REINFORCEMENT EFFECT OF KEVLAR FABRIC ON THE MECHANICAL PROPERTIES OF EPOXY RESIN

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Abstract - ***In this study the effect of 10wt% Kevlar reinforcement on the mechanical properties of the epoxy has been evaluated. The epoxy resin used in the current investigation was Bisphenol A. Hand layup technique was used to prepare the composite. Results of the mechanical properties of composites were obtained by tensile, bending and compression tests. SEM was used to observe reinforcement and matrix fractures. Addition of Kevlar to the epoxy matrix led to a noticeable increase in the mechanical properties of the composite. A moderate rise in compression strength was observed.***

Key Words: *Polymer matrix composites, Kevlar fabric, Mechanical properties, SEM analysis.*

1. INTRODUCTION

Epoxy resins offer unique combination of mechanical properties which are least formed by other thermoset materials. Most of the PMC's are produced using epoxy resins as matrix due to its high mechanical properties. Varieties of techniques are being used to improve its mechanical properties; one of them is reinforcement of composites which is produced by combining various reinforcements with neat epoxy. Thus the properties of different individual materials are contributed in a single composite [1]. Aramid fiber such as Kevlar is very widely used reinforcement material in current use of composites. The high degree of toughness of the fibers made them tolerable to failure mechanism. The failure of aramid fibers or when they break, they do not scatter like glass but fail by a series of small fibril failures. Most of the energy is absorbed by these small failures and high toughness is formed [2]. Hybridization is also an approach to improve mechanical properties of epoxy resin. In this combination there is a reinforcement material which has a property by virtue of which the defect of other reinforcing material is covered up [3].

2. EXPERIMENTAL

2.1MATERIALS

Kevlar fabric 460gsm, with thickness 1.5mm supplied by Super safety services, Mumbai was used. The matrix material used was an epoxy from the family of thermoset polymers, named Bisphenol A (POLYFLEX GR 200-30) and hardeners viz., promoter (POLYFLEX SC 999-40), accelerator (POLYFLEX SC 999-30) and catalyst (ANDONOX KP-9) were supplied by Naptha Resins and Chemicals, Bangalore.

2.2 Specimen preparation:

10wt % Kevlar fabric corresponding to neat epoxy was weighed using digital weighing machine. The fabric was cut suitably to fit into the mold. The resin (90 wt %) was taken in a beaker and proportionate quantity of promoter, accelerator and catalyst were added to the epoxy resin. Once the hardeners were added, the mixture was stirred well using handheld electric blender. The mixture was kept aside and was allowed to settle down so that the bubbles rise and collapse. Two separate molds were used for tensile/bending test and compression test respectively. Once it was confirmed that all the bubbles were collapsed in the resin, the moulds were sprayed with releasing agent and a single layer of resin was slowly transferred into the mould, avoiding any turbulence. The releasing spray was meant for easy removal of the composite after curing. After this, the pre-cut Kevlar fabric of 460 gsm was laid on the layer of pre-poured resin in the mould. Rolling was facilitated to avoid formation of voids in the composite. Apart from assisting escaping entrapped gas, it also makes the resin to penetrate between the Kevlar fibers and enable thorough impregnation. Thus the porosity in the composite was controlled which otherwise would have be the reason for composite failure. One more layer of resin was poured into the mould. The uncured composite was allowed to cure at room temperature for 48 hours. In case The cured composite material removed from the tensile/bending mold was a rectangular slab which was cut to the required dimensions as per ASTM standards. The specimens were cut by using high speed cutting machine (Hitachi PDA 100D available at KLS's Gogte Institute of Technology, Belagavi) according to ASTM standard D 3039/D 3039M for tensile test, D 790 – 02 for bending test and D 695 – 02a for compression test respectively.

2.3 Measurement of mechanical property

The mechanical properties viz., tensile strength, bending strength and compression strength were determined by testing the prepared specimens using Universal Testing machine, with a maximum loading capacity of 400kN available at KLS's Gogte institute of technology, Belagavi. The tensile test specimens were provided with tabbing. The tabbing was done using a commercially available adhesive named Araldite on both the faces and both the ends of the specimen and was allowed to dry for 24 hours. 45^{o} grooves were made on the tabbing to facilitate better grip during testing. The prepared specimens were loaded and load was applied until the specimens were fractured.

The bending test specimens were of rectangular cross section. 3-point bend test was used to obtain bending strength. For supports, the span to depth ratio was maintained at 16:1 as per the ASTM standard. The test specimen was supported at its ends of the span length and the bending load was applied at the centre of the span through a cylindrical loading nose. The specimens were loaded until the composite specimen fractured under bending load.

Compression test specimens were cut in prism shapes with the dimensions as per ASTM standard. The ends of the specimens were machined so that flat surfaces were obtained. The test specimen was placed between the surfaces of the compression tool, aligning the centre line of long axis of specimen with the centre line of the plunger, ensuring the parallelity between the ends of the specimen with the surface of the compression tool. The cross head of the UTM was adjusted such that the compression test tool plunger just touches the top surface of the specimen. Compression load was applied until the specimen fractures.

of compression test specimens, alternate layers of resin and fabric were laid for 10wt% of the reinforcement.

3. CONCLUSIONS

The results of the tests carried out were tabulated in Table 1. It was observed that with 10wt% Kevlar fabric reinforcement, there was improvement in tensile, bending and compression strength compared to the neat epoxy. The tensile strength of neat epoxy as given in Table 1 was found to be 76.41MPa. Bending and compression strength were 88.21 MPa and 100.36 MPa respectively. These values were compared with the Kevlar reinforced epoxy composite.

From Table 1 it was observed that the tensile strength of Kevlar reinforced epoxy resin is 91.62 MPa which shows 19.9% increase in tensile strength compared to the neat epoxy. The Young's modulus of the Kevlar reinforced composite was found to be increased by 7.23%. The increase in tensile strength and Young's modulus was due to inherent properties possessed by Kevlar fabric. As a result when epoxy resin was reinforced with Kevlar, the tensile strength was improved.

The bending strength of Kevlar reinforced epoxy resin composite was found to be 88.21 MPa which exhibits 16.17% increase in bending strength compared to neat epoxy.

Table-1: tensile, bending and compression test results

Material	Tensile Strength	Young's modulus	Bending Strength	Compressive Strength
Neat Epoxy	71.86	8.98	93.78	91.96
	82.94	10.36	82.73	104.74
	74.45	9.30	88.12	104.38
Mean	76.41	9.54	88.21	100.36
	91.56	11.44	117.45	106.40
	95.76	11.97	93.73	111.78
	87.56	7.30	96.27	107.10
Mean	91.62	10.23	102.48	108.42

The load applied on the composite was uniformly distributed to the woven fibers. Kevlar fabric is more efficient in this regard as short fibers relatively carry lesser load than the woven fabric. Overall sharing of load was possible with Kevlar fabric which tends to improve bending strength of the resin.

The compressive strength obtained for the composite was 108.42 MPa which shows 8.03% increase as compared to neat epoxy. From the compressive test results it was also proved that the compressive strength of the prepared composite is better. The alternative layers of Kevlar fabric and resin helped in sharing the compressive load applied and withstanding pre-mature deformation. The higher mechanical properties of Kevlar fabric and better bonding between the resin and reinforcement together improved compressive strength of the composite.

Chart 1 shows graph of comparison of tensile, bending and compressive strength of neat epoxy and Kevlar reinforced epoxy composite. The Kevlar fibers possess high tensile strength and also the fibers are tougher. When epoxy resin was reinforced with Kevlar fabric all the properties of Kevlar fabric contributed in improving the mechanical properties of the neat epoxy.

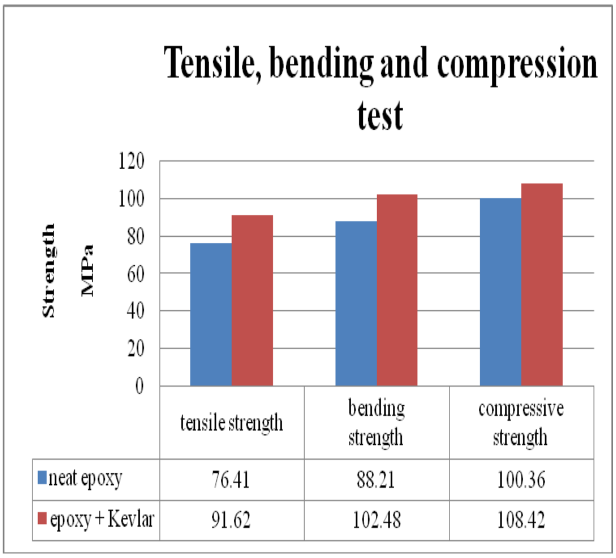

Chart -1: Comparison graph of tensile, bending and compression tests

Fractured surface of resin and reinforcement was studied by Scanning Electron Microscopy. The tests were carried out using machine JSM-6360LV. Samples of volume from the fractured tensile test specimen were used for conducting the test. Fig. 1a) shows test specimen of Kevlar fabric reinforced epoxy resin composite, with magnification of 500X. From the image it was observed that the fibers were extended outward. This was due to highest stretching under tensile load. In Fig. 1b) with magnification 2000X the extended fibers were clearly visible. It was observed that traces of epoxy resin were present on the fiber surface indicating a better bonding between Kevlar fabric and epoxy resin in composite [3]. The better bonding between epoxy and Kevlar resulted in improving mechanical properties of the composite.

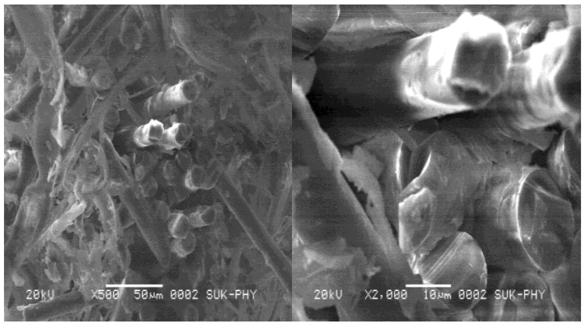

Fig -1: a) and b) SEM Micro structure of Kevlar reinforced epoxy resin

4 CONCLUSIONS

From the tests carried out namely tensile, bending and compression tests and the SEM test, the properties of the composite were studied in this investigation. 10wt% Kevlar fabric corresponding to neat epoxy improves mechanical properties of the epoxy resin. Kevlar is an economical reinforcement material possessing high mechanical properties. It is recommended to use Kevlar fabric to improve mechanical properties of epoxy resin. Mechanical properties of epoxy resin can be further improved by varying amount or reinforcement. Kevlar reinforced epoxy resin composite is stronger composite and is suitable for use in light weight applications. Filler addition to epoxy/Kevlar can be further studied to produce hybrid composite.

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