Section: Research Paper
ISSN 2063-5346

THERMOGRAVITY, DYNAMIC ANALYSIS AND MECHANICAL TESTING OF HYBRID NATURAL FIBER COMPOSITES- A REVIEW

*P. Jagadeeswaran[1],
[1]Research Scholar, Department of Mechanical Engineering,
Vels Institute of Science Technology and Advanced Studies, Chennai.
[1*]pjagadeeswaran1978@gmail.com

M. Chandrasekaran[2],
[2] Professor, Department of Mechanical Engineering,
Vels Institute of Science Technology and Advanced Studies, Chennai
[2]director.mech@velsuniv.ac.in
* Corresponding Author

Article History: 16/05/2023 **Revised Date: 15/06/2023** **Accepted Date: 12/07/2023**

Abstract:

Bio-compounds are simple to manufacture and good for the environment, and because natural fibers have a low density they can reduce overall costs and provide lightweight. Due to its great reliability and performance, the advancement of composite materials has been very robust in recent decades. Because of their expanding use in a wide range of applications, several breakthroughs in fibre composites are emerging. The specific biological fibre composites may not be the best solution towards achieving ideal qualities in strategies to succeed with synthesized reinforced hybrids composites . The specific biological fibre composites may not be the best solution towards achieving ideal qualities in strategies to succeed with synthesized reinforced hybrids composites . As a result, composite materials are created by combining three or more natural fibres to achieve enhanced tensile, chemical, temperature, water permeability, electromagnetic, and vigorous properties, and others. The review mainly focused on effect of fiber length, loading and types of natural fibers and effect of volume concentration, chemical treatments and implementation of fillers. That peer-reviewed research even has the ability to guide all composites inventors, processors, including buyers inside the appropriate choice using lightweight products for high - temperature requirements including mechanical parts, thermal management, and braking system , amid many others.

Keywords: Dynamic gravity analysis, Mechanical testing, Glass transition temperature, Biological fiber

1. INTRODUCTION

Fiber Reinforced Polymer Composites (FRPC) is fabricated by adding reinforcement material as fiber and matric material consider a polymer. During the years of 1980s, initially FRP utilized in civil construction structural members such as timber, masonry, aggregate concretes and strengthened the steel structures and restore the entire structures. For it the fibers of mechanical and physical properties, the integrated interface reactions of fiber and matrix play an important role in changing the stress between the fiber and the matrix structure. Therefore, the review focuses on the interface reactions between the fiber and the matrix in the following areas, such as chemical bonding, mechanical locking, dynamic mechanical testing, thermographic analysis (TGA) and biodegradation analysis. Thermal properties of investigation play a significant role in industries due to the generation of natural and inert chemicals components, polymer matrix composites, food, petrochemical preparation, and biomedical applications. Based on the temperature and time the physical and chemical properties were analyzed as part of the main research in material science [1,2]. The first thermal analysis technique was invented by Le Chatelier in 1887, located on thermocouple clay samples, and used a furnace to heat it. After the heating process, a glass galvanometer was used to mark the heating curve on a glass plate [3]. RobertsAusten made a tremendous enhancement in 1899 by implementing two different temperature sensors in opposite directions to determine the thermal resistance among the specimen as well as an impartial comparison. The mass variation has only been estimated by reverse weighing until the development of TGA techniques in 1915. Further researches in current scenarios is using dynamic mechanical measurements to determine the characterstics of natural fiber with variational preferred frequencies. Researchers' initiatives and the creation of effective computerized equipment and programming are credited with recent breakthroughs in thermal evaluation methods and subsequent spectacular use in metal characterisation.The different thermal approaches are dynamic mechanical analysis (DMA), thermomechanical analysis (TMA), differential thermal analysis (DTA), differential scanning calorimetry (DSC), and thermogravimetric analysis (TGA) has achieved the effcieint thermal properties based on the wide range of applications. Knowing the thermodynamic behaviour of materials necessitates a more comprehensive quantitative approach. This analytical approach has gathered information on novel development, design improvements and overall performance prediction in new materials. It can be used to diagnose the problem and test the materials for uniformity aginst the provisions. The analytical changes are phase transition from solid to liquid state, material crytsallazation, mechanical properties such as stress-strain and vibration behavior and thermal characteristics such as thermal expansion, crystallization temperature, shrinkage, and liquid phase chemical reactions and thermal flexibility in gaseous environment [5-6]. Nevertheless, such thermoplastic composites' vast number of different approaches is limited due to relatively inferior thermal conductivity and durability, applications where high heat dissipation and minimal expansion coefficient are desired [8]. The variations in chemical reactions and functioning parameters experienced by functional properties of natual polymeric composites which is depending upon the structural aspects. In the synthesis of hybrids, all of this very important to consider at the thermal characteristics of fibres. This can be used for determined the effect of thermophysical and thermo-dielectric properties of the new designed fiber. Natural fiber is ecofriencdly to the composite structures potential feed stock for large area production. However, physcial and chemical properties were limit their effectivenees in several applications [9]. As a result, understanding their tribological and thermal properties is required to solve these problems [10-11]. Fiber has limitations in many applications due to their poor thermal properties, compounds that improve the strength of the polymeric material. The shape, size, and composition of the fiber also affcted their mechancial proeprties [12]. The main aim of this invesigation is to understand their effect of natural fiber reinforcement such as bamoo, snake grass fiber with epoxy/sisal on thermogravity analysis, various mechanical testing, thermomechanical analysis of hybrid composites. These overview additionally provides an information on recent data on the thermal behaviour of advanced materials for various applications.

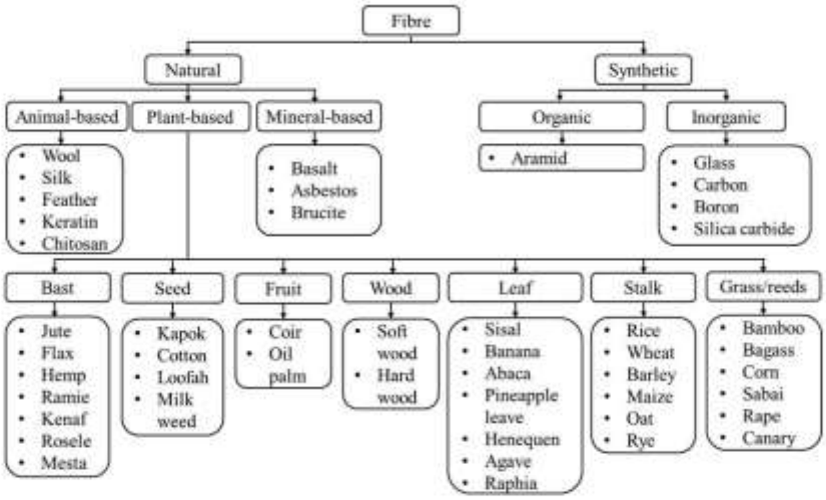

Fig. 1. Classification of natural fiber reinforced polymer composites [42]

2. MECHANICAL TEST PROPERTIES ON NATURAL COMPOSITES

Fiber reinforced hybrid composites are characterized by interfacial properties based on the shear strength between the natural fiber and parent material. Thus, becomes laminated fiber composites evaluated depending upon the fracture toughness, and inter-laminar shear strength. The surface morphology have been characterized by using Scanning Electron Microscope (SEM) and Transmission electron Miscroscope (TEM), in order to ensure the interfacial shear strength behaviour. Table 1 shows the various types of mechanical testing methods and associated with the ASTM standards. The interfacial properties of natural fiber reinforced hybrid composites were characterized based on the three types of measurements (i) Micro (ii) Macro (iii) Nanoscale measurements. These measurements of experiments was conducted by using AFM or SPS method. Table 2 shows the mechanical properties of the various fiber reinforced natural compounds listed from previous studies. During the fiber pull-out test, the matrix material must have a high degree of ductility compared to the fiber matrix. These test is very adoptable for the fiber , which could carry the compressive load such as ceramic and glass fibers. The structural qualities of strands are not required in fibre lift testing. It is also worth noting as micro-bond examinations can't determine the intermediate fracture toughness of the natural fiber contact in FRP that has been pressed together. Similarly, macro scale includes plane beam shear test, fracture toughness test, and short beam test which are excaxt method for fiber laminated composites. For the in-plane shear test, laminated FRP composites must be constructed with an isotropic strand pattern. he specifications of most of these tensile testing have been given following.Sathishkumar et al reported the mechanical beahviour of snake grass fiber with polyethylic resin by single testing fiber method. According to the ASTM D3379-75 standards, load cell 1000g and gauge length 10 mm was used for tensile testing. The snake grass fibers of guage length 100 mm and diameter (45µm to 100µm) was selected for the tensile test and multiple layer was tested wihout any changes on the surface. Hybrid composites of weight reduction is more important, the experimental results clearly shows that density of snake grass fiber was efficient than elephant grass, coirs, root, kneaf, petiole and also equal to the sisal and very close to the bamboo. From the csnake grass grow up with significant features that replace the any natural fibers [36].Yong et al investigate the bamboo fiber and identified the optimum strength of the composites by the K-S experiment [37]. Silva et al examined the tensile properties of sisal fiber with different gauge length. Herrera-Franco et al explained the stress-strain relation between the fiber and matrix for discontinuous fiber provides excellent strength compared with continuous fiber.

Table 1. Mechanical testing standards

S.No	Test	ASTM	ISO Standards
1	Tensile	ASTM D3379-75	ISO 527-2
2	Flexural	ASTM D790	ISO 178
3	Dynamic Mechanical analysis	(ASTM)-D4065-01,	-
4	Impact	ASTM D6110, (charpy)	ISO 179
		ASTM D256 (Izod Notched)	ISO 180 (Izod Notched)
		ASTM 8412 (Izod unnotched)	ISO 180 (Izod unnotched)
5	Compression	ASTM D695	ISO 604

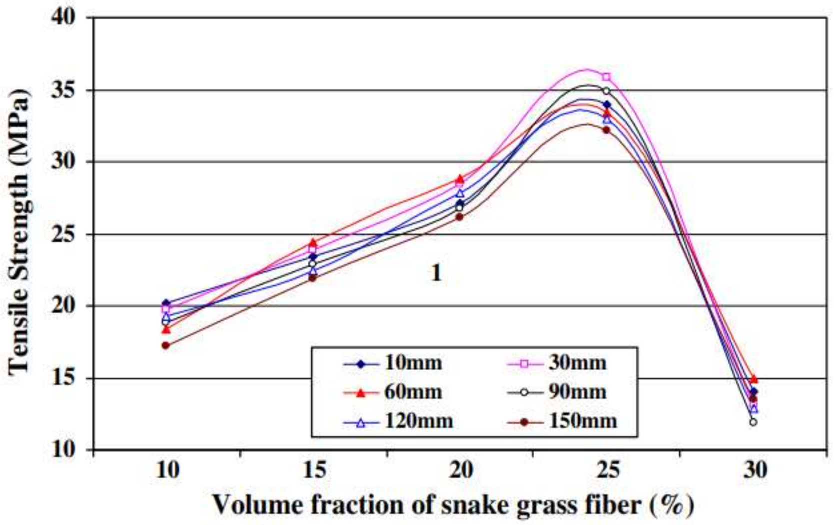

Fig. 2. Snake grass fiber with different volume fractions [36]

2.1 Nanoscale measurement

SPM or AFM methods widely demonstrated the fiber pull out test in nano sclales measurements. The test method usually followed for two types of samples, one is performed for thermoset and thermoplastic, secondary method only measured during the matrix phase is thermoplastic. The scenario of a MWCNT epoxy surface has been presented to illustrate the initial technique employing SPM. They produced a 200 mm thick film using nanotubes scattered on epoxy resin. After curing the thick film is splitted into 70-100 mm by dimond knife ultra-cut microtome. The quasi technique is being exploited for SPM image analysis to discover the important location in which the epoxy hole is replaced by a nanotube. After determining the subject of concern, the point is pushed from around opening in continuous mode. The moving orientation is orthogonal to the longitudinal plane of the suspension that intersects the direction of the nanotube [43]. The matrix and fiber of the interface shear strength were estimated using a pull-out test embedded in the area of the nanotubes. Therefore, MWCNT was obtained the average interfacial strength is 150MPa, the strength variations are relatively high and differed from prepared samples to samples . The minimum and maximum shear strength was obtained as 35 MPa to 376 MPa respectievly.

Table 2. Mechanical Properties of natural fibers

Fibers With length	Origin	Youngs Modulus (GPa)	Tensile strength (Mpa)	Elongation (%)	Density (g/cm^3)	References
Bamboo	Ligno cellulose	27	575	-	-	[25]
Natural fibers	Coir	4-6	131-220	15-30	1.2	
	Flax	27-80	345-1830	1.2-3.2	1.5	
	Hemp	58-70	550-1110	1.6	1.5	
	Sisal	9.4-28	507-855	2-2.5	1.3-1.5	
Snake Grass	-	9.71	278.82	2.87	0.887	
Bamboo	Snake Grass	35.91	503	1.4	0.910	[35]

Table 3. Typical properties of epoxy resin [27]

Properties	Units	Values
Color	-	Yellow (Liquid)
Solid content (%)	-	84
Specific gravity	g/cm^3	1.10
Density	g/cm^3	1.1-1.4
Impact strength	kJ/m^2	9
Flexural strength	MPa	67
Tensile strength	MPa	31
Tensile modulus	GPa	0.83
Stiffness	kN/mm	10-25

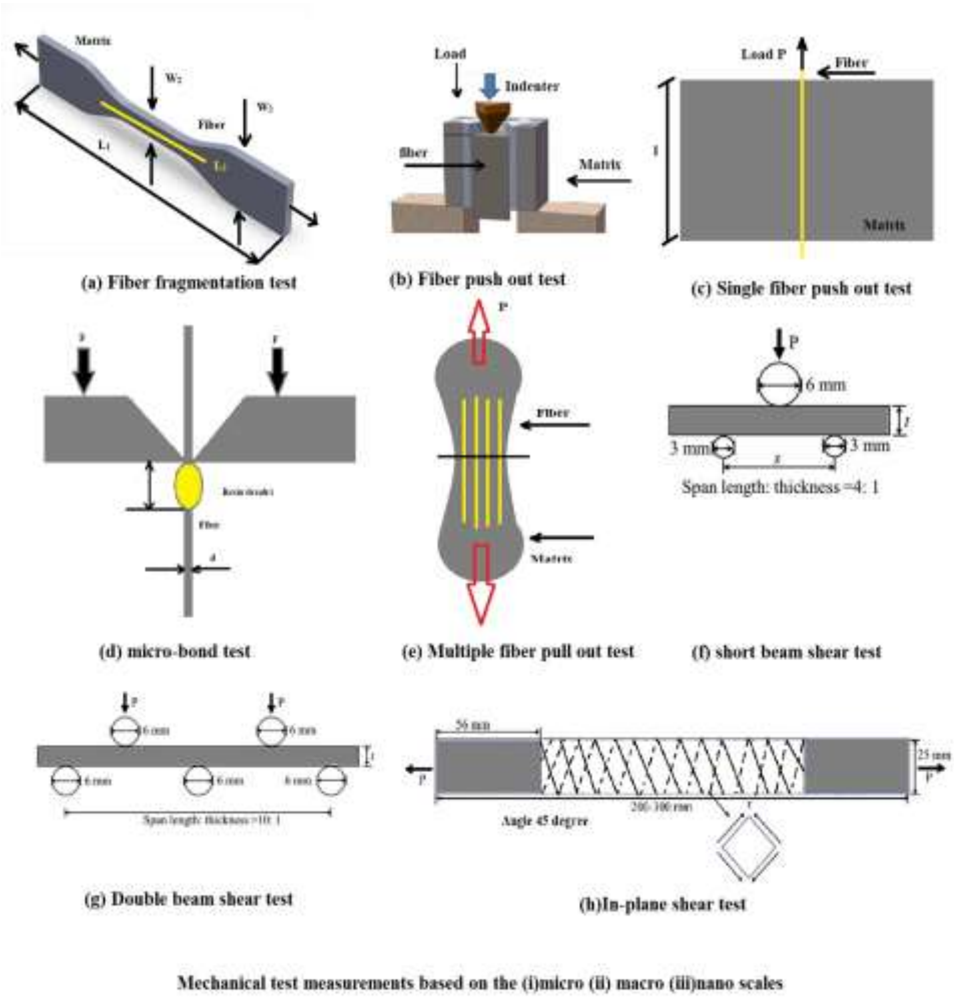

Fig. 3. Mechanical Measurements

2.2 Fiber shattering

Figure 3(a) shows the schematic illustrations of frgmentation test specimen terminologies. The specimen geometrical dimension as giben in the following Table 4. Kim et al condcut the fiber pull-out test, results shows that most of the maximum strain failures occurred by matrix material compared with fiber [49]. Huang and Young [50] used Spectroscopic methods that record the displacement of the fibreglass, based solely on the observation that when the fibre is elongated, the range at 1580 and 2720 cm-1 in the Raman spectra changes towards smaller wavenumbers [50]. This test have been evaluated based on the force equllibrium eqation as $\tau_{FFT} = \frac{\sigma_f d_f}{2l_c}\sigma_f \tau_{FFT} = \frac{\sigma_f d_f}{2l_c}\sigma_f$-Tensile strength of fiber, $d_f d_f$-diamaeter of the fiber , $l_c l_c$-crictical length of the fiber [49].

Table 4 Fiber Pull-out test specimen dimensions

References	M. J. Rich [47]	Feih S [46]	Khan Z [45]	Seghini MC [48]	Budiman BA [44]
L1	61.5	35	35	73	2
L2	25.5	16	16	15	2
W1	10.5	6.45	6.4	13	-
W2	4	2	1	3	2
Thickness	2	2	-	2	2

2.3 Single, multiple fiber and microbond test

Single fiber and multiple fiber pull out test is used to identified the interface relationship between the fiber and matrix. Figure shows the fiber reinforced on the matrix materials, while perforaming the test load data and dsiplacement were recorded. The IFSS data were calculated after the pull-out test by using the following $\tau_{pull} = \frac{P_{max}}{\pi d_f l} P_{max} \tau_{pull} = \frac{P_{max}}{\pi d_f l} P_{max}$-Maximum load, $d_f and l\, d_f and l$ is fiber diameter and length.Multi-layered fiber pull out test has been shows in Figure 3(e). This setup clearly shows the matrix blocks are always connectd by the fiber and it uses different fiber colume fractions to determined the strength of the natural composites. Microbond test of experimental setup is one of the method in single fiber in pull out test as shows in Figure 3(d). A droplets of material is injected towards the fibre and hardened it create a spheroid structure without the need for additional stress. The fibre is given a tension force and taken out from the mixture once the matrix has been cured. That uniform bending across the fibre matrix functionality could relieve pressure accumulation and therefore lessen intermediate stress - strain fluctuation in this measurement. Furthermore, since force cannot be introduced even during hardening phase of the droplets, the micro-bond experiment will assess the IFSS of the fibre matrix interaction in FRP once it is made with pressure.

2.4 Fiber push out test

This test have used only when the composites materials are linear elastic model and no elastic modulus always eqaul, whereas there is no mismatch between the fiber/matrix [51]. To get a thin layer, clean the upper outer layer of the fibre and the matrix composite that touches the probe. A micro-indenter compresses the fibre into the composite until something drifts away as from substrate after compressive stresses (Figure 3(b)).The IFSS can be estimated by the folloing equation $\tau_{FPT} = \frac{\sigma_e d_f}{4l} \sigma_e \tau_{FPT} = \frac{\sigma_e d_f}{4l} \sigma_e$-axial stress of the fiber, it is expresses as applied load to the ratio of cross-section area of the fiber, $d_f d_f$-diameter of the fiber, ll-debonding length of the fiber. $l = \frac{E_f \delta}{\sigma_e} l = \frac{E_f \delta}{\sigma_e}$, $E_f E_f$ -Youngs modulus of the fiber , $\delta\delta$-displacement. According to Hsueh et al's Poison rate increases the shear strength of the fiber, making it more effective to transfer the pressure from the fiber to the matrix [52].

2.5 In-plane shear test

This test results generated from the tensile test followed by according to ASTM D3518, while the test material will be continious fiber and symmetric lay-up composed of +450 to -450 plies angle, reuired. For unidirectional $4 \le n \le 64 \le n \le 6$, woven fabric $2 \le n \le 42 \le n \le 4$ by assembling sequence of the fibers directions in the composite. The defailt controlled displacmeent sequnces is 2mm/min. Figure 3(h) shows the in-plane shear test experimental setup and dimesions as per the standards.In plane shear strength have been calculated based on the force equallibrium eqaution as follows $\tau_{ISPT} = P_{max}/2A \tau_{ISPT} = P_{max}/2A$. A-cross sectional area. P_{max} - maximum load

2.6 Short and double beam shear test

This short and double beam shear tests or three point bending test are used for ILSS among the matrix and fiber for laminated fiber reinforced composites. According to the ASTM D2344 standards the specifications of the specimen thickness is range between 2mm to 4mm. Figure 3 (f) and (g) shwos the standard dimensions of Short and double beam shear test setup.EulereBernoulli beam theory $\tau_{SBST} = \frac{3P_{max}}{4bt} P_{max} \tau_{SBST} = \frac{3P_{max}}{4bt} P_{max}$-applied load, b and t is breadth and thickness. Double beam shear test is a five point test, according ot the ISO 19927 diameter 6 mm with fiver rollers are used in the test. Unitl the specimen fails, load is applied through at the test roller by the speed of 1mm/min.Similar to single beam test Eulere Bernoulli beam theory $\tau_{NBST} = \frac{33P_{max}}{64bt} \tau_{NBST} = \frac{33P_{max}}{64bt}$, $P_{max} P_{max}$-applied load, bsand t is breadth and thicknessThe short and double shear experiments to investigate composite laminates fracture in an unidirectional fibreglass reinforced epoxy composites. That the double beam test was done, significantly higher shear strength were achieved [54]. The double sheat test experiment results shows that 33% higher than the value based which have predicted from the short beam shear test. This may be attributable to the fact that in a twin beam shear test, the impact of tensile stress beneath the load - carrying snout and stress distribution is decreased. Double beam shear test has an advantages over the single beams shear test in that it can compute the composite laminates modulus and strength. The young's modulus in longitudinal and transverse directions, Poisson's ratio, and the in-plane shear of the FRP composite are used to calculate the interfacial modulus and strength.

3 Dynamic mechanical analysis

Polymers are elastic polymers with mechanical properties which are similar to neither solid and aqueous materials. Dynamic Mechanical Analysis (DMA) is one of the most widely used for identify the viscoeelstic properties of naturally synthesized polymer composites. DMA involves applying a moderate stress and strain to a material and measuring the effects to load.

Table 5 Natural fiber reinforced composites thermal properties

Materials	**Diameter**	**Temperature**	**Tg (°C)**	**Tg (°C) E**	**References**
R : woven jute fabric & E-glass fiber mat M: polyester resin	20-200µm & <17 µm	Room temperature to 160 °C at 1 Hz frequency	78.66	72.77	[17]
Jute/epoxy	-	-	85.67	76.44	[22]
Hemp/jute/ flax/ epoxy	-	-	79	83	[56]
Short bagasse/coir/ epoxy novolac composites	-	-	116.3	113.1	[57]

The dynamic analysis carried out for the different applications based on the different intermolecular motions between the composite structures, improvement in mechanical and thermal properties, enhanced the structural changes between the relationship properties. From the previous research studies of dynamic analysis of hybrid composites investigated based on the (i) reinforcement percentage, (ii) types of filler materials (iii) fibers chemical reaction (iv) biodegradable, thermosets, thermoplastic resins

3.1 Layer pattern

Bamboo/kenaf epoxy hybrid composites of layered pattern of storage modulus 50:50>70:30> 30:70 > kneaf >epoxy. The losses has been recored from the order of unreinforced finber is 30:70>70:30>50:50 >epoxy.

Significantly bamboo> epoxy and neph / epoxy have the highest quenching factor of pure epoxy materials. Bamboo compounds form fewer voids compared to kenaf fiber due to their higher cellulose percentage and closer location in the bamboo fiber [20-21]. Table 5 clearly shows that hybrid natural composites of dynamic mechanical behaviour variations in glass transition temperature, based on the materials reinforcing diameter, high intensity of storage moduls, fiber layered pattern and stacking arrangements. The storage modulus of hybrids reinforced with 3 unique natural materials in fiber orientation was higher than that of hybrid composites with two natural fibers in the stacking order. Nevertheless, it works best after the glass transition temperature phase.

3.2 Effect of Chemical treatment

Chemical treatment is play a important role in natural fiber hybrid composites. Saw et al examined the NaOH treated epoxy composites (Jute/coir/epoxy) and in addition with furfuryl alcohol enhanced the excellent mechanical and thermal properties, while compared with the pure coir and Jute matrix materials. Due to the fiber-fiber accumulation, the increase in the size of the coir fibers resulted in a moderate drop in mechanical properties in the storage modulus curve. However, the effectiveness was achieved for the fiber ratio 1:1 by the smaller value 0.12 in tan delta [23]. Karsli et al also reported the 2% NaOH implementation in polycarbonate/flax/PLA fiber composites enhanced the peak value in tan delta [24]. Prabhu et al fouced on the biodegradable waste tea leaf fiber (WTLF) and flax fiber were chemically treated with NaOH solution by using compression moulding techniques. The addition of 5% of WTLF and 25 % banana leaf fiber enhanced the mechanical properties of hybrid natural polymer composites [26]. Similarly, with the exception of PALF: KF ratio 30:70, PALF and KF had better modulus compared to unreinforced natural fiber compounds [37]. However, reinforced and unreinforced composites of ratio 70:30 PALF:KF obtained the maximum glass transition phase temperature and greater tangent modulus. As a result, the fibre processing aided in the enhancement of rigidity while also maintaining adequate mechanical interlocking both with the fibers/matrix. Therefore, dissipiation of energy have been controlled inside the natural fiber composites and also improved the mechanical properties. Bilayer epoxy hybrid compounds represent a high energy dissipation at the interface bond of the material. That was ensured the greater modulus of the hybrid composite materials. The sisal reinforced composites obtain the lower damping factor, where, combined treatement of jute/curaua and jute/ramie composites enhanced higher magnitude while compare with the unreinforced composites. The implementation of combined alkali treatment provides the more benefits to increases in storage value as well as greatest glass transistion temperature and have better loss moduli [29].The glass transition temperature was characterized based on the stress transfer between the matrix and natural fiber reinforcement with different length and volume fractions.

3.3 Contribution of fillers

The natural fiber reinforced composites of three main structural tests such as dynamic mechanical behaviour (Glass trnasitoin temperature (Tg and TgE'), different mechanical test (tensile, impact, hardnesss and flexural test) and thermogravity analysis were developed by fillers (Ag_2O, Fe_2O_3, $Mg(OH)_2$ and MgO and CaO (20–30 wt%), SiO_2 and Al_2O_3. Wang et al used the flax fiber epoxy reinforced composites associated with the nanclay to investigated the dynamic mechanical analysis. Under the sonification technique, a silane agent was used to insert nanoclay into the flax natural fibers. The analysis indicate those fibres patched with nanoclay-based FFRP had the highest transition temperature of 96.21 °C, which corresponded to the greatest improvement in interfacial binding. The insertion of the nanoclay material of FRP achieved excellent interface bonding between the matrix-fiber composites (palm/clay particles/HDPE) by NaOH treatment. The ratio 12.5:12.5 has achived the good dynamic mechniacal beahviour due to the reinforcement of nanoclay particles of temperature degradation leads to provide the thermal flexibility to the natural fiber reinforcements.The weight percentage 10% to 25% of magnesium hydroxide have ben contributed to imrove the viscelastic properties of epoxy with kneaf fiber hybrid composites [32]. The findings indicate that perhaps the magnesium hydroxide filler efficiently accounted for the fiber-matrix stiffness disagreement and strengthened interfacial binding, resulting in a higher mechanical properties. In addition, there was an enhancement in complex formation seen both fiber and matrix. It must have been employed to reduce the substance's segmented heavy equipment, which resulted throughout a significant increase in the mechanical properties. Furthermore, while contrasted to natural fibre, the MH exhibited greater rigidity and elasticity, which decreased thermoplastic strand motion also additional retention elasticity level. As relative to natural kenaf fibre composites, the tan delta of composite materials were reduced in amplitude. Such outcome were related towards the MH fillers' efficient assimilation and better adhesion. The superior connection and reduced mobility of resin molecules were also verified by that of the hybrids alloys' larger tan delta maxima.

3.4 Factors influencing of fiber length, orientation and loading

Fiber weaving, length, and loading and resin types and different types of blends are broadly improved the cellulose properties of hybrid composites. Aji et al reported the effect of fiber loading on kenaf/PALF/HDPE composites. The test carried out for three phases (i) first case total fiber loading of kenaf/PALF consistant with 40% along with 0.25 mm fiber length (ii) continuously fiber length utilized from 10%-60% with fiber length 0.25mm (iii) The tertiary fiber length is 0.25 mm and the fiber loading is 50% constant, but the different fiber lengths vary by 0.25 mm, 0.50, 0.75 and 2.00 mm, respectively. According to the findings, the preliminary retention model of all composite materials with different fiber content has been significantly improved compared to the HDPE matrix. It was clearly found that the elasticity of natural fibers is affected by their fiber content. To achieve knife hybridization with a positive effect, PALF is required at the lowest percentage in hybrid compounds. Whenever the heating is upgraded to approximately 130 C, the retention viscosity value increases, with the greatest effect being the higher fiber load. As the fiber loading improved, the maximum damping factor increased simultaneously with the temperature. Therefore, the fiber length also increased from room temperature to approximately 65°C, the storage modulus has increased. Considering the difference in fiber length, there was always a small variation in the loss modulus, but any variation was found in the tangent loss.

4 TGA analysis on Natural fibers

Overall thermal properties of a composites is measured using TGA by calculating the environmental decomposition temperature and losing weight % from the acquired image, as well as the quantity of coal material left in the container following overheating to the optimum range of temperature. Organic fibres include biomasses materials having a fibre morphology that contains both cellular and noncellulosic elements.

Among the quasi elements are phenol, cellulose, paraffin, and humidity, as highlight a handful. Throughout the TGA, various components degrade in order to lose mass at distinct temperature extremes. Weight loss should be determined in three stages based on the fiber composition work in the reinforcemnt mix with matrix material.Moisture content, biopolymers, and non-cellulosic components, accompanied by biocomposite and structural hydrolysis process, are responsible for the preliminary losing the weight in the earliest, second, and concluding phases.

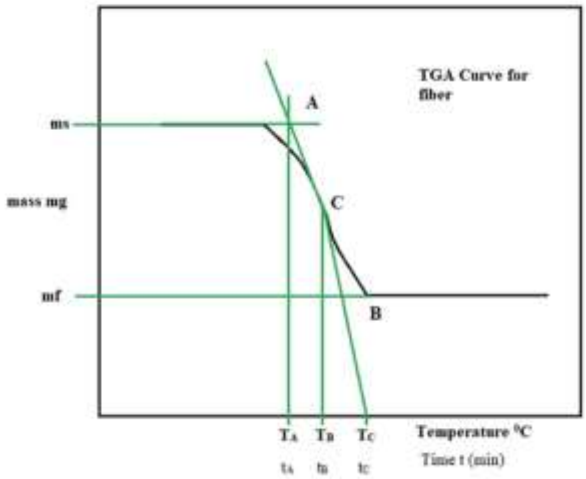

Fig. 4. TGA chart TA, TB, TC- start, middle and end point temperature and ms, mf-startig mas and final mass

4.1 Char preciptation

For the hybridization materials bonded using 2 separate renewable materials, the charred remnant and perhaps ultimate breakdown temperature. When hybridization fresh fruit bunch (EPFB), kenaf fibre (KF), , and francisco natural board powder were replaced by empty fruit fibre (PALF), jute, and teak wood flour, the char residue and ultimate degrade temperature improved significantly.

4.2 Fiber chemical treatments

Earlier research has additionally shown both synthetic and bonding agent preparation of organic fibre reinforced composite materials can improve their heat transfer performance. The breakdown point of sisal/jute/epoxy hybrids having NaOH processed fibres, for illustration, was greater than that of combinations with unaffected fibres [13]. According to the fibre processing by 5% NaOH for 1 hour, the breakdown threshold of Sansevieria acquired in the course composite materials enhanced from 355 to 358 °C [14]. The elimination of lignocellulosic materials as well as other quasi elements throughout the fibre processing caused modifications in the fibre structure, which had a good influence upon the thermo characteristics. Along with particular to removing the quasi constituents as from fibres, bonding compounds including methoxy and 2-hydroxyethyl acrylate (HEA) added to the aggregates' early and subsequent disintegration. As the consequence of fibre pretreatment with 2- hydroxyethyl acrylate, both starting and ultimate deterioration temperatures with

EPFB/jute/epoxy and PALF/kenaf/phenolic hybrids moved to greater scores [15]. The combinations having fiber content, on the other hand, had lesser flame waste and greater losing weight compared the combinations containing untreated fibres.

Table 6 Natural fiber hybrid composites chemiccaly reacted TGA propeties

Properties	Storrage modulus (MPa)	Peak modulus (MPa)	Peak tan delta	Tg Loss modulus	Tg Tan delta	Fiber Matrix ratio
Jute/coir/ epoxy	4200	-	0.25	-	150	50%Jute/50% coir modulus
Jute/sisal/ epoxy	9289.7	1617	98.5	110.04	-	Mixed treatement
KF/PALF/ Phenolic	4750	190	-	101.68	134	70%KF/30%PALF
Kenaf/ magnesium hydroxide (MH)/epoxy	4000	450	0.45	-	100	Kenaf/20% MH (MH)/epoxy
Kenaf/oil palm nanofiller/ epoxy	3990	375	0.45	80	90	Equally treated

4.3 Fillers

Apart from fibre modifications, absorption of nano-fillers throughout the aggregate might improve the temperature characteristics of the organic fibre reinforcement polymer composites. Bagasse ash infusion impacted the heating behaviour of the hybrid composites by shifting the beginning and deterioration ultimate temperatures. Nanosilica included into KF/epoxy matrices generated more flame residues compared those lacking nanocomposites in separate investigation. The heat was insulated by nanoclay in the matrix, which prevented the discharge of flammable fibre components and resulted in a bigger deposit with greater levels of temperatures [16]. Fillers are used to improve the thermal properties of natural polymer composites by activating low volume fillers. Previous experimental studies of majority report recommneded that nanoclay fillers material good bonded with the thermostat and thermoplastic composite materials. They introduce filler materials into blends to achieve better thermal properties. Interestingly, just a limited investigations on TGA of fillers incorporated into biocomposites with biological fibres have been published.

4.4 Biodegradable polymers with TGA analysis

Biodegradeable composites has been developed by using several sources of thermoset resins, for example epoxy, Polymer and includes the thermoplastic polypropalene, hydrocarbon polymer as preffered as a main synthetic resources. Natural fibers are only used to moderately solve biodegradability problems. Therefore, natual fibers completely developed by several matrices such as PLA. Liquid rubber, and starch [17-18]. According to Jumaidin et al. [55], enhancing the cellulosic fibre percentage in the sugar palm manioc matrix offered greater decomposition temperature and maximum occurrence temperature, whereas increasing the seawater generated more char deposit. It is attributed towards the carbonate substance, remains on heating and sugar palm acting as a lignocellulosic material. It has been developed the temperature owing to evaporated nature in their fiber structure.

5 Conclusion

This review article clearly visualized the effect of different fiber reinforcements on epoxy matrix and others based on the Thermo Gravity Analysis (TGA), Dynamic Mechanical Analysis (DMA) various stages of mechanical measurements with different experimental testings, fillers contribution in natural fiber composites, chemical reactions results outcomes of the findings are drawn.

- The primary factor different volume fraction fiber compounds in the matrixs of hybrid compounds is weight loss.
- Dicontinous fibers more effective to compared with contonous fiber.
- Char residue performed based on the fibers thermal resitivity in hybrid composites.
- The inclusion of bonding solutions plus fibre exterior modifications additionally worked to boost their thermal performance. As comparing with untreated fibre hybrid composite, the processed fibre hybridization hybrids had lesser char residue and maximum volume losses were obtained.
- Chemical treatment is play a significant role in fabrication hybrid natural composites due to after the reinforcement have provide a good interfacial properties between the matrix and fiber, dissipiation of energy inside the composite materials.
- The fillers play a part of the role to improved the properties of hybrid composites, fillers material such as (Ag_2O, Fe_2O_3, $Mg(OH)_2$ and MgO and CaO (20–30 wt%), SiO_2 and Al_2O_3).
- The mechanical analysis were used to identified the material tensile strength, interfacial shear strength, and material toughness are primary measurements in hybrid analysis method.
- TMA's findings can be utilised to an array of substances.Coatings and pigments, polymers and synthetic rubber, structural components, and other plastic resin, Ceramics, glass, films, fibres, and adhesion films are some of the materials used.
- TMA was also appropriate for examining biochemical variables, including such the effects of ions (i) chemical mass, (ii) crosslinking, (iii) tacticity, and (iv) structural bands have such a major impact on the polymer's transformation point and contraction.
- Future possibilities on the exploration of transplanting nanomaterials on hybrid FRPs, biochemical or mechanical principles of the nanoscale functionality, and modelling of nanoparticle-modified interfaces are considered.

Acronym

E	-	Young Modulus
FRPC	-	Fiber Reinforced Polymer Composites
TGA	-	Thermographic Analysis
DMA	-	Dynamic Mechanical Analysis
TMA	-	Thermomechanical Analysis
DTA	-	Differential Thermal Analysis
DSC	-	Differential Scanning Calorimetry
SEM	-	Scanning Electron Microscope
TEM	-	Transmission electron Miscroscope
AFM	-	Atomic force microscopy
SPS	-	Sandwich Plate System
MWCNT	-	Multi-walled carbon nanotubes
IFSS	-	Interfacial shear strength
ILSS	-	Interlaminar shear strength

References

1. Pleşa, P. Noţingher, S. Schlögl, C. Sumereder, M. Muhr, Properties of polymer composites used in high-voltage applications, *Polymers* 8 (5) (2016) 173.
2. N. Saba, M.T. Paridah, K. Abdan, N.A. Ibrahim, Thermal properties of oil palm nanofiller/kenaf reinforced epoxy hybrid nanocomposites, *AIP Conference Proceedings* 1787 (2016).
3. A. Fortunato, Drug–Biomembrane Interaction Studies: 5. DSC: History, Instruments and Devices, *Elsevier Inc.* Chapters, 2013.
4. M. Wagner, Thermal Analysis in Practice: Fundamental Aspects, *Carl Hanser Verlag GmbH* Co KG, 2017.
5. J. Liszkowska, B. Czupryński, J. Paciorek-Sadowska, Thermal properties of polyurethane-polyisocyanurate (PUR-PIR) foams modified with tris (5- hydroxypenthyl) citrate, J. Adv. Chem. Eng. (2) (2016) 6.
6. N. Saba, M. Jawaid, M.T.H. Sultan, Thermal properties of oil palm biomass based composites, Lignocellulosic Fibre and Biomass-Based Composite Materials, *Elsevier* 2017, pp. 95–122.
7. Yan L, Kasal B, Huang L. A review of recent research on the use of cellulosic fibres, their fibre fabric reinforced cementitious, geo-polymer and polymer composites in civil engineering. *Compos B Eng* 2016;92:94-132.
8. X. Yang, C. Liang, T. Ma, Y. Guo, J. Kong, J. Gu, J. Zhu, A review on thermally conductive polymeric composites: classification, measurement, model and equations, mechanism and fabrication methods, *Advanced Composites and Hybrid Materials* 1 (2) (2018) 207–230.
9. T.S.M. Kumar, N. Rajini, K. Obi Reddy, A. Varada Rajulu, S. Siengchin, N. Ayrilmis, Allcellulose composite films with cellulose matrix and Napier grass cellulose fibril fillers, *Int. J. Biol. Macromol*. 112 (2018) 1310–1315.
10. R.A. Ilyas, S.M. Sapuan, M.R. Ishak, E.S. Zainudin, Development and characterization of sugar palm nanocrystalline cellulose reinforced sugar palm starch bionanocomposites, *Carbohydr. Polym*. 202 (2018) 186–202.

11. R.A. Ilyas, S.M. Sapuan, M.R. Ishak, E.S. Zainudin, Sugar palm nanofibrillated cellulose (Arenga pinnata (Wurmb.) Merr): effect of cycles on their yield, physic-chemical, morphological and thermal behavior, *Int. J. Biol. Macromol.* 123 (2019) 379–388.
12. R.A. Ilyas, S.M. Sapuan, M.R. Ishak, E.S. Zainudin, Effect of delignification on the physical, thermal, chemical, and structural properties of sugar palm fibre, *BioResources* 12 (4) (2017) 8734–8754.
13. M.K. Gupta, R.K. Srivastava, Mechanical, thermal and water absorption properties of hybrid sisal/jute fiber reinforced polymer composite, *Indian Journal of Engineering and Materials Sciences* 23 (4) (2016) 231–238.
14. M.A. Kumar, G. Ramachandra Reddy, Mechanical & thermal properties of epoxy based hybrid composites reinforced with jute/Sansevieria cylindrica fibres, *International Letters of Chemistry, Physics and Astronomy* 38 (May) (2014) 191–197.
15. M. Jawaid, O.Y. Alothman, N. Saba, P.M. Tahir, H.P.S.A. Khalil, Effect of fibers treatment on dynamic mechanical and thermal properties of epoxy hybrid composites, *Polym. Compos.* 36 (9) (2015) 1669–1674.
16. N. Saba, M.T. Paridah, K. Abdan, N.A. Ibrahim, Thermal properties of oil palm nano filler/kenaf reinforced epoxy hybrid nanocomposites, *AIP Conference Proceedings* 1787 (2016).
17. M. Jacob, S. Jose, S. Thomas, K.T. Varughese, Stress relaxation and thermal analysis of hybrid biofiber reinforced rubber biocomposites, *J. Reinf. Plast. Compos.* 25 (18) (2006) 1903–1917.
18. R. Jumaidin, S.M. Sapuan, M. Jawaid, M.R. Ishak, J. Sahari, Thermal, mechanical, and physical properties of seaweed/sugar palm fibre reinforced thermoplastic sugar palm starch/agar hybrid composites, *Int. J. Biol. Macromol*. 97 (2017) 606–615.
19. Das, S. C., Paul, D., Grammatikos, S. A., Siddiquee, M. A. B., Papatzani, S., Koralli, P., … Petousis, M. (2021). Effect of stacking sequence on the performance of hybrid natural/synthetic fiber reinforced polymer composite laminates. *Composite Structures,* 276, 114525.
20. S.S. Chee, M. Jawaid, M.T.H. Sultan, O.Y. Alothman, L.C. Abdullah, Evaluation of the hybridization effect on the thermal and thermo-oxidative stability of bamboo/ kenaf/epoxy hybrid composites, *J. Therm. Anal. Calorim*. (2019) 1–9.
21. S.S. Chee, M. Jawaid, M.T.H. Sultan, O.Y. Alothman, L.C. Abdullah, Thermomechanical and dynamic mechanical properties of bamboo/woven kenaf mat reinforced epoxy hybrid composites, Compos. Part B 163 (October 2018) (2019) 165–174.
22. M. Jawaid, H.P.S.A. Khalil, Effect of layering pattern on the dynamic mechanical properties and thermal degradation of oil palm-jute fibers reinforced epoxy hybrid composite, *BioResources* 6 (3) (2011) 2309–2322.
23. S.K. Saw, G. Sarkhel, A. Choudhury, Preparation and characterization of chemically modified Jute–Coir hybrid fiber reinforced epoxy novolac composites, *J. Appl. Polym. Sci.* 125 (4) (2012) 3038–3049.
24. N.G. Karsli, A. Aytac, Properties of alkali treated short flax fiber reinforced poly(lactic acid)/polycarbonate composites, *Fibers and Polymers* 15 (12) (2014) 2607–2612.
25. Seki, Y., Innovative multifunctional siloxane treatment of jute fiber surface and its effect on the mechanical properties of jute/thermoset composites. *Materials Science and Engineering:* A, 2009. 508(1): p. 247-252.
26. Prabhu, L., Krishnaraj, V., Sathish, S., Gokulkumar, S., Karthi, N., Rajeshkumar, L. Jayakumar, H. (2021). Experimental investigation on mechanical properties of flax/banana/ industrial waste tea leaf fiber reinforced hybrid polymer composites. *Materials Today: Proceedings*, 45, 8136–8143.
27. K. Palanikumar, M. Ramesh, R.K.J. Hemachandra, Nat. Fibers 13 (2016) 321– 331.
28. M. Asim, M.T. Paridah, N. Saba, M. Jawaid, O.Y. Alothman, M. Nasir, Z. Almutairi, Thermal, physical properties and flammability of silane treated kenaf/pineapple leaf fibres phenolic hybrid composites, Compos. Struct. 202 (2018) 1330–1338.
29. J.S.S. Neto, R.A.A. Lima, D.K.K. Cavalcanti, J.P.B. Souza, R.A.A. Aguiar, M.D. Banea, Effect of chemical

treatment on the thermal properties of hybrid natural reinforced composites, *J. Appl. Polym. Sci.* 136 (10) (2019), 47154.

30. A. Wang, D. Xia, G. Xian, H. Li, Effect of nanoclay grafting onto flax fibers on the interfacial shear strength and mechanical properties of flax/epoxy composites, Polym. Compos. (2019) 1–11.
31. R. Boujmal, M.O. Bensalah, D. Rodrigue, R. Bouhfid, A.E.K. Qaiss, Mechanical and thermal properties of hybrid composites: oil-palm fiber/clay reinforced, high density polyethylene, Mech. Mater. 98 (2016) 36–43.
32. N. Saba, O.Y. Alothman, Z. Almutairi, M. Jawaid, Magnesium hydroxide reinforced kenaf fibers/epoxy hybrid composites: mechanical and thermomechanical properties, Constr. *Build. Mater.* 201 (2019) 138–148.
33. I.S. Aji, E.S. Zainudin, A. Khalina, S.M. Sapuan, M.D. Khairul, Thermal property determination of hybridized kenaf/PALF reinforced HDPE composite by thermogravimetric analysis, *J. Therm. Anal. Calorim.* 109 (2) (2012) 893–900.
34. I.S. Aji, E.S. Zainudin, S.M. Sapuan, A. Khalina, M.D. Khairul, Study of hybridized Kenaf/PALF-reinforced HDPE composites by dynamic mechanical analysis, *Polymer - Plastics Technology and* Engineering 51 (2) (2012) 146–153.
35. Murali Mohan Rao K, Mohan Rao K. Extraction and tensile properties of natural fibers: Vakka, date and bamboo. Compos Struct 2007;77:288–95.
36. Sathishkumar, T. P., Navaneethakrishnan, P., & Shankar, S. (2012). Tensile and flexural properties of snake grass natural fiber reinforced isophthallic polyester composites. *Composites Science and Technology,* 72(10), 1183–1190.
37. Cao Yong, Wu Yi-qiang. Evaluation of statistical strength of bamboo fiber and mechanical properties of fiber reinforced green composite. *J Cent Southuniv Technol* 2008;15:564–7.
38. Silva Flavio de Andrade, Chawla Nikhilesh, Filho Ramildo Dias de Toledo. Tensile behavior of high performance natural (sisal) fibers. *Compos Sci Technol* 2008;68:3438–43.
39. Herrera-Franco PJ, Valadez-Gonzalez A. A study of mechanical properties of short natural-fiber reinforced composites. Composites: Part B , 2005;36:597–608.
40. Kuruvilla Joseph, Romildo Dias Toledo, Beena James, Sabu Thomas, Laur Hecker de Carvalho. A review on sisal fiber reinforced polymer composites. *Rev Brasi Eng Agricola Ambiental* 1999;3(3):367–79.
41. Jayabal S, Natarajan U. Influence of fiber parameters on tensile, flexural, and impact properties of nonwoven coir–polyester composites. *Adv Manuf Technol* 2010;70:2969–77.
42. Huang, S., Fu, Q., Yan, L., & Kasal, B. (2021). Characterization of interfacial properties between fibre and polymer matrix in composite materials – A critical review. *Journal of Materials Research and Technology*, 13, 1441–1484.
43. Cooper CA, Cohen SR, Barber AH, Wagner HD. Detachment of nanotubes from a polymer matrix. Appl Phys Lett 2002;81(20):3873e-5.
44. Budiman BA, Suharto D, Kishimoto K, Triawan F, Takahashi K, Inaba K. Single fiber fragmentation test for evaluating fiber-matrix interfacial strength: testing procedure and its improvements. *In: Seminar Nasional Tahunan Teknik Mesin* XV (SNTTM XV); 2016 Oct 5.
45. Khan Z, Yousif BF, Islam M. Fracture behaviour of bamboo fiber reinforced epoxy composites. Compos B Eng 2017;116:186e99.
46. Feih S, Wonsyld K, Minzari D, Westermann P, Lilholt H. Testing procedure for the single fiber fragmentation test.
47. Rich MJ, Drzal LT, Hunston D, Holmes G, McDonough W. Round robin assessment of the single fiber fragmentation test. In: The American Society for Composites 17th Technical Conference; 2002 Oct 21.
48. Seghini MC, Touchard F, Sarasini F, Chocinski-Arnault L, Mellier D, Tirillo J. Interfacial adhesion assessment

in flax/epoxy and in flax/vinylester composites by single yarn fragmentation test: correlation with micro-CT analysis. Compos Part A Appl Sci Manuf 2018;113(7):66-75.

49. Kim J-K, Mai Y-W. Measurements of interface/interlaminar properties. In: Kim Jang-Kyo, Mai Yiu-Wing, Mai Yiu-Wing, editors. Engineered interfaces in fiber reinforced composites. *Elsevier;* 1998. p. 43-92.
50. Huang Y, Young RJ. Analysis of the fragmentation test for carbon-fibre/epoxy model composites by means of Raman spectroscopy. *Compos Sci Technol* 1994;52(4):505-17.
51. Krishnan P. Evaluation and methods of interfacial properties in fiber-reinforced composites. In: Mechanical and physical testing of biocomposites, fibre-reinforced composites and hybrid composites. *Elsevier;* 2019. p. 343-85.
52. Hsueh C-H. Fibre pullout against push-down for fibrereinforced composites with frictional interfaces. *J Mater* Sci 1990;25(2):811-7.
53. ISO 19927:2018, Fibre-reinforced plastic composites. Determination of inter-laminar strength and modulus by double beam shear test.
54. Merzkirch M, Foecke T. Investigation of the interlaminar shear properties of fiber-reinforced polymers via flexural testing using digital image correlation. *Matls Perf Charact* 2020;9(5):20190206.
55. Kim WC, Dharan CKH. Analysis of five-point bending for determination of the interlaminar shear strength of unidirectional composite materials. *Compos Struct* 1995;30(3):241-51.
56. V. Chaudhary, P.K. Bajpai, S. Maheshwari, An investigation on wear and dynamic mechanical behavior of jute/hemp/flax reinforced composites and its hybrids for tribological applications, *Fibers and Polymers* 19 (2) (2018) 403–41.
57. S.K. Saw, G. Sarkhel, A. Choudhury, Dynamic mechanical analysis of randomly oriented short bagasse/coir hybrid fibre-reinforced epoxy novolac composites, *Fibers and Polymers* 12 (4) (2011) 506–513.