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RESEARCH ARTICLE

Mechanical and Tribological Characterization of Hybrid Natural Fiber Reinforced Composites

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ARTICLE HISTORY

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Abstract: ***Background***: The technological enhancement in various disciplines enhances the demand for the new material which can replace the conventional materials. This has initiated the idea of composite materials. Synthetic fiber reinforced polymer matrix composites are being widely used due to its mechanical properties, but these fibers lack in terms of biodegradability, initial processing cost, recyclability and health hazard. An alternative to tackle these drawbacks can be found in natural fibers, that give an advantage in terms of strength to weight ratio, ease of availability and biodegradability.

Methods: This work is aimed to determine the effect of hybrid basalt - banana reinforced epoxy composite and their effectiveness in substituting few conventional materials in terms of their mechanical properties, wear resistance and water absorption rate.

Results: Basalt Banana Hybrid Composite (BBHC) is tested for their mechanical strength, hardness, impact strength, flexural strength, wear rate and water absorption rate. The test results of mechanical properties for the BBHC are compared to the other hybrid materials and conventional materials.

Conclusion: The test results reveal that the hybrid basalt banana epoxy composite is a good substitute over various conventional materials. The water absorption test results reveal that the hydrophilic nature of the natural fibers reduces a lot after the hybridization.

Keywords: Hybrid composites, mechanical characterization, natural fiber reinforced composites, tribological characterization, wear, basalt banana hybrid composite, biodegradability.

1. INTRODUCTION

Synthetic fibers are being widely incorporated in polymer-based composites due to their mechanical properties. But, these fibers lack in terms of biodegradability, initial processing cost, recyclability, abrasion and health hazard [1]. An alternative to tackle these drawbacks can be found in natural fibers. Also a significant increase in the automotive and construction industries emphasized on the alternative to the conventional materials. The natural fiber polymer composites give an advantage in terms of strength to weight ratio, ease of availability and biodegradability. In line with this, the present research work focuses on basalt and banana fibers due to their strength and wide temperature range.

Banana fibers have found a good source of cellulose and strength ranging from 175 MPa to 525 MPa, Flexural strength 75 - 80 MPa and moisture absorption 10-15 [2].

Basalt fibers have strength ranging from 400 - 695 MPa, high elastic modulus and high working temperature range [3].

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Many researchers have worked on different Fiber Reinforced Polymer (FRP) composites and analyzed their mechanical and tribological properties, listed in Table **1**.

The literature shows many works on the mechanical and tribological characterization of natural fiber-reinforced polymer matrix composites and most of the studies came to the same conclusion that natural fiber improves the mechanical properties and wear resistance of the material however it is not attuned to the synthetic fibers and conventional materials. In line with those in the present study basalt and banana hybrid composite used with the epoxy resin and its tensile strength, impact strength, hardness, flexural strength, moisture absorption rate and wear properties were evaluated and compared with the different materials. The basalt fiber was selected due to its high tensile strength and modulus, better chemical resistivity, high-temperature range, and recyclability. The banana fiber was selected due to its high strength, light weight and biodegradability.

2. EXPERIMENTAL

2.1. Specimen Preparation

Fibers: Basalt and banana continuous fiber filament mat procured from Go green fibers, Chennai is shown in Fig. (**1**). Properties of the materials listed in Table **2**.

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Table 1. Different research for evaluating the behavior of FRP composites.

Author	Study	Remarks
Singh *et al.* [4]	Tensile and Flexural strength of sisal, jute, banana fiber reinforced epoxy composites.	Jute fiber composites can replace the conventional materials like steel and wood.
Hiral Parikh & Piyush Gohil [5]	Wear analysis of graphite filled cotton fiber reinforced polyester composites.	Wear Resistance improved with a percentage of graphite filler.
Piyush Gohil and A.A. Shaikh [6]	The tensile strength of the banana, coir and sisal fiber reinforced polyester composites	The strength of the polymer resin improved with the natural fiber reinforcement.
Yu *et al.* [7]	Tensile, Flexural strength of ramie fiber poly (lactic acid) composites.	Tensile, flexural strength of the composites increased with the addition of Maleic anhydride.
Zhongyu Lu, Guijun Xian [3]	Tensile strength and tensile modulus of basalt fiber reinforced epoxy composites.	The tensile strain of the material increased with the temperature range.
M. Ramesh *et al.* [2]	Tensile and flexural strength of banana fiber reinforced epoxy composites.	Maximum tensile strength and flexural strength achieved with 50 % banana fibers.
V. Lopresto *et al.* [8]	Tensile and flexural strength of basalt fiber plastic laminates.	The hybrid basalt and glass fibers revealed good mechanical properties.
N. Amir *et al.* [9]	Tensile and flexural strength of banana fiber polymer composites.	Banana fiber, banana yarn and banana mat polymer composites prepared to evaluate the tensile and flexural strength.
William Jordan & Patrick Chester [10]	Flexural and tensile strength of banana fiber, low-density polyethylene (LDPE) composites.	Two chemical treatment Peroxide and permanganate treatment were used to determine the adhesive bonding with polyethylene.
Bin Bakri *et al.* [11]	Tensile strength of banana fiber polymer composites.	The alkaline treatment was used to evaluate the tensile properties of banana fiber polymer composites.
B. Soares, R. Preto, L. Sousa, L. Res [12]	Tensile and compression test of basalt fiber polyester composites.	Basalt fiber reinforced polyester composites were prepared by a resin transfer molding process and its tensile strength evaluated.
Bhoopathi *et al.* [13]	Wear and friction analysis of Borassus fruit fiber epoxy composites.	The fiber weight percentage had a greater effect on the wear and friction behavior of the material.
B.F. Yousif & N.S.M. El-Tayeb [14]	Wear and friction analysis of treated oil palm, polyester composites.	Treated oil palm, polyester composites revealed higher wear resistance than the untreated one.
S.S. Mahapatra & C.Vedansh [15]	Wear and frictional properties of different length sugar cane fiber composites.	Natural fiber reinforced composites showed good wear resistance.

(a) **(b)**

Fig. (1). a) Banana fiber mat **b)** Basalt fiber mat.

Table 2. Properties of fiber mat.

Fiber Mat	Thickness of Mat (cm)	Density (g/cm^3)
Basalt	0.1 to 0.13	1.32
Banana	0.12 to 0.14	1.41

Resin: LY 556 Epoxy Resin procured from ARK Golden India Pvt. Ltd., Vadodara, Gujarat.

Hand lay-up compression molding was used to prepare the composite materials. The wooden mold of size 250 mm* 250 mm was used. Initially wax layer spread on the mold surface for easy material removal. Resin mixed with the hardener HY 951 in a ratio of 10:1. The first layer of resin coated on the mold surface followed by basalt fiber mat. The second layer of resin coated followed by banana fiber mat. This process continued until the required material thickness achieved for different test. The uniform pressure of 50 KPa applied on the material for 24 hrs.

The composition of fabricated composites listed in Table **3**.

Table 3. Formulation of manufactured composite material.

Material	Resin Wt. %	Fiber Wt. %	Size
Basalt – Banana Epoxy Composite	81	19	250*250*3.5
Basalt – Banana Epoxy Composite	75	25	250*250*10

2.2. Preparation of Specimen for Testing

The dimensions required for the specimens for tensile, flexural, impact, hardness, water absorption and wear test along with their shapes and ASTM standards are shown in the Figs. (**2-7**) (All the dimensions are in mm).

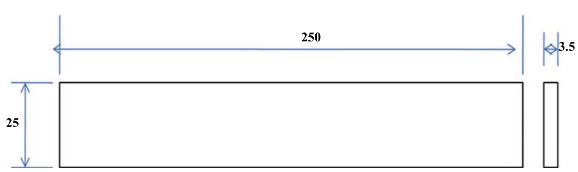

Fig. (2). Tensile test specimen (ASTM D 3039).

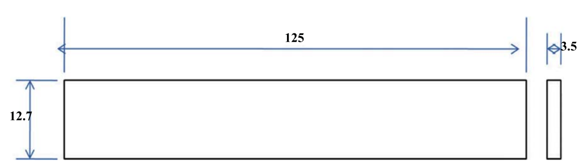

Fig. (3). Flexural test specimen (ASTM D 790).

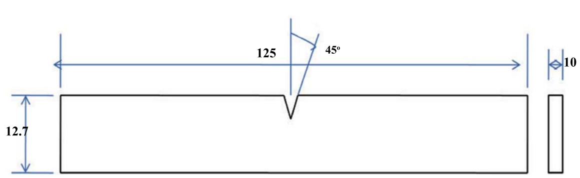

Fig. (4). Impact test specimen (ASTM D 7136).

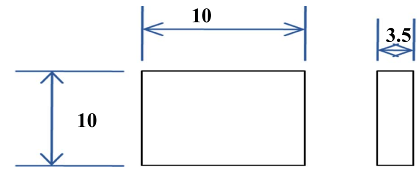

Fig. (5). Water absorption test (ASTM D 570).

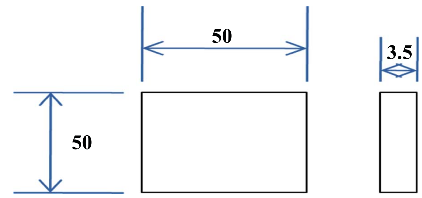

Fig. (6). Hardness test (ASTM D 2583-95).

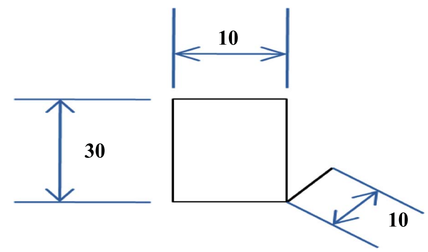

Fig. (7). Wear test (ASTM G 99).

2.3. Testing of Specimens

Various tests were performed on the basalt - banana hybrid composites to determine its mechanical properties, water absorption rate and wear properties.

2.3.1. Tensile Test

Tensile test was done on the Universal Tensile Testing Machine (UTM) with maximum load 10 KN on five specimens shown in Fig. (**8**). The specimens were prepared as per ASTM D 3039 standard and emery clothes were used to tap the specimens. The specimen under the tensile test shown in Fig. (**9**).

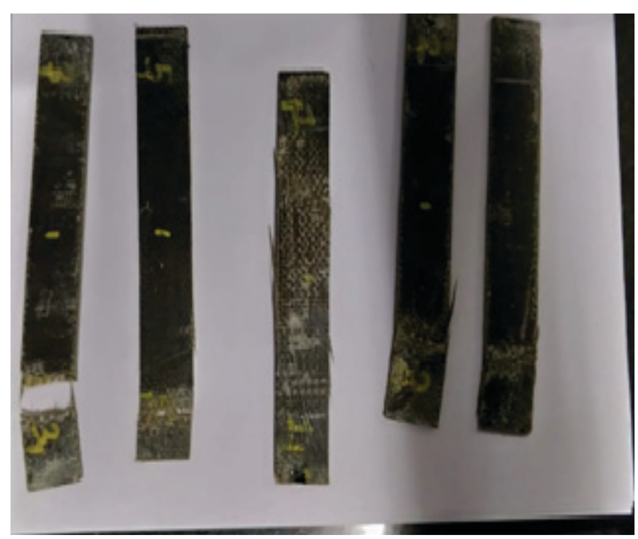

Fig. (8). Specimens after the Tensile Test.

Fig. (9). Tensile test.

2.3.2. Flexural Test

Flexural test was done on a 3 point flexural test set up on UTM machine. The experiments were done on five different specimens shown in Fig. (**10**) and average strength calculated. The load was applied on the middle of the span and the strength calculated by Eq. **1**.

$$\text{Flexural Strength} = 3\ PL / 2\ b\ t^2 \qquad (1)$$

Where,

P is the load in N

L is the gauge length in mm

b is the width of the specimen in mm

and t is the thickness of the specimen in mm.

2.3.3. Impact Test

Impact test was done on Charpy impact test set up by using ASTM D 256 standard. Five specimens were tested as shown in Fig. (**11**) and the energy required to break each specimen noted.

2.3.4. Hardness Test

Hardness measurement was done on the Rockwell hardness tester by using ASTM D 2583-95 standard. The truncated steel indenter, with cone shape and an angle 26° between two opposite faces were used to measure the hardness. The hardness measured along the x-direction on five different points with a constrained load of 25 N and the average value of hardness noted. The hardness test setup is shown in Fig. (**12**).

2.3.5. Water Absorption Test

Five test specimens were merged in the water for the 15 days and the weight of the specimens before the test and after the test noted. The water absorption rate was determined by using Eq. **2**.

Water absorption rate = {(The weight of the specimen after test – Weight of the specimen before the test) / Weight of the specimen before test} * 100. (2)

2.3.6. Wear Test

Wear experiments were done on the pin on disc machine with a load (2 Kg, 2.5 Kg, 3 Kg) and sliding speed (0.35 m/s, 0.54 m/s, 1.57 m/s) as variables and for fixed track radius 50 mm as shown in the Fig. (**13**). The wear measured in terms of mass loss. Each test conducted for 10 minutes. Weight of each specimen before and after the test noted and listed in Table **4**.

Fig. (10). Specimens after flexural test.

Fig. (11). Impact test on specimen.

Fig. (12). Hardness test set up.

Fig. (13). Wear test on pin on disc setup.

Table 4. Wear Test results for hybrid composite.

Load (Kg)	Sliding Speed (m/s)	Mass Before Test (gm)	Mass After Test (gm)	Δw (gm)
2.00	1.57	3.377	3.373	0.004
2.50	1.57	3.381	3.377	0.004
3.00	1.57	3.479	3.474	0.005
2.00	0.35	3.2	3.193	0.007
2.50	0.35	3.337	3.33	0.007
3.00	0.35	3.378	3.365	0.008
2.00	0.54	3.377	3.366	0.011
2.50	0.54	3.474	3.462	0.012
3.00	0.54	3.33	3.318	0.012

3. RESULTS AND DISCUSSION

3.1. Tensile Test

Tensile test was performed on the universal tensile testing machine for five test specimens and obtained results plotted in Table **5**. The test result revealed that the average tensile strength of the basalt banana hybrid composite obtained 84.39 MPa and average percentage elongation is 3.943. The test result compared with the different other materials is shown in Fig. (**14**) to identify the replacement of different materials.

3.2. Flexural Test

The flexural test was done on five test specimens and the average strength noted was 280 N. The obtained flexural strength compared to the other materials and plotted in Fig. (**15**).

3.3. Impact Strength

Five sample test specimens were used to measure the impact energy of the hybrid composite material and the average value of the impact energy noted was 22.4 J. This value was compared to the other materials and plotted in Fig. (**16**).

3.4. Hardness Test

Rockwell hardness tester was used to measure the hardness of the specimens. The test was conducted on five test specimens and the average value of the hardness noted for the hybrid composite and compared with the different material and plotted in Fig. (**17**).

3.5. Water Absorption Test

As the natural fibers are hydrophilic in the nature water absorption test was carried out on the hybrid composite. The test specimen was merged in water for twenty days and the mass before the test and after the test was noted. The test result revealed that there was no change in the mass This reveals that hydrophilic nature of the natural fibers reduced due to the hybridization.

3.6. Wear Test

The average wear based on load and sliding distance was calculated and plotted in Fig. (**18**). The test results revealed that, as the load increasing the wear also increasing, this is due to the fact that interface temperate increase at the higher load condition may lead to more wear of the material. As the sliding speed increased the wear increased, but after certain speed is reduced. At maximum speed it revealed more wear resistance, this may be due to the fact that at the higher speed the removed material layer formed on the pin surface which breaks the direct materials contact and increases wear resistance.

Table 5. Tensile and elongation test results for basalt banana hybrid composites.

Width (mm)	Thickness (mm)	Area (mm^2)	Max Load (N)	Max. Extension (mm)	Tensile Strength (MPa)	Elongation (%)
25	3.50	87.50	6753	5.167	100	4.142
25	3.50	87.50	6700	5.776	77.70	4.620
25	3.50	87.50	7625	6.040	87.15	4.091
25	3.50	87.50	6575	4.233	75.14	3.385
25	3.50	87.50	7166	4.367	61.92	3.477
Average					84.39	3.943

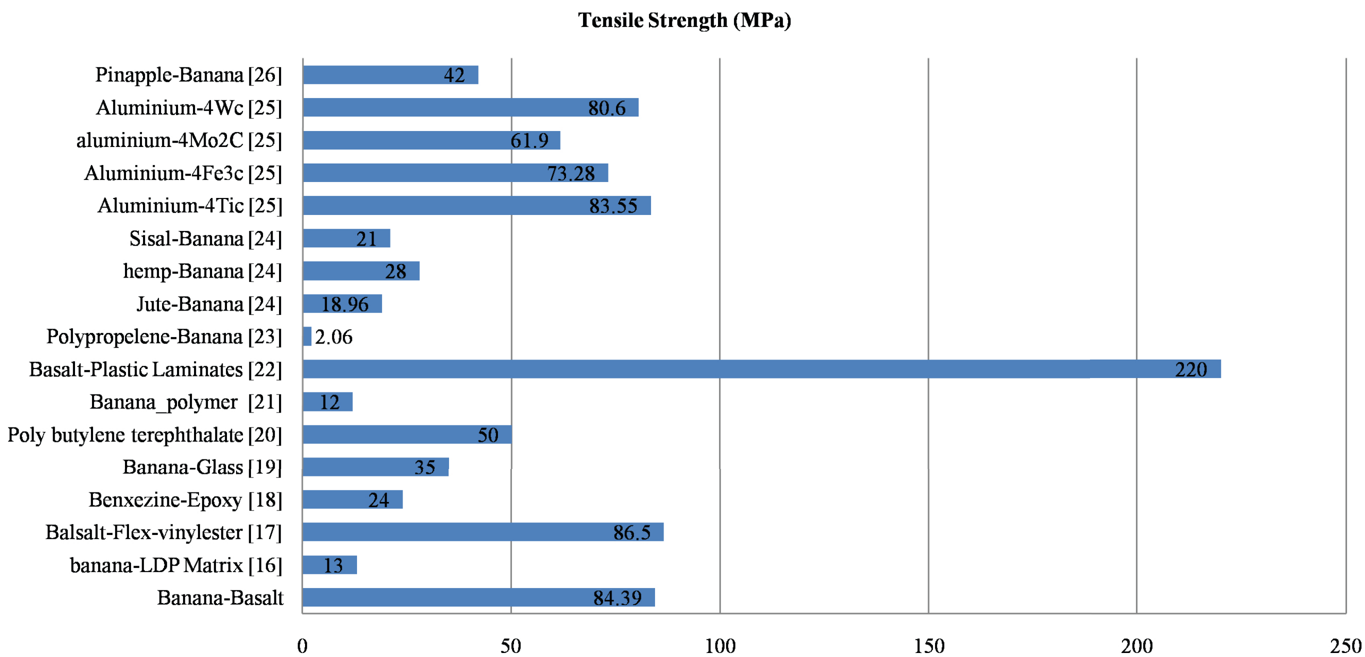

Fig. (14). Tensile strength comparison of banana - basalt hybrid composites with different materials.

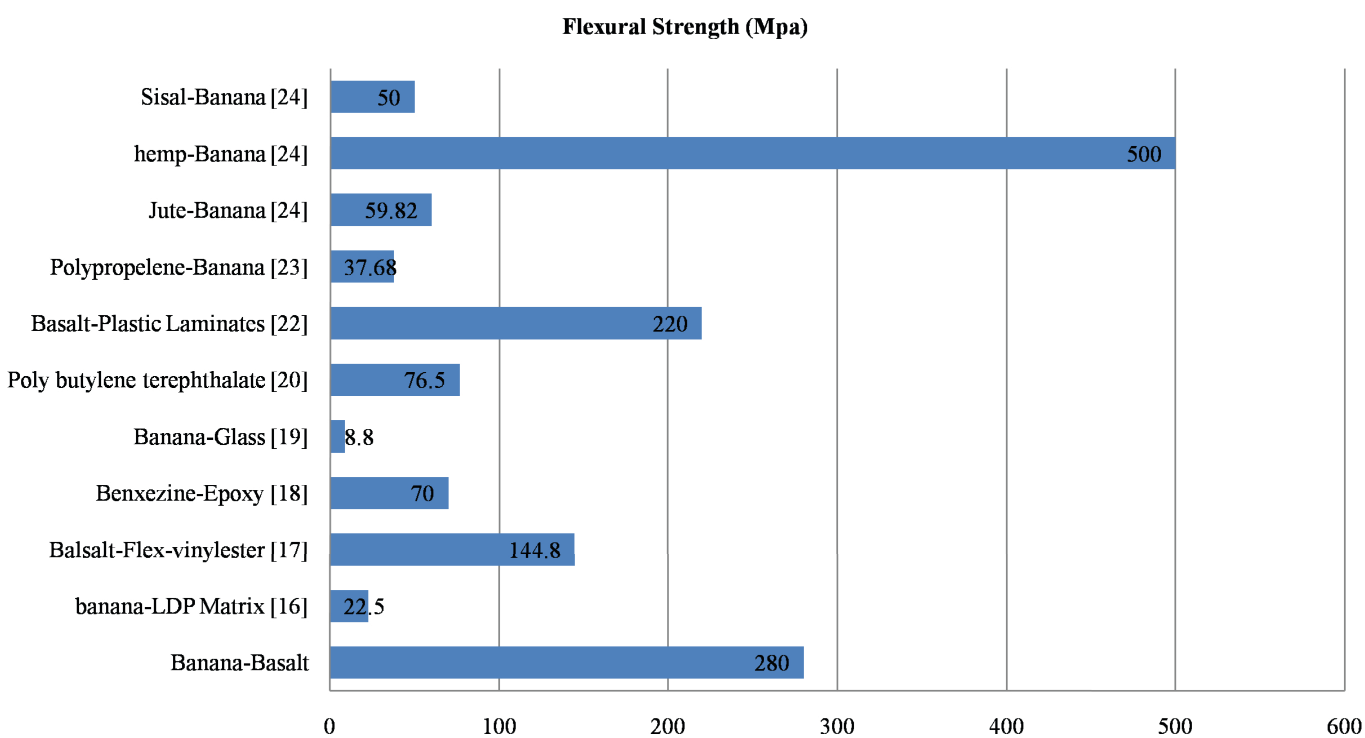

Fig. (15). Flexural strength comparison of banana - basalt hybrid composites with different materials.

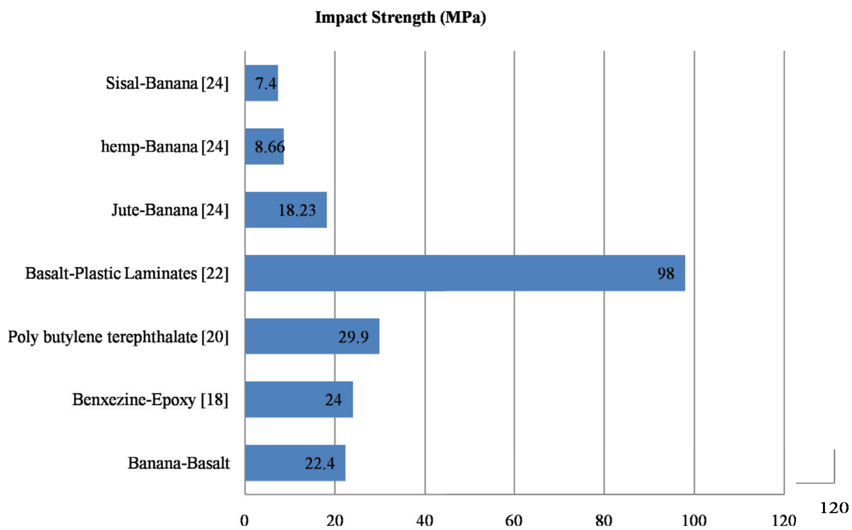

Fig. (16). Impact strength comparison of banana - basalt hybrid composites with different materials.

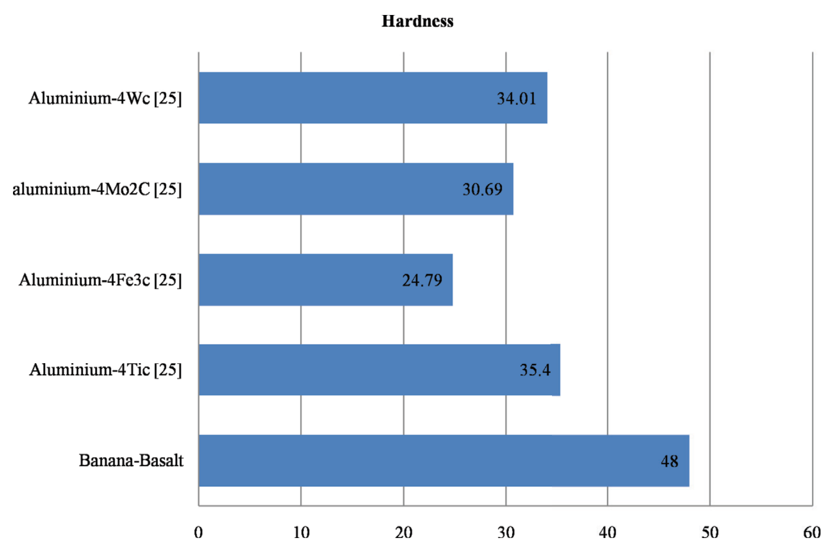

Fig. (17). Hardness comparison of banana - basalt hybrid composites with different materials.

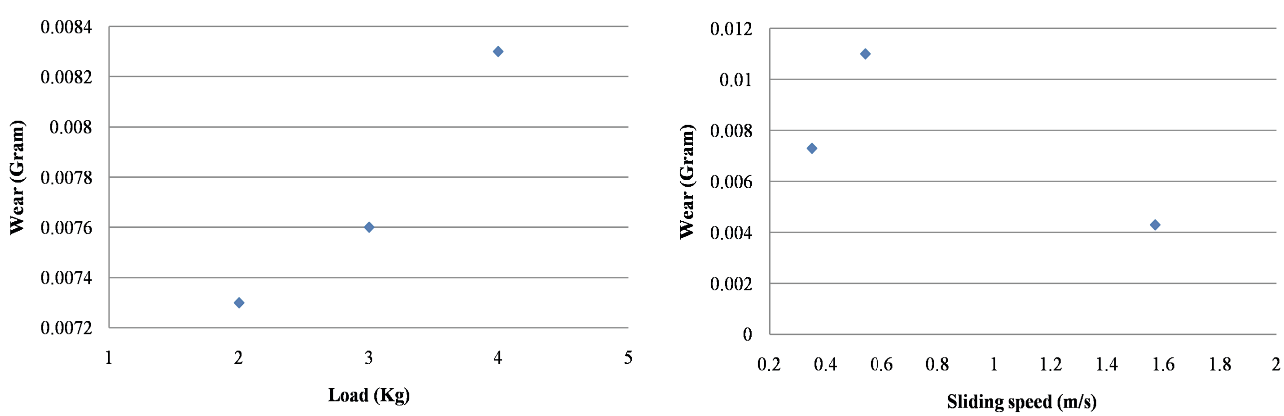

Fig. (18). Wear behavior with load and sliding distance.

CONCLUSION

The following points summarized from the study, "Mechanical and Tribological Characterization of Hybrid Natural Fiber Reinforced Composites":

- The aim of the study was to identify the effect of hybrid natural fiber-reinforced composite in substituting the other materials, in line with this tensile, hardness, impact and flexural test results of the hybrid composites were compared with the different materials.
- Water abortion test results revealed that there was no change in the mass of the hybrid composite after submerging it for 20 days in water. This shows that the hydrophilic nature of the natural fibers reduced due to the hybridization.
- Wear test results revealed more wear at high load condition and good wear resistance at high-speed condition.

CONSENT FOR PUBLICATION

Not applicable.

AVAILABILITY OF DATA AND MATERIALS

The authors confirm that the data supporting the findings of this study are available within the article.

FUNDING

None.

CONFLICT OF INTEREST

The authors declare no conflict of interest, financial or otherwise.

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Declared none.

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