Available online at
www.mdl.mazedan.com

MTESD

www.mazedan.com

www.mazedan.com/mtesd

Review of different synthetic reinforced fiber with high viscosity epoxy polymer based on mechanical characterization

MAZEDAN TRANSACTIONS ON ENGINEERING SYSTEMS DESIGN
Article id-MTESD0103001
Vol-1, Issue-3
Received: 20-Jan-2020
Revised: 27-Feb-2020
Accepted: 05-March 2020

JITENDRA KUMAR*, VIKAS JYOTI SHARMA, NITESH KUMAR DIXIT

Citation: Jitendra Kumar,Vikas Jyoti Sharma, Nitesh Kumar Dixit "Review of different synthetic reinforced fiber with high viscosity epoxy polymer based on mechanical characterization" Mazedan Transactions on Engineering Systems Design, Vol-1, Issue-3, pp-1-7, 2020.

ABSTRACT

An araldite-cured thermosetting epoxy polymer was modified by incorporating 10 wt.% of well-disperse fiber reinforced. The mechanical property like as a tensile property, flextural property, hardness was investigated for bulk specimens of the neat and the fiber-modified epoxy. The addition of the fiber increased the mechanical property and fatigue life more than 30% times. The neat and the fiber- modified epoxy resins were used to fabricate synthetic fiber reinforced plastic (SFRP) composite laminates by resin infusion under Sol gel method. Tensile, hardness, flextural tests were performed on these composites, during which the matrix tensile strength and bending strength was monitored. It is observed that the fatigue life of the SFRP composite was increased by about 30% due to the fiber content of 3%. Tensile strength is increased four times when percentage of fiber increased about 7% and also hardness will improve than less fiber content. It is observed from the literature that mechanical property of the composite material is increases when fiber content increased and the other content such as epoxy, etc are fixed or decreased. Developed natural and synthetic fiber composite is widely used in automobile, railways and aerospace industry.

KEYWORDS- Natural and synthetic fiber, tensile properties; flexural properties, elongation percentage.

1. INTRODUCTION

Ecological concerns such as biodegradability, recyclability and environment safety have resulted in an increasing interest in green materials [1]. Natural fiber polymer composites are more ecofriendly as compared to polymer composites with manmade synthetic fibers reinforced like carbon fibers and glass fibers. The various advantages of natural fibers such as jute, bamboo, sisal, cotton, abaca, banana, coir, hemp, pineapple etc. over man-made glass and carbon fibers are recyclability, less cost, bio-degradability, low density, comparable strength, reduced energy consumption, less health risks [2]. The researchers have used natural fiber as reinforcement in the polymer composite but they have the challenges of less moisture absorption resistance, less strength, less modulus as compared to glass and carbon fibers. To overcome these challenges the hybrid composites are fabricated by taking two different natural fibers and a combination of natural and a synthetic fiber (carbon and glass fibers). The other approaches which can be adopted to overcome the limitations of natural fibers are use of filler materials. Lot of research is carried in the use of different fillers of various sizes like $Al2O3$, ZnO, $TiO2$, $SiO2$, $ZrO2$, etc. with the polymer matrix. But less literature is available in the use of filler with natural fiber composites.

2. LITERATURE SURVEY

N. Saba et al. [3] noticed the impact of nano oil palm void organic product pack fillers on common fiber kenaf in the non-woven tangle structure with epoxy composite. The exploratory outcomes show that expansion of nano oil palm void natural product bundle filler with kenaf epoxy composite improves the elasticity in contrast with kenaf epoxy composite due to limiting the free spaces by the nano fillers. The effect quality of nano filler half and half composite is expanded by 28.3%. K. Mohan et al. [4] watched the impact of multi divider carbon nano tubes on the crossover composite of glass-flax fiber. Glass and flax fiber half breed fortified composites by epoxy tar with muti walled carbon nano tubes were created utilizing pressure shaping procedure. MWCNT are included epoxy pitch by utilizing ultra-sonic test sonicator. The greatest elasticity was raised upto 28.26% with consolidation of 1% MWCNT whereas compressive quality is expanded with 1% of MWCNT by weight. The SEM pictures speak to the uniform scattering of MWCNT in the epoxy tar. Ahmer Hussain Shah et al. [5] utilized acacia Catechu (AC) particles which are biodegradable as fortification with epoxy/amine by weight % of 0.5, 1.0, 1.5, and 2.0. The mechanical properties of the composite and portrayal is concentrated by tests differential examining calorimetry (DSC), Fourier change infrared checking (FTIR), electron magnifying lens (SEM) spectroscopy, thermogravimetric examination (TGA), dynamic mechanical investigation (DMA). FTIR spectroscopy shows the expanded hydrogen holding in the AC/epoxy composites. Differential filtering calorimetry (DSC) brought about

Dept. of Mechanical Engineering, Institute of Engineering & Technology Faizabad India 224001
*Corresponding author email- jitenderku1994@gmail.com

better transformation of epoxy when the AC particles are added to make composites. With 1% of AC by weight expanded the flexural quality by 14% and sway quality by 94%. Improved warm conduct was likewise seen because of structure of fragrant tannin phenol. Wang et al. [6] embedded the nano TiO2 in unidirectional fiber of flax by technique for drenching in nano TiO2 , KH560 suspension through sonification. The amount of embedded nano TiO2 is 0.89% by weight to 7.14% by weight, relies upon the centralization of suspension. The intense change in increment of 23.1% of rigidity and 40.5 % of interfacial shear quality by the streamline's substance of nano TiO2 (2.34% by weight) was watched. Foruzanmehr et al. [7] considered flax strands joined with TiO2 were utilized to make Ploylactic corrosive (PLA) composites. The TiO2 film was embedded on the flax fiber by a procedure of sol-gel-plunge technique and furthermore the filaments were oxidized for the reason to upgrade the interfacial attachment between the flex strands and TiO2 film. The effect opposition of the composite of TiO2 united flax filaments was expanded by multiple times when contrasted with unadulterated poly lactic acid (PLA). The hygroscopic conduct was additionally watched and measure of dampness retention was diminished by 18% in the composites of flax fiber united with altered TiO2. Mahesha et al. [8] researched the mechanical and tribological conduct of Basalt fiber fortified composites with Epoxy lattice with addition of nano TiO2 alone just as blend of nano TiO2 with nano mud by the strategy for vacuum helped pitch imbuement method (VARI). The test perceptions show s that elasticity and dimensional steadiness of the basalt-Epoxy composite was expanded with the fillers of nao Tio2. Wear test shows that minor increment in coefficient of grinding in basalt-Epoxy with nano dirt and lessening in coefficient of contact for basalt Epoxy with nano TiO2 and TiO2/earth. Miriam et al. [9] examined the impact of two fillers ashlar formed CaCO3 and platy kaolin in non-woven Jute fortification sheet shaping compound (SMC) and hacked Jute support mass embellishment compound (BMC). The mechanical properties of jute in nonwoven structure sheet shaping compound are very more when contrasted with those essentially jute fortified composites. The mechanical properties of kaolin fillers sheet forming compound was additionally more than that of CaCO3 material because of state of platy fillers. Prasob P.A. et al. [10] noticed the expansion in rigidity by 30.79% and increment in compressive quality by 34.03% for composite with fillers of TiO2, 4% by weight in amount. Nayak et al. [11] checked the impact of expansion of nano TiO2 0.1% by weight on glass fiber fortified polymer compostes (GFRP) and found that 9% water dissemination coefficient has decreased, leftover flexural quality expanded by 19%, lingering interlaminar shear quality expanded by 18%. The impact of nano OPEFB, MMT and OMMT to kenaf epoxy shows the huge increment away modulus, misfortune modulus, tan delta and glass change temperature [12]. Mechanical, dampness ingestion properties and warm conduct was concentrated by added the nano TiO2 to the flax fiber strengthened epoxy composites manufactured by pressure forming procedure. The best execution was acquired at 0.7% in the variety of 0.5, 0.7 and 0.9 nano TiO2 in the network. Vishnu Prasad et al. [13] Dampness retention inclination is additionally diminished by option of nano TiO2. The dispersion coefficient is diminished by 31.66% for nano TiO2 added to flax fiber epoxy composite when contrasted with flax fiber epoxy composite without nano TiO2 addition. G. Seshanandan et al. [14] made the cross-breed composites by taking jute and glass with various weight proportions of nano TiO2 by hand layup technique. They noticed the intense increment in elasticity, flexural quality and shear quality. The addition of TiO2 nano particles in FRP brought about improved quality because of split redirection and break sticking toughening, split tip blunting instruments.

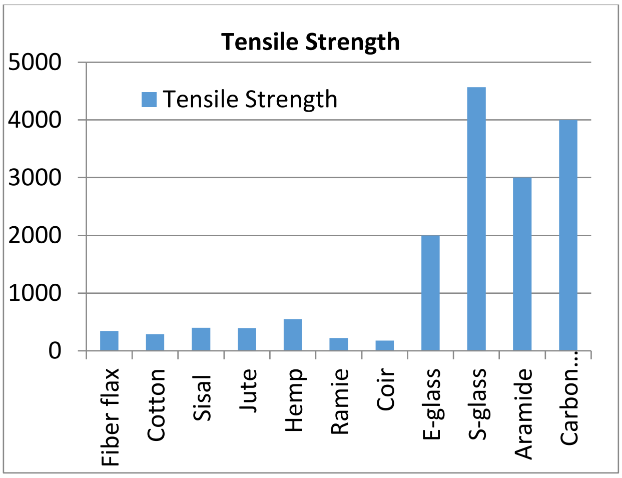

Figure 1 Tensile strength (Mpa) of natural fibers as compared to conventional reinforcing fibers [15]

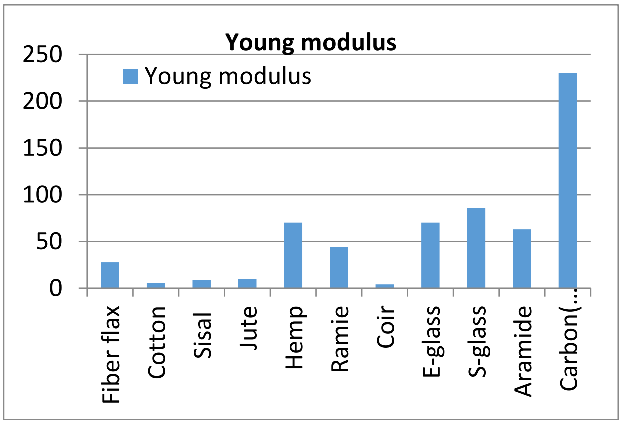

Figure 2 Young modulus (Mpa) of natural fibers as compared to conventional reinforcing fibers [15]

Table 1 Review of composite material with respect to change in material composition and mechanical property

S. N	Research Finding	Material with Percentage	Effect on Mechanical Property	Authors
1	The expansion of the silica nanoparticles expanded the exhaustion life by around three to multiple times. The perfect and the nanoparticle-adjusted epoxy gums were utilized to create glass fiber fortified plastic (GFRP) composite lami-nates by gum imbuement under adaptable tooling (RIFT)	Silica 10% GFRP	Tensile fatique strength increase 3-4 times Tensile strength -19% Fatique strength -17%	Manjunatha, C. M. Taylor, A. C. Kinloch, A. J. Sprenger, S. [16] (2011)

	strategy. The exhaustion life of the GFRP composite was expanded by around three to multiple times because of the silica nanoparticles. The DGEBA epoxy gum was gauged and degassed at 50 °C and 1 atm.			
2	The mechanical properties of the composite materials are touchy to the temperature. Expanded temperature prompts diminishing of the underlying rigidity, a definitive elasticity and the module of flexibility followed by expanding of the strain	Matta (M) with density 0,315 kg/m2 Rowing (R) with density 0,535 kg/m2	Indoor temperature Average tensile strength [MPa]- 9201 Average module of elasticity [MPa] -12170 Increased temperature Average tensile strength [MPa]- 3965 Average module of elasticity [MPa] -2423	Trombeva-Gavriloska, Ana Cvetkovska, Meri Gavriloski, Viktor Samardzioska, Todorka [17] (2011)
3	another half breed composite with epoxy as a gum and strengthening both biowaste (jute) and conventional fiber (glass) as proceeds with layered tangle composites and furthermore concentrate tentatively the impact of the stacking arrangement on pliable, flexural, and interlaminar shear properties. Composites were set up by utilizing hand lay-up strategy.	Jute a-Cellulose (wt%) 61% Hemicellulose (wt%) 23% Lignin (wt%) 15.86 Ash (wt%) 1.29	Jute fiber gives 61% tensile strength of GFRP	Gujjala, Ojha, S., Mcharya, S.K.,&Pal, [18] (2014).
4	Carbon fiber fortified epoxy composite overlays are read for upgrades in semi static quality and firmness and strain pressure weariness cycling at pressure proportion (R-proportion) = +0.1 through deliberately consolidating amine functionalized single divider carbon nanotubes (a-SWCNTs) at the fiber/texture lattice interfaces over the cover cross-segment	Plastic fiber Carbon nano tube	Improvements in quasi static tensile strength and stiffness.	Davis, Daniel C. Wilkerson, Justin W.Zhu, Jiang Hadjiev, Viktor G.[19] (2011)
5	wear execution of glass–polyamide strengthened epoxy crossover composites was researched tentatively utilizing a pin–on–circle analyzer considering the impact of water assimilation. The composites were created utilizing the hand layup strategy. Examples were drenched in refined water and ocean water for 200 days at room temperature.	roving polyamide fiber with density of 0.3 + 0.01 g/m chopped glass mat Kemapoxy 150RGL as a matrix	When the applied load and the sliding time increase, the wear rate increases.	Selmy, A. I. Abd El-baky, M. A Hegazy, D. A. [20] (2020)
6	Micromechanical Response of Two-Dimensional Transition Metal Carbonitride (MXene) Reinforced Epoxy Composite	4'Methylenebis(cyclohexylamine) (PACM, Sigma Aldrich). Ti 3AlCN hydrofluoric acid (HF, 49.5 wt%) tetrabutylammonium hydroxide (TBAOH, 40wt% solution in water,Sigma Aldrich	Improved mechanical properties Young's modulus 12.8 GPa for 90 wt% Ti 3CN. An increase in creep resistance of 46% compared to neat epoxy.	Christine B. Hatter1, Jay Shah1, Babak Anasori2, Yury Gogotsi1 [21] (2020)
7	Examination of disappointment modes for a non-pleat basalt fiber strengthened epoxy composite under flexural and interlaminar shear stacking	Basalt fibe Epoxy resin PrimeTM27 and slow hardener (Prime 20)	Crack observed the fiber-matrix interface of the 90° fiber tows. lower strength	Indraneel R. Chowdhury, Niamh H. Nash, Alexandre Portela [22] (2019)
8	Handling and interfacial impact of gelatin gel on coconut jute fortified egg shell bio-composite.	coconut jute gelatin gel egg shell	Variation of hardness 1%CJ+ 99%ES—71Shore D 2%CJ+ 98%ES—68Shore D 3%CJ+ 97%ES—66 Shore D	Mayank Agarwal, Ajit Kumar N. Shukla [23] (2019)
9	Impact of graphene on the properties of flax texture strengthened epoxy composites	Bisphenol epoxy resin (LY 556), hardener (HY 951) Graphene nano powder	Increasing the graphene content to 0.1 wt%, then, tensile strength, and flexural strength were increased.	M. Kamaraj, E. Anush Dodson and Shubhabrata Datta [24] (2019)
10	60 wt %, CPCs had higher flexural quality, more slow oxidative debasement and consume rate, and lower water retention in contrast with business WPCs, recommending better execution and soundness in building applications.	Coal powder particle sizes <125 μm Resin	Highest flexural properties were demonstrated by CPCs with 60 wt % coal with 29.9 and 100% greater strength and modulus	Yahya A. Al-Majali, Clive T. Chirume [25] (2019)
11	Improving damping property of carbon-fiber strengthened epoxy composite through novel mixture epoxy-polyurea interfacial response	Corbon fiber Epoxy resin + polyurea	Interfacial reaction between curing epoxy and polyurea produces strong cohesion and material damping in CHMC.	Thomas L. Attarda, Li Hea, Hongyu Zhoub [26] (2019)
12	mechanical properties of epoxy-fly debris cenosphere syntactic froths	Fly ash, epoxy resin SiO_2- 50-60% Al_2O-25-35% Fe_2O_3 2-4%- SO_3- 0.1-0.2% CaO -0.2-0.4% Na_2O- 0.9% TiO_2-3%	Compressive strength and modulus of ESFs improved firstly and then retard with the increase of fly ash contents compressive strength and modulus are 80.25MPa and 1468MPa, increasing 11.8% and 19.3% compared to neat EP	Chengwang Chen; Jiaan Liu [27] (2019)
13	Examination of Mechanical Characteristics of Fly Ash Cenospheres Reinforced Epoxy Composites	silica and alumina epoxy resin	25%-30% improvement in the toughness for both 130-nanometer and 30-nanometer silica reinforced composite materials Fly ash	CHEN Ping1, LI Jianchao1, ZHANG Lei [28] (2017)

			chemosphere's in the epoxy matrix can resist crack propagation, improve the fracture absorption energy, increase the load-bearing capacity	
14	Relative Analysis of Mechanical Characteristics of Sisal Fiber Composite with and without Nano Particles	Zinc Oxide Zirconium Oxide 0.5wt% sisal fibers	improves the tensile strength, Impact and Brinell hardness of the Sisal composites. improve the load bearing capacity.	A. Devaraju*, P. Sivasamy[29] (2017)
15	Mechanical properties of polymer composites with ZnO nano-molecule	Palm fiber ZnO NP with 0.1 wt%, 0.3 wt% and 0.5 wt%.	0.5 wt% ZnO NP gives better mechanical properties	A. Devaraju, P. Sivasamy, Ganesh Babu Loganathan [30] (2019)
16	Test examination of mechanical and tribological properties of palm fiber composite with Al2O3 earthenware particles.	Al2O3 ceramic particles 0.3 wt% Palm Fiber Epoxy resin	CPFC composites exhibits excellent resistant to wear.hardness, tensile, impact and flexural strength of CPFC have improved significantly when compared to plain PFC	A. Devaraju, P. Murali [31] (2019)
17	Elastic and Bending Strength Analysis of Ramie Fiber and Woven Ramie Reinforced Epoxy Composite	Ramie Fiber woven ramie	highest tensile and bending strengths were found in five layers (plies) of woven ramie composite,	Zulkifli Djafar, Ilyas Renreng, and Miftahul Jannah [32] (2020)
18	Planning and property assessment of Glass/Ramie Fibers Reinforced Epoxy Cross Breed Composites	Glass/Ramie Fibers	increasing in the tensile strength of HFREC by an amount of 1.44% than GFREC and by 69.9% than RFREC	R.Giridharan, [33] (2018)
19	Mechanical properties of woven jute-glass cross breed strengthened epoxy composite	Woven jute 4% Glass fiber	jute fiber gives 61% strength of the glass fibers composites. The maximum tensile strength is observed in L5(GJJG) after glass fiber composites. The L5 hybrid composites give 75% strength of the glass fibers composites.	Raghavendra Gujjala, Shakuntala Ojha, SK Acharya and SK Pal [34] (2013)
20	A complete examination of mechanical qualities of carbon nanotube metal grid nanocomposites	carbon nanotube metal aluminum nano composite	Increased volume fraction of CNT then improves mechanical property.	M.K. Hassanzadeh-Aghdam, M.J. Mahmoodi [35] (2017)
21	Test Analysis on the Application of Polymer Lattice Composites Containing Al2O3 for Automotive Light Reflector	Al2O3 PBT and PA6 were used as the polymer matrix	alumina filler added to the polymers for thermal conductivity improvement.	Young Shin Kim, Jae Kyung Kim, Seung Jun Na 2 and Euy Sik Jeon [36] (2019)
22	The elastic exhaustion conduct of a silica nanoparticle-adjusted glass fiber strengthened epoxy composite	silica nanoparticle 4% glass fiber 20%	Tensile fatigue strength increases 3-4 times Tensile strength -24% Fatigue strength -21%	C.M. Manjunatha, A.C. Taylor a, A.J. Kinloch a, S. Sprenger [37] (2019)
23	Numerical and Experimental Investigation on Boding Strength Optimization of Glass Fibers-Reinforced Epoxy Composites on a Structural Steel Substrate.	Glass Fibers steel	Tensile and shear strength improved	Osouli-Bostanabad K MSc, Tutunchi A, Eskandarzade[38] (2019)
24	Impact of Silane Treated Silicon (IV) Oxide Nanoparticle Additionon Mechanical, Impact Damage and Drilling Characteristics of KenafFiber-Reinforced Epoxy Composite	Kenaf natural fiber of 50 vol.% silicon oxide particles of 0.5, 1.0 & 2.0 vol.%	Maximum tensile, flexural and impact strength of 172 MPa, 255 MPa and 6.45 J was observed for composite contain 50 vol.% of fiber and 2.0 vol.% of silicon oxide.	N. Parthipan1& M. Ilangkumaran2 &T. Maridurai3 & S. C. Prasanna [39] (2019)
25	Mechanical conduct of nanoparticulate TiO2 fortified magnesium matrix composite	nano powder titanium dioxide magnesium matrix 4 wt%, 8 wt%, 12 wt%, 16 wt%, and 20 wt%	Hardness improved due to the synergetic effect of TiO2particles as the weight percentage of TiO2increases.	Ganesh Radhakrishnan, Anirudh P V, and Anujan Kumar S [40] (2019)
26	Creation of epoxy composites fortified by various natural fibers and their mechanical properties	birch, palm, and eucalyptus fibers epoxy resin and hardener were Araldite LY 1564and Aradur®3487.	highest tensile strength and bending stress were found for eucalyptusfiber reinforced composites (45.25, and 79.92 MPa, respectively). Palm fiber reinforced composite had the highest impact energy (130 J)	Engin Sarikayaa, Hasan Çallioğlub, Hakan Demire [41] (2019)
27	Wear conduct of glass–polyamide strengthened epoxy hybrid composites	gass–polyamide fibers/epoxy	Correction factor decreases thediffusion coefficient by about 24% and 26%. wear resistance of the composites decreases but the temperature at the specimen pin–disc interface increases	AI Selmy, MA Abd El-bakyand DA Hegazy [42] (2020)
28	Mechanical Characterization Of Epoxy Polymer Composite Reinforced with Ramie and Synthetic Fiber	Ramie fiber/glass fiber/ Kevlar fiber Epoxy resin	Tensile strength is maximum at sample A is 115.76 MPa. Impact strength is maximum at sample D is 9 J	Lokesh. M1, Joseph Xavier2, Kevin D Rodney3, Saravanan R4, Sidharth J Prakash [43] (2019)
29	Impact of Nano Filler Reinforcement on Mechanical Properties of Epoxy Composites	Nano-clay (N-C) Nano-calcium carbonate (N-CC)	Tensile and flexural moduli of N-C reinforced epoxy Nanocomposites increased with increase in filler loading compared to N-CC reinforced epoxy and neat epoxy.	Suresha B1 *, C A Varun1, Indushekhara N M1, Vishwanath H R1, Venkatesh [44] (2019)
30	Adequacy offlame-based surface treatment for glue holding ofcarbonfiber strengthened epoxy framework composites	Carbon fiber Epoxy resin	Increase in adhesion is reflected in the high strength and failure mode of the ITRO-treated CFRP joint specimens.	Tomo Takeda*, Tetsuo Yasuoka, Hikaru Hoshi [45] (2019)
*Carbon-fiber reinforced epoxy-polyurea Hybrid Matrix Composite-CHMC *fly ash cenosphere (FAC)				

3. DISCUSSION

All research paper study with their result then we find out some variance like as, Fig 1 show that the tensile strength of different natural and synthetic fibers then finds out minmun tensile strength in coir and maximum strength is 4500Mpa in S-glass. But if study young modulus then carbon(standard) have max. young modulus.in this paper silica used in 10% and glass fiber fortified plastic (GFRP) then Tensile fatique strength increase 3-4 times,Tensile strength -19%,Fatique strength -17%[16].if used Jute a-Cellulose (wt%) 61%Hemicellulose (wt%) 23%,Lignin (wt%) 15.86,Ash (wt%) 1.29 then tensile strength increased 61%[18].but if consider Handling and interfacial impact of gelatin gel on coconut jute fortified egg shell bio-composite then maximum hardness get at 1%CJ+ 99%ES-71Shore D[23].if we make a sandwiched composite with Ramie Fiber woven ramie fiber then max. strength get at five layer [32].but if used in nanomaterials silica nanoparticle 4%, glass fiber 20% then Tensile fatique strength increase 3-4 times ,Tensile strength -24%,Fatique strength -21% [37].some paper study that Impact of Silane Treated Silicon (IV) Oxide Nanoparticle Additionon Mechanical, Impact Damage and Drilling Characteristics of KenafFiber-Reinforced Epoxy Composite then get Maximum tensile, flexural and impact strength of 172 MPa, 255 MPa and 6.45 J was observed for composite contain 50 vol.% of fiber and 2.0 vol.% of siliconoxide [39]. But some paper checked mechanical property with Ramie fiber/glass fiber/ Kevlar fiber/Epoxy resin then get Tensile strength is maximum at sample A is 115.76 MPa and Impact strength is maximum at sample D is 9 J [43].and last review paper in study with Carbon fiber/Epoxy resin then get Increase in adhesion is reflected in the high strength [45].and after that we notice that if we used single any natural fiber then get a normal improvement in mechanical property .but if used any nano powder with fiber then get maximum result and improve more than 50% in respect to normal fiber.

4. CONCLUSION

Natural fibers are considered as low-cost fiber to change for man-made fibers in composite materials. Although natural fibers have advantages of being low cost and rarity, they're not totally freed from problems. a significant problem of natural fibers is their strong polar character which creates incompatibility with most polymer matrices. Chemical treatments can increase the interface adhesion between the fiber and matrix, and reduce the water absorption of fibers. Therefore, chemical treatments are often considered in modifying the properties of natural fibers. Fiber modification methods discussed during this paper have different efficacy in causing adhesion between the matrix and therefore the fiber. Yet most sorts of fiber and particle added in composite then improving tensile strength,hardness, elongation % and other mechanical property in natural fibre reinforced composites. The mechanical properties of jute/polyester composites, they are doing have better strengths than wood composites and plastics. Therefore, these composites could be considered for future materials usages.all change in property are showin table1 and fig no 1,2,3 Since the reinforcing material is green composite, harmless, nonhealth hazardous, in low cost and simply available as compared to standard fibers like optical fiber , Kevlar fiber, kenaf fiber etc., the composites are an honest substitute for wood in indoor applications, automobile components.

REFERENCES

[1] M. Sain,S.Panthapulakkal, 2004. Green fiber thermoplastic composites Green composites: Polymer Composites and the Environment. Woodhead Publishing, Cambridge, UK, pp. 181-206(2004)

[2] Malkapuram R, Kumar V and Yuvraj S N. Recent Development in Natural Fiber Reinforced Polypropylee Composites. Journal of Reinforced Plastics and Composites, 2008, Vol. 28, pp. 1169-1189.

[3] N. Saba, M.T. Paridah, K. Abdan, N.A. Ibrahim, Effect of oil palm nano filler on mechanical and morphological properties of kenaf reinforced epoxy composites, Construction and Building Materials 123pp 15–26 (2016)

[4] K. Mohan, T. Rajmohan Effects of MWCNT on Mechanical Properties of Glass-Flax Fiber Reinforced Nano Composites, Materials Today: Proceedings 5 pp11628–11635(2018)

[5] Ahmer Hussain Shah, Xiao Lia, Xiaodong Xu, Abdul Qadeer Dayo, Wen-bin Liu, Jianwei Bai, Jun Wang, Evaluation of mechanical and thermal properties of modified epoxy resin by using acacia catechu particles, Materials Chemistry and Physics 225 pp239–246 (2019)

[6] Hongguang Wang, Guijun Xian, Hui Li, Grafting of nano-TiO2 onto flax fibers and the enhancement of the mechanical properties of the flax fiber and flax fiber/epoxy composite, Composites: Part A 76 pp 172–180(2015)

[7] M Reza Foruzanmehr, Pascal Y. Vuillaume, Saïd Elkoun, Mathieu Robert, Physical and mechanical properties of PLA composites reinforced by TiO2 grafted flax fibers, Materials and Design 106 pp 295–304(2016)

[8] Mahesha C R, Shivarudraiah, N Mohan, Rajesh M, Role of Nano fillers on Mechanical and Dry sliding Wear Behavior of Basalt- Epoxy Nanocomposites, Materials Today: Proceedings 4 pp 8192–8199(2017)

[9] Miriam I. Lautenschlager, Lukas Mayer, Julian Gebauer, Kay A. Weidenmann , Frank Henning, Peter Elsner ,Comparison of filler-dependent mechanical properties of jute fiber reinforced sheet and bulk molding compound, Composite Structures 203 pp960–967(2018)

[10] Static and dynamic behavior of jute/epoxy composites with ZnO and TiO2 fillers at different temperature conditions, Polymer Testing 69 pp 52–62 (2018)

[11] Ramesh Kumar Nayak, Kishore Kumar Mahato, Bankim Chandra Ray, Water absorption behavior, mechanical and thermal properties of nano TiO2 enhanced glass fiber reinforced polymer composites.

[12] N. Saba, M.T. Paridah, K. Abdan, N.A. Ibrahim, Dynamic mechanical properties of oil palm nano filler/kenaf/epoxy hybrid nano composites, Construction and Building Materials 124 pp 133–138(2016)

[13] Vishnu Prasad, M.A. Joseph, K. Sekar, Investigation of mechanical, thermal and water absorption properties of flax fiber reinforced epoxy composite with nano TiO2 addition, Composites Part A 115 pp 360–370 (2018)

[14] G. Seshanandan, D. Ravindran and T. Sornakumar, Mechanical properties of nano titanium oxide particles – hybrid jute-glass FRP composites, Materials Today: Proceedings 3 pp. 1383–1388 (2016)

[15] Chen L, Wei F, Liu L, Cheng W, Hu Z, Wu G, et al. Grafting of silane and graphene oxide onto PBO fibers: multifunctional interphase for fiber/polymer matrix composites with simultaneously improved interfacial and atomic oxygen resistant properties. Compos Sci Technol;106(1):32–8. (2015)

[16] Manjunatha, C. M., et al. "The tensile fatigue behaviour of a silica nanoparticle-modified glass fibre reinforced epoxy composite." Composites Science and Technology 70.1 (2010): 193-199.

[17] Trombeva-Gavriloska, Ana, et al. "Influence of the Composite Components on the Tension Behavior of FRP Materials." Physics Procedia 22 (2011): 584-589.

[18] Gujjala, Ojha, S., mcharya, S.K.,&Pal,. Design and characterization of natural flax fibre reinforced polymer tube encased coir fibre reinforced concrete composite structure. Diss. University of Auckland, 2014.

[19] Davis, Daniel C., et al. "A strategy for improving mechanical properties of a fiber reinforced epoxy composite using functionalized carbon nanotubes." Composites Science and Technology 71.8 (2011): 1089-1097.

[20] Selmy, A. I., M. A. Abd El-Baky, and D. A. Hegazy. "Wear behavior of glass–Polyamide reinforced epoxy hybrid composites." Journal of Thermoplastic Composite Materials 33.2 (2020): 214-235.

[21] Hatter, Christine B., et al. "Micromechanical response of two-dimensional transition metal carbonitride (MXene) reinforced epoxy composites." Composites Part B: Engineering 182 (2020): 107603.

[22] Chowdhury, Indraneel R., et al. "Analysis of failure modes for a non-crimp basalt fiber reinforced epoxy composite under flexural and interlaminar shear loading." Composite Structures (2020): 112317.

[23] Agarwal, Mayank, and Ajit Kumar N. Shukla. "Processing and interfacial effect of gelatin gel on coconut jute reinforced egg shell bio-composite." Materials Today: Proceedings (2020).

[24] Kamaraj, M., E. Anush Dodson, and Shubhabrata Datta. "Effect of graphene on the properties of flax fabric reinforced epoxy composites." Advanced Composite Materials (2020): 1-16.

[25] Al-Majali, Yahya A., et al. "Coal-Filler-Based Thermoplastic Composites as Construction Materials: A New Sustainable End-Use Application." ACS Sustainable Chemistry & Engineering 7.19 (2019): 16870-16878.

[26] Attard, Thomas L., Li He, and Hongyu Zhou. "Improving damping property of carbon-fiber reinforced epoxy composite through novel hybrid epoxy-polyurea interfacial reaction." Composites Part B: Engineering 164 (2019): 720-731.

[27] Chen, Chengwang, and Jiaan Liu. "Study on mechanical properties of epoxy-fly ash cenosphere syntactic foams." IOP Conference Series: Earth and Environmental Science. Vol. 242. No. 3. IOP Publishing, 2019.

[28] Chen, Ping, Jianchao Li, and Lei Zhang. "Analysis of mechanical characteristics of fly ash cenospheres reinforced epoxy composites." Journal of Wuhan University of Technology-Mater. Sci. Ed. 33.1 (2018): 139-145.

[29] Devaraju, A., and P. Sivasamy. "Comparative analysis of mechanical characteristics of sisal fibre composite with and without nano particles." Materials Today: Proceedings 5.6 (2018): 14362-14366.

[30] Devaraju, A., P. Sivasamy, and Ganesh Babu Loganathan. "Mechanical properties of polymer composites with ZnO nano-particle." Materials Today: Proceedings 22 (2020): 531-534.

[31] Devaraju, A., and P. Murali. "Experimental investigation of mechanical and tribological properties of palm fiber composite with Al2O3 ceramic particles." Materials Today: Proceedings 22 (2020): 1161-1166.

[32] Djafar, Zulkifli, Ilyas Renreng, and Miftahul Jannah. "Tensile and Bending Strength Analysis of Ramie Fiber and Woven Ramie Reinforced Epoxy Composite." Journal of Natural Fibers (2020): 1-12.

[33] Giridharan, R. "Preparation and property evaluation of Glass/Ramie fibers reinforced epoxy hybrid composites." Composites Part B: Engineering 167 (2019): 342-345.

[34] Gujjala, Raghavendra, et al. "Mechanical properties of woven jute–glass hybrid-reinforced epoxy composite." Journal of Composite Materials 48.28 (2014): 3445-3455.

[35] Hassanzadeh-Aghdam, M. K., and M. J. Mahmoodi. "A comprehensive analysis of mechanical characteristics of carbon nanotube-metal matrix nanocomposites." Materials Science and Engineering: A 701 (2017): 34-44.

[36] Kim, Young Shin, et al. "Experimental Analysis on the Application of Polymer Matrix Composites Containing Al2O3 for Automotive Lamp Reflector." Applied Sciences 9.21 (2019): 4525.

[37] Tsang, Wing Lam, and Ambrose C. Taylor. "Fracture and toughening mechanisms of silica-and core–shell rubber-toughened epoxy at ambient and low temperature." Journal of Materials Science 54.22 (2019): 13938-13958.

[38] Osouli-Bostanabad, K., et al. "Numerical and Experimental Investigation on Boding Strength Optimization of Glass Fibers-Reinforced Epoxy Composites on a Structural Steel Substrate."

Modares Mechanical Engineering 19.2 (2019): 387-396.

[39] Parthipan, N., et al. "Effect of silane treated silicon (IV) oxide nanoparticle addition on mechanical, impact damage and drilling characteristics of Kenaf fibre-reinforced epoxy composite." Silicon 12.2 (2020): 459-467.

[40] Radhakrishnan, Ganesh, P. V. Anirudh, and S. Anujan Kumar. "Mechanical behavior of nanoparticulate TiO2 reinforced magnesium matrix composite." IOP Conference Series: Materials Science and Engineering. Vol. 574. No. 1. IOP Publishing, 2019.

[41] Sarikaya, Engin, Hasan Çallioğlu, and Hakan Demirel. "Production of epoxy composites reinforced by different natural fibers and their mechanical properties." Composites Part B: Engineering 167 (2019): 461-466.

[42] Selmy, A. I., M. A. Abd El-Baky, and D. A. Hegazy. "Wear behavior of glass–Polyamide reinforced epoxy hybrid composites." Journal of Thermoplastic Composite Materials 33.2 (2020): 214-235.

[43] Xavier, Joseph, Kevin D. Rodney, and Sidharth J. Prakash. "Mechanical Characterisation of Epoxy Polymer Composite Reinforced with Ramie and Synthetic Fiber." (2019).

[44] Suresha, B., et al. "Effect of Nano Filler Reinforcement on Mechanical Properties of Epoxy Composites." IOP Conference Series: Materials Science and Engineering. Vol. 574. No. 1. IOP Publishing, 2019.

[45] Takeda, Tomo, et al. "Effectiveness of flame-based surface treatment for adhesive bonding of carbon fiber reinforced epoxy matrix composites." Composites Part A: Applied Science and Manufacturing 119 (2019): 30-37.