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Research Article

Mechanical and Water Absorption Properties of Hybrid Sisal/Glass Fibre Reinforced Epoxy Composite

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Abstract

Our environment is being pullulated due to the great use of synthetic fibre as reinforcement for polymer composites. Natural fibres may be better choice for replacement of synthetic fibre for polymer composite to reduced environment burden. Hybrid sisal/glass fibre reinforced epoxy composites are prepared by hand lay-up technique using different weight fractions (10, 20, 30 and 40 %) with 10 mm length of fibres. Mechanical and water absorption properties of prepared composites are investigated. This study shows that the addition of glass fibre into sisal fibre reinforced composite has increased its mechanical properties. Statistical analysis is also carried out using T-test and ANOVA and found significant variation among composites.

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1. Introduction

Natural fibres (jute, banana, sisal, Kenaf, hemp, bamboo etc.) are being used in place of glass and other synthetic fibres due to its acceptable mechanical properties. Natural fibres have many advantages such as low cost, low density, availability in abundance, environmental friendly, renewability, biodegradability, relative easy processing, high specific strength and modulus [1-8]. Recently, natural fibre reinforced polymer composites are being used in automotive parts, building materials and electrical industries [9-14]. However, natural fibres have some disadvantages such as lower impact strength and higher moisture absorption which cause unsuitability of these composite in outdoor applications.

Single natural fibre reinforced polymer composites have lower mechanical strength than synthetic fibre reinforced polymer composite due to its limitations. Hybridization process can improve the mechanical strength of natural fibre reinforced polymer composite by reducing its limitations. Addition of another type of fibres having higher elongation into single natural fibre reinforced polymer composite is hybridization. Various researchers have reported study on hybrid composites in which the glass fibre is reinforced with different types of natural fibres due to its excellent properties such as light weight and high strength. Sreekala et.al [15] investigated the mechanical properties of hybrid glass and oil palm fibre reinforced phenol-formaldehyde composite. The composites were prepared by Hand lay-up method followed by compression moulding. The results indicated that the tensile and flexural properties of oil palm fibre composite enhanced by incorporation of small volume fraction of glass fibre. Similar type of work on tensile and interfacial properties of unidirectional flax/glass fibre reinforced hybrid composites is reported by Zhang et.al [16]. They found that flax fibre exhibited better tensile properties due to incorporation of glass fibre. Ramesh et.al [17] investigated the mechanical property of sisal/jute/glass fibre reinforced polyester composites. Their results indicated that the jute/glass polyester composites showed maximum tensile strength, sisal/glass polyester composite showed maximum impact strength and sisal/jute/glass polyester composite showed maximum flexural strength. The present study aims to investigate the mechanical and water absorption properties of sisal fibre reinforced epoxy composite. Morphological analysis of sample is studied to observe the fracture behaviour of hybrid sisal/glass fibre reinforced epoxy composites using scanning electron microscope.

2. Materials and Experimental Procedure

2.1. Material

The Epoxy resin (AY-105), Hardener (HY-951), sisal fibre and glass fibres are purchased from local resources. The density and dynamic viscosity of epoxy claimed by dealer at 25 ℃ are 1.109 g/cm^3 and 11.79 Pa.s respectively.

2.2. Preparation of composite

Hand lay- up technique is used to fabricate the hybrid composite by reinforcing sisal and glass fibres into epoxy matrix. Composites are prepared in different weight fractions (10, 20, 30 and 40 wt. %) with randomly oriented 10mm of glass and sisal fibre. A stainless steel mould having dimensions of 500 × 300 × 3 mm^3 is used for casting of composites. Silicon spray is used to facilitate easy removal of the composite from the mould after curing. The cast of each composite is cured under a load of 50 kg for 24 hours before it is removed from mould. Dimension of specimens are cut as per ASTM standard using a diamond cutter for tensile, flexural and impact test. The different composites are manufactured with varying wt. % of fibres as given in Table 1.

Table 1 Nomenclature of hybrid composites

Hybrid composites	Wt.% of sisal fibre	Wt.% of glass fibre	Wt.% of reinforcement	Wt.% of matrix
S5G5	5	5	10	90
S10G10	10	10	20	80
S15G15	15	15	30	70
S20G20	20	20	40	60

2.3. Mechanical Testing

Mechanical test (Tensile test, flexural test and impact test) on the specimens of epoxy and hybrid sisal/glass reinforced epoxy composite are carried out. Five separate specimens of each composite are tested and their average value is reported.

2.3.1. Tensile Test

The tensile test of epoxy and hybrid composites is conducted on Tinius Olsen H 10 K-L (Bi-axial testing machine) at crosshead speed 2 mm/min. The specimen for tensile test is of dimension 165 mm × 20 mm × 3.2 mm with gauge length 53 mm as per ASTM D 638. The tensile modulus is calculated from slope of initial straight-line of stress-strain curve.

2.3.2. Flexural Test

The flexural test is conducted by using three point bending test method on Tinius Olsen H10 K-L (Bi-axial testing machine) at room temperature (30 ℃) with crosshead speed 2mm/min. The specimen having dimension 80 mm × 13mm × 3.2mm with span length 48mm as per ASTM D 790 is used for flexural test of epoxy and hybrid composites. Flexural strength and flexural modulus are calculated by equations (1) and (2) respectively.

$$\text{Flexural strength} = \frac{3FL}{2wd^2} \tag{1}$$

$$\text{Flexural modulus} = \frac{mL^3}{4wd^3} \tag{2}$$

where F is ultimate failure load (N), L is span length (mm), w and d are width and thickness of specimen for flexural test respectively and m is the slope of the initial straight-line of the load-deflection curve.

2.3.3. Impact test

Tinius Olsen Impact 104 machine is used to conduct Izod impact of epoxy and hybrid composites. The specimen of dimension 65 mm × 13 mm × 3.2mm with 2.5mm notch thickness as per ASTM D 256 is used for impact test.

2.3.4. Statistical analysis

Significance of testing of composites is determined by statistical analysis. T-test and Analysis of variance (ANOVA) are used to find out the statistical analysis of tensile, flexural and impact test. Probability value P =0.05 is consider as an analytical of significance compared to the control composite (S5G5).

2.3.5. Water absorption properties

Tendency of moisture absorption in humid air or in water was found by natural fibres reinforced polymer composite. The effect of moisture absorption causes the degradation of fibre-matrix interface region as resulting in a reduction of mechanical properties along with change in dimensions of composites. Water absorption properties of hybrid sisal/glass fibre reinforced epoxy composite are investigated as per ASTM D 570. The content of water absorption by sample is found out using a precise 4-digit balance. The percentage of water absorption is given by [21]:

$$\text{Water absorption (\%)} = \frac{W_2 - W_1}{W_1} \times 100 \qquad (3)$$

Where W_1 = weight before soaking into water (g) and W_2 = weight after soaking into water (g).
Water absorption characteristics parameters such as diffusion coefficient, sorption coefficient and permeability coefficient are calculated as follows.

$$\text{Diffusion coefficient } (D) = \pi \left(\frac{t^2 m^2}{16 M_s^2} \right) \qquad (4)$$

where m is the slope of linear portion of the sorption curve and t is the initial sample thickness in (mm).

$$\text{Sorption coefficient, } S = M_s \,/\, M_t \qquad (5)$$

Where M_s and M_t are percentage of water uptake at saturation time and at a specific time t.

$$\text{Permeability coefficient, } P = D \times S \qquad (6)$$

2.3.6. Scanning electron microscopy

The fracture surface of the composite samples is studied using a scanning electron microscope (Carl Zeiss EVO MA 15). The samples are mounted on an aluminum stub using double sided tape and all specimens are coated with very thin layer of gold to prevent electric charging during examinations. The SEM micrographs are obtained under conventional secondary electron imaging conditions.

3. Results and Discussions

3.1 Tensile Properties

The tensile properties of epoxy and hybrid sisal/glass fibre reinforced epoxy composite are given in Table 2 and these corresponding data are also plotted in Fig.1. The tensile properties of hybrid sisal/glass fibre reinforced epoxy composite is found increase up-to 30 wt.% and then decrease due to poor adhesion between fibres and matrix. The hybrid composite S15G15 shows the maximum value of tensile strength (87.22 MPa) and tensile modulus (0.908 GPa). The maximum value of tensile properties for hybrid composite S15G15 is due to strong adhesion between fibres and matrix, and minimum numbers of voids present in composite. The tensile strength of S15G15 composite is found to be enhanced by 61%, 22%, 3% and 2% as compared to Epoxy, S5G5, S10G10 and S20G20 composite respectively. The tensile modulus of S15G15 composite is found to be improved by 21%, 4%, 3% and 2% as compared to Epoxy, S5G5, S10G10 and S20G20 composite. Fracture of hybrid sisal/glass fibre reinforced epoxy composite after tensile test is explained by SEM image as shown in Fig. 5. According to statistical analysis the value of tensile strength and tensile modulus is found to be significant as compared to the S5G5 composite. The results of ANOVA also show the significant difference between composites (Table 2).

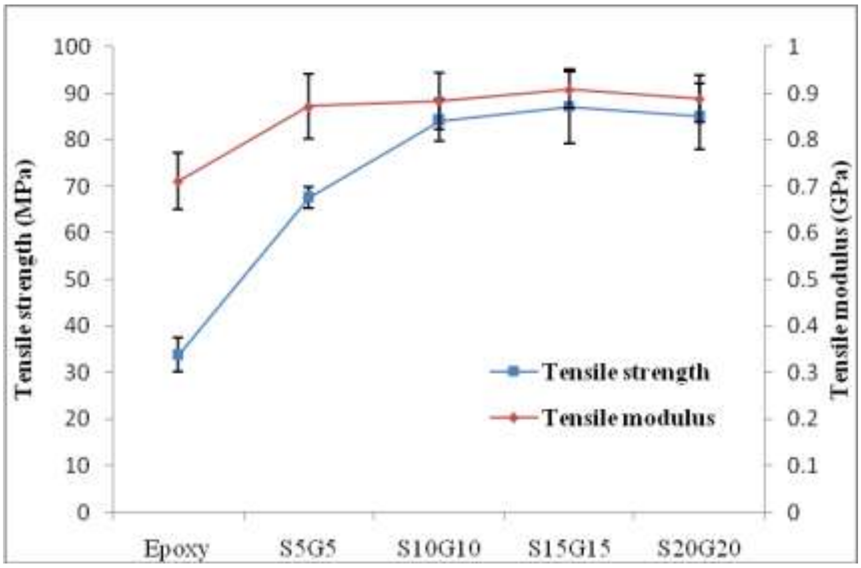

Figure 1 Tensile properties of hybrid sisal/glass reinforced epoxy composites

Table 2 Tensile properties of epoxy specimen and sisal/glass fibre reinforced epoxy composite.

Composite	Tensile strength (MPa)	S.D.	Tensile modulus (GPa)	S.D.
Epoxy	33.86	3.66	0.712	0.06
S5G5	67.73	2.26	0.872	0.07
S10G10	84.31	4.59	0.884	0.06
S15G15	87.22	7.97	0.908	0.04
S20G20	85.13	7.12	0.889	0.05

3.2 Flexural Properties

The flexural properties of epoxy and hybrid sisal/glass fibre reinforced epoxy composite are given in Table 3 and these corresponding data are plotted in Figure 2. The flexural properties of hybrid sisal/glass fibre reinforced epoxy composite is also found to be increased up-to 30 wt. % and then decreased. The hybrid composite S15G15 shows the maximum value of flexural strength (411.43MPa) and flexural modulus (20.81 GPa). The flexural strength and flexural modulus of S15G15 composite is 71% and 72% more than epoxy matrix respectively. The flexural strength of S15G15 composite is found to improve by 60%, 50% and 20% as compared to S5G5, S10G10 and S20G20 composites respectively. The flexural modulus of S15G15 composite is found improved by 47%, 37% & 12% as compared to composites S5G5, S10G10 and S20G20 respectively. Fracture of hybrid sisal/glass fibre reinforced epoxy composite after flexural test is explained by SEM image as shown in Fig. 6. According to statistical analysis the values of flexural strength and flexural modulus are found to be significant as compared to the S5G5 composite. The results of ANOVA also show the significant difference between composites (Table 3).

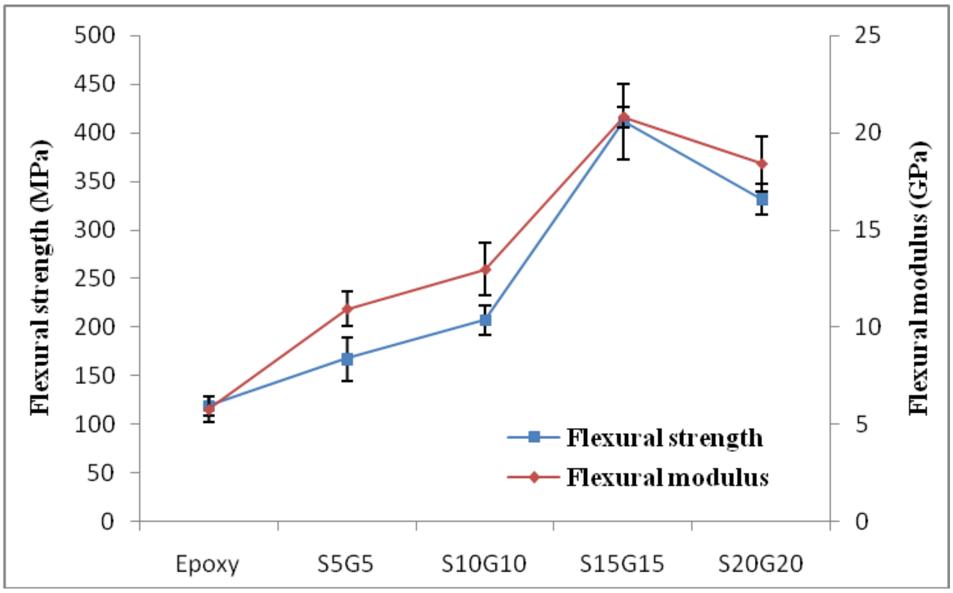

Figure 2 Flexural properties of hybrid sisal/glass reinforced epoxy composites

Table 3 Flexural properties of epoxy specimen and sisal/glass fibre reinforced epoxy composite.

Composite	Flexural strength(MPa)	S.D.	Flexural modulus (GPa)	S.D.
Epoxy	118.73	9.9	5.78	0.64
S5G5	166.88	22.07	10.95	0.87
S10G10	207.02	14.94	12.97	1.35
S15G15	411.43	39.08	20.81	0.53
S20G20	331.63	15.86	18.40	1.42

3.3 Impact Properties

The impact properties of epoxy and hybrid sisal/glass fibre reinforced epoxy composite are given in Table 4 and these corresponding data are plotted in Fig. 3. The impact properties of hybrid sisal/glass fibre reinforced epoxy composite is also found to be increased up-to 30 wt. % and then decreased. The hybrid composite S15G15 shows the maximum value of impact strength (22.58kJ/m^2) and impact energy (1.306 J). The impact strength of S15G15 composite is 75% higher than that of epoxy matrix. The impact strength of S15G15 composite is found improve by 75%, 28% and 20% as compared to S5G5, S10G10 and S20G20 composites respectively. Fracture of hybrid sisal/glass fibre reinforced epoxy composite after impact test is explained by SEM image as shown in Fig. 7. According to statistical analysis the value of impact strength and impact energy is found to be significant as compared to the S5G5 composite. The results of ANOVA also show the significant difference between composites (Table 4).

Table 5 shows the comparison of mechanical properties of different short fibre reinforced polymer composites with present work.

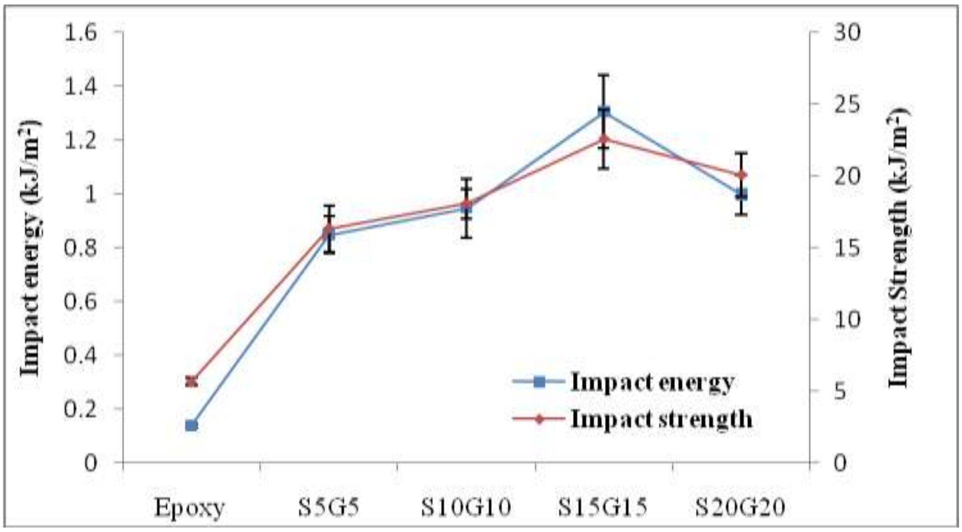

Figure 3 Impact properties of hybrid sisal/glass reinforced epoxy composites

Table 4 Impact properties of epoxy specimen and sisal/glass fibre reinforced epoxy composite.

Composite	Impact Energy (J)	S.D.	Impact strength (kJ/m^2)	S.D.
Epoxy	0.140	0.006	5.67	0.25
S5G5	0.849	0.069	16.35	1.60
S10G10	0.948	0.109	18.08	1.01
S15G15	1.306	0.136	22.58	2.09
S20G20	0.999	0.074	20.08	1.48

3.4. Water absorption behaviour

The percentage water absorption of hybrid sisal/glass fibre reinforced epoxy composite is plotted against the square root of time as shown in Fig. 4. The percentage of water absorption is found to be increased with increasing fibre content in all cases. The hybrid composite S20G20 shows higher water absorption which is 32%, 17% and 13% more than composites S5G5, S10G10 and S15G15 respectively. The increasing water absorption is due to the hydrophilic nature of sisal fibre and greater interfacial area between fibre and matrix. The moisture absorption by epoxy is almost negligible due to its hydrophobic nature. The sorption, diffusion and permeability coefficient of hybrid sisal/glass fibre reinforced epoxy composite are shown in Fig. 4.

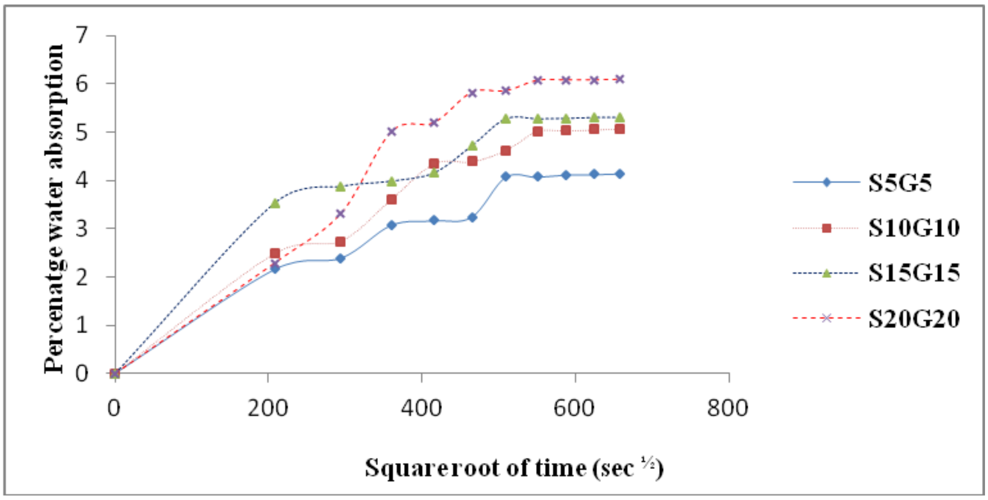

Figure 4 Percentage water absorption of hybrid glass/sisal reinforced epoxy composites as a function of square root of time

Table 5 Comparison of the maximum mechanical properties of short fibre reinforced polymer composites reported by different researchers with present work.

Reinforcement	**Matrix**	**Manufacturing method**	**Tensile strength (MPa)**	**Flexural strength (MPa)**	**Impact strength**	**Ref.**
Vakka/glass	Polypropylene	Injection moulding	24.83	46.26	48.66 (J/m)	[18]
Banana/glass	Polypropylene	Injection moulding	24.59	270.86	29.35 (J/m)	[19]
Jute	Polypropylene	Compression moulding	32.00	38.00	18.0 (kJm^2)	[20]
E-glass	Polypropylene	Compression moulding	31.00	36.00	18.5 (kJm^2)	[20]
Sisal/glass	Epoxy	Hand lay-up	87.22	411.43	22.58 (kJm^2)	Present work

Table 6 Sorption, diffusion and permeability coefficient of sisal/glass fibre reinforced epoxy composite.

Composites	Percentages of water uptake at infinite time	Sorption coefficient S	Diffusion coefficient D (mm^2/s)	Permeability coefficient P(mm^2/s)
S5G5	4.14	1.91	1.242E-5	2.372E-05
S10G10	5.06	2.03	1.124E-5	2.285E-5
S15G15	5.30	1.50	2.039E-5	3.058E-05
S20G20	6.09	2.66	0.655E-5	1.744E-5

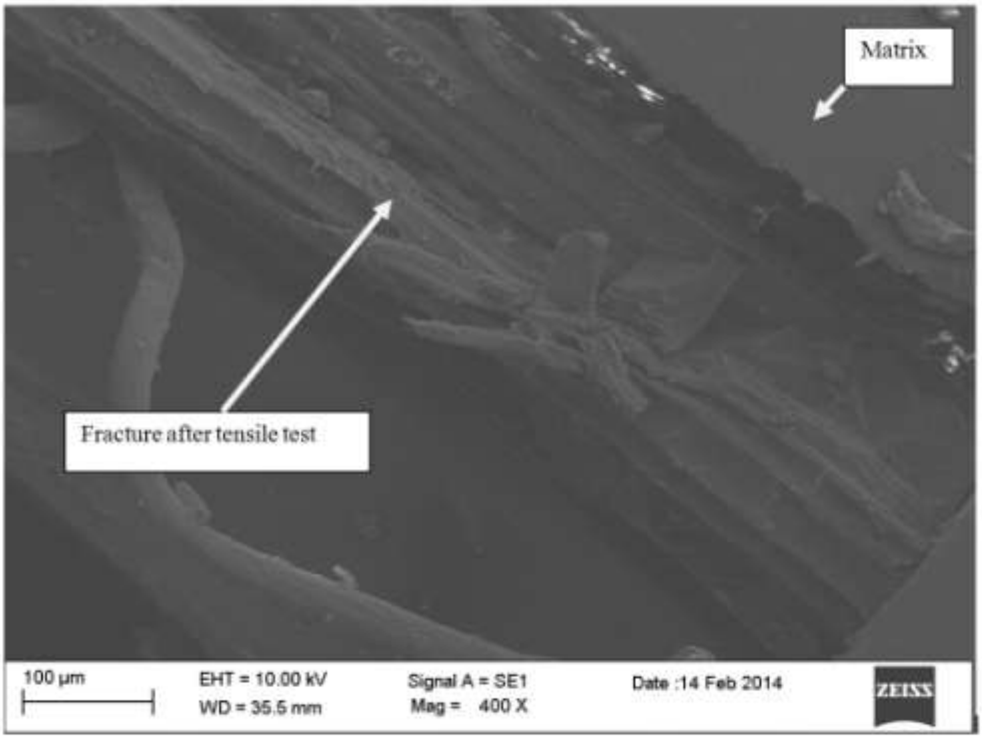

Figure 5 SEM image of hybrid glass/sisal reinforced epoxy composites after tensile test

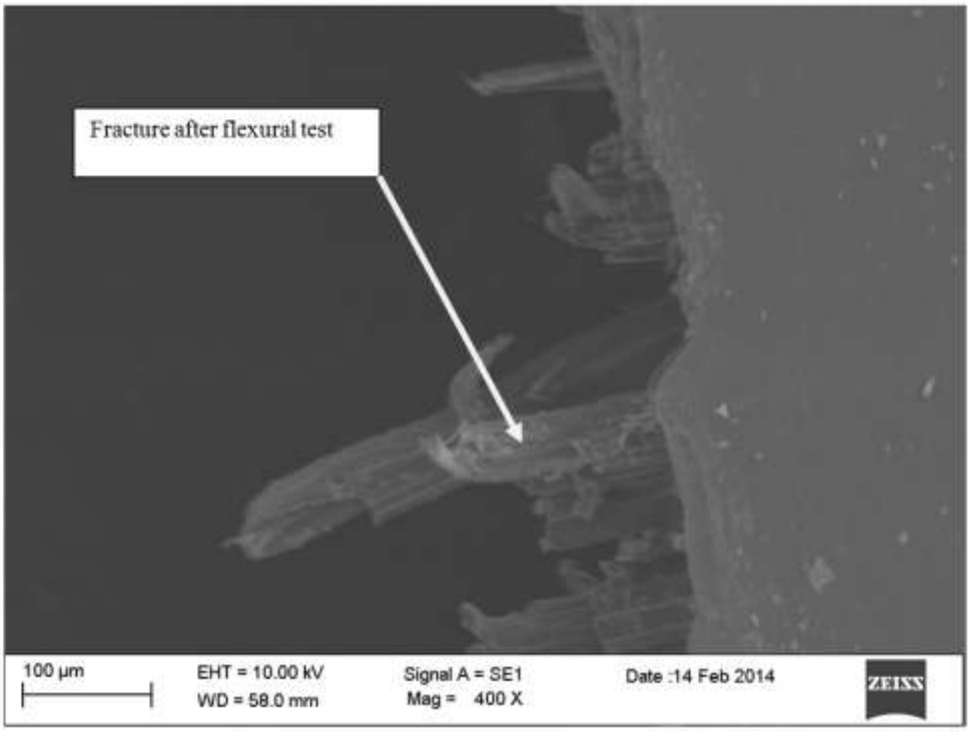

Figure 6 SEM image of hybrid glass/sisal reinforced epoxy composites after flexural test

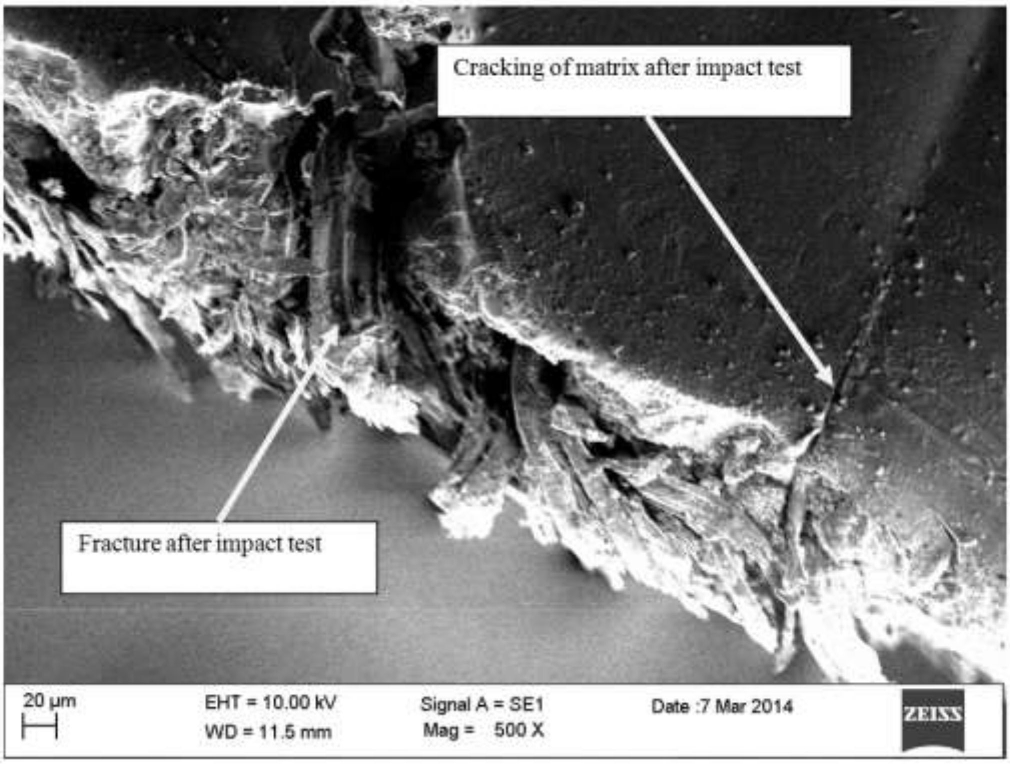

Figure 7 SEM image of hybrid glass/sisal reinforced epoxy composites after impact test

4. Conclusions

In the present research effort, mechanical and water absorption properties of hybrid sisal/glass reinforced epoxy composites are conducted and following conclusions can be drawn:

Mechanical properties of epoxy resin are increased by reinforcement of sisal and glass fibres up-to 30 wt. % and then decreased. The mechanical properties (tensile, flexural and impact properties) is found maximum for the composite S15G15. The statistical analysis shows that the all composite samples are significant. Water absorption property is found to increase on increasing the fibre contents in composites. The prepared composite can be regarded as light weight and low manufacturing cost engineering materials for industrial applications.

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