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Evaluation of Tensile and Flexural Properties of Polymer Matrix Composites

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ABSTRACT: *The work presented in this project is to evaluate tensile and flexural properties of Glass, Graphite and Kevlar fiber reinforced polymer matrix composites. Behaviour of different fibre-reinforced composite materials are studied with respect to different thickness. The test specimens are fabricated by simple hand lay-up technique followed by vacuum bag moulding and prepared according to ASTM standards.*

Keywords: *Graphite fiber, Epoxy resin, Glass fiber, Kevlar fiber*

I. INTRODUCTION

The Technology advancements are necessitating exploring materials of unusual combination of properties (mechanical, electrical, corrosion, optical, magnetic, semi conducting dielectric etc). taking cue from natural composite such as wood (which is a composite of cellulose fibers in lignin matrix) and bone (a composite of soft protein called collagen in which hard appetite particles are naturally embedded by bio mineralization process), man has synthesized composite materials to meet the ever increasing property spectrum. This property spectrum is otherwise not obtainable by using metal, ceramics and polymeric materials alone.

The most remarkable features of wood and bones are that the low density, strong and stiff fibers are embedded in a low density matrix resulting in a strong, stiff and light weight composite. Wood and bones in many respects may be considered as predecessors to modern man made composites. The main characteristics of wood and bones are that they are fiber-reinforced composites having low weight and directional properties. Early man used rocks, wood and bones effectively in their struggle for existence against natural and various kinds of other forces. The primitive people utilized these materials to make weapons, tools and many utility articles and also built shelters. Later on they utilized several other materials such as vegetable fibers, shells, clays as well as horns, teeth, skins and sinews of animals. Natural fibers like straws from grass plants and fibrous leaves were used as roofing material. The limitations experienced in using these materials and search for better materials taught them to combine two or more materials to obtain a more efficient material with better properties. This is turn laid the foundation for development of man made modern composite materials. Composite materials have been used from earliest know civilization.

Composite materials were recognized for their strength and lightweight when used in the construction of the first all composite, radar proof airplane. Honeycomb exemplifies natural sandwiched composites which was guided man to build airframe structure. Composite materials in the form of sandwich construction showed that primary aircraft structures could be fabricated from these materials. World War II gave birth to glass-fiber polyester composites for secondary aircraft structures, such as doors and fairings, which were designed and produced. Glass fiber composites were recognized as valid materials for fabrication and production of Polaris submarine missile casings. In the 1950s, fiber technology identified the need for fibers that could compete in strength and stiffness when the state –of- the –art development led to high performance glass fibers, in the late 1950s, research efforts focused on lightweight elements in the search for fibers of even greater strength that could compete successfully in the market place with aluminum and titanium. Boron fibers were the result of this effort (1963), followed by carbon, beryllium oxide, and graphite. A material such as aluminum that served as a matrix surrounded these filaments. These developments, by the collective efforts of government, NASA, industry and universities, gave rise to advanced composites. With continuing quest for new generation of materials, which have improved properties over conventionally available materials, vigorous research activities were pursued in this over conventionally available materials, vigorous research activities [3] were pursued in this desired direction to develop a new class of materials, having light weight, higher strength and a lower costs, the result of extensive research in this specialized field led to the development of composites.

By the broadest definition, a composite material in one in which two or more materials that are different are combined to form a single structure with an identifiable interface, the properties of that new structure are dependant upon the properties of the constitutes material as well as the properties of the interface. In the most familiar world of metals, the mixing of different materials typically forms bonds at the atomic level (alloys); composites typically form molecular bonds in which the original materials retain their identity and mechanical properties.

II. HEADINGS

The Polymer matrix composites are predominantly used for the aerospace industry, but the decreasing price of carbon Fibres is widening the applications of these composites to include the automobile, marine, sports, biomedical, construction, and other industries [4]. Carbon Fibre polymer-matrix composites have started to be used in automobiles mainly for saving weight for fuel economy. The so-called graphite car employs carbon Fibre epoxy-matrix composites for body panels, structural members, bumpers, wheels, drive shaft, engine components, and suspension systems. This car is 570 kg lighter than an equivalent vehicle made of steel. It weighs only 1250 kg instead of the conventional 1800 kg for the average American car. Thermoplastic composites with PEEK and polycarbonate (PC) matrices are finding use as spring elements for car suspension systems [5]. An investigation was conducted by Issac M Daniel et.al [6] on failure modes and criteria for their occurrence in composite columns and beams. They found that the initiation of the various failure modes depends on the material properties, geometric dimensions and type of loading. They reported that the loading type or condition determines the state of stress throughout the composite structure, which controls the location and mode of failure. The appropriate failure criteria at any point of the structure account for the biaxiality or triaxiality of the state of stress. Jeam Marc et.al [7] investigates the modeling of the flexural behavior of all-thermoplastic composite structures with improved aesthetic properties, manufactured by isothermal compression moulding. A four noded plate element based on a refined higher order shear deformation theory is developed by Topdar et.al [8] for the analysis of composite plates. This plate theory satisfies the conditions of inter-laminar shear stress continuity and stress free top and bottom surfaces of the plate. Moreover, the number of independent unknowns is the same as that in the first order shear deformation theory. Banerji and Nirmal [9] reported an increase in flexural strength of unidirectional carbon Fibre/ Poly(methyl methacrylate), composite laminates having polyethylene Fibres plies at the lower face.

III. INDENTATIONS AND EQUATIONS

The reinforcing material such as plain weave bi-woven glass fibres, plain weave bi-woven graphite fibres and plain weave bi-woven kevlar fibres are cut into required size and are laid on the flat surface of the mould. The fibres of the required size are laid along the required direction as per the design requirements. The resin that is LY556 and hardener HY 951 are mixed in the proportions as recommended by the manufacturer in the required proportions that is in the proportions of 10:1 as suggested by the manufacturer is mixed thoroughly and is applied on the laminated surface to be laminated. The resin is spread evenly on the reinforcing fibres, the resin is squeezed evenly on the surface using a roller and compressed thoroughly with the roller it self. The reinforcing fibres are stacked one above the other and the above mentioned procedure is repeated repeatedly. The laminated composite material is enclosed in a bagging and a recommended vacuum pressure is applied on the laminate to remove the entrapped air bubbles in the layers of the laminated composites. The laminated composites are allowed to cure for 24 hours. These laminated composites are post cured at a temperature of 120^0c for 2 hours to ensure the even distribution of the resin and to ensure the proper percolation of the matrix into the reinforcing material. The laminate is ready and this laminate is cut into required size as per ASTM standard and subjected to various tests.

Fig. 1: Vacuum Bag Moulding

Fig. 2: Tensile test specimens before and after test

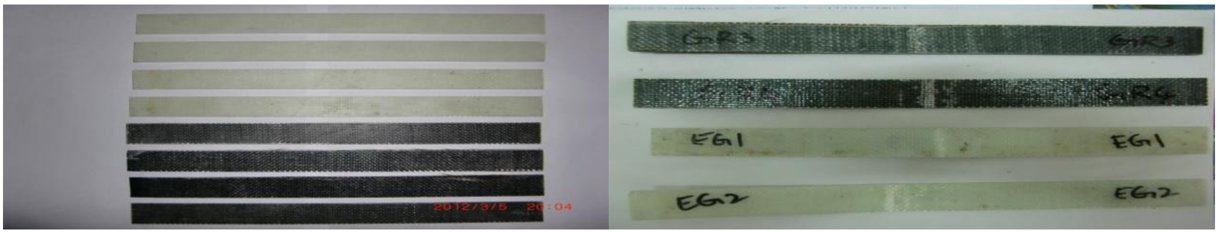


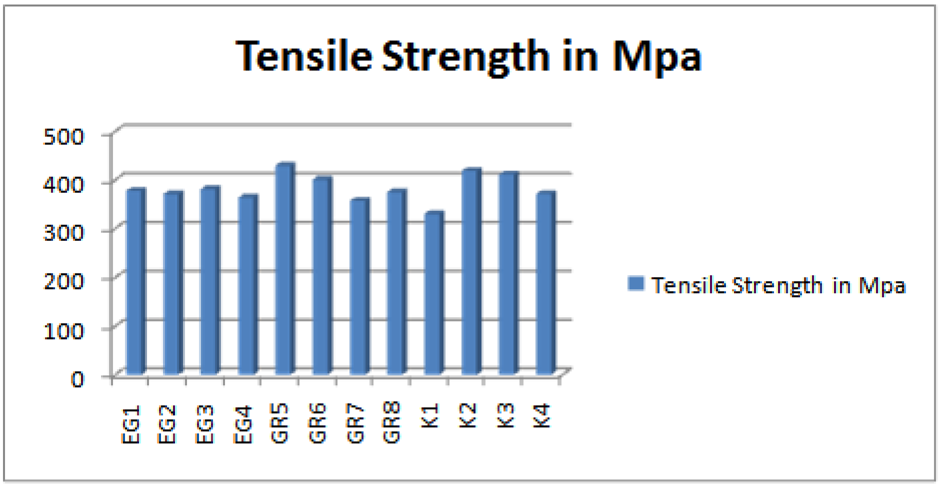
Fig. 3: Flexural test specimens before and after test

IV. FIGURES AND TABLES

Table : 1: Tensile Test Results

Specimen No.	Width (b) mm	Thickness (d) mm	Span length (L) mm	Maximum load (F) (kN)	Deflection at Max. load (mm)	Tensile strength (σ) N/mm^2
EG1	25.2	2.25	50	21.40	13.5	377.43
EG2	24.05	2.25	50	20.08	9.8	371.08
EG3	24.92	3.47	50	32.96	11.2	381.16
EG4	24.62	3.39	50	30.36	12.6	363.76
GR5	25.2	1.83	50	19.80	7.5	429.35
GR6	25.08	1.83	50	18.40	7.6	400.90
GR7	24.96	4.8	50	42.76	13.9	356.90
GR8	24.84	4.8	50	44.72	13.3	375.07
K1	12.73	1.99	50	8.36	9.2	330.01
K2	12.71	2	50	10.64	12.2	418.57
K3	12.99	2.98	50	15.92	12.7	411.26
K4	13.09	2.88	50	14.00	12.8	371.36

EG: E-Glass Laminates, GR: Graphite Laminates, K: Kevlar Laminates

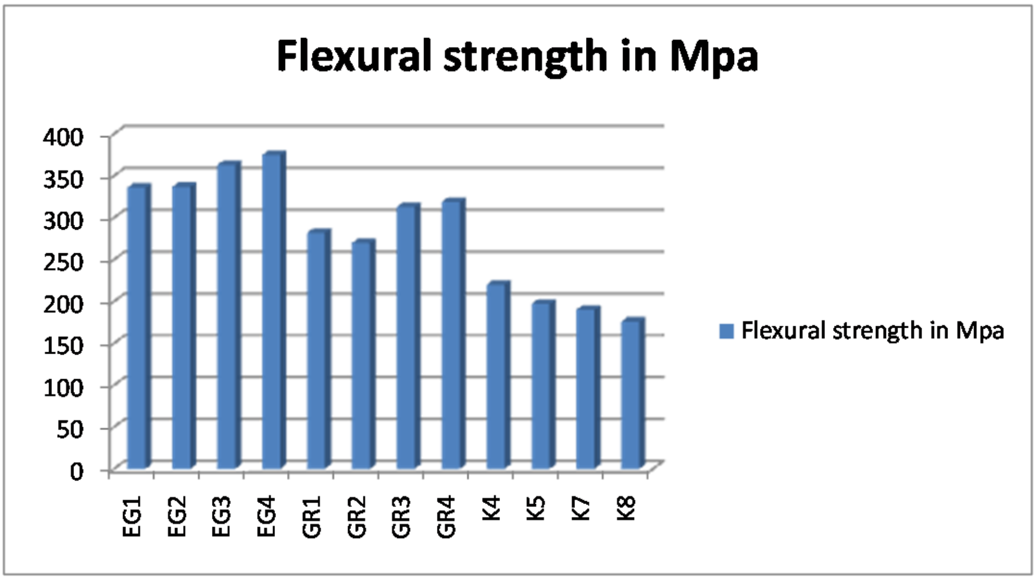


Graph: 1: Tensile strength vs specimen

As a preliminary method of investigation, the tension test is conducted on the three types of the specimens that is, glass, graphite and kevlar reinforced laminates. The basic desired mechanical property like the tensile strength and % elongation of the specimen is evaluated by performing the tension test on the three different types of the laminates for 2mm and 4mm thick specimens. Table shows the ultimate tensile strength and % elongation for glass fibre reinforced laminates, graphite fibre reinforced laminate and kevlar fibre reinforced laminate. The graphite fibre reinforced laminates show greater strength when compared with glass fibre reinforced laminates. The graphite fibre reinforced laminates exhibit less strength than kevlar fibre reinforced laminates. Glass fibre reinforced laminates shows a moderate strength under tension strength but satisfies the required value of strength requirement for the mechanical applications that can be used for the sheet moulded components. The different strength values are attributed to their basic properties of the reinforcement materials. Glass fibre reinforced specimen exhibits more elongation than the graphite and kevlar reinforced laminates.

Table : 2: Flexural Test Results

Specimen No.	Width (b) mm	Thickness (d) mm	Span length (L) mm	Maximum load (F) (kN)	Deflection at Max. load (mm)	Stiffness (P/Δ) N/mm	Flexural strength (σ) MPa
EG1	24.9	2.2	100	0.27	18.5	20	336
EG2	24.8	2.2	100	0.27	16.5	22	337
EG3	24.3	3.5	100	0.72	10.2	70	363
EG4	25.5	3.5	100	0.78	11.0	76	375
GR1	25.3	2.2	100	0.23	13.5	17	282
GR2	25.2	2.2	100	0.22	13.8	15	270
GR3	25.4	3.5	100	0.65	8.8	75	313
GR4	25.3	3.5	100	0.66	9.4	75	319
K4	11.0	2.1	100	0.071	16.0	8.6	220
K5	12.1	2.1	100	0.070	15.8	8.4	197
K7	12.5	3.0	100	0.142	9.5	29	190
K8	12.5	3.0	100	0.132	8.5	28	176



Graph: 1: Flexural strength vs specimen

Table 2 shows the influence of the reinforcing fibre type and thickness used that is the influence of the glass, graphite and kevlar Fibres on the flexural properties of the specimen. It was observed that glass Fibre reinforced laminates dominates in its flexural properties with other fibres having the lower value in the series. But when these laminates compared with some of the auto parts (presently used in automotive vehicles), the laminated composites made of bi- woven fabrics of glass, graphite and kevlar laminates exhibited excellent properties. Even the glass Fibre laminates with 4mm thickness which recorded the highest flexural strength is observed to be having better flexural properties.

V. CONCLUSION

- A simple tensile and flexural test was conducted to estimate the tensile and flexural strength in variety of Composites with varying thicknesses.
- The graphite fibre reinforced laminates show greater strength when compared with glass fibre reinforced laminates. The graphite fibre reinforced laminates exhibit less strength than kevlar fibre reinforced laminates. Glass fibre reinforced specimen exhibits more elongation than the graphite and kevlar reinforced laminates.
- Possible Failure modes of the composite specimens with different fibres have been analyzed and maximum load corresponding to the Failure mode that can occur have been computed and compared with the non-linear point of the load versus deflection plot and excellent agreement has been found.
- The tensile and flexural test conducted illustrated that with increase in thickness of the specimen of the same type there is an increase in the tensile and flexural properties of the specimens.
- The studies further showed that with the variation in the fibre type used has a significant effect on the tensile and flexural properties of the specimens, the three varieties of fibres used are plain bi-woven glass fibre reinforced laminate, plain bi-woven graphite fibre reinforced laminate and plain bi-woven kevlar Fibre reinforced laminate.

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