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Evaluation of Mechanical Properties of Alkali treated Basalt and Pineapple Leaf Fiber reinforced Hybrid polymer composite

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Abstract : The current study investigates the effect of alkali surface treatment for basalt fiber and pineapple leaf fiber (PALF) on mechanical properties of basalt fiber and pineapple leaf fiber reinforced epoxy hybrid composite. Vacuum bag moulding technique is used to fabricate the unidirectional basalt, and pineapple leaf fiber hybrid reinforced epoxy matrix. The basalt and pineapple leaf fibres are subjected to alkaline (NaOH) surface treatment to improve the adhesion property between the matrix and the reinforcement. By varying the fiber orientation and stacking sequence, four different samples were fabricated. The fabricated samples were tested for tensile, impact and flexural strength for the hybrid composites with and without alkali treatment. The scanning electron microscope images are obtained for fractured tensile test specimen to explore the arrangement of fibres and fibre pull-out. The result shows that fiber orientation, stacking sequence and surface treatment of reinforcements influences the mechanical properties of the hybrid composite.
Keywords : Basalt fiber, Pineapple Leaf fiber, Vacuum bagging, Alkali treatment, Mechanical properties.

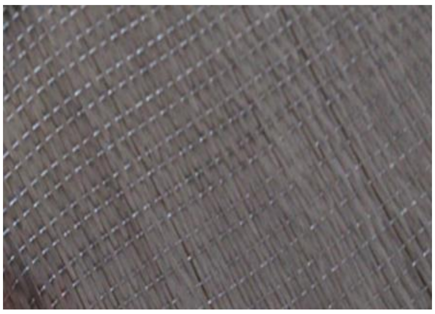
1. Introduction

In recent times natural fiber composites have got great attention due to their superior properties such as low cost, low density, pollution free and adequate mechanical properties. So the natural fiber composites can be a better alternative for synthetic fiber composites in civil, automobile, marine and aerospace applications. Chen and Huang [1] investigated the mechanical and interfacial properties of bare basalt fiber and found that bare basalt fiber produces smooth surface in axial and homogeneous in radial directions. Petrucci et al. [2] tested the mechanical properties of basalt fiber with a combination of flax, hemp and glass fiber reinforced hybrid composites. The addition of glass and flax to basalt fiber reinforced composite gives better mechanical properties than other combinations. Lopresto et al. [3] carried out an extensive study on mechanical properties of basalt fiber reinforced plastic and suggested that basalt fiber will be a suitable replacement for glass fiber. Narendiranath Babu [4] conducted an experiment on wear test for basalt fiber with titanium oxide, barium sulphate and silicon carbide reinforced hybrid polymer composite and presented the results along with the microstructure images before and after the wear test. Arib et al. [5] studied the mechanical properties of pineapple leaf fibre reinforced polymer composites, and the study reveals that the tensile strength and tensile modulus of the composites were found to be improving with the rule of mixtures of the fiber and matrix. Ary Subagia et al. [6] investigated the stacking sequence effect of basalt fiber, and carbon fiber reinforced hybrid composite, and the outcome shows that there is a strong agreement between the flexural properties and stacking sequence of fiber. Manikandan et al. [7] carried out the impact of surface modifications on mechanical properties of basalt fiber reinforced composite. The results reveal that the mechanical properties of surface treated basalt fiber composite are superior to untreated basalt fiber composite. Nisini et al. [8] characterised the mechanical and impact properties of carbon, basalt and flax fiber reinforced hybrid composites. Here two laminates with sandwich and intercalation sequence have been prepared and compared. Scalici et al. [9] carried out the vacuum assisted resin infusion, and hand-impregnated vacuum bagging techniques to test the mechanical properties of basalt fiber reinforced composite. The hand-impregnated vacuum bagging technique yields better shear strength and fracture toughness. Czigany [10] reported the results of mechanical properties and acoustic emission study of basalt fiber reinforced hybrid polypropylene composites. The fibers were subjected to surface treatment with the reaction mixture of maleic acid anhydride and sunflower oil for better adhesion. The treated composite gives better mechanical properties than untreated composite. Wang Mingchao et al. [11] studied the mechanical properties of alkali and acid treated basalt fiber reinforced epoxy composites and found that alkali resistance of basalt fiber is better than acid resistance. Antonio Greco et al. [12] done tests on mechanical properties and adhesion behaviour of basalt fiber reinforced polypropylene composites and observed that the adhesion behaviour is improved by increasing the polarity of the polymer matrix. Asim et al. [13] reported an extensive study about the properties of pineapple leaves fiber by reviewing various articles. It is learned from the literature study that the basalt fiber can be used in place of glass fiber. Also, it is observed that the fiber orientation, stacking sequence and surface treatment of fibers improves the mechanical properties of the polymer composites significantly. The current paper investigates the mechanical properties and microstructure behaviour of alkali surface treated basalt fiber, and pineapple leaf fiber reinforced hybrid composite.

2. Materials and Methods

2.1Basalt Fibre

The continuous basalt fiber is a non-metal inorganic fiber, which was made from the natural volcanic rock and it has the good comprehensive performance with high-cost effectiveness. Basalt fibrer has excellent physical property, high temperature, wear and corrosion resistance compared to carbon and glass fibers. The continuous basalt fiber rovings were purchased from Basaltex, Belgium and weaved into an unidirectional mat. The properties of the basalt fiber are given in table 2.1. Continuous basalt fiber roving and woven unidirectional mat are shown in figure 2.1.



(a) **(b)**

Figure 2.1 Basalt fiber (a) Roving (b) Woven unidirectional mat

2.2 Pineapple Leaf Fibre (PALF)

PALF is a natural fibre which has better mechanical properties than other natural fibres. Pineapple is a fibrous plant contains the fibre on its leaf. The fibres are purchased from Jolly Enterprises, Kolkatta and formed into an unidirectional mat. The properties of PALF are given in table 2.1. PALF continuous fiber and unidirectional mat are given in figure 2.2.


(a) (b)

Figure 2.2 Pineapple leaf fiber (a) Continuous fiber (b) Unidirectional mat

2.3 Epoxy

Epoxies have superior mechanical properties than other resins and resistance to environmental degradation. Epoxies generally outperform most other resin types in terms of mechanical properties and resistance to environmental degradation. LY556 epoxy resin with HY951 hardener is used as matrix. Epoxy resin and hardener were mixed in the ratio of 9:1. The properties of the epoxy resin are given in table 2.1.

Table 2.1 Properties of Basalt fiber, PALF and EPOXY resin

Properties	**Basalt fiber**	**PALF**	**EPOXY**
Tensile strength (MPa)	2100	413–1627	55–65
Modulus of elasticity (GPa)	84	34.5–82.5	3.0–4.0
Breaking extension (%)	2.8	1.6–3.0	1.5–2.5
Fiber diameter (µm)	10–17	20–80	-
Density (g/cm^3)	2.16	1.52	1.15

2.4 Surface treatment of fibers

For effective bonding, the adhesives must thoroughly wet the surface of each reinforcement being joined together. Further, strong attractive interactions must form between adhesives and the substrates. So the surface of the reinforcement must be clean, reasonably smooth, and chemically receptive to chosen adhesive. The surface treatment is the process whereby the adherent surface is cleaned or chemically treated to improve the adhesion. Alkali treatment is done on the fibers by using NaOH solution. The steps involved in alkali treatment of fibers are as follows. NaOH salt has been taken and mixed with distilled water in the ratio of 1:5. The Basalt fiber and Pineapple fiber are immersed in NaOH solution for 6 hours at room temperature. Then the fibers are thoroughly washed with distilled water to remove the impurities from the fibers. Now the fibers were dried at room temperature for 24 hours. Finally, the dried fibers are made in the form of a unidirectional mat. Figure 2.3 shows the surface treatment of Basalt and PALF fiber in alkali (NaOH) solution.


(a) (b)

Figure 2.3Alkali (NaOH) surface treatment of (a) Basalt fiber (b) PALF fiber

2.5 Fabrication of Hybrid Composite

The Basalt and PALF reinforced epoxy resin matrix composite was fabricated by Vacuum bagging method. Four different hybrid composite samples were fabricated with and without alkali surface treatment by varying the fiber orientation and stacking sequence. The stacking sequence and fiber orientation of unidirectional Basalt fiber and PALF are given in table 2.2 and also shown in figure 2.4.

Table 2.2 Fiber orientation and stacking order of the hybrid composite samples.

Composite sample code	Fiber orientation	Stacking sequence*	Composite type
S1	0/90/90/0	BPPB	Sandwich
S2	90/0/0/90	BPPB	Sandwich
S3	0/90/90/0	BPBP	Inter-ply
S4	90/0/0/90	BPBP	Inter-ply

*B-Basalt fiber, P-Pineapple leaf fiber

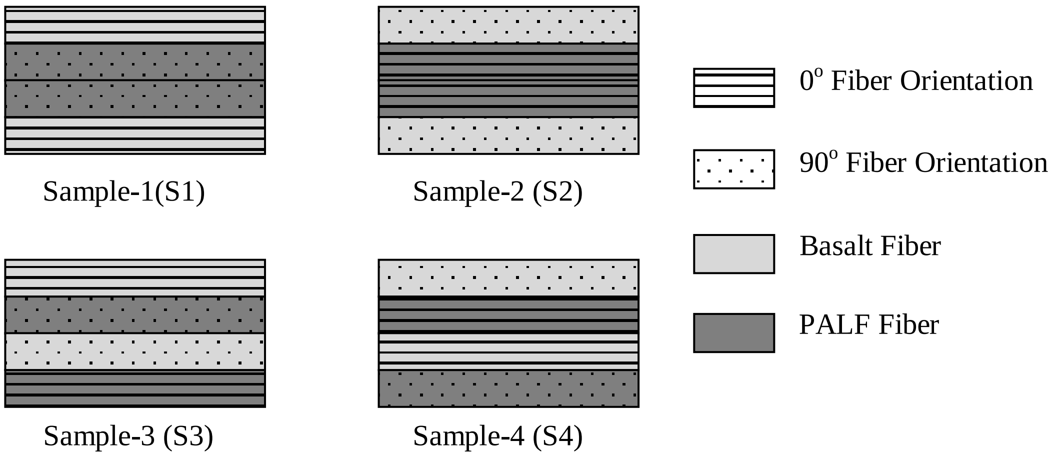


Figure 2.4 Stacking sequence and fiber orientation of Basalt fiber+PALF hybrid composite

In Vacuum bagging method a peel ply is placed over the flat mould to separate the composite from the mould. According to the stacking sequence and fibre orientation, the unidirectional fibre mats are placed one over another by applying the resin over each lamina. The weight ratio between the resin and hardener is 10:1 and fibers were stacked as per stacking sequence is shown in figure 2.4. A breather is placed above the laminate to extract the excess resin, and finally, a vacuum bag is used to close the laminate without any air gap. Then air inside the setup has been sucked out by using a compressor at 600 Pascal for 2 hours. Then post curing process was carried out on the resultant hybrid epoxy composite. In curing process, the hybrid composites are heat treated to accelerate the natural chemical reaction between the fibers and the matrix. The resultant polymer matrix composite is heat treated at 100 ºC for 2 hours. The schematic diagram of vacuum bagging method is shown in figure 2.5.

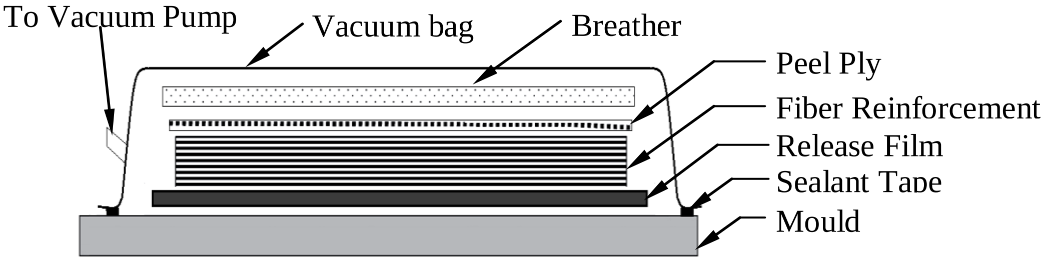


Figure 2.5 Schematic representation of hybrid composite fabrication by Vacuum bagging method

3. Mechanical Properties

The mechanical properties of the fabricated composite samples were tested and compared. Five test specimens are cut as per ASTM standards from each fabricated samples for tensile, flexural, impact and hardness tests. Tensile strength is the maximum strength of the composite before the breaking point when it is subjected to tensile load. The tensile test has been carried out as per the ASTM-D638 standard for the given specimen with the gauge length of 75 mm. The test specimen is mounted in the grippers of the Universal testing machine UTE-40, and the tensile load is applied to the specimen until it breaks, simultaneously the deformation corresponding to the applied load is recorded. The tensile strength of each specimen is calculated using the applied load and the cross-sectional area of the specimen, and the average is taken. Similarly, the tensile stress and strain are calculated using the recorded load and deformation. The tensile test has been repeated for all the specimens and samples.

Flexural strength of material is the maximum stress obtained at the moment of rupture. Flexural strength of the test specimens is obtained by the three-point flexural test. The composite is cut as per ASTM-D790 standard. The specimen is supported at its ends and load is applied at the centre of the specimen. The load is applied to the specimen until it breaks and the corresponding break load is noted. The flexural strength and modulus are calculated from the breaking load and cross-sectional area of the specimen. The test has been performed on all the other specimens and samples. Impact strength indicates the ability of material to withstand an impact load and the energy absorbed by the material is expressed in terms of Joules. It is mainly performed to determine the service life of the specimen. The notched specimen is prepared as per ASTM D256 standard. Izod impact setup is employed to perform the impact test on the hybrid composite. In Izod impact test a pendulum is dropped from an angle of 90^{o} to impact the specimen and to fracture it. The amount of energy absorbed during the breaking of the specimen is noted. Similarly, the energy absorbed by all the other specimens and samples were identified. Hardness is the ability to resist a small indentation, abrasion and plastic deformation. The Shore D hardness test was conducted as per the ASTM-D785 standard to determine the hardness of the hybrid composites. Tescan Vega3 scanning electron microscope is used to obtain the microstructure of the specimens. The scanning electron microscope (SEM) images are produced by focusing the beam of electrons on the sample

4. Results and Discussion

4.1 Tensile properties

The test specimens are prepared from four different combinations of the hybrid composite according to ASTM D638 standard for conducting the tensile test. The test is performed in a Universal Testing Machine UTE-40 at room temperature. The specimen is held between grippers of the UTM, and the load is applied by the crosshead with a velocity of 2 mm/min until a fracture occurs, and the stress versus strain graph is generated. The breaking and ultimate tensile strength of the samples were noted and compared. The tensile test specimen before and after testing is shown in figure 4.1. The tensile strengths are shown in Table 4.1. It was observed that S3 has better tensile properties compared to other samples. Also, the tensile strength of S1 and S2 increased when it was treated with alkali (NaOH) solution, but at the same time, the values of S3 and S4 are decreased because of the fiber direction and stacking sequence. The tensile strength comparison of all the hybrid composites with and without alkali treatment is shown in figure 4.2.

(a)

(b)

Figure 4.1 Tensile test specimens (a) before fracture and (b) after fracture

Table 4.1 Tensile strength of Basalt and PALF reinforced hybrid composites

Sample	Tensile Strength in MPa	
	Without alkali treatment	With alkali treatment
S1	68.2	54.4
S2	13.0	5.7
S3	72.1	75.3
S4	6.7	7.3

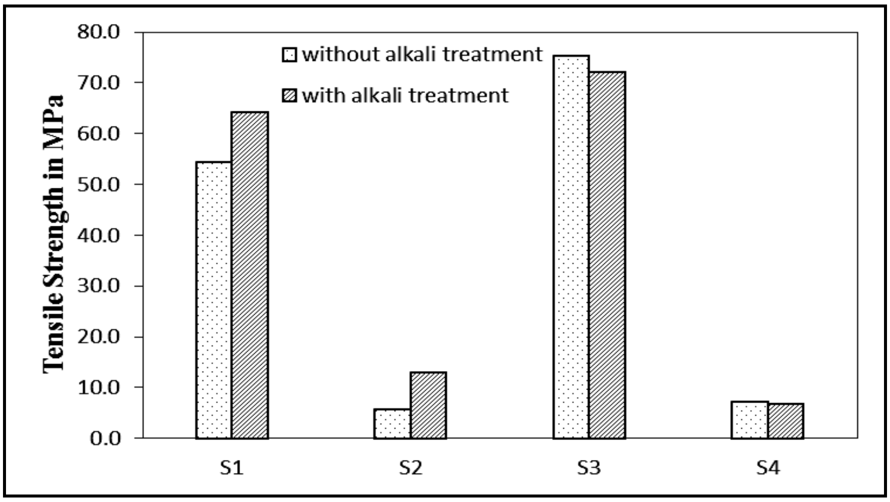
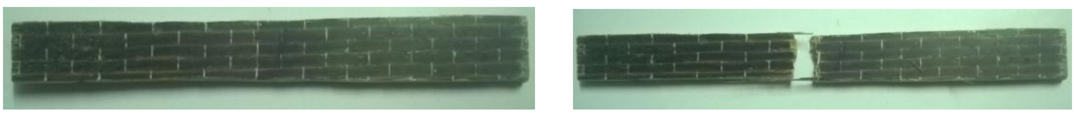


Figure 4.2 Tensile strength comparisons of hybrid composites with and without alkali treatment

4.2 Flexural properties

The flexural strength and flexural modulus are obtained by a three-point bending test. The specimens are prepared as per the ASTM D790 standards. A point load with 5mm/min speed is applied at the mid of the test specimen kept between the supports. The variations of the load and deflection are recorded from the test, and the corresponding flexural strength and flexural modulus were obtained. The flexural test specimen before and after fracture are shown in Figure 4.3. The Flexural strength and modulus of S1 are higher than all the other samples and which is observed in Table 4.2. Flexural strength and modulus of S1 and S2 are increased when it is subjected to alkali treatment, but at the same time, the values are decreased in S3 and S4. The flexural strength and modulus values of all the samples are compared and shown in figure 4.4 and 4.5.



(a) **(b)**

Figure 4.3 Flexural test specimens (a) before fracture and (b) after fracture

Table 4.2 Flexural properties of hybrid composites

Sample	without alkali treatment		with alkali treatment	
	Flexural strength MPa	Flexural Modulus MPa	Flexural strength MPa	Flexural Modulus MPa
S1	138.0	4322.2	216.2	10194.0
S2	7.1	1198.6	16.4	2348.2
S3	124.3	8892.0	90.1	3624.4
S4	24.1	2686.4	16.2	1274.5

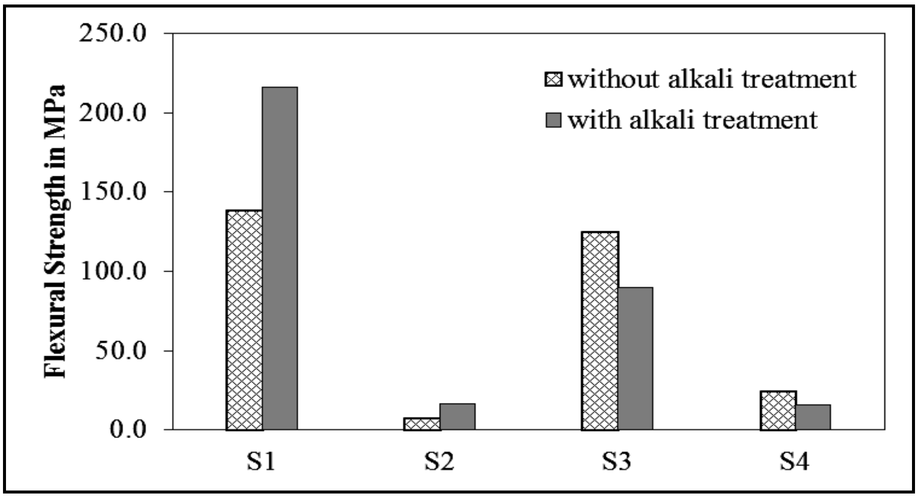


Figure 4.4 Flexural strength comparisons of hybrid composites with and without alkali treatment

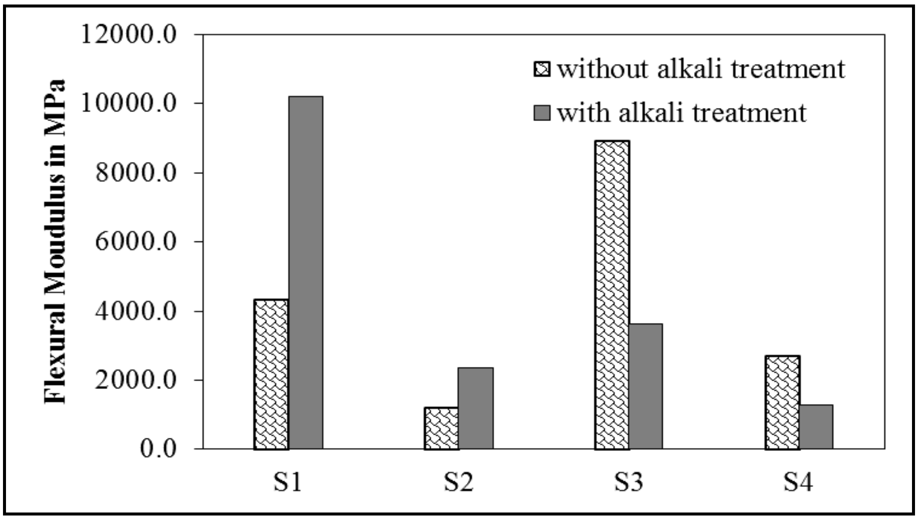


Figure 4.5 Flexural modulus comparisons of hybrid composites with and without alkali treatment

4.3 Impact Properties

The energy absorbed by the hybrid composites are obtained by conducting the Izod impact test. The test specimens are cut from the samples according to ASTM D256 standard. The impact test will be conducted by dropping a load on the specimen from certain height and angle. In Izod impact test the pendulum is dropped from an angle of 90 degrees to impact the specimen. The notched specimen is placed on the fixture, and the arm pendulum is dropped to hit the notched specimen. The energy absorbed by the specimens during the fracture is noted and listed in table 4.3. The test result shows that the energy absorbed by the samples S1 and S3 are higher than S2 and S4 and the impact strength of S1 and S2 with alkali treatment is increased, but the values are decreased in the case of S3 and S4. Figure 4.6 shows the comparisons of the energy absorption by the hybrid composites.

Table 4.3 Impact properties of hybrid composites

Sample	without alkali treatment		with alkali treatment	
	Energy absorbed (J)	Impact strength (J/m)	Energy absorbed (J)	Impact strength (J/m)
S1	3.43	34.3	3.65	36.5
S2	0.27	2.7	0.30	3.0
S3	2.13	21.3	1.82	18.2
S4	0.27	2.7	0.17	1.7

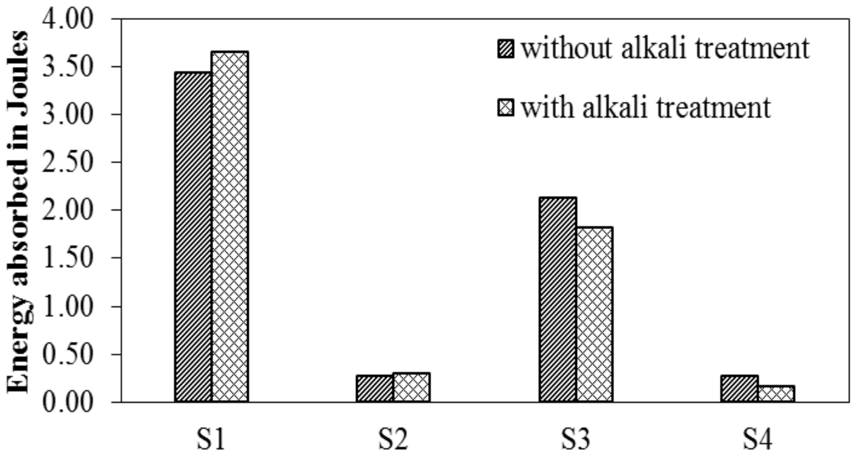


Figure 4.6 Comparisons of Energy absorption by the hybrid composites with and without alkali treatment

4.4 Hardness

The hardness of material is the ability of resistance to deformation due to a compressive force caused by a sharp object. The Shore D hardness test has been conducted on the test specimens as per ASTM-D785 standard. Alkali surface treatment of fibers increases the hardness from 2.4 to 6.5 %. Also, hardness of S1 and S2 are equal due to simialar stacking sequnce and the results are tabulated in Table 4.4.

Table 4.4 Hardness values of hybrid composites

Sample	Shore D Hardness Value	
	Without alkali treatment	With alkali treatment
S1	81	83
S2	81	83
S3	71	76
S4	71	76

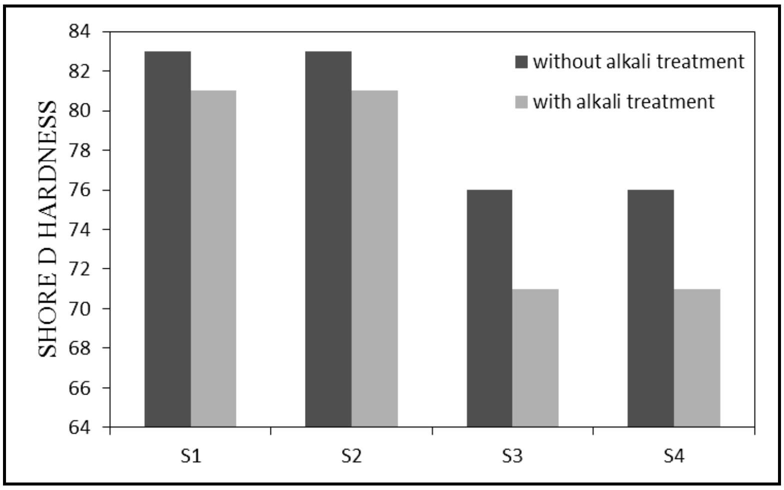
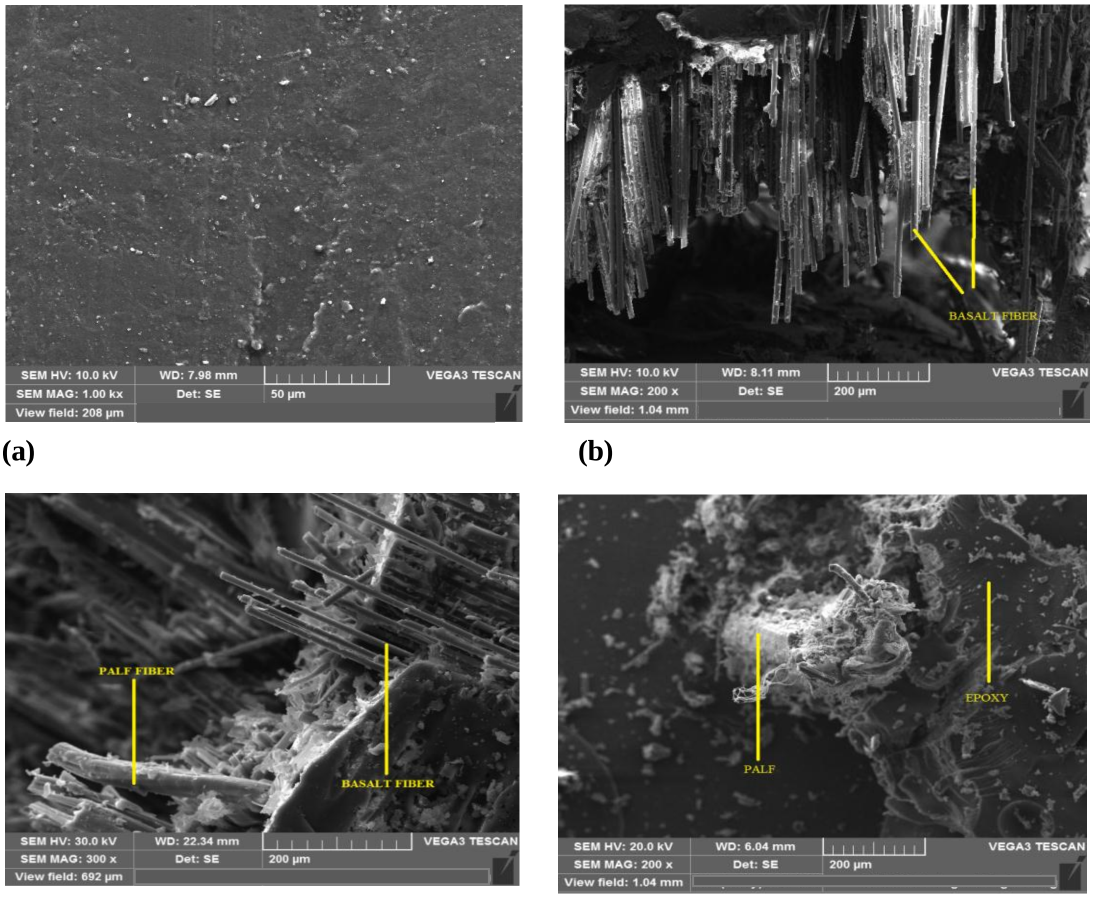


Figure 4.6 Comparisons of hardness values of hybrid composites with and without alkali treatment

4.5 Morphological Study

The images of the fractured specimens are obtained by Tescan vega3 scanning electron microscope (SEM). The morphological structure of the epoxy composite is presented in figure 4.7(a). From the figure of the epoxy composite, no stretching and pulling of polymer on the surface of the epoxy composite were observed, but there is a sharp cut surface due to brittle nature of epoxy composite. The stretching and elongation of basalt fiber are presented in figure 4.7(b) due to the applied tensile strength. The stretching of fiber indicates that the strength of the polymer increased due to the incorporation of basalt fiber with epoxy composite. The figure 4.7(c) shows the fiber pull out on the fractured surface due to the tensile load. The pineapple leaf fiber and matrix bonding are good, but due to brittle nature of pineapple leaf fiber, the breakage is observed from figure 4.7(d). The SEM images the hybrid composites are shown in figure 4.7.



(a) **(b)**

(c) **(d)**

Figure 4.7 SEM image of (a) Epoxy surface (b) & (c) Tensile tested specimen (d) PALF breakage

5. Conclusions

The mechanical properties of the Basalt and PALF reinforced hybrid composites were tested, and the effect of surface modifications on the reinforcements by alkali treatment has been reported. The tensile strength of S3 (0/90/90/0) BPBP is 72.1MPa which is higher than S1, S2 and S3 whose values are 68.2MPa, 13.0MPa and 6.7MPa respectively. Tensile strength values of S3 and S4 are increased when the fibers were subjected to alkali treatment, but it is decreased in case of S1 and S2. From the flexural test, it was observed that the flexural strength of S1 (0/90/90/0 BPPB) is 138.0MPa and it is higher than the other samples. In addition, the alkali treatment improves the flexural strength in S1 and S2, but the values are decreased in S3 and S4. Similar kind of results was obtained in flexural and impact tests. The energy absorbed by S1 is 3.43J, which is higher than S3, S2 and S4 with 2.13J, 0.27J and 0.27J respectively. Alkali treatment increases the energy absorption significantly in S1 and S2 compared to untreated sample results. The hardness of S1 and S2 are higher than S3 and S4. The SEM image shows the interfacial bonding between the fiber and matrix. It was found that the bonding is improved when the fibers are subjected to alkali treatment. Also, the image shows the dispersion of basalt and pineapple leaf fiber into the epoxy resin matrix. Eventually, it was found that the fiber orientation, stacking sequence and surface treatment of reinforcements influences the strength of the composite.

References

1. Z. Chen and Y. Huang, "Mechanical and interfacial properties of bare basalt fiber," Journal of Adhesion Science and Technology, vol. 4243, Published online on May 2016.
2. R. Petruccia, C. Santullib, D. Pugliaa, E. Nisinic, F. Sarasinid, J. Tirillod, L. Torrea, G. Minakc, J.M. Kennya, "Impact and post-impact damage characterization of hybrid composite laminates based on basalt fibres in combination with flax, hemp and glass fibres manufactured by vacuum infusion", Composites: Part B, vol. 69. pp. 507–515, 2015.
3. V. Lopresto, C. Leone, and I. De Iorio, "Mechanical characterization of basalt fibre reinforced plastic," Composites: Part B, vol. 42, pp. 717–723, 2011.
4. T. Narendiranath Babu, D. Ramesh, D. R. Prabha, and T. Lavanya, "Wear Behaviour of Hybrid Composite of Basalt Fiber with Titanium Oxide, Barium Sulphate and Silicon Carbide," International Journal of ChemTech Research, vol. 8, no. 4, pp. 2053–2062, 2015.
5. R. M. N. Arib, S. M. Sapuan, M. M. H. M. Ahmad, M. T. Paridah, and H. M. D. Khairul Zaman, "Mechanical properties of pineapple leaf fibre reinforced polypropylene composites," Materials & Design, vol. 27, pp. 391–396, 2006.
6. I. D. G. Ary Subagia, Y. Kim, L. D. Tijing, C. S. Kim, and H. K. Shon, "Effect of stacking sequence on the flexural properties of hybrid composites reinforced with carbon and basalt fibers," Composites: Part B, vol. 58, pp. 251–258, 2014.
7. V. Manikandan, J. T. Winowlin Jappes, S. M. Suresh Kumar, and P. Amuthakkannan, "Investigation of the effect of surface modifications on the mechanical properties of basalt fibre reinforced polymer composites," Composites: Part B, vol. 43, pp. 812–818, 2012.
8. E. Nisini, C. Santulli, and A. Liverani, "Mechanical and impact characterization of hybrid composite laminates with carbon, basalt and flax fibres," Composites: Part B, Published online 2016.
9. T. Scalici, G. Pitarresi, D. Badagliacco, V. Fiore, and A. Valenza, "Mechanical properties of basalt fiber reinforced composites manufactured with different vacuum assisted impregnation techniques" Composites: Part B, vol. 104. pp. 35–43, 2016.
10. T. Czigany, "Special manufacturing and characteristics of basalt fiber reinforced hybrid polypropylene composites: Mechanical properties and acoustic emission study," Composites Science and Technology, vol. 66, pp. 3210–3220, 2006.
11. W. Mingchao, Z. Zuoguang, L. Yubin, L. Min, and Z. Sun, "Chemical Durability and Mechanical Properties of Alkali-proof Basalt Fiber and its Reinforced Epoxy Composites," Journal of Reinforced Plastics and Composites, vol. 27, no. 4, pp. 393–407, 2008.
12. A. Greco, A. Maffezzoli, G. Casciaro, and F. Caretto, "Mechanical properties of basalt fibers and their adhesion to polypropylene matrices," Composites: Part B, vol. 67, pp. 233–238, 2014.
13. M. Asim, Khalina Abdan, M. Jawaid, M. Nasir, Zahra Dashtizadeh, M. R. Ishak, and M. Enamul Hoque, "A Review on Pineapple Leaves Fibre and Its Composites," International Journal of Polymer Science., vol. 2015, pp. 1–17, 2015.

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