"FLEXURAL STRENGTH OF BASALT FIBER REINFORCED WITH TUNGSTEN CARBIDE FILLER FILLED EPOXY COMPOSITES"

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Abstract: This article presents the flexural behaviour of basalt fiber reinforced polymer epoxy composites. The natural basalt fiber is reinforced with filler material such as Tungsten Carbide of different proportion like 2%, 4%, 6% and 8 wt. %. Total 5 composition specimen was considered for experimental work. A Vaccum bag pressure method is used to fabricate the laminates. The addition 2wt. % of tungsten carbide filler material shows excellent flexural properties compared to other combination of basalt fiber and filler ratio. It's clearly reveled the, the addition of filler material shows a better results than the without filler filled epoxy composites. In conclusion, the results highlighted the importance of incorporation filler material with results to flexural behaviour of laminates.

***Index Terms* – Basalt, Flexural Strength, Polymer Composites, Tungsten Carbide.**

I. INTRODUCTION

In present years, basalt fiber attention of all automobile and aerospace application area where all possibilities of replacement the conventional all metal and other high cost material. Basalt having exceptional properties likes environmental friendly, physical and chemical properties than other synthetic fibers. In one point, many authors concluded the basalt fiber is having higher strength and durability than the E-glass, but unfortunately lower strength than carbon fiber reinforced epoxy composites. When compared with carbon fiber in particular application point of view like strain rate basalt fiber is having better strain rate. Now a day's basalt fiber playing an extensive role in high temperature, chemical stability and higher impact properties. In this paper, basalt fiber is filled with tungsten carbide filler material in order to improve the flexural properties of material. Thus it can be improve thermal conductivity and high temperature application.

Thus, they can be used at high-temperature applications. However, these are restricted to moulding only. Polymers will be incorporated with some reinforcements to generate a composite so that the mechanical properties of polymer improve in most practical applications. Polymer matrix composites have generated a significant amount of attention in the current material research field because the structural components are manufactured with fibers/fabrics composites, and hence leading to a high strength-to-weight ratio [1]. Industry often faces some scientific problems for the composites. The lack of knowledge/understanding/mass production or new processing technique, materials, standardization/design/solution methods and recycling are the key fields, which must be developed. Thus, then the costs for the composites will be decreased and can found many new applications. Another obstacle may be added as the lack of long durability and performance when servicing at various environment/temperature, especially for polymer composites.

In the last few years, basalt fibers have been used as reinforcements for thermoset plastics such as epoxy, polyester and vinyl ester resin to manufacture composite's structural parts. Among them, epoxy is one of the most important matrixes that have found a special place for the thermoset polymers due to having its excellent mechanical properties associated with chemical and corrosion resistance [2]. Lopresto, et al. [3] investigated some mechanical property using E glass and basalt fiber to evaluate the substituting the basalt fibers for the glass fibers. The experimental results exhibited that basalt revealed higher for elastic modulus, compressive, bending strength, impact force and energy, but a better tensile strength was obtained for the glass fibers. Dorigoto and Pegoretti [4] studied the tensile and fatigue behavior of epoxy reinforced with woven basalt, E-glass and carbon fibers. They reported that higher performance of the laminate was obtained using basalt fabrics when compared to glass fiber composite. Colombo, et al. [5] found a higher mechanical property against vinyl ester and indicated a more compact failure mode since fibers did not tend to explode. Wei, et al. [6-7] demonstrated that the better acid resistance was obtained for the basalt reinforcements when they were treated with sodium hydroxide hydrochloric acid solutions in various times. Wei, et al. [8] found that anti-seawater corrosion properties of both composites like basalt and glass fibers were the same approximately. Carmisciano, et al. [9] indicated that a higher flexural modulus and interlaminar shear strength was obtained for the basalt fiber composites had when compared with E-glass fibers; however, a lower flexural strength was observed, while similar electrical properties were provided. Fiore, et al. [10] investigated the glass-basalt/epoxy composites for ship applications using three-point bending tests. Tensile tests were also carried out to evaluate the impact number and position of basalt layers. The results exhibited that the existence of external layers of basalt could cause the highest escalations in the mechanical properties of hybrid laminates with respect to glass fiber reinforced plastic laminates. The basalt polyester composites under static three-point bending loading and low-velocity impact loading were analyzed by Gideon, et al. [11], with the conclusion that unidirectional laminate indicated a superior performance with respect to woven and cross-ply in static loading, but cross-ply and woven laminate composite were superior in dynamic loading condition, respectively. In addition, vinyl ester-basalt fiber reinforced composites were used as matrix [12]. Basalt fibers can be used with thermoplastics like polypropylene, phenolic and polyethylene. The mechanical properties including tensile and flexural strength of various polymers improved when basalt and other fibers were introduced [13].

II. MATERIALS

Basalt reinforced polymer epoxy composites were fabricated through Vaccum Bag Resin Transfer method. The twill weave fabric having 350 GSM supplied from Nickunj Pvt. Ltd, Mumbai. The resin LY556 and Hardener HY951 were used in the ratio of 100:10, but fiber and epoxy ratio maintained in the ratio of 60:40. There are five types of basalt reinforced epoxy composites were fabricated without and with the incorporation of filler such as Tungsten Carbide having different weight percentage proportion like 0%, 2%, 4%, 6% and 8%. A typical hand layup molding process used followed by Vaccum Resin Transfer Technique.

Table 2. 1. Properties of Tungsten Carbide

Tungsten Carbide	Properties
Molecular weight	195.9
Color	Grey
Physical state	Hexagonal Crystal
Melting point (°C)	2,785°C
Boiling point (°C)	6,000°C
Density	15.6 gm/cm3
Solubility Water nitric acid Hydrogen fluoride	 In soluble Soluble
Micro-hardness	1730 kg/mm2
Hardness	89.5 HRA
Bending strength	1550 N/mm2

Table 2. Properties of Twill Weave Basalt Fabric

Properties	Values
Base Material	Basalt Fabric
Density of un-sized filament material	2.63 kg/dm3
Moisture content of basaltic rock	0.1 %
Melting point	1350 °C
Specific surface weight	350 g/m2
Weave Type	Twill
Weft & warp Yarn Specification	13micron
Weft & Warp picks	5 X 5 (ends/10mm)
Width	1000 mm
Sizing type	Silane
Moisture content(fabric)	<0.3%
LOI (Loss of Ignition) sizing content	<0.4-0.6 %

III. METHODOLOGY

In this section, a detailed procedure followed for preparation of laminates and cut the specimen as per ASTM standard to carry out experimentation.

I. Preparation of laminates includes following steps.
II. Mold preparation (Floor cleaning process with the help of acetone) and applying the releasing agent to remove the laminates from the moulding plate easily without any defecting the laminates.
III. Fabric/fiber preparation (Cut into 300*300 mm) cross-section
IV. Resin preparation (incorporation of filler material)
V. Resin impregnation
VI. Laying up/ stack up the fabric one over others (11 plies) to make the thickness of laminates as per ASTM standard 2.8- 3.0mm.
VII. Seal the laminates and apply Vaccum pressure to release the excess resin in the molding.
VIII. Curing the laminates at room temperature about 24 hours and post-curing at 100^{o} for 2 hours.

The laminates (300*300*3.0 mm) were prepared and cut the specimen as per ASTM D-790 with the help of Abrasive Water Jet Cutting Machine. A systematic study has been carried out to learn the flexural behaviour of basalt fiber reinforced with tungsten carbide filler material.

Fig3.1. Basalt Twill Weave Fabric

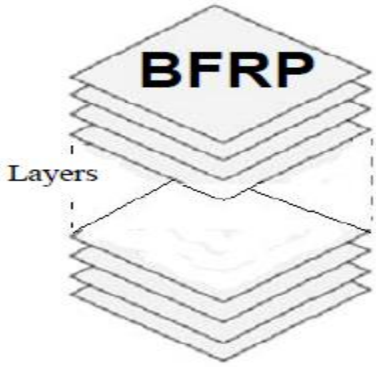


Fig 3.2. Stacking Sequence of Basalt Fabric Layers

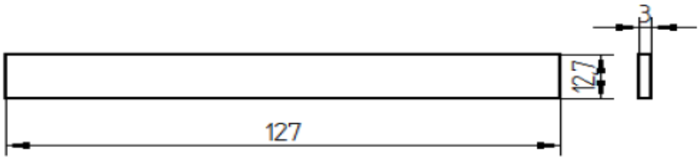


Fig 3. 3. ASTM D 790 Dimension

IV. EXPERIMENTAL STUDY

The flexural strength of a material is defined as the maximum bending stress that can be applied to that material before it yields. The most common way of obtaining the flexural strength of a material is by employing a transverse bending test using a three-point flexural test technique. The flexural strength of the composite was determined for the following specimen.

Table 4.1. Composition of laminates

Composition	Fiber Wt.%	Epoxy Wt. %	Filler (Tungsten Carbide) Wt.%
Basalt Epoxy (B-E)	60	40	0
B-E + 2% WC	60	38	2
B-E + 4% WC	60	36	4
B-E + 6% WC	60	34	6
B-E + 8% WC	60	32	8

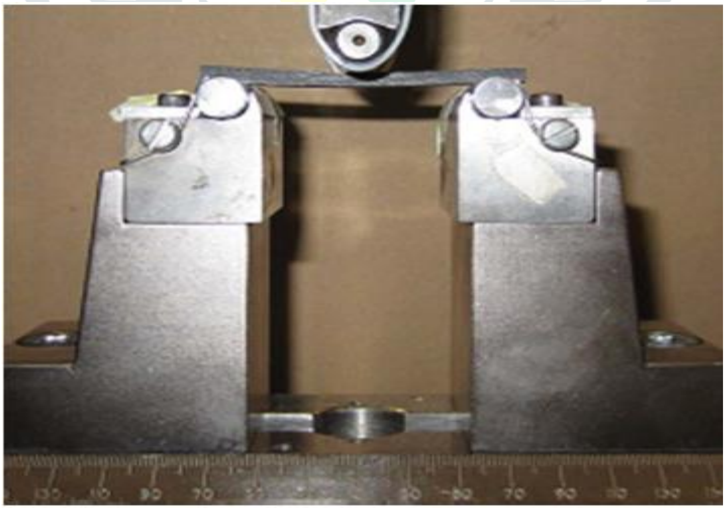


Fig 4.1. Three Point Bending Testing Machine

Table 4.2. Composition of laminates

Composition	Filler %	Peak Load (N)	% of Deflection (mm)	3 Pt. Bend Flexural Strength (MPa)
Basalt-Epoxy	0%	239	7.46	250.70
Basalt-Epoxy	2%	421	8.43	442.25

+ Tungsten Carbide	4%	269	10.72	281.91
	6%	312	6.69	328.08
	8%	353	7.43	370.70

V. RESULTS AND DISCUSSION

It's clearly reveals the, addition of filler material in the basalt fiber shows the better flexural strength than no filler filled basalt epoxy composites. Flexural peak load increase with the increase with increase in the addition of filler material at 2 wt. % again decrease at 4wt.% , then gradually increase at further 6 wt.% and 8 wt. %. The 3point bend flexural strength varies between 250.70 MPa to 442.25 MPa. From table 4. Basalt fiber reinforced without filler has shown similar trend with basalt fiber reinforced with 4% tungsten carbide filler material. But more effectiveness in flexural strength can be observed other weight ratio of filler filled basalt epoxy composites. As the fiber reinforced with excessive filler material may act as crack initiation and also require less energy to fail due to more hardening of fibers. Basalt fibers have ability to resist cracking in specimen and attain more stiffness and deflection, while reinforced with filler material compared with no filler filled epoxy composites.

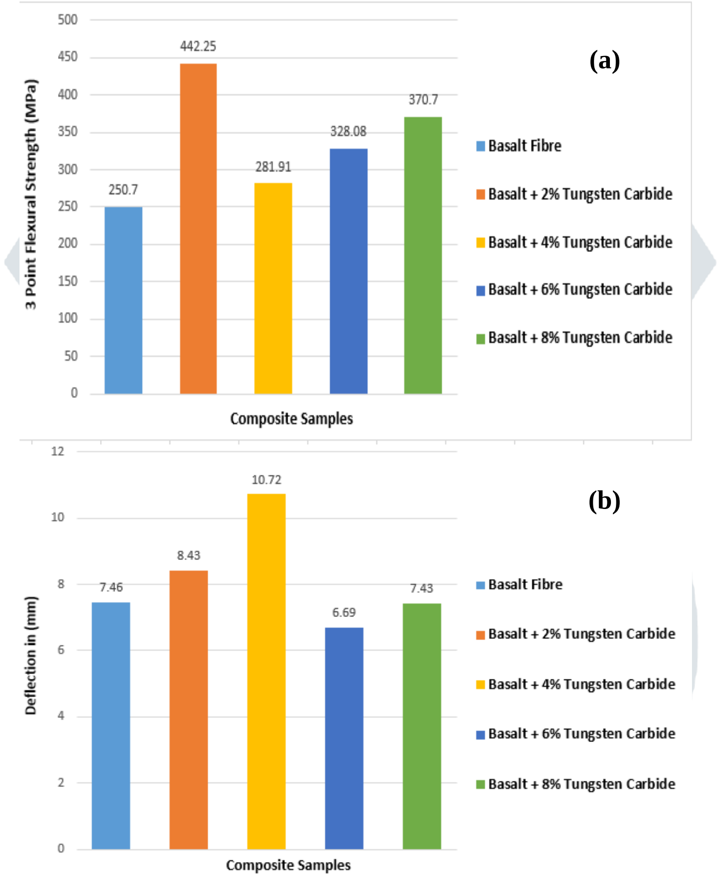
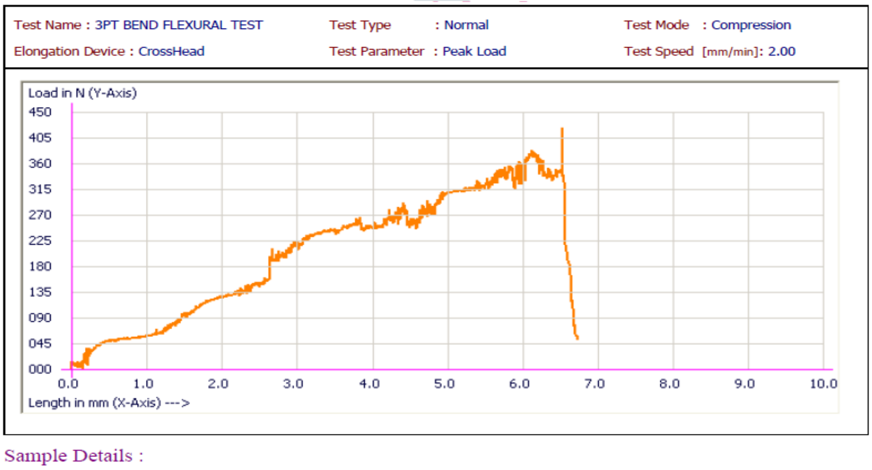


Fig 5.1. (a) 3 Point Flexural strength of Basalt Epoxy Composites (b) % of Deflection in Basalt Epoxy Composites



Sample No.	CS Area (mm²)	Peak Load (N)	%Elongation	Break Load (N)	3Pt Bend Flexural Strength (MPa)	3Pt Bend Flexural Moduli (GPa)
000001	38.10	421.00	8.43	35.30	442.25	4113.62

Fig 5.2. Load v/s Length of 2% of Tungsten Carbide Filler Filled Epoxy Composite Graphical Report

VI. CONCLUSION

- In this context, the fiber-reinforced polymer composite was fabricated with Basalt fiber using Vaccum Pressure Bagging Method. The primary mechanical property flexural strength from computerized Universal Testing Machine is investigated and the following conclusions were drawn.
- The flexural strength of basalt epoxy without filler is low compared from filler filled basalt epoxy composites, which varies from 250.70 MPa to 442.25Mpa.
- The percentages of deformation also vary from 6.69% to 10.72%, which clearly shows deformation not proportional to loading condition.
- The flexural strength shows the maximum value at 2% wt. of filler material and further addition filler material results in lower the tensile strength but better than without filler filled basalt epoxy composite.

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