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Investigation on Dynamic Analysis of Polylactic Acid Based Natural Hybrid Fiber Composite Using Nanotechnology

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Abstract

Dynamic analysis of a polylactic acid (PLA) based natural hybrid fiber composite involves studying its behavior under varying mechanical loads, vibrations, or other dynamic forces. Natural hybrid fiber composites are materials that combine nano synthetic polymers like PLA with natural fibers (e.g., jute, sisal, and hemp) to improve their mechanical properties and sustainability. Dynamic analysis helps understand how these composites respond to dynamic loading conditions and provides insights into their structural integrity, fatigue resistance, and performance characteristics using nanotechnology.

Keywords

Dynamic analysis, Statistical analysis, Dynamic forces, ASTM D3039, ASTM standard

Introduction

Dynamic analysis can be conducted through experimental testing using various methods like impact testing, modal analysis, and fatigue testing. The composite specimens are subjected to controlled dynamic loads, and their responses are measured using sensors and data acquisition systems. PLA based natural hybrid fiber composites represent a fascinating and eco-friendly class of materials that combine the benefits of biodegradable polymers with natural fibers to create versatile and sustainable alternatives to traditional plastics and synthetic composites [1, 2]. Enhanced properties can be achieved in metal matrix composites by reinforcing aluminum matrices with nanoparticles. A recent study by the authors involved incorporating iron particles into pure Al-Fe composites using multipass friction stir processing [3]. Similarly, the authors utilized the friction stir processing method to incorporate nickel particles into a cast aluminum A413 matrix [4]. Another study by the same authors successfully incorporated various nano powders (such as Al_2O_3, SiC, and B_4C) into an AA5059 substrate [5]. Additionally, AA1100 was strengthened with micro-powders of glass, polymer, and carbon fibers through attrition milling [6]. In a separate investigation, researchers examined the effects of TiO_2 nanoparticles on inclusions in AA5052 subjected to friction stir processing [7]. Furthermore, authors studied the influence of process conditions and particle size on AA2024 matrix composites and used the same matrix to produce B_4C particle surface reinforcements [5, 8].

Experimentation

Characterization for mechanical property

Pull loads are more frequent among technological applications. Therefore, such characterization is necessary for new materials. A 400,000 N capacity universal testing machine was utilized in this study. According to the ASTM D3039

standard, the specimen and testing procedures were performed in an inch wider, 10 inches long rectangular-shape specimen, the gauge length was 6 inches. Progressive load of a millimeter per minute speed has been set up [8-12]. During the spring season, the study was conducted at room temperature. Figure 1 demonstrates the sample that is utilized in this analysis. Table 1 lists the breaking load of dry and wet of Class-a and Class-b G/S/B hybrid composites in accordance with tensile load.



Figure 1: Sample specimens of Class-a and Class-b G/S/B hybrid composites for characterizing under tension.

Similarly, table 2, table 3, and table 4 list the tensile strength, tensile modulus, and % of elongation achieved for dry and wet of Class-a and Class-b G/S/B hybrid composites, respectively [13].

Characterization for transverse rupture strength

The flexibility of the material is also the principal character of a material. This is usually performed in the nature of a simply supported beam with the load on its medium span which is a reaction load at either endpoint or midpoint. The very same universal testing machine is used for this study and loading velocity was a millimeter per minute. A half an inch more broadly 6 inches long and 3 mm thicker samples have been utilized according to the ASTM D790 standard. The test was performed at ambient temperature during the spring in the atmosphere condition. The samples were presented in figure 2. Table 5, table 6, table 7, and table 8 demonstrate the detected as well as derived capacities of breaking loads of the relevant specimens, rapture strength, rupture modulus, and toughness of each category of sample.

Scanning electron microscopic (SEM) analysis of proposed G/SB/SB/SB/G Class-b

The analysis of SEM demonstrates the inner structure and

Table 1: Breaking load of dry and wet of Class-a and Class-b G/S/B hybrid composites for under tensile load.

Category of hybrid	Breaking load in kN			
	Dry specimen		Wet specimen	
Composite	Treated by technique - a	Treated by technique - b	Treated by technique - a	Treated by technique - b
Specimen 1	4.14	6.23	5.41	7.92
Specimen 2	5.23	7.53	6.11	8.89
Specimen 3	6.58	8.23	7.78	9.11

Table 2: Tensile strength of dry and wet composites of Class-a and Class-b G/S/B hybrid composites.

Category of hybrid	Tensile strength in MPa			
	Dry specimen		Wet specimen	
Composite	Treated by technique - a	Treated by technique - b	Treated by technique - a	Treated by technique - b
Specimen 1	55.6	57.8	56.8	58
Specimen 2	58.2	59.9	59.5	60.2
Specimen 3	60.2	61.9	60.8	62

Table 3: Tensile modulus of dry and wet of Class-a and Class-b G/S/B hybrid composites.

Category of hybrid	Tensile modulus in MPa			
	Dry specimen		Wet specimen	
Composite	Treated by technique - a	Treated by technique - b	Treated by technique - a	Treated by technique - b
Specimen 1	290.11	296.96	292.41	298.78
Specimen 2	270.23	288.43	272.56	290.48
Specimen 3	300.47	312.47	305.45	313.88

Table 4: Percentage of elongation of dry and wet of Class-a and Class-b G/S/B hybrid composites.

Category of hybrid	Percentage of elongation in %			
	Dry specimen		Wet specimen	
Composite	Treated by technique - a	Treated by technique - b	Treated by technique - a	Treated by technique - b
Specimen 1	5.70	6.70	5.90	7.10
Specimen 2	5.10	6.20	5.50	6.80
Specimen 3	7.70	8.60	8.10	8.90

Table 5: Breaking load of dry and wet of Class-a and Class-b G/S/B hybrid composites under bending.

Category of hybrid	Breaking load in kN			
	Dry specimen		Wet specimen	
Composite	Treated by technique - a	Treated by technique - b	Treated by technique - a	Treated by technique - b
Specimen 1	4.3	4.9	4.9	5.3
Specimen 2	4.1	4.6	4.6	4.9
Specimen 3	5.0	6.0	5.5	6.9

Table 6: Rapture strength of dry and wet of Class-a and Class-b G/S/B hybrid composites.

Category of hybrid	Transverse rapture strength in MPa			
	Dry specimen		Wet specimen	
Composite	Treated by technique - a	Treated by technique - b	Treated by technique - a	Treated by technique - b
Specimen 1	12.9	13.9	13.3	14.0
Specimen 2	12.5	13.1	13.0	13.8
Specimen 3	13.6	14.5	14.1	15.5

Table 7: Rapture modulus of dry and wet of Class-a and Class-b G/S/B hybrid composites.

Category of hybrid	Transverse rapture modulus in MPa			
	Dry specimen		Wet specimen	
Composite	Treated by technique - a	Treated by technique - b	Treated by technique - a	Treated by technique - b
Specimen 1	1480	1580	1530	1599
Specimen 2	1316	1456	1414	1498
Specimen 3	1552	1652	1590	1695

Table 8: Toughness of dry and wet of Class-a and Class-b G/S/B hybrid composite.

Category of hybrid	Energy absorbed in Joules while shock loading			
	Dry specimen		Wet specimen	
Composite	Treated by technique - a	Treated by technique - b	Treated by technique - a	Treated by technique - b
Specimen 1	13.21	16.77	13.96	16.92
Specimen 2	12.41	14.50	12.77	14.57
Specimen 3	14.50	18.86	14.89	18.97



Figure 2: Sample specimen of Class-a and Class-b G/S/B hybrid composites for characterizing under bending.

the inner surface have been discovered to be broken and the fragmented surface materials. Figure 3 demonstrates the SEM image of the specimen which undergoes tensile experimentation of G/SB/SB/SB/G fashioned Class-b G/S/B hybrid composites material. It demonstrates the discontinuous fibers and the void formed at the broken surface of the specimen because of the tensile load. Composite material which undergoes cross-disciplinary rapture investigation. The image clearly shows the hairline fracture of the fiber package and a partial scattering of fibers in the framework of the composite of the G/SB/SB/SB/G fashioned G/S/B hybrid composite material. It can be understood from the figure that during the impact of the specimen there is a breaking point and disintegration of fibers in the composite material. Figure 4 demonstrates the samples as per the ASTM standard.

Dynamic mechanical analysis (DMA) of Class-a and Class-b G/S/B hybrid composite

The DMA Q800 V20.6 build 24 is utilized to implement DMA in composites. It is a type of analysis of bending mode. The 3 mm thick, ½" x 2½" sized rectangular samples have been utilized [14]. The heating rate of 4 °C/min in the range of 28 to 200 °C, the vibration frequency is 1 Hz. The findings of the dynamic characterization are described in detail in the following section.

Results and Discussion

The suggested composite materials (through the use of artificial fiber glass and natural fibers of the banana and sisal which are processed by the technique-a/technique-b) have been synthesized and described for static and dynamic characteristics in accordance with wet and dry conditions. In this section, the analysis of the results of the study is being presented in detail. The efficiency of natural fiber treatment was examined in a scientific manner with the help of Tukey's multiple range tests. In the MINITAB 17 software, the importance level of the value of p is not more than 0.05. A comparative study is displayed sequentially in this section.

Analysis on moisture absorbability of Class-a and Class-b G/S/B hybrid composites

The hybrid composites which have been synthesized by the natural fibers that are treated by technique-a (Class-a) absorbing more humidity in comparison to the hybrid composites that have been synthesized by the natural fibers that are treated by technique-b (Class-b). According to the specimen, the measured highest values are 5.92 g, 5.77 g, and 5.24 g in the Class-a of hybrid composite specimens of specimen-1, specimen-2 and specimen-3, respectively (refer figure 5). The Class-b composites absorb less humidity in comparison to Class-a. The impact of the decrease of moisture absorption was smaller as 25.42%, 26.537% and 24.76% for specimen 1, specimen 2 and specimen 3, respectively, in comparison to Class-a type of hybrid composites. That's why treatment-b was carried out by less moisture absorption. In addition to the 3 specimens, specimen 3, that is a Class-B of glass/sisal-banana/glass hybrid composite (G-SB-SB-SB-G) is carried out by very much less moisture absorption. Figure 5 demonstrates the bar-chart representation of Tukey test results of the water absorption test. Figure 5 shows water absorption (g) of various chemical treatments (1% NaOH and 0.5% NaOH + 0.5%

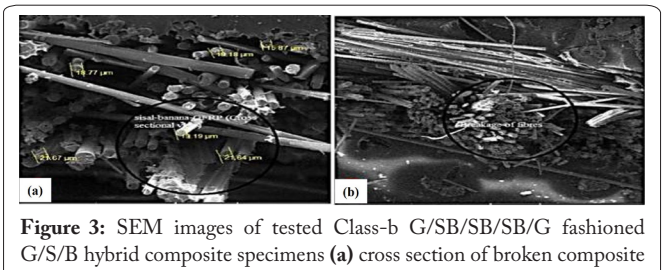


Figure 3: SEM images of tested Class-b G/SB/SB/SB/G fashioned G/S/B hybrid composite specimens **(a)** cross section of broken composite and **(b)** arrangement of fibers after breakage.



Figure 4: Sample specimens of Class-a and Class-b G/S/B hybrid composite for characterizing under shock load.

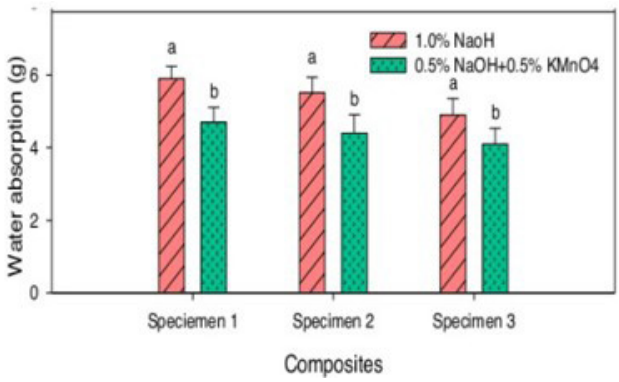


Figure 5: Moisture absorption by Class-a and Class-b composites and Tukey test result.

$KMnO_4$) of fibers in the three various fashions of composite (specimens). It was observed from the figure (± SE i.e., means standard error). In the Tukey test results the letter 'a' displayed above Class-a G/S/B hybrid composites for all three fashions of fabrication. This means that there was no significant difference in the fashion that followed in making up the composite at the level of $p \leq 0.05$. Similarly, the letter 'b' was displayed over Class-b G/S/B hybrid composites that also implied the same. But the letters vary for the treatment process. It indicates that there is a considerable difference among the treatment process of natural fibers at the level of $p \leq 0.05$.

Analysis of dry and wet Class-a and Class-b of G/S/B hybrid composites under tensile loads

The ultimate tensile strength is the first mechanical feature of the material and used for safety computing in the design for particular applications. The specimen-1 (with layer fashions of G/S/S/SG), specimen-2 (with layer fashions of G/B/B/B/G) and specimen-3 ((with layer fashions of G/SB/SB/SB/G) of both Class-a (where natural fibers were treated by technique-a) and Class-b (where natural fibers were treated by technique-b) type composites were included for characterization.

Analysis of breaking load in tension on Class-a, Class-b G/S/B hybrid composites under dry and wet conditions

One of the observations is the breaking load of every single specimen. Figure 6 depict the results for statistical analysis by Tukey test on breaking load.

The 'Class-a' hybrid composites with fashions of G/S/S/S/G, G/B/B/B/G and G/SB/SB/SB/G failed at tensile loads of 4.14 kN, 5.23 kN, and 6.58 kN, respectively. These Breaking loads are comparatively lower in comparison to the Class-b hybrid composites with the fashions of G/S/S/SG, G/B/B/B/G and G/SB/SB/SB/G that broke at 6.32 kN, 7.53 kN and 8.23 kN, respectively, by tensile load. The Class-a of specimens of G/S/S/SG, G/B/B/B/G and G/SB/SB/SB/G broke at 5.41 kN, 6.11 kN and 7.78 kN, respectively, and which are comparatively smaller in comparison to the Class-b G/S/B hybrid composites of G/S/S/SG, G/B/B/B/G and G/SB/SB/SB/G which broke at the tensile loads of 7.92 kN, 8.89 kN and 9.11 kN. In the Tukey test results the letter 'a' displayed above Class-a G/S/B hybrid composites for all three fashions of fabrication. This means that there was no significant difference in the fashion of that followed in making up the composite according to standard error ± SE at the level of $p \leq 0.05$. Similarly, the letter 'b' is displayed over Class-b G/S/B hybrid composites which also signified the same. But the letters vary for the treatment process. It indicates that there is considerable difference among the treatment process of natural fibers according to standard error ± SE at the level of $p \leq 0.05$.

Analysis of tensile strengths of Class-a, Class-b G/S/B hybrid composites under dry and wet conditions

Tensile strength or ultimate strength is a derived quantity from the test of samples on a tensile test. Figure 7 demonstrates the Tukey results of tensile strength in accordance with the dry and wet conditions of Class-a and Class-b G/S/B hybrid composites. The tensile strength of Class-a G/S/B hybrid composites of G/S/S/S/G, G/B/B/B/G and G/SB/SB/SB/G are 55.6 MPa, 58.2 MPa and 60.2 MPa in accordance with dry condition. At wet condition, the tensile strength of Class-a G/S/B hybrid composites of G/S/S/S/G, G/B/B/B/G and G/SB/SB/SB/G are 56.8 MPa, 59.5 MPa and 60.8 MPa, respectively.

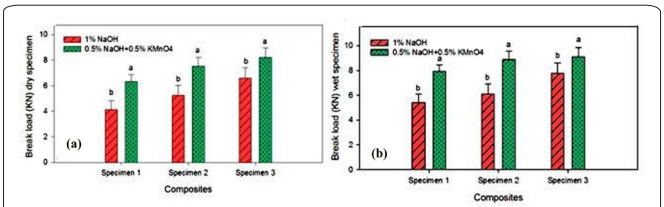


Figure 6: Tukey test result on breading load by the tension of Class-a and Class-b of G/S/B hybrid composites under **(a)** dry and **(b)** wet conditions.

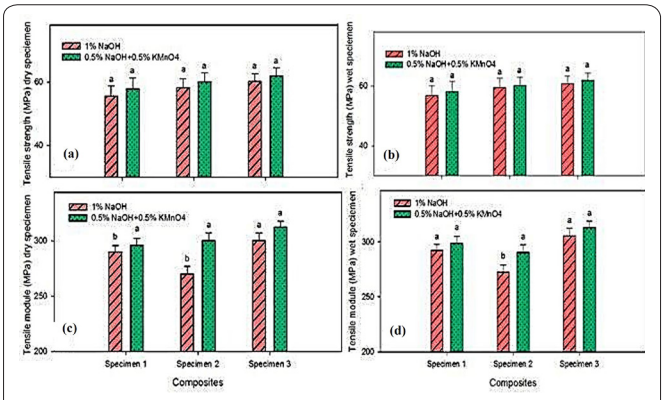


Figure 7: Tukey test result on **(a** and **b)** tensile strength and **(c** and **d)** tensile modulus of Class-a and Class-b of G/S/B hybrid composites under dry and wet conditions.

The tensile strength of Class-a G/S/B hybrid composites in accordance with wet conditions is greater in comparison to dry conditions. Similarly, in dry condition, the tensile strength of Class-b G/S/B hybrid composites of G/S/S/S/G, G/B/B/B/G and G/SB/SB/SB/G are 57.8 MPa, 59.9 MPa and 61.9 MPa, respectively, and in wet condition, those values were 58 MPa, 60.2 MPa, and 62 MPa. The tensile strength of Class-b G/S/B hybrid composites in accordance with the wet condition is greater in comparison to dry condition. The tensile strengths of Class-a type G/S/B hybrid composites in dry and wet conditions are comparatively smaller in comparison to the composites under tensile strength of Class-b type G/S/B hybrid composites in all three kinds (G/S/S/S/G, G/B/B/B/G, and G/SB/SB/SB/G). In the Tukey test results, the letter 'a' will be displayed above in both Class-a and Class-b G/S/B hybrid composites for all three fashions of fabrication (G/S/S/S/G, G/B/B/B/G, and G/SB/SB/SB/G). This means that there are no significant differences in the fashion of that followed in making up the composite and techniques of the processing of natural fibers according to standard error ± SE at the level of $p \leq 0.05$.

Analysis of tensile modulus of Class-a and Class-b G/S/B hybrid composites under dry and wet conditions

The wet and dry condition on the basis of tensile modulus

of both Class-a of G/S/B hybrid composites are 290.11MPa, 270.23 MPa and 300.47 MPa (dry) and 292.41 MPa, 272.56 MPa and 305.45 MPa (wet), respectively, for all three fashion of fabrication G/S/S/S/G, G/B/B/B/G and G/SB/SB/SB/G and which are comparatively smaller in comparison to the Class-b composites. That is, tensile modulus of those composites is 296.96 MPa, 288.43 MPa and 312.47 MPa (dry) and 298.78 MPa, 290.48 MPa and 313.88 MPa (wet), respectively, for G/S/S/S/G, G/B/B/B/G, and G/SB/SB/SB/G specimens). In the Tukey test results, the letter 'a' will be displayed above in most of the both Class-a and Class-b G/S/B hybrid composites for all three fashions of fabrication (G/S/S/S/G, G/B/B/B/G, and G/SB/SB/SB/G). In dry conditions the tensile modulus of Class-a specimen's G/S/S/S/G and G/B/B/B/G differ significantly in comparison to another composite. This means that in case of Class-a type G/S/B hybrid composites the fashion of fabrication G/SB/SB/SB/G is best and in case of Class-b type G/S/B hybrid composites, all three fashions are best comparatively Class-a of respective fashion of G/S/B hybrid composite in accordance with ± SE at the level of $p \leq 0.05$. In dry and wet cases, among all six modes of fabrication, Class-b type G/SB/SB/SB/G is best and higher in the case of wet in comparison to dry condition.

Analysis of percentage of elongation by tensile loads on Class-a and Class-b G/S/B hybrid composites under dry and wet conditions

Figure 8 demonstrates the percentage of elongation by a tensile load of dry and wet specimens. Tukey test result on the percentage of elongation of Class-a type of G/S/B hybrid composite are 5.7%, 5.1% and 7.7% for G/S/S/S/G, G/B/B/B/G and G/SB/SB/SB/G specimens under dry conditions and in wet conditions, the results are 5.9%, 5.5% and 8.1%, respectively. Similarly, the results of Class-b type of G/S/B hybrid composite are 6.7%, 6.2% and 8.6%, for G/S/S/S/G, G/B/B/B/G and G/SB/SB/SB/G specimens in dry conditions and in wet conditions the results are 7.1%, 6.8%, and 8.9%, respectively.

In the Tukey test results, the letter 'a' will be displayed above in most of the Class-a and Class-b G/S/B hybrid composites all three fashions of fabrication (G/S/S/S/G, G/B/B/B/G, and G/SB/SB/SB/G). In wet conditions the percentage of elongation differs significantly only for G/S/S/S/G fashioned composite. But in other cases, there is absolutely no significance in accordance with the percentage of elongation.

Analysis of breaking loads by bending of Class-a and Class-b G/S/B hybrid composites under dry and wet conditions

At 4.3 kN, 4.1 kN and 5 kN, respectively, of transverse load in accordance with the dry condition of Class-a type of G/S/B hybrid composite, the specimens had broken for G/S/S/S/G, G/B/B/B/G and G/SB/SB/SB/G specimens which is comparatively smaller in comparison to the composite at 4.9 kN, 4.6 kN and 6 kN of failure load of Class-b, respectively.

At 4.9 kN, 4.6 kN and 5.5 kN of transverse load in accordance with the dry conditions of Class-a type of G/S/B hybrid composite, the specimens had broken down for G/S/S/S/G, G/B/B/B/G and G/SB/SB/SB/G specimens which is comparatively smaller in comparison to the composites at 5.3 kN, 4.9 kN and 6.9 kN, respectively of failure load of Class-b. In the Tukey test results, the letter 'a' is displayed above in most of the Class-a and Class-b of G/S/B hybrid composites all three fashions of fabrication (G/S/S/S/G, G/B/B/B/G, and G/SB/SB/SB/G). In dry and wet conditions, the tensile modulus of Class-a specimen's G/S/S/S/G and G/B/B/B/G is much different in comparison to G/SB/SB/SB/G fashioned composite. This means that the Class-a and Class-b kinds of G/S/B hybrid composites differ significantly just for the fashion of fabrication G/SB/SB/SB/G in both dry and wet conditions where the strength of the composite is greater (6.9 kN) in wet conditions (Figure 9).

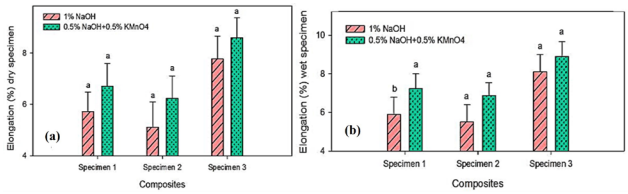


Figure 8: Tukey test result on the percent of elongation by a tensile load of Class-a and Class-b of G/S/B hybrid composites under **(a)** dry and **(b)** wet conditions.

Analysis of transverse rapture strengths of Class-a and Class-b G/S/B hybrid composites under dry and wet conditions

The flexural strength under dry condition of Class-a type of G/S/B hybrid composite are 12.9 MPa, 12.5 MPa, and13.6 MPa, respectively, for G/S/S/S/G, G/B/B/B/G and G/SB/SB/SB/G specimens. In wet conditions, flexural strength for Class-a type of G/S/B hybrid composite are 13.3 MPa, 13 MPa and 14.1 MPa, respectively, for G/S/S/S/G, G/B/B/B/G and G/SB/SB/SB/G specimens. Similarly, the flexural strength under dry condition of Class-b type of G/S/B hybrid composite are 13.9 MPa, 13.1 MPa and 14.5 MPa, respectively, for G/S/S/S/G, G/B/B/B/G and G/SB/SB/SB/G specimens. In wet conditions, flexural strength for Class-b type of G/S/B hybrid composite are 14 MPa, 13.8 MPa and 15.5 MPa, respectively, for G/S/S/S/G, G/B/B/B/G and G/SB/SB/SB/G specimens. Overall findings show that the flexural strength of composites was better in wet conditions in comparison to dry. Class-b type composites have a higher flexural strength in comparison to Class-a. In the case of the fashion of fabrication of composite, the G/SB/SB/SB/G specimen was better in both Class-a and Class-b composites. In the Tukey test results, the letter 'b' is displayed above for all Class-a and the letter 'a' is displayed above for Class-b of G/S/B hybrid composites for dry case. This means that there is no signifi-

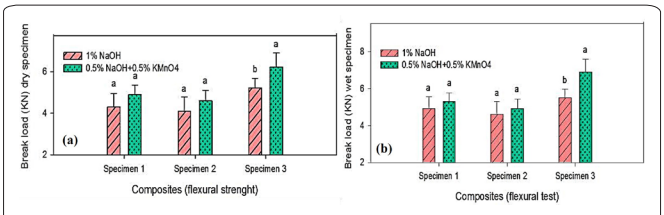


Figure 9: Tukey test result on failure by a transverse load of Class-a and Class-b of G/S/B hybrid composites under **(a)** dry and **(b)** wet conditions.

cant difference between the fashion of composite fabrication in Class-a and Class-b. However, there are considerable differences in the treatments with regard to statistics through ± SE at the level of p ≤ 0.05. In the case of wet conditions, the letter 'a' is displayed regardless of classes and the samples (Fashions of composite fabrication). This means that there is no significant difference in flexural strength variant regarding the treatment technologies as well as the fashion of composite complied with for the fabrication (Figure 10).

Analysis of transverse rapture modulus of Class-a and Class-b G/S/B hybrid composites under dry and wet conditions

The flexural modulus in accordance with the dry condition of Class-a type of G/S/B hybrid composite is 1480 MPa, 1316 MPa, and 1552 MPa, respectively, for G/S/S/S/G, G/B/B/B/G and G/SB/SB/SB/G specimens. In wet conditions, flexural modulus for Class-a type of G/S/B hybrid composite are 1530 MPa, 1414 MPa and 1590 MPa, respectively, for G/S/S/S/G, G/B/B/B/G and G/SB/SB/SB/G specimens. Similarly, the flexural modulus under dry of Class-b type of G/S/B hybrid composite are 1580 MPa, 1456 MPa and 1652 MPa, respectively, for G/S/S/S/G, G/B/B/B/G and G/SB/SB/SB/G specimens. In wet conditions flexural modulus for Class-b type of G/S/B hybrid composite are 1599 MPa,1498 MPa and 1695 MPa, respectively, for G/S/S/S/G, G/B/B/B/G and G/SB/SB/SB/G specimens. The overall results show that the flexural modulus of composites was better at wet conditions in comparison to dry conditions. The Class-b type composites possess higher flexural modulus in comparison to Class-a. In the case of the fashion of fabrication of composite, the G/SB/SB/SB/G specimen was better in both Class-a and Class-b composites. In the Tukey test results the letter 'a' is displayed above all Class-a and Class-b of G/S/B hybrid composites for both dry and wet cases. This means that there was no difference between the fashion of composite fabrication in Class-a and Class-b and treatments for natural fibers regarding the statistics through ± SE at the level of p ≤ 0.05.

Analysis of fracture toughness of dry and wet Class-a and Class-b G/S/B hybrid composites

Fracture toughness is due to the failure of dry and wet composites in accordance with the shock load condition. It usually occurs as the amount of energy in Joules which has been detected before breaking, in accordance with the shock load condition. Tukey test result on fracture toughness of Class-a type of G/S/B hybrid composite for G/S/S/S/G, G/B/B/B/G and G/SB/SB/SB/G specimens in accordance with the dry conditions are: 13.21 J, 12.41 J and 14.5 J and in wet conditions are 13.96 J, 12.77 J and 14.89 J, respectively. Similarly for Class-b type of G/S/B hybrid composite for G/S/S/S/G, G/B/B/B/G and G/SB/SB/SB/G specimens under dry conditions are: 16.77 J, 14.5 J and 18.86 J, and in wet conditions are 16.92 J, 14.57 J and 18.97 J, respectively (Figure 11).

In the Tukey test results of all three modes of fabrication, the letter 'b' displayed above Class-a G/S/B hybrid composite material. It means that there was no considerable difference

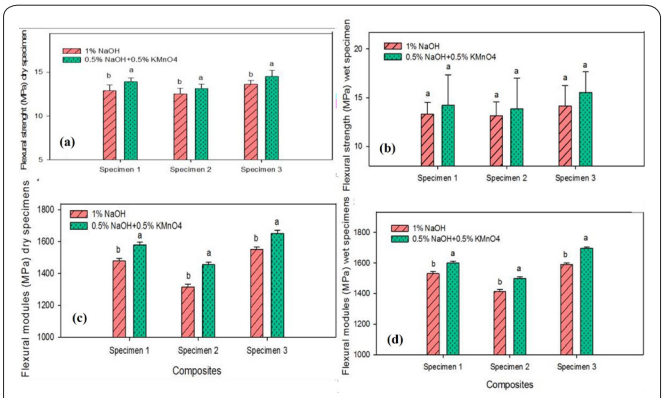


Figure 10: Tukey test result on **(a** and **b)** tensile strength and **(c** and **d)** tensile modulus of Class-a and Class-b of G/S/B hybrid composites under dry and wet conditions.

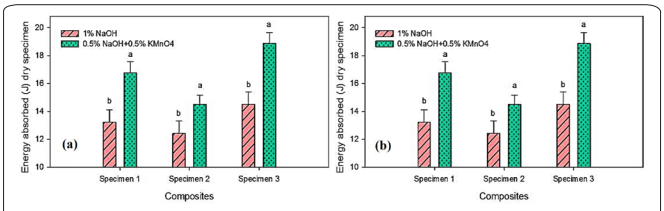


Figure 11: Tukey test result on fracture toughness of Class-a and Class-b of G/S/B hybrid composites under **(a)** dry and **(b)** wet conditions.

in the fashion which followed in making up the composite in accordance with the ± SE at the level of p ≤ 0.05. Similarly, the letter 'a' appeared over Class-b G/S/B hybrid composites which also implied the same. But the letters vary for the treatment technique. It shows that there is considerable difference among techniques of the processing of natural fibers in composting the G/S/B hybrid composites in accordance with the ± SE at the level of p ≤ 0.05.

DMA of Class-a and Class-b G/S/B hybrid composites for storage modulus

The storage modulus (E') in MPa is utilized here to describe the suggested composites. The frequencies of various kinds of natural fiber ratio for biocomposites with storage module is a maximal of 1 Hz frequency. The values of the storage module are statistically achieved among the diverse natural fiber hybrid composites of Class-a and Class-b of G/S/B hybrid composites and demonstrated in figure 12. The values were significant for the fashion of sisal/banana/glass hybrid composite (G/SB/SB/SB/G) of class a hybrid composites at 90.27 °C of maximum temperature and the values are significant at 89.58 °C for G/S/S/S/G (Sisal/glass) and at 82.11 °C for G/B/B/B/G (Banana/glass). Similar findings have been observed in the Class-b of G/S/B hybrid composites. The composite with G/SB/SB/SB/G of Class-b G/S/B hybrid composites attained significant values of (E') at 91.57 °C in comparison to the other two fashions (refer figure 12). Besides, the temperature has been slightly maximal in Class-b of G/S/B hybrid composites in comparison to Class-a. The storage modulus curves also prove that natural composites' integration considerably improves the values of E'. The loss modulus (E") is utilized here to describe the suggested com-

posites. The DMA curves for the loss modulus of anticipated composites exhibited that the Class-a of G/S/B hybrid composites with the manufacture of fashion of G/SB/SB/SB/G achieves a maximal dispersal of mechanical energy as 362.0 MPa in comparison to composite fashion of G/S/S/S/G (330.11 MPa) and G/B/B/B/G (303.42 MPa). Similarly, tendencies have been observed in the Class-b composites i.e., the greatest dispersal of mechanical energy of 368.1 MPa was attained for G/SB/SB/SB/G Class-b composite. It is also clearly demonstrated that in the loss modulus data the amalgamation of diverse kinds of biocomposites composition grounds the peak percentage of the loss modulus extension due to the improvement in procession partitions.

The loss modulus to storage modulus is a ratio (E"/E') whose base for taking into account damping results. Generally, the combination of natural fibers ratio grades the performance of damping in biocomposites due to the shear-stress dosage with fibers combined into the company of energy of viscous-elastic indulgence on natural fiber matrix. These experimental data support the foregoing results in G/SB/SB/SB/G composite of Class-b, considerable peak area of 0.457 delivered in 102.01 °C in comparison to G/S/S/S/G composite (0.3907 in 105.56 °C), for G/B/B/B/G fashion of Class-b G/S/B hybrid composites (0.3540 at 96.36 °C). Similarly, at 102.11 °C, the significant peak area of 0.437 was produced in the fashion of G/SB/SB/SB/G composite of Class-a G/S/B hybrid composites (Figure 13).

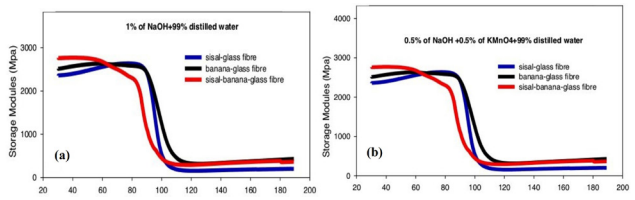


Figure 12: DMA of Class-a and Class-b G/S/B hybrid composites for loss modulus.

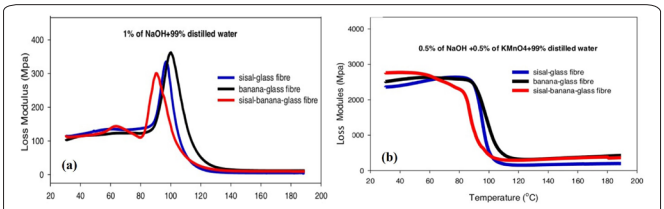


Figure 13: DMA of Class-a and Class-b G/S/B hybrid composites for tan delta.

Conclusions

The dynamic analysis of PLA-based natural hybrid fiber composites involves a combination of experimental testing and numerical simulations to understand their behavior under dynamic loading conditions. This information is essential for designing and engineering materials that meet specific performance requirements in various applications. The composite that uses these treated fibers is categorized as Class-a and Class-b hybrid composites. The three fashions like G/S/S/S/G, G/B/B/B/G and G/SB/SB/SB/G were followed by composite materials where they are synthesized. Therefore, six different types of hybrid composites were synthesized and characterized by dry and wet applications. All composites have a great finish, encompasses a good variety of strength and desirable characteristics, better results were obtained in wet conditions, absorbs less humidity and so on. Following are the specific results.

- As per the ASTM D570 standard, the lowest net moisture absorbability of 4 g is achieved in Class-b type, G/SB/SB/SB/G fashion hybrid composite.
- As per the ASTM D3039 standard, the tensile test was performed. In Class-b type, G/SB/SB/SB/G fashion hybrid composite, the breaking load of 8.23 kN was attained in dry condition and 9.11 kN was achieved under wet condition.
- In Class-b type, G/SB/SB/SB/G fashion hybrid composite, the ultimate tensile strength of 61.9 MPa was attained in dry condition and 62 MPa was attained under wet condition and the tensile modulus of 312.47 MPa has been attained in dry condition and 313.88 MPa was achieved under wet condition and the breaking load of 6 kN was attained at transverse loading in dry condition and 6.9 kN have been attained under wet condition.
- In Class-b type, G/SB/SB/SB/G fashion hybrid composite, the bending strength of 14.5 MPa was attained in dry condition and 15.5 MPa was attained under wet condition and the flexural modulus of 1652 MPa was attained in dry condition and 1695 MPa was attained under wet condition and the percentage of elongation 8.6% was attained in dry condition and 8.9% has been achieved under wet condition and the fracture toughness of 18.86 J has been attained in dry condition and 18.97 J was achieved under wet condition.
- The storage module (E') values were considered for Class-a G/SB/SB/SB/G hybrid composite at 90.27 °C of maximal temperature and for Class-b G/SB/SB/SB/G hybrid composite at 91.57 °C.
- The loss modulus (E") G/SB/SB/SB/G hybrid composites have reached its maximum dispersal of mechanical energy of 362.0 MPa for Class-a and 368.1 MPa for Class-b.
- In damping results of tan delta, the G/SB/SB/SB/G fashioned hybrid composite efficiency has been found well that is with a considerable peak area of 0.457 is delivered within 102.01 °C by Class-a hybrid composite and 0.437 is delivered in 102.11 °C by Class-b hybrid composite.
- The SEM analysis was carried out on broken/tested/SB/SB/SB/G fashioned hybrid composites based on cross-section, fiber's orientation subsequent to the brakes, by tensile, bending and impact review and was presented with a brief analysis.

Acknowledgements

None.

Conflict of Interest

None.

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