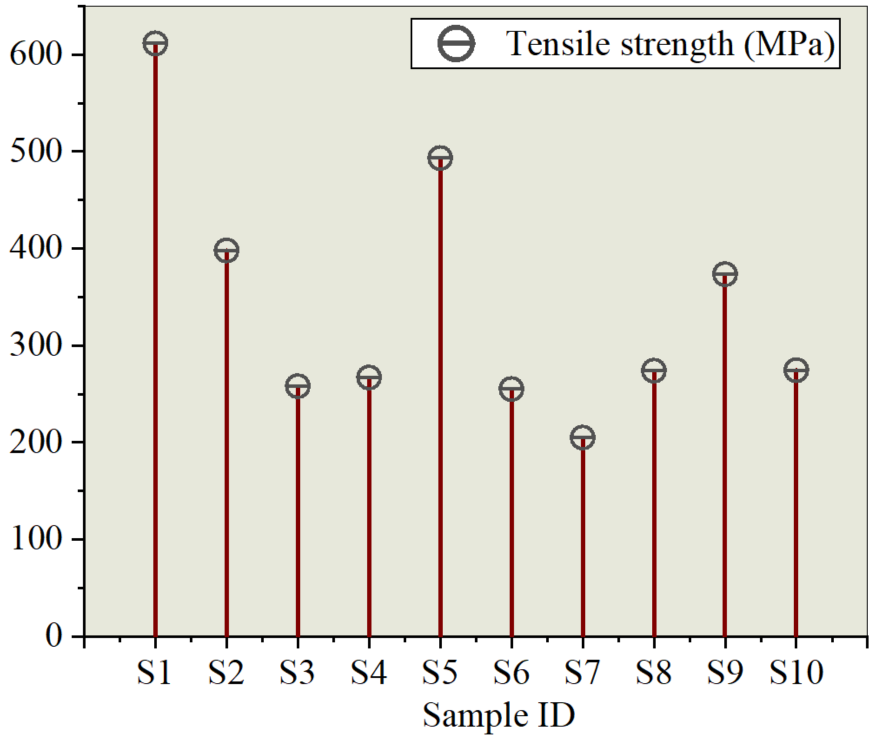
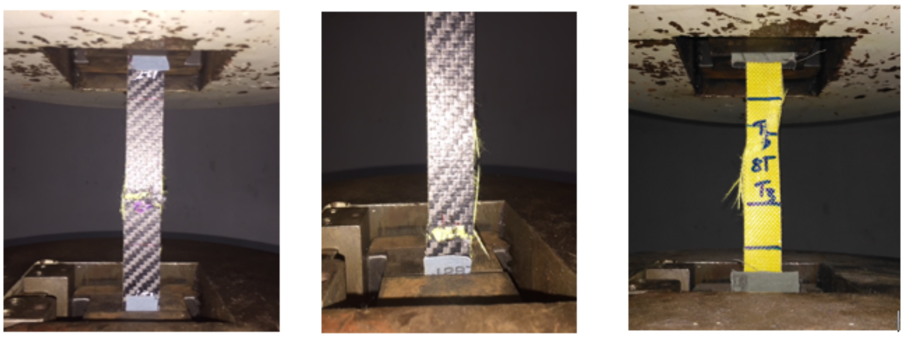


Figure5. Effect of Fiber Loading on Tensile Strength

Table: 1 Tensile Properties of all samples configuration

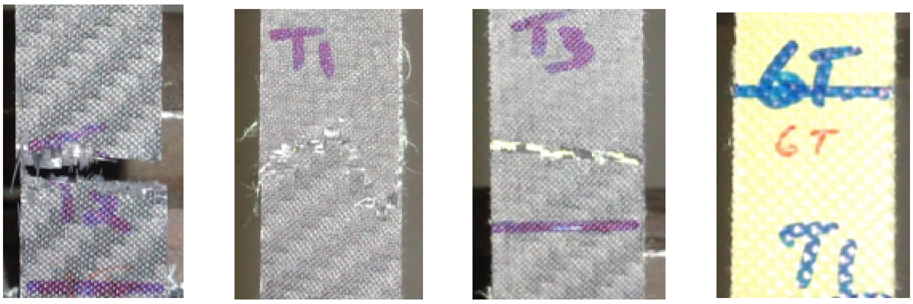
Sample	Load KN	Tensile Strength MPa
S1	40.57	611.61
S2	26.76	397.87
S3	17.49	257.85
S4	18.56	266.94
S5	36.64	493.33
S6	18.18	254.95
S7	16.12	204.88
S8	18.57	274.01
S9	25.49	373.51
S10	24.02	274.45

The various failure modes are observed, typical failures are LAT (Lateral, At grip, Top), LAB (Lateral, At grip, Bottom) and MGT (Multimode: lateral, explosive, edge delamination, At grip, Top). The failure modes are captured during the testing for the sample S1, S9 and S10 are shown in fig. 4. The sample S1 which is carbon reinforced epoxy composites showed that the material is failed due to its brittle behavior as seen in fig. 6(a). The Kevlar reinforced epoxy composite i.e. sample S8 showed a mutli-stepped fractures where the all layers of fibers are fractured and viewed like a brush at the edges at the end of fractures as seen in fig. 7(b). The samples having more content of Kevlar fibers showed a failure behavior of fiber slipping off and fibrillation during tensile testing. In other hand the samples having more content of carbon fibers showed a transverse fracture quite opposite to the loading direction. It is observed that samples fractures were mainly initiated and caused by carbon fiber breakages and delamination of Kevlar fibers and there was small sign on the Kevlar fiber crack. The failure modes of all sample configurations under tensile loading are shown in fig. 7, fig. 8 and fig. 9.



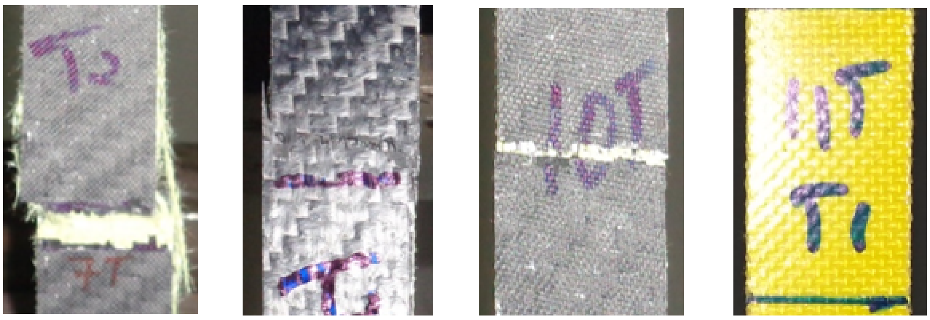
(a) (b) (c)

Figure6.Typical Failure Modes Captured during Testing (a) Sample S1 (b) Sample S9 (c) Sample S10



(a) (b) (c) (d)

Figure7. Typical Failure Modes under Tensile Loading(a) Sample S1 (b) Sample S2 (c) Sample S3 (d) Sample S4



(a) (b) (c) (d)

Figure8. Typical Failure Modes under Tensile Loading(a) Sample S5 (b) Sample S6 (c) Sample S7 (d) Sample S8

(a) (b)

Figure9. Typical Failure Modes under Tensile Loading (a) Sample S9 (b) Sample S10

CONCLUSIONS

Based on the experimentation on characterization for inter-ply hybridization of carbon and Kevlar fibers under tensile loading, presence of carbon fiber content in the samples directly influenced on the tensile strength and strength is independent of fiber orientation. The decrease of Kevlar weight fraction and the increase of carbon fiber content, results gave a higher tensile strength to the hybrid composites. The typical failures of LAT (Lateral, At grip, Top), LAB (Lateral, At grip, Bottom) and MGT (Multimode: lateral, explosive, edge delamination, At grip, Top) were observed in tensile loading.

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