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Comparative Analysis of Mechanical and Water Absorption Properties of Nano/Micro-Sized Alumina Filler-Based Glass-Jute Hybrid Composites

Ramanuj Kumar[1]*, Kartik Singh[1], Ekta Gogna[1], Himansu Ranjan Sinha[1], Ashok Kumar Sahoo[1]

School of Mechanical Engineering, KIIT Deemed to be university,
Patia, Bhubaneswar, Odisha-751024

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Abstract: In recent years, the addition of nano and micro size filler material for fabricating composite materials are emerging concepts through which mechanical properties of the composite can be enhanced. Filler based hybrid polymer composite materials are substituting metallic materials because of their low specific wear rate, high specific strength modulus, and less water absorption. In current work, nano and micro Al_2O_3 filler based Glass-Jute hybrid composite have been fabricated to study the mechanical properties like hardness, impact test, specific wear rate, and flexural strength for each type of composite sample. Water absorption analysis is also carried under three different fluid media namely normal water, river water and de-ionized water-based Al_2O_3 nanofluid. Nano filler enriched composite attributed the higher magnitudes of hardness, impact strength, flexural strength and lower value of specific wear rate and water absorption compared to micro and normal composites. However, a nanofiller based composite is more suitable for automotive, aerospace and ship manufacturing industries.

Keywords: Alumina, Flexural strength, Impact strength, Micro-composite, Nano-composite, Specific wear rate, Water absorption

1. Introduction

The application and research development in hybrid composites materials have got the attention of many researchers because of its light in weight, lower cost, easy to available, less density and high strength modulus which make them an immersing structural material since few years [1-7]. Natural fibre comes under low-cost material which is abundantly available in nature and works as renewable material [8-9]. Natural fibres worked superiorly as a reinforcement material compared to synthetic fibres with wide availability, worthy specific modulus, low weight, low cost, less energy necessity, biodegradability, fewer hazards to the surrounding, renewable resources and eco-friendly [10-12]. Further, the limitations of the natural fibres such as poor dimensional accuracy and stability, greater moisture absorption, low wettability, rapidly aging at reasonably elevated temperature, incapability with hydrophobic resins, etc. limit its implementation in extravagant applications. Jute comes under the category of cheap and abundantly available fibres and it is popularly used in the fabrication of composite matrix. Jute fibres are cellulosic fibres which are made of cellulosic molecules. Jute cells are formed by embedding in hemicelluloses and lignin matrix in cellulosic fibrils. Individual jute cell is interconnected to each other by lignin to establish an extensive filament [12-13]. Glass fibres are fabricated using very fine glass fibres. Thin silica strands and other glass formulations were squeezed together by applying high pressure to form the glass fibre. It is cheaper and less brittle than carbon and other plastic fibres. It can be used for fabricating the composites to increase the strength and reduce the weight. Glass reinforced plastic (GRP), also known as 'fibreglass' & E-glass (alumina-borosilicate glass) are the most common glass used in the fabrication of

*Corresponding author: ramanujkumar22@gmail.com

composite matrix. Fibre glasses possess good resistance towards tensile and compressive forces. Glass fibres are used for high strength fabrics, corrosion-resistant fabrics, thermal insulation, sound insulation, electrical insulation, etc. These fibres are widely used for making fibre-reinforced plastic (FRP) vessels and tanks [14].

In order to overcome the disadvantage of natural fibres, artificial fibres are introduced in the matrix, leading to the fabrication of hybrid matrix composites. On fabricating a hybrid composite matrix, it was found that the fabricated composites possess the combined properties of its consequent in a single hybrid matrix. Hybrid matrix has the improved characteristics compare to its consequent as the disadvantage of one fiber can be overcompensated by other fibres. The mechanical properties of the hybrid fibre composites are influenced by the arrangement of each fibre, orientation of fibre, length of individual fibre, aspect ratio of fibre content, properties of fibres, failure strain of the individual fibres and also on the extent of interface bonding of fibres [15-16]. In order to achieve augmented mechanical and additional properties of matrices, hybridization is an emerging technique which can be implemented in the fabrication of composites. The application of filler material in hybrid composite improves the property of composite. Nano or micro-sized spherical fillers are most suitable to achieve improved mechanical properties and surface quality of the fabricated composites [17]. The application of nano and micro alumina filler material in ship, aerospace and automotive industries are increasing day by day as these composite have less wear rate and high strength. As the wearing is a dominant factor for the piston, connecting rod, the piston head and structural frame in automobile and aerospace, hence nano and micro composites matrices are widely utilized in these industries [18-20]. According to Bowman et al. [21] sizing agents significantly influence carbon fiber matrix due to larger molecular weight of sizing agent which acted as a linkage between carbon fiber and matrix resin. The water absorption rate of the nano and micro filler is less so, these composites can be used in ship industries. Epoxy resin is used as reinforcement material during fabricating a composite as it has greater strength, stiffness, resistance toward chemical reactivity and shows good dielectric behavior [9, 23-27]. Quality of laminated influenced the void content. As the quality of lament is poor, it enhances the void content thus attributed to the poor mechanical properties of the composite [28].

In recent years, due to favorable advantages of natural fibers, lots of works were reported on natural fiber composites in literature. Some major works findings are summarized as follows: Burris et al. [29] found that the composite with nano alumina filler has high wear resistance relative to without nano filler composite. Deb et al. [30] compared the mechanical properties in between jute-polyester and jute-steel-polyester composites and found higher tensile and flexural moduli of jute-steel-polyester composites compared to jute-polyester. Rao et al. [31] concluded that alkali-treated bamboo/glass hybrid composite exhibited the better flexural and compressive characteristics relative to untreated hybrid composite. Jha et al. [32] studied the corrosion and mechanical performance of jute and e-glass hybrid composite and found that the jute fiber attributed a higher tensile strength compared to e-glass composite while it has lower wear rate compared to e-glass composite. Acharya et al. [33] investigated the effect of arrangement of glass and jute fiber composite on the mechanical properties of composite matrix and found that the glass-jute-jute-glass arrangement attributed the higher flexural, inter-laminar shear stress compared to the arrangement like jute-glass-glass-jute and glass-jute-glass-jute. Mishra et al. [34] investigated the physical and mechanical properties of jute fibre composite reinforced with epoxy resin. It was concluded that the hardness, tensile strength and impact strength were increased with fibre loading. Gujjala et al. [35] investigated the mechanical properties of jute-glass (woven) hybrid composite and concluded that the inclusion of nano-sized alumina filler in jute composite enhanced the tensile strength and flexural property of the fabricated composite matrix. Wang et al [36] studied the chemical modification and dyeing properties of jute fiber. It was concluded that the glytac-treated jute sample had greater exhaustion, fixation and higher fixation than those of untreated and it could also be dyed with reactive dye using little salt and alkali. Ozawa et al. [37] studied about the thermal property of jute fibre composite at high temperature and found that the compressive strength of hele-shaw-convection cell with jute fibre was reduced by 40% at 100°C and attributing the best strength when the temperature was varied from 200°Cto 300°C. Sigwadi et al. [38] investigated the tensile strength of the Nafion® membrane and ZrO_2 nano-membrane under both dry and wet conditions. Modified wet Nafion® membrane and dry ZrO_2 nano-membrane using impregnation method exhibited the better tensile strength compared to dry Nafion® membrane using recast method and wet ZrO_2 nano-membrane using impregnation method. By addition of inorganic nano filler, the elastic modulus was improved. Arsyad et.al [39] studied the effects of chemical treatment (NaOH, $KMNO_4$, H_2O_2) on the coconut fiber surface. It was found that the by application of chemical treatment the surface morphology of surface changed but its mechanical strength slightly reduced. Nayak et al. [40] studied the influence of nano alumina filler and cross head velocity on inter-laminar shear stress of fabricated glass fiber composite and found that the addition of nano Al_2O_3 by 3 % of weight didn't influence inter-laminar shear stress more. Up to 1 to 100 m/min of crosshead velocity, inter-laminar shear stress was increasing while beyond 100 m/min the inter-laminar shear stress was decreasing. In another work, Nayak et al. [41] found that the addition of nano alumina filler (1 % weight) was beneficial as the flexural strength of the composite was increased by 12%, inter-laminar shear stress increased by 11% and the seawater coefficient was decreased by 175 compared to the simple glass fiber composite. According to Wang et al. [42] chemically treated jute fibers composites attributed the enhanced properties like tensile strength, void-fraction, and interfacial adhesion compared to raw jute composites. Ray et al. [43] found about 28 % improvement in impact strength of hybrid composite due to inclusion of 15% marble filler [44]. Latif et al. stated that the inclusion of silica enriched rice husk ash enhanced the yield as well as ultimate strength of the fabricated composites.

Based on the literature survey, very rare works are available on nano/micro filler based composites. Also, comparative analysis of mechanical and water absorption properties between nano, micro and without filler composites is not available yet. Therefore, considering these literature gaps, the current work emphasized on a comparative analysis of mechanical (hardness, impact strength, specific wear rate, flexural strength) and water absorption properties of nano and micro-sized alumina filler based glass-jute composites. This work will be definitely beneficial for marine, aerospace vehicles, automotive, windmill making industries and researchers.

2. Materials and Methods

2.1 Fabrication of glass-jute hybrid composites

In order to fabricate the hybrid composite material, glass fiber, jute fiber, epoxy resin, K-6 hardener, nano, and micro alumina filler are used. Four layered hybrid composite matrix is fabricated using hand lay-up method. Three different composite matrices are fabricated, one with nano alumina filler, second with micro alumina filler and third with no filler material. For easy removal, silicon spray is sprayed on the Teflon sheet. The nano and micro alumina filler are heated till 100˚C to avoid moisture content and then it was mixed in epoxy using temperature assisted magnetic stirrer. Further to get a uniform paste of epoxy and alumina, an ultrasonic bath is used for 60 minutes. Two layers of jute fibers are sandwiched between two glass fibers. During fabricating nano-composites, nano alumina filler powder of 1% weight is mixed with epoxy resin (2.5 times of fiber weight) and hardener (0.1 times of fiber weight). Further, 1kgf of force is applied to the sandwiched composite to avoid bubble formation during fabrication. After fabrication of the composite, a constant load is applied for 72 hours. The overall fabrication process of the composite matrix is displayed in Fig. 1 and Fig. 2. A similar procedure is adopted for micro composite. For normal composite, without alumina filler is used and the remaining procedure is the same. After 72 hours, fabricated composites are cut into desired dimensions for different experimental test.

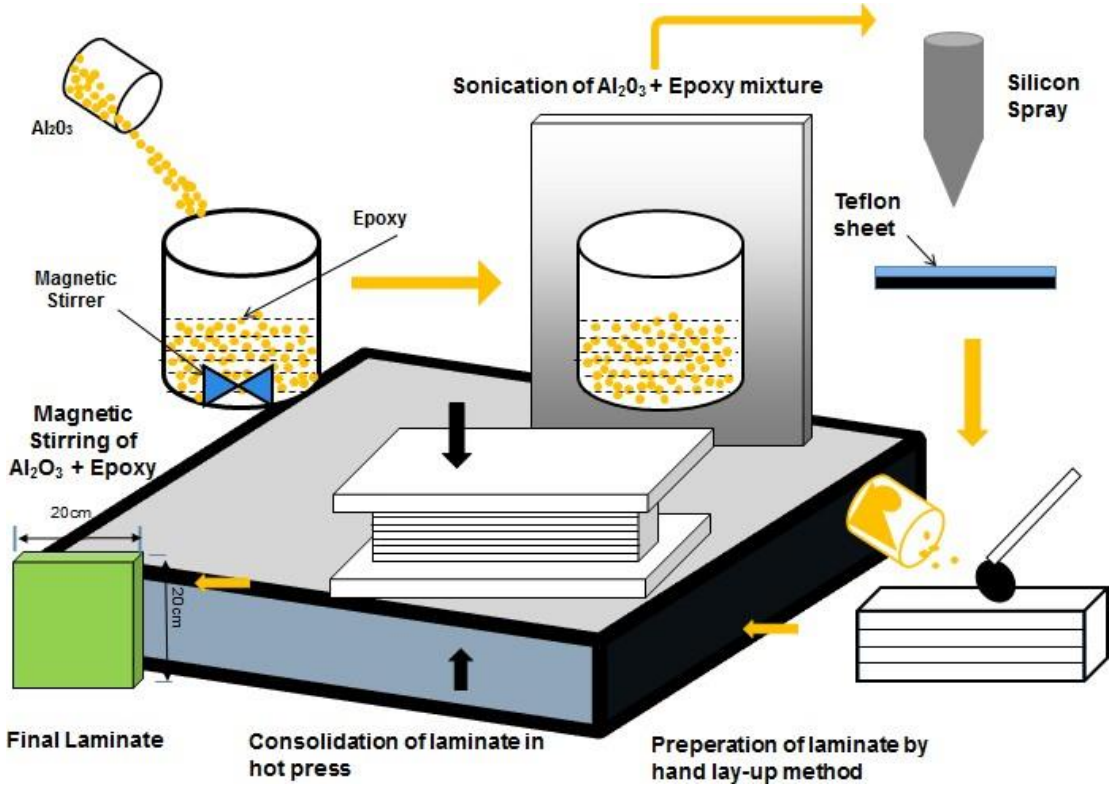
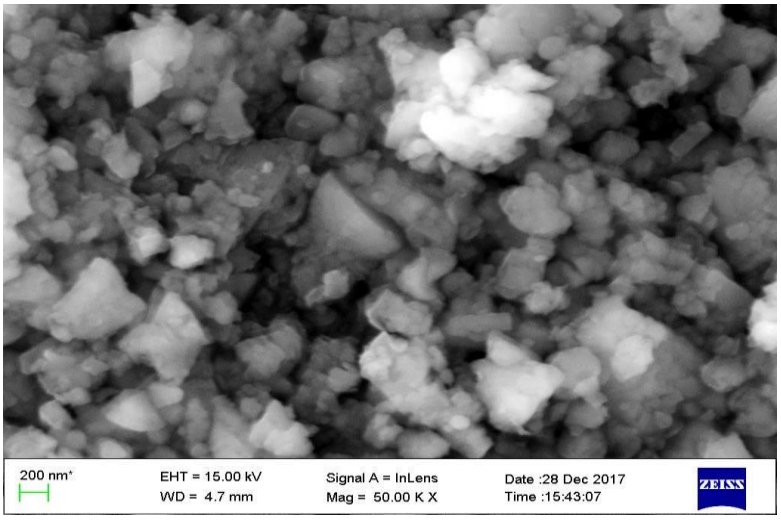


Fig. 1 - Schematic process for fabrication of composite laminate

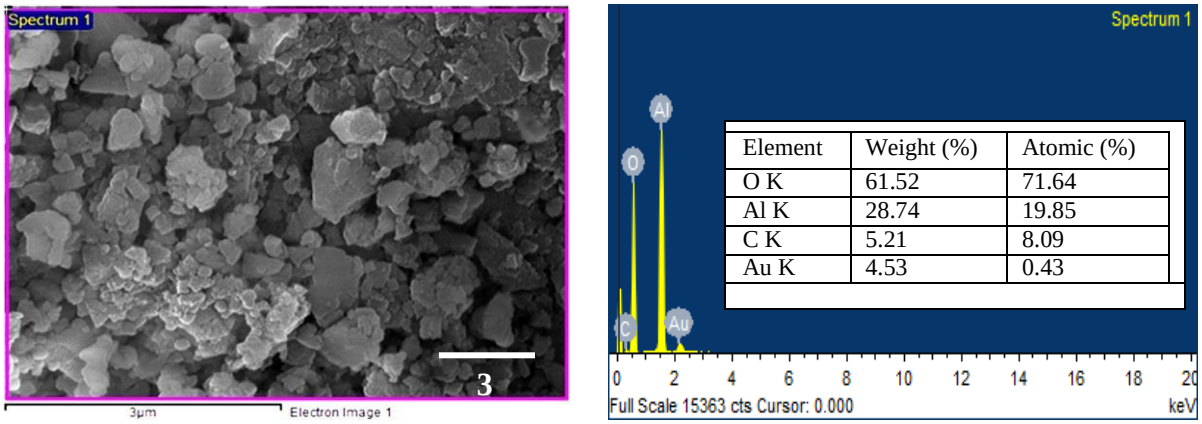
2.2 Alumina filler materials

In the current work, micro and nano-sized alumina filler materials are used while fabricating the composites. Micro- sized alumina powder is commercially purchased from the Sigma Aldrich. Nano-sized alumina powder is made from micro-sized alumina powder using a ball mill. Wet ball milling concept is utilized for preparing the nano-sized alumina powder. The FESEM and EDS analysis of nano sized alumina powder have been carried and its details are given in Fig. 3a and Fig. 3b consequently. The working distance (WD) for FESEM analysis is 4.7 mm with an accelerating voltage of 15 kV and beam energy of 2-5 kV.

Fig. 2 - Fabrication of composite laminate



(a)



Element	Weight (%)	Atomic (%)
O K	61.52	71.64
Al K	28.74	19.85
C K	5.21	8.09
Au K	4.53	0.43

(b)

Fig. 3 - (a) FESEM view of nano alumina powder; (b) EDS analysis of nano alumina powder

The size of the nano particle is estimated through FESEM micrograph (Fig. 3a) and it is found to be 100 nm (average). Agglomeration of nano particles clearly noticed in the FESEM micrograph, hence it was properly mixed in epoxy resin by using magnetic stirrer and further kept for sonication to minimize the agglomeration tendency of nano particles. The EDS analysis of powder is carried as displayed in Fig. 3b where electron image and their contents are shown. From this EDS analysis, it is verified that the majority of % involved in the powder is Aluminium (Al) and Oxygen (O).

2.3 Sample preparation, procedure and measurements

For analysis of impact strength test, the sample dimensions 65 (length) ×12.7 (width) ×3.8 (thickness) mm has been used for each type of composite matrix. Also, a V-notch of 45° and 2 mm deep was cut in the middle of each specimen. Further, the specimen was placed into vise and a pendulum was allowed to hit the specimen and the energy

absorbed before the fracture of the specimen under observation was measured. Impact strength (IS) was calculated by using the Eq. 1.

$$IS = \frac{E}{A} = \frac{E}{W_a \times t} \quad (1)$$

Where, 'E' represents the energy absorbed, 'A' denotes the actual cross-sectional area of sample, w_a is the actual weight and t is the thickness of sample.

For analysis of specific wear rate (SWR), the sample dimension of 76 (length) × 25.4 (width) ×3.8 (thickness) mm is cut from the parent fabricated composite matrix. To estimate the SWR of the specimen, the dry abrasion test is performed on to the DUOCM TR 50 dry abrasion machine. For the wear test, dry silicon sand AFS-60 is utilized. The initial weight of each sample is measured before the test. For the test, the composite sample is placed normal to the direction of the sliding wheel and abrasive sand is allowed to pass between sample and rubber wheel while rubber wheel was kept in contact with the sample by applying 25.5 N forces by means of the liver arm of ratio 1:2.6. The rotating wheel was set at a speed of 125 rpm and a total sliding distance of 10 m. After the abrasion test, final specimen weight was measured and the specific wear rate was intended using Eq. 2.

$$SWR = \frac{\Delta V}{L.d} \quad (2)$$

Where, 'SWR' is specific wear rate; 'ΔV' is change in volume; 'L' is load applied; and'd' is sliding distance.

For analysis of flexural strength, the sample dimension is kept as 76 (length) ×12.7 (width) × 3.8 mm (thickness) for each sample. The universal testing machine INSTRON 3369 having 50 KN maximum load capacity was utilized to accomplish the flexural property of the sample. Span length and cross head speed were kept fixed as 60 mm and 2mm/min respectively. The maximum average load applied is 181.5 N to estimate the flexural strength. The flexural strength is calculated using the Eq. 3.

$$\sigma_f = \frac{3P_{max}L}{2bt^2} \quad (3)$$

Where, 'σ_f' is flexural strength to be calculated, 'P_{max}' is maximum load before rupture, 'L' is the span length,'t' and 'b' are thickness and width of the test sample respectively. For water absorption test, the specimen size of 65 (length) ×12.7 (width) ×3.8 (thickness) mm is used. Three different fluid media namely tap water, Ganga river water, and de-ionized water-based Al_2O_3 nano fluid are used to carry the water absorption test. Two steps methodology is used to prepare the de-ionized water based nano fluid. 1% weight of nano alumina powder is immersed in the water and mixed properly through magnetic stirrer for 24 hours. Further, the mixed nano fluid is kept in an ultrasonic bath for 4 hours of sonication which ensure the uniform mixing of nano particles in water. The nano fluid is sable for 10 days. Therefore for avoiding cluster phenomena of nano particles, the nano fluid is again steering by a magnetic stirrer for 5 hours followed by sonication of 1 hour. A similar procedure was adopted by Nayak et al. [41]. All three samples were kept in each type of fluid for 90 days. Initial weight is measured before placing the samples in liquid. With 15 days of interval, the weight of each sample is measured in order to check the change in weight due to moisture absorption.The time gap between the removal of samples from fluid and weight measurement is very short. Before weight measurement, adhered fluid on composites is wiped off using fresh cotton. The amount of fluid absorbed by composite is calculated using the Eq. 4.

$$W_{ab} = \frac{(W_w - W_d)}{W_d} \times 100\% \quad (4)$$

Where, W_{ab} represents weight of water absorption in percentage, W_w denotes the weight of wet composites after removal from fluid and W_d is the weight of the composite sample at the dry condition.

The following ASTM standards are used for measurement of mechanical properties:

- For hardness measurement: Barcol hardness tester of ASTM D2583 standard.
- For impact strength measurement (Charpy test): Izod impact of ASTM D256 standard.

- For dry abrasion measurement: ASTM G65 standard.
- For flexural strength test: ASTM D790 standard.

Different mechanical tests (Hardness, Impact strength, SWR and Flexural property) have been repeated five times and the average value of each test is considered in the present analysis. The measurement error for hardness, impact strength, specific wear rate, and flexural strength are displayed in **Table 1**. From this measurement error analysis, maximum error for hardness, impact strength, specific wear rate, and flexural strength are found to be ± 2.59 %, ± 4.93 %, ± 4.72 % and ± 2.97 % respectively which ensures the measurement process is correct and within 5%.

Table 1 - Error Measurement

	Hardness (BHN)			**Impact test (KJ/m^2)**		
	Nano Composites	**Micro Composites**	**Normal Composites**	**Nano Composites**	**Micro Composites**	**Normal Composites**
Test-1	32.5	28.0	23.0	35.22	26.93	18.64
Test-2	34.3	26.2	26.0	37.29	20.72	16.57
Test-3	34.6	27.8	24.7	31.08	26.93	17.6
Test-4	33.6	26.0	23.8	35.22	22.79	20.72
Test-5	35.0	27.0	22.5	37.29	24.86	16.57
Average	34.0	27.0	24.0	35.22	24.44	18.02
Standard Deviation	0.9823	0.9055	1.2946	2.5352	2.6989	1.7360
% Error	1.29	1.49	2.59	3.22	4.93	4.30
	Specific wear rate (mm^3/Nm)			**Flexural strength (MPa)**		
Test-1	0.03783	0.05317	0.05112	7343.890	7004.958	5776.244
Test-2	0.02583	0.05073	0.06161	8434.979	7331.814	6550.524
Test-3	0.03462	0.05674	0.06346	7089.942	7442.701	6090.343
Test-4	0.03645	0.04612	0.06903	7679.864	7367.775	6383.354
Test-5	0.03392	0.05547	0.06153	7787.675	7132.845	6163.563
Average	0.03573	0.05244	0.06135	7667.270	7256.019	6192.806
Standard Deviation	0.00153	0.00421	0.00648	510.371	181.168	295.443
% Error	1.92	3.59	4.72	2.97	1.11	2.13

3. Results and discussion

3.1 Analysis of hardness

Hardness of the fabricated composite matrices is measured using barcol hardness tester which utilizes the indention hardness techniques. The indentation hardness has rough collinear relation with the tensile strength of material [30]. From the test **(Fig. 4),** the average hardness is found to be maximum in nano-composite (34 BHN) compared to micro-composite (27 BHN) and normal (without filler) composite (24 BHN). This result shows that the nano-composite possesses 25.9 % more hardness compared to micro composite whereas 41.6% more hardness compared to normal-composite. Also, the hardness of micro composite is 12.5% higher than normal composite. The nano-composite shows the highest hardness, because of good interface bonding capability of nano-particles which also reduces the voids and micro-crakes formation in the composite. The propensity of micro-cracks development is increasing in interphase with higher particle size of alumina due to that the hardness of micro composite is lower to nano-composite.

3.2 Analysis of impact strength

Impact strength is the amount of energy absorbs by an object before fracturing under deformation. In another means, it is the ability of a material to resist the high rate of deformation. The test results **(Fig. 5)** indicated that the impact strength of nano-composite samples is found to be highest (35.22 KJ/m^2) compared to micro-composite (24.44 KJ/m^2) and normal-composite (18.02 KJ/m^2). However, nano-composite has 44.1% more impact strength compared to micro-composite whereas, it has 95.44% more impact strength compared to normal-composites. Nano filler with reinforcing material led to great adhesion between composite laminate, hence it requires more force to crack the laminate resulting good impact strength. The impact strength of the sample increases with an increase in fiber loading [45]. Further, the impact strength of the micro-composite matrix is 35.62% higher than the normal-composite because of higher adhesion characteristics between composite laminate of micro-sized alumina filler compared to normal epoxy.

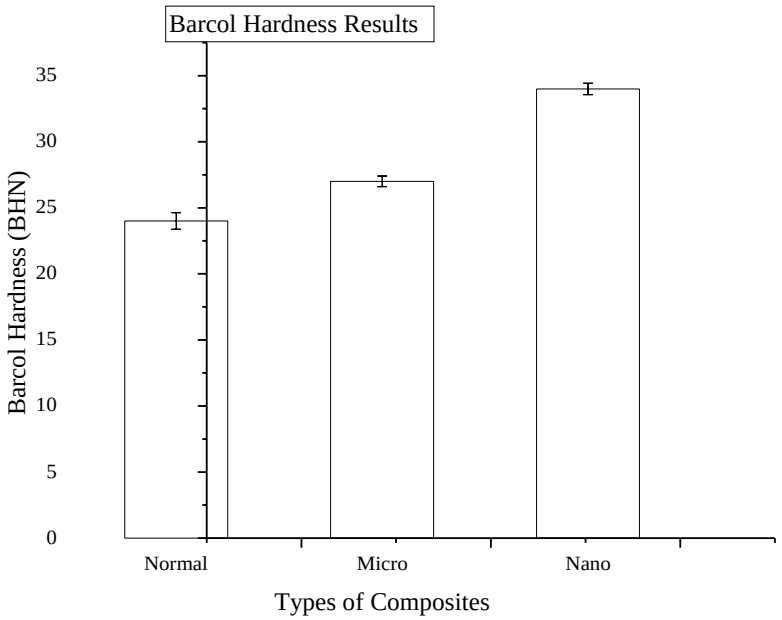


Fig. 4- Hardness test results

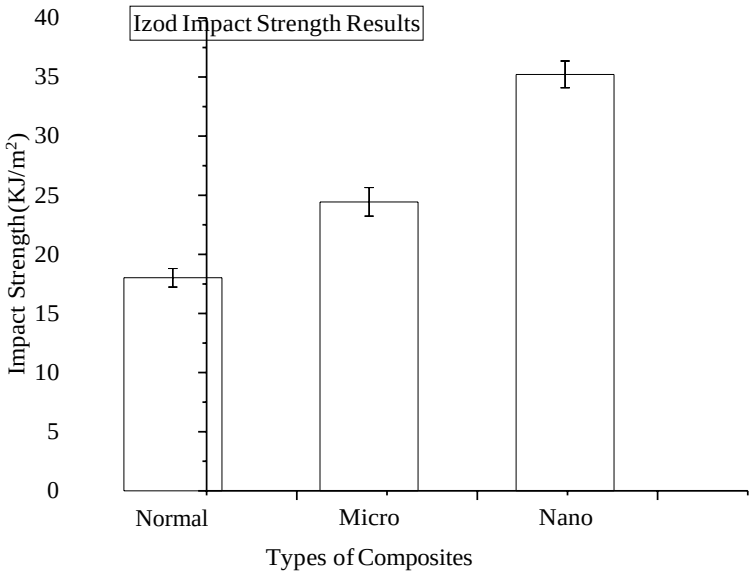


Fig. 5- Impact strength test results

3.3 Analysis of specific wear rate

Specific wear rate (SWR) analysis is a prime index to check the performance of the composite matrix under friction or rubbing condition. Lower wear rate is a favorable characteristic of any composite matrix. The results of average SWR for nano, micro and normal composite matrices are displayed in **Fig. 6**. From the results, nano composite has lowest SWR (35.730×10^{-3} mm^3/Nm) compared to micro-composite (52.446×10^{-3} mm^3/Nm) and normal-composite (61.350×10^{-3} mm^3/Nm) i.e. Nano-composite has 31.8 % lower SWR compared to micro-composite while it has 41.7% lower SWR relative to normal composite matrix. It happens due to perfect bonding of nano filler between composite laminates which leads its hardness as a result lower wear rate is noticed. Micro-sized alumina may increase the voids and micro-cracks in the interphase bonding due to that micro composite attributed the higher SWR compared to nano composite. But while comparing the SWR of micro composite to normal composite it was 14.51% lower SWR

compared to normal composite. It may happen due to relatively higher hardness of micro-sized filler epoxy composite compared to without alumina added composite [46].

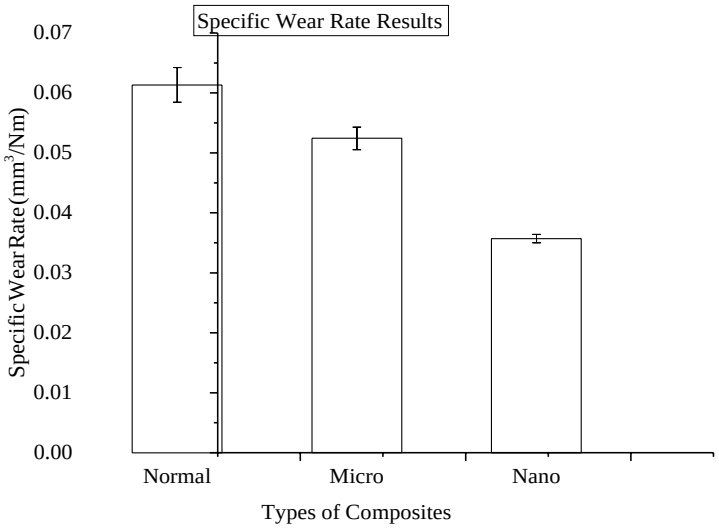


Fig. 6 - Specific wear rate results

3.4 Analysis of flexural strength

Flexural strength of a material is defined as internal stress induced in the material. The stress-induced just before yielding is called flexural strength. It is also called modulus of rupture [47]. Higher the flexural strength i.e. lesser will be the deflection. Modulus of rupture of composite matrix is calculated by the mechanical properties of the utmost fiber layer of matrix. The composite material underwent simultaneous compressive and tensile stress and most of the samples are failed due to tensile stress. The failure begins on the side underwent tension side of the beam and slowly propagates in the upward direction. Investigated flexural strength test results are displayed in **Fig. 7.** Average flexural modulus is found to be the maximum for nano-composite (7667.2MPa) compared to micro composite (7256MPa) and normal composite (6192.8MPa) i.e. Nano-composite has 5.66% greater flexural strength as compared to micro- composite and 23.8% greater flexural strength as compared to normal-composite. Also, micro-composite has 17.16% higher flexural strength compared to normal composite. Flexural stress vs flexural strain graph (**Fig. 8**) clearly shows that the nano-composite has higher flexural strength compared to micro and normal composite. Nano particle enriched filler is most suitable to fabricate the composite as it increases the interphase bond strength which reduces the chances of micro-cracks formation which results the flexural strength of nano composite is on the higher side compared to micro and normal composites. As size of alumina particle in micro-composite is higher which creates the micro voids in the interface layer which helps in the micro-cracks formation as a result the flexural strength reduces in micro- composites compared to nano-composite.

3.5 Analysis of water absorption

When natural fibers are kept in contact with moisture it's their tendency to absorb the moisture. Moisture absorption takes place due to the presence of hemi-cellulose in the fiber. The presence of hydrophilic hydroxyl group and lignin makes them moisture repellent. As moisture is absorbed by the fibers, swelling takes place until the cells of fibers are saturated. The presence of moisture degrades the binding resin leads to weakening of matrix hence possess less tensile, flexural and impact strength. According to Nayak et al. engrossed moisture content supports the matrix to enlarge/bulge, plasticize, and creation of cracks which boosts the diffusion of water phenomena into the matrices thus, mechanical as well as thermal properties were degraded [46]. In the current investigation, the moisture content for nano, micro, and normal composites are analyzed in three different fluids (tap water, Ganga river water and Al_2O_3nano fluid). The graphical relation between time period (days) and water absorption (%) are displayed for tap water in Fig. 9, for Ganga river water in Fig. 10 and for de-ionized water based Al_2O_3 nano fluid in Fig. 11. In each fluid, the increasing order of water content is nano, micro and nano matrix respectively i.e the nano matrix attributed the least water content compared to micro and normal matrix. It happens due to the bigger surface area of nano Al_2O_3 which attributed the good interface bonding in between the matrix and fiber as compared to normal and micro composites. Micro composites have larger size of alumina particles which may create voids as result water diffuses into the interface bond through capillary action easily thus water absorption rate is higher compared to nano composite.

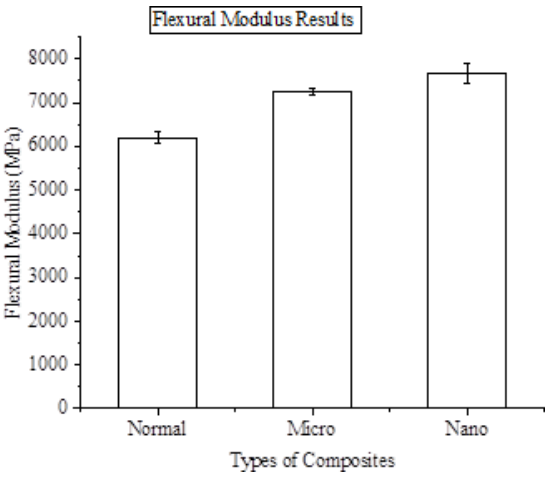


Fig. 7 - Flexural modulus results

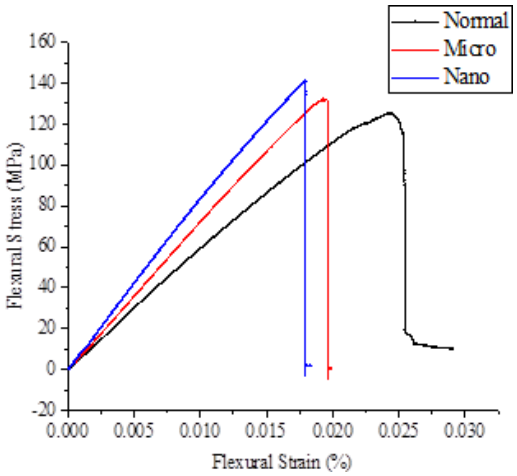


Fig. 8 - Graphical view of flexural stress Vs flexural strain

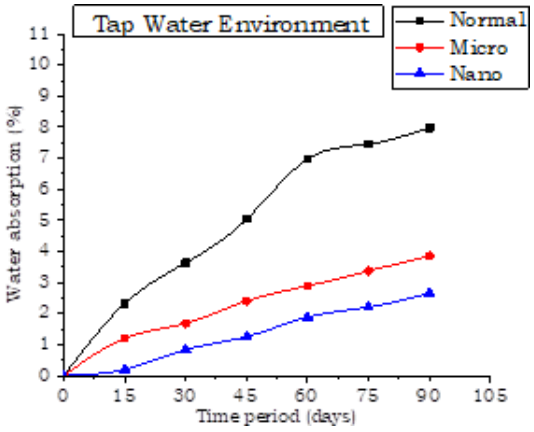


Fig. 9 - Graphical view of water absorption Vs time period under tap water environment

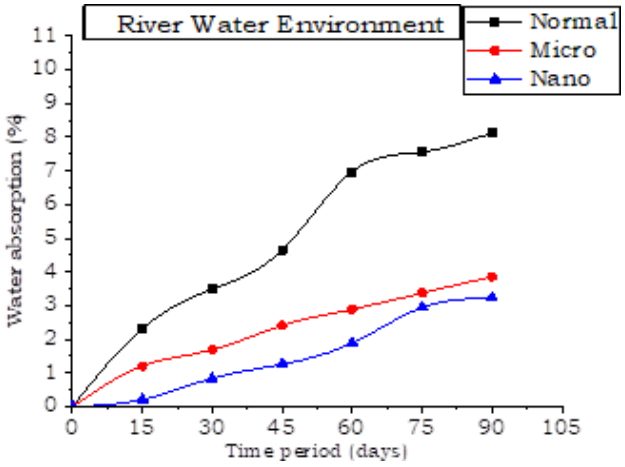


Fig. 10 - Graphical view of water absorption Vs time period under river water environment

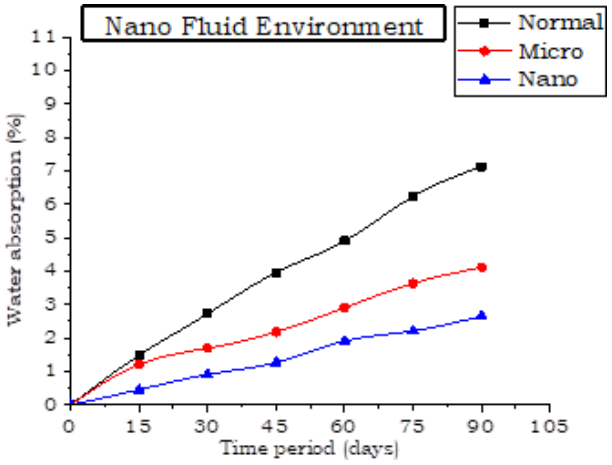


Fig. 11 - Graphical view of water absorption Vs time period under Al_2O_3 nano fluid environment

4. Conclusion

The current work presents a comparative analysis of mechanical and water absorption properties of alumina-based (nano/micro-sized) hybrid glass-jute composite and normal glass-jute composite. Based on the several measurement results, the following conclusions have been drawn as follows:

- The alumina-nano composite has 25.9 % more hardness compared to alumina-micro composite whereas it has 41.6% more hardness compared to normal composite due to perfect bonding of nano alumina filler between composite laminates.
- The alumina-nano composite has 44.1% more impact strength compared to alumina-micro composite whereas, it has 95.44% more impact strength compared to normal composites. Nano filler with reinforcing material led to great adhesion between composite laminate, hence it requires more force to crack the laminate resulting in good impact strength.
- Nano-composite has 31.8 % lower SWR compared to micro-composite while it has 41.7% lower SWR relative to the normal composite matrix. It may happen due to perfect bonding of nano filler between composite laminates which leads its hardness as a result, lower wear rate is noticed.
- Nano composite has 5.66% greater flexural modulus than that of micro composite and 23.8% greater than normal composite. Nano particle increases the interphase bond strength of the composite which reduces the chances of micro-cracks formation which result that the flexural strength of nano- composite is in the higher side compared to micro and normal composites.

- Nano alumina enriched filler works superbly as water absorption of nano matrix is less compared to micro and normal matrix due to good interface bonding in between the matrix and fiber as compared to normal and micro composites.

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