

GLASS FIBER REINFORCED POLYMER COMPOSITES FOR POWER EQUIPMENT

1A. Kiran Kumar Algot, 2G. Laxmaiah, 3P. Ramesh Babu

1Research Scholar of Mechanical Engineering Department, University College of Engineering (A), Osmania University, Telangana, India.

2Professor of Mechanical Engineering Department, CBIT, Telangana, India.

3Professor of Mechanical Engineering Department, University College of Engineering (A), Osmania

University, Telangana, India.

ABSTRACT

Glass fibers reinforced polymer composites have been prepared by various manufacturing technology and are widely used for various applications. Initially, ancient Egyptians made containers by glass fibers drawn from heat softened glass. Continues glass fibers were first manufactured in the 1930s for high-temperature electrical application. Nowadays, it has been used in electronics, aviation and automobile application etc. Glass fibers are having excellent properties like high strength, flexibility, stiffness and resistance to chemical harm. It may be in the form of roving's, chopped strand, yarns, fabrics and mats. Each type of glass fibers have unique properties and are used for various applications in the form of polymer composites. The mechanical, tribological, thermal, water absorption and vibrational properties of various glass fiber reinforced polymer composites were reported.

Keywords Glass fiber, polymer composites, mechanical property, thermal behaviour, vibrational behaviour, water absorption

INTRODUCTION

Composite materials produce a combination properties of two or more materials that cannot be achieved by either fiber or matrix when they are acting alone.1 Fiber-reinforced composites were successfully used for many decades for all engineering applications.2 Glass fiber-reinforced polymeric (GFRP) composites was most commonly used in the manufacture of composite The matrix comprised organic, materials. polyester, thermostable, vinylester, phenolic and epoxy resins. Polyester resins are classified into bisphenolic and ortho or isophtalic.3 The mechanical behaviour of a fiber-reinforced composite basically depends on the fiber strength and modulus, the chemical stability, matrix strength and the interface bonding between the fiber/matrix to enable stress transfer.4 Suitable compositions and orientation of fibers made desired properties and functional characteristics of GFRP composites was equal to steel, had higher stiffness than aluminum and the specific gravity was one-quarter of the steel.5 The various GF reinforcements like long longitudinal, woven mat, chopped fiber (distinct) and chopped mat in the composites have been produced to enhance the mechanical and tribological properties of the composites. The properties of composites depend on the fibers laid or laminated in the matrix during the composites preparation.6 High cost of polymers was a limiting factor in their use for commercial applications. Due to that the use of fillers improved the properties of composites and ulitimately reduced the cost of the preparation and product.7 Composite materials have wide range of industrial applications and laminated GFreinforced composite materials are used in

marine industry and piping industries because of good environmental resistance, better damage tolerance for impact loading, high specific strength and stiffness.8 Polymeric composites were mainly utilized in aircraft industries such as rudder, elevator, fuselage, landing gear doors, that is due to light weight, reduction of higher fatigue resistance in the fasteners and number of components.9 Polyester matrix-based composites have been widely used in marine applications; in marine field the water absorption was an important parameter in degradation of polymer composites. The different mechanisms were used to identify the degradation of material such as propagation, initiation. branching and termination.10 Epoxy resins have been widely used for above applications that have high chemical/corrosion resistance properties, low shrinkage on curing. The capability to be processed under various conditions and the high level of crosslinking epoxy resin networks led to brittle material.11 Energy dissipation of composite was important when they were subjected to vibration environment. Several factors influenced the energy dissipation of FRP composites such as fiber volume, fiber orientation, matrix material, temperature, moisture and others like thickness of lamina and thickness of the composites.12 All polymeric composites have been temperature-dependent mechanical properties. The dynamic stability of polymer matrix composites like the storage modulus and damping factors were essential to investigating under cold and higher temperature.13

Four different techniques were used for determining the damping based on time domain and frequency domain methods. The time domain method was considered in logarithmic decrement analysis and Hilbert transform analysis. The moving block analysis and half power bandwidth method were considered in the frequency method.14 In tribological applications, the composites were subjected to different conditions such as sliding, rubbing, rolling against other materials or against themselves. Load, sliding distance, duration of sliding, sliding speed and sliding conditions were considered for calculating

JNAO Vol. 13, Issue. 2: 2022

the effect of tribological performance.2 Optimum wear rate and coefficient of friction was found for GFRP matrix with addition of fillers.15 The composite materials have been used for many tribological applications such as bearing, gears, wheels and bushes.16 The Figure 1 describes the methodology of the GFRP matrix composites preparation and characterization, and its application.

Classification of GF The major classification of GFs and the physical properties are shown on Figure 2. Also, the chemical compositions of GFs in wt% are shown in Table 1. The physical and mechanical properties of GF are shown in Table 2.

Preparation of GFRP matrix composites The GFRP composites were prepared by adopting various manufacturing techniques as discussed below. The preparations of random and woven mat GFs are shown in Figures 3 and 4.



Figure 1. Flowchart of the GFRP matrix composites preparation and characterization.Silicone rubber mouldAramide et al.1 prepared the woven-mat GFreinforced unsaturated polyester composite using silicone rubber mould. The mould was cleaned and dried. The mould surface was coated with releasing agent of hard wax for easy removal of composites. Initially, unsaturated polyester resin containing curing additives was applied in the mould surface by using brush. The GF was placed on the resin and fully wetted. A steel roller was used to make full wetting of fiber in resin. A final sealing layer of resin was poured on the fiber. Over the period of time, the laminated composite was fully hardened and it was removed from the mould. The hand file was used to time the edges of the cured composites plate for obtaining the final size. The different fiber contents (5% to 30%) were used to prepare the composites plates.Hand lay-up method followed by compression mouldingErden et al.4 prepared the woven roving mat E-GF/ unmodified and modified polyester matrix composites



Figure 2. Classification and physical properties of various glass fibers.

	0	
Table 1.	Charneal compositions of gian Ma	ers in well.

- Type	(9D)	(A),O))	Tiop	B _{plp}	(CeO)	(PigCI)	Na ₂ O	Kat	Fepole .	. Nat
E-gimi	55.0	148	8.2	7.0	22.6	1.6	0.5	0.3		17
Coglass	64.6	4.1		5.0	13.4	13	8.6	0.5	-	
S-glass	#5.0	25.0		-		10.0	-	-	-	
Aghie	67.5	3.5	-	15	6.5	4.5	13.5	3.9		
Digfass	740		-	22.5	-		1.5	2.0		
R-plan	+0.0	24.0	-		9.0	6.0	0.5	0.1		
EGR-plot	41.0	13.0	-	-	22.0	3.6	-	0.5	-	
fault	32.0	173	10	-	8.4	\$3	5,0	1.0	5.0	

using hand lay-up technique followed by compression moulding at a pressure of 120 bars at room temperature for 120 min with 37% fiber volume fraction (Vf) and 3.5 mm thickness of laminates. Hot press technique Atas et al.18 prepared the woven mat GFreinforced epoxy composites using hot press technique. Non-

JNAO Vol. 13, Issue. 2: 2022

orthogonal woven fabric prepared with dimension of 305 mm 305 mm, an orthogonal fabric was transformed into non-orthogonal fabric by using shearing process with various weaving angles between fill and warp. The weight ratio epoxy resin to hardener was 10:3. The composite panels were cured at 60C for 2 h and 93C for 4 h, during the curing process 0.35MPa pressure was employed on the laminated composites. Aktas et al.19 prepared unidirectional GF-reinforced epoxy laminates using hot press method. The 65% weight fraction of laminates fabricated in two different stacking sequences like [0/90/0/90] and [0/90/ +45/45], CY225 epoxy resin and HY225 hardener were mixed, the mixture and 509 g/m2 of GF composition cured into hot press technique under constant pressure of 15 MPa and temperature 120C for 2 h, the fabricated composite plate thickness was 3 mm.Mixing and mouldingGupta et al.7 prepared the discontinuous E-GF-reinforced epoxy composites with addition of filler-like flyash. The diameter of GF was 10 mm and cut into 2.54 cm length for composite preparation. The ratio of epoxy resin and hardener mixed is around 100:10.



The two different concentrations of flyash filler were selected as 2.5 and 5% vol%, along with calcium carbonate fillers added during the mixing of resin and hardner. Small size and spherical shape of the flyashparticles facilitate their good

600

mixing and wetting of fiber and matrix. The mould was prepared with Hand lay-up method followed by hydraulic press Suresha et al.21 prepared woven mat GF-reinforced epoxy composite using hand lay-up method. The epoxy resin was mixed with the hardener in the weight ratio of 100:12. The resin and fibers were mixed to make 3 mm thickness of sample with application of hydraulic press of 0.5 MPa. The specimen was allowed to cure for a day at room temperature. After de-molding, the post curing was done at 120C for 2 h using an electrical oven. The prepared laminate size was 250 mm 250 mm 3 mm



Dry hand lay-up method Suresha et al.22 prepared the woven fabric GFreinforced vinyl ester composites using dry hand lay-up technique and the individual fiber diameter was 8-12 mm. The resin was mixed into Methyl ethyl ketone peroxide (MEKP) as catalyst, cobalt naphthanate as accelerator and, N-dimethyl aniline as promoter used, vinyl ester resin, cobalt naphthanate and MEKP were mixed the weight ratio of 1: 0.015: 0.015. Two different fillers are mixed into resin such as 50 mm of graphite and 25 mm size of silicon carbide (SiC), The woven mat stacking one above other and the mixure f resin spreaded over the fabrics by dry hand lay-up moulding, and the whole die assembly compressed at constant pressure 0.5 MPa of by using hydraulic press. The prepared slabs size was 250 mm 250 mm 3 mm.H-type press Mohan et al.23 prepared oil cake-filled woven fabric GF-reinforced epoxy composites with the individual fiber diameter 18 mm. The magnetic stirrer was used to mix the epoxy resin and hardner with the weight ratio of 100:38. Above the prepared mat the resin mixture was applied using roller and brush and the laminate was cured under the pressure of 0.0965 MPa for 24 h by using h-type press, after the moulding process the post curing was conducted at 100C for 3 h. The prepared laminated size was

JNAO Vol. 13, Issue. 2: 2022

300 mm 300 mm 9 2.6 mm. Mechanical properties of GFRP matrix compositesAramide et al.1 investigated the mechanical properties of woven-GF-reinforced unsaturated mat polyester composite with different fiber Vfs like 5, 10, 15, 20, 25 and 30%. The tensile strength, Young's modulus and elastic strain increased with increase of the GF Vf. Impact strength decreased with increase of the GF Vfof 25%. The maximum tensile and flexural properties were found at 30% Vf of GF as shown in Table 3. The maximum strain was found at 25% Vf. Erden et al.4 investigated the mechanical behaviourof woven roving E-GF-reinforced unsaturated polyester composites with matrix modification technique. The oligomeric siloxane was added to polyester resin in different levels like 1, 2, and 3 Wt% respectively. Incorporation of oligomeric siloxane into the polyester resin increased the mechanical properties such as interlaminar shear, flexural and tensile strength, modulus of elasticity and vibration values. Glass/polyester with 3wt% of oligomeric siloxane composite was found to be better mechanical properties compare to other combinations. The tensile strength increased from 341.5 to 395.8 MPa while the. Flexural Strength increased from 346.1 MPa to 399.4 MPa, Interlaminar Shear strength increased from 25.5 to 44.7 MPa, natural frequency increased from 6.10 to 7.87 Hz as shown in Table 3. Al-alkawi et al.24 investigated the fatigue behaviourof woven strand mats E-GF-reinforced polyester composites under variable temperature conditions such as 40C, 50C and 60C. The S-N curve reported that the tensile and fatigue strength decreased with increasing temperature up to 60C at 33% fiber Vf. The percentage reduction factor for fatigue strength was higher than the percentage reduction factor for tensile strength for all temperature level. Awan et al.5 investigated the tensile properties of GFreinforced unsaturated polyester composite with various cross sections of fibers at various ply of 1ply, 2-ply and 3-ply sheets. The higher weight percentage of

GF in composites gives stronger reinforcement. The number of layers, thickness and the cross sectional area was different for each specimen. Maximum tensile strength observed in three ply reinforcement (Table 3). Higher Vf of fibers increased the strength and stiffness of the composite. Chen et al.25 investigated the mechanical properties of polyamide66 (pellets)/polyphenylene sulfide blend matrix with different GF volume contents such as 5%, 10%, 20% and 30% respectively. The maximum tensile strength was found at 30% Vf of fiber and flexural strength was found at 25% Vf. The maximum impact strength was found at 0% Vf of fiber compare to fiber incorporated composites. But the maximum impact strength was found at 20% Vfof fiber that was lower the above. In wear testing, the minimum frication coefficient (0.35) was found at 20% Vf of fiber and wear volume was lower at 30% Vf of fiber. Yuanjian et al.26 investigated the low-velocity impact and tension-tension fatigue properties of GFreinforced polyester composites with two fiber geometries like [x0005 45] at 42% Wf of fiber and [0/90] at 47% Wf of fiber. The result showed that the residual tensile strength and stiffness decreased with increasing impact energy from 0 to 25 J at 5 J increments. The maximum properties were sustained up to 10 J test and the above properties were highly reduced due to increasing the testing energy from 10 to 20 J. The impact damage was similar for the two geometries. Low-impact energy of GF-reinforced composites cause of matrix damage. The tensiontension fatigue failure test was performed at various impact damage energies of 1.4 J, 5 J and 10 J respectively. In the S-N curve the fatigue lifetimes was slowly decreased and higher at 1.4 J with higher stress at [0/90] and at $[x0005_45]4$, the fatigue lifetimes was suddenly dropped and found lower stress value compared to doped [0/90]. Faizal et al.8 investigated the tensile behaviourof plane woven E-GF-reinforced polyester composite with different curing pressure like 35.8 kg/m2, 70.1 kg/m2, 104 kg/m2 and 138.2 kg/m2. Different lay-up like symmetrical and non-symmetrical was used to prepare the composites. The stress-strain curve showed that the tensile modulus was decreased with increasing curing pressure for both symmetrical and nonsymmetrical lay-up. The symmetrical lay-up was less on the stiffness of composites. The ductility

JNAO Vol. 13, Issue. 2: 2022

increased with increasing curing pressure for nonsymmetrical arrangement and symmetrical arrangement decreased. Husic et al.27 investigated the mechanical properties of untreated E-glassreinforced polyurethane composites with two polyurethanes like soypolyol and petrochemical polyol Jeffol resin. The result showed that the soypolyol based composite was lower flexural, tensile and inter laminar shear strength compare to petrochemical polyol Jeffol-based composite. This was due to lower cross linking density and the presence of the side dangling chains in the matrix. The interlaminar shear strength was similar for both for two resin composites. Atas et al.18 investigated the Impact response of woven mat GF-reinforced epoxy composites with orthogonal fabric and non-orthogonal fabric of a weaving angle of 20, 30, 45, 6075and 90respectively from vertical direction (warp direction). The energy absorption increased with decrease of weaving angle between interlacing yarns. Woven composites with smaller weaving angle of 20and 30between interlacing yarns, have lower peak force, larger contact duration, larger deflection and higher absorbed energy than larger weaving angle of 60, 75and 90. The [0/ 20] woven composite was absorbed higher compared to [0/90] woven composite. Leonard et al.9 investigated the fracture behaviourof chopped strand mat GF-reinforced polyester (CGRP) matrix composites with different Vf of fibers like 12%, 24%, 36%, 48% and 60%. The stress-strain curve reported that 60% Vf of GF composite obtained maximum improvement of tensile strength of 325MPa, Young's modulus of 13.9 GPa, fracture toughness of 20-fold and critical energy release rate of 1200-fold. Putic et al.28 investigated the interlaminar shear strength of the random/woven GF mat-reinforced polyester matrix composite with three-layer and eight combinations of the composition patterns. The glass fabric with various densities, various polyester resins like bisphenolic resin, waterresistant resin and acid-resistant resin were used to analyse the strength. Outer layers were short GF and inner layers were woven mat fiber and thickness of outer layers 1 mm, middle layer 0.5-0.8 mm. The P6 [Glass mat (240 g/m2)/woven mat (0/90) (800 g/m2)/Glass mat (240 g/m2)] pattern model bisphenolic resin-based composites had higher interlaminar shear strength compared to other patterns. Avci et al.29 used three-point bending tests and investigated the Mode I fracture behaviour of chopped strand GF-reinforced particle-filled polymer composites with varying notch-to-depth ratios (a/b ratios 0.38, 0.50, 0.55, 0.60 and 0.76). The two different Vfof GF like 1% and 1.5% with various Vf of polyester resins like 13.00%, 14.75%, 16.50%, 18.00% and 19.50% were used for the experiments. In 0% Vfof GF the maximum flexural modulus was found at 16.50% Vf of polyester, in 1% Vf of GF was found at 18.00% and in 1.5% Vf of GF was found at 19.50% Vf. A similar trend was found in flexural strength. The stress intensity factor (KIC) was found by using three methods like (1) Initial notch-depth method, (2) Compliance method and (3) J-integral method. Ininitial notch-depth method and compliance method, the GF content increased the KIC values for all polymer content. The lower KIC values were found at 0% grass fiber content. The maximum J-integral energy was found at the 0.6 notch-to-depth ratio. Alam et al.6 investigated the effect of orientation of chopped strand and roving GFRP composites with different fiber orientation such as 0, 45and 90. Fiber orientation was not affected by the density and hardness of composites. At 90fiber orientation the maximum tensile strength was obtained. The short fiber was found to be reducing the impact strength. Shyr et al.37 investigated the impact resistance and damage characteristics of E-GFreinforced polyester composite with various thicknesses of the laminates and three different glass fabrics were multiaxial warpknit blanket (MWK), woven fabric (W) and non-woven mat (N). Impact tests were conducted using a guided drop-weight test rig. The composites were prepared with various layers with various Vfs of fiber like 24 (sample code of N-13a, b and c), 28(sample code of N-7a, b and c), 40 (sample code of R-800-13a, b and c), 40 (sample code of R800-7a, b and c), 37 (sample code of M-800-13a, b and c), 40 (sample code of M- 800-13a, b and c), 45 (sample code of MWK-800-13a, b and c) and 46 (sample code of MWK-800-13a, b and c).

JNAO Vol. 13, Issue. 2: 2022

In code, 7 and 13 were the no of layers in the composites with a, b and c the 8, 16 and 24 nominal impact energies (NIE), respectively. The test was conducted at various velocity of drop weight. The maximum Hertzian failure force of the laminates was found for MWK-13 laminate in 16 NIE. The maximum Hertzian failure energy of the laminates at various NIE was found for M-80013 in 24 NIE. The major damage energy at maximum impact load was found for MWK-13 laminate in 16 NIE. The maximum subjected energy and final absorbed energies of the impenetrated laminates at various NIE were found for MWK-13 laminate at 24 NIE. Araujo et al.30 investigated the mechanical properties GF/virgin GF wastes-reinforced polyester matrix composites with various fiber weight content of fiber like 20, 40. 50 and 60%, respectively. 30. The polyester/virgin GF-reinforced composite showed higher tensile strength and modulus at 40% Wf. The maximum impact strength and hardness were found at 40 and 40% Wf. Hossain et al.38 investigated the flexural and compression properties of woven E-GF-reinforced polyester matrix composites with addition of various weight percentages of carbon nano filler (CNF). The test was performed on the conventional and 0.1, 02, 03 and 0.4 wt% CNF-filled composites. The stress versus strain curve showed that 0.2 wt% of CNFfilled composite obtained maximum mechanical properties. Thiswas due to excellent dispersion, maximum enhancement in compressive strength, modulus and better interfacial interaction between fiber and matrix. Khelifa et al.39 investigated the fatigue behaviourof E-GF-reinforced unsaturated polyester composite with different orientation of fiber (0, _x0005_ 45, 0/90). Experimental and theoretical results reported that the unidirectional [0] and cross-ply [0/90] composite laminates had more static bending strength compared to other laminated composites. Baucom et al.40 investigated the low-velocity impact damage of woven E-glass-reinforced vinyl-ester composites with various laminates like 2D plain-woven laminate, a 3D orthogonally woven monolith and a biaxial reinforced warp-knit. Drop-weight apparatus result showed that the 3D composites was more resistant to penetration and dissipated

more total energy (140 J) compared to other systems. Iba et al.41 investigated the mechanical properties of unidirectional continuous GFreinforced epoxy composites with three fiber diameters like 18, 37, 50 mm, respectively, and fiber Vf from 0.25 to 0.45. The stress-strain curve reported that the longitudinal Young's modulus and tensile strength of the composite increased with increasing the fiber Vf and the mean strength increased with decreasing the fiber diameter. The maximum strength and modulus was higher for the fiber diameter of 18 mm at 0.45 Vf. Ya'acob et al.42 investigated the mechanical properties of E-GF-reinforced polypropylene composites prepared injection using moulding and compression moulding processes. Results show that the tensile strength decreased with the increasing of GF content. The tensile modulus increased with increasing the fiber content and the maximum values were obtained at 12-mm fiber length composites compared to 3 and 6 mm fiberlength composites. Mohbe et al.31 investigated the mechanical behaviour of glass fiber reinforced polyester composites with constant volume fraction of glass and Na-MMT (sodium montmorillonite). Mechanical properties were improved with increase in the Na-MMT quantity in composites; 3% weight of Na-MMT was found to have maximum tensile strength (130.03 MPa), impact strength (153.50 kJ/m2) and flexural strength (205.152 MPa). Gupta et al.7 investigated and compressive impactbehaviour the of discontinuous E-GFreinforced epoxy composites with addition of fillers such as fly ash and calcium carbonate. Fly ash particles led to reduced compressive and impact strength of the composites compared to the calcium carbonate filler in the composites. The aspect ratio of the fiber increased the compressive strength and decreased the impact strength. Pardo et al.43 investigated the tensile dynamic behaviour of a quasi-unidirectional E-glass/polyester composite. This composite was not a pure unidirectional material; it was composed of 5% Vf of weft fibers. The weft fibers Vf of 5% observed greater Young's modulus and improved the failure stress (40MPa). Yang et al.32 investigated the compression, bending and shear behaviour of

JNAO Vol. 13, Issue. 2: 2022

woven mat E-GF-reinforced epoxy composites with different fabrics like unstitched plain weave, biaxial non-crimp and uniaxial stitched plain weave fabrics. From the experiments they have concluded that the Z-directional stitching fibers increased the delamination resistance, reduced the impact damage and as well as lowered the bending strength of the composites. The compressive strength of the non-crimp laminate was 15% higher than woven fabric composite. Hameed et al.44 investigated the dynamic mechanical behaviour of E-GF-reinforced poly (styrene-co-acrylonitrile)-modified epoxy matrix composites with the differentVfs of fibers ranging from 10% to 60%. Under three-point bending mode the viscoelastic properties were measured at the frequency of 1 Hz and samples were heated up to 250C at the heating rate of 1C/min. While increasing the temperature the storage modulus decreases. Storage modulus versus temperature curve reported that the 50 vol% fiber content of composites had the maximum storage modulus (15.606 GPa). Loss modulus versus temperature plot indicated that the loss modulus increased up to 50 vol% fiber content. Further increase in the fiber content decreases the loss modulus. Aktas et al.19 investigated the impact response unidirectional E-GF-reinforced epoxy matrix composite with two different stacking sequences such as [0/90/0/ 90] and [0/90/+45/45]. Damage process and damage modes of laminates were investigated under varying impact energies ranging from 5 J to 80 J. The penetration threshold for stacking sequence [0/90/+45/45] was smaller than [0/90/0/90] and the mismatch coefficient for [0/90/0/90] laminates were higher than +45/45] laminates. [0/90/ Aktas et al.45 investigated compression after impact (CAI) behaviour of unidirectional E-GF-reinforced epoxy matrix composite subjected to low-velocity impact energy for various temperatures such as 40C, 60C, 80C and 100C. Two stacking sequences [0/90/0/90] and [0/90/45/45] were tested to investigate the vertical and horizontal orientation effects on CAI strength and CAI damage mechanism. CAI strength decreases with increase in temperature and impact energy. The maximum reduction in CAI strength was found

between undamaged specimen and impacted specimen at 100C and 70 J for each stacking sequences and each impact damage orientation. The CAI strength of horizontal impactdamage was lower than vertical impact damage for all impact test temperatures and all energy levels. Aktas et al.46 investigated the impact and postimpact behaviour of E-glass/epoxy eight plies laminated composites with different knitted fabrics such as Plain, Milano and Rib. Different impact energy levels were ranging from 5 J to 25 J. The experimental result showed that the Rib knitted structure had maximum mechanical properties for irregular fiber architecture, Milano knitted structure showed maximum performance in transverse direction and as well as better mechanical properties than Plain knitted structure. Patnaik et al.33 investigated the mechanical behaviour of randomly oriented E-GF-reinforced epoxy composites with particulate filled like Al2O3, SiC and pine bark dust and the different composition of specimen were prepared such as GF (50 wt%) +epoxy (50 wt%), GF (50 wt%) +epoxy (40 wt%) +alumina (10 wt%), GF (50 wt%) +epoxy (40 wt%) +pine bark dust (10 wt%), GF (50 wt%)+ epoxy (40 wt%)+ SiC (10 wt%). The test result showed that the GF + epoxy had maximum tensile strength (249.6 MPa) and strength (368MPa) than flexural other compositions, GF + epoxy + pine bark dust combination having the maximum interlaminar shear strength (23.46 MPa), GF + epoxy+ SiC combination having higher impact strength (1.840 J) and higher hardness (42 Hv). Karakuzu et al.47 investigated the impact behaviourof unidirectional E-glass/epoxy composite plates with the stacking sequence of plates selected as [0/30/60/ 90]. Four different impact energies were 10 J, 20 J, 30 J and 40 J and four impact masses were selected like 5 kg, 10 kg, 15 kg and 20 kg. Absorbed energy versus impact energy curve reported that the energy absorption capability of the specimen subjected to equal mass was lower than the specimen subjected to equal velocity for the same impact energy. Delamination area versus impactor mass curve reported that the delamination area in the sample was subjected to a lower impact mass with higher velocity was lower than the

JNAO Vol. 13, Issue. 2: 2022

delamination area in the sample was subjected to higher impact mass with lower velocity for same impact energy. Icten et al.48 investigated the low temperature effect on impact response of quasiisotropic unidirectional EGF-reinforced epoxy matrix composites with stacking sequence [0/90/45/45] tested at varied impact energies ranging from 5 J to 70 J and the test were performed at different temperatures such as 20C, 20C and 60C. The experimental result showed that the damage tolerance and impact response of the composite was same for all temperatures up to the impact energy of 20 J and after 20 J of impact energy, the temperature affects the impact characteristics. Liu et al.34 investigated interlaminar shear strength of woven E-GFreinforced/epoxy composites with unmodified and modified matrix modification technique. Initial epoxy matrix was diglycidyl ether of bisphenol-F/diethyl toluene diamine system and modi- fied matrix was multiwalled carbon nanotubes (MWCNT) and reactive aliphatic diluent named n-butyl glycidyl ether system. The three point bending test result showed that the modified epoxy/GF composite inter-laminar shear strength was higher than the unmodified epoxy/GF composite; 0.5 wt% MWCNTs and 10 phr butyl glycidyl ether (BGE) adding epoxy/ GF composite was 25.4% increased the inter laminar shear strength (41.46 MPa) than unmodified composites. Belingardi et al.49 investigated the low-velocity impact tests of woven and unidirectional GF-reinforced epoxy matrix composite with three different stacking sequences [0/90], [0/+60/60] and [0/+45/45]. Different impact velocities were (0.70, 0.99, 1.14, 1.72, 1.85, 1.98, 2.10, 2.22 and 2.42 m/s) and different deformation rate (25, 50, 100, 150, 175, 200, 225, 250 and 300 mm). The experimental result showed that the maximum saturation energy (53.08 J) was found at [0/90] unidirectional composites compared with the other stacking sequences. Mohamed Nasr et al.50 investigated the fatigue behaviour of woven roving GFreinforced polyester matrix composites with the fiber Vf ranging from 55% to 65% and two different fiber orientations like [_x0005_ 45] and [0, 90]. The torsional fatigue test was performed

on thin wall tubular specimens at different negative stress ratios (R) such as 1, 0.75, 0.5, 0.25 and 0. The experimental result shows that the strength degradation rate depends on the stress ratio and the static strength of the material and the [_x0005_ 45] lay-up specimen had maximum rate. Mohammad Torabizadeh35 failure investigated the tensile, compressive, in-plane shear behaviour of unidirectional GF-reinforced epoxy matrix composites under static and low temperature (25C, 20C, 60C) conditions. The tensile test result showed that the stress-strain curve decreases with increase in temperature. The maximum tensile strength (784.94 MPa), young's modulus (28.65 MPa), compression strength (186.22 MPa) and shear strength (1.33 108 MPa) was found at 60C. Ahmed El-Assal et al.51 investigated the fatigue behaviour of unidirectional GF-reinforced orthophthalic polyester matrix composites under torsional and combined bending loads at room temperature and the tests were conducted on constant deflection fatigue machine with the frequency of 25 Hz. Different fiber Vfs are used such as 15.8, 31.8 and 44.7%. The experimental result showed that the number of stress cycles andties of jatropha oil cake-filled woven mat E-GFreinforced epoxy composites. The experimental test conducted at longitudinal direction of composite specimen and the surface fracture exposed that the similar breakage of fibers and matrix, which represent good adhesion between fibers and matrix. The experimental result showed that 6 wt% of jatropha oil cake fillers filled composite specimen was found maximum tensile strength (311 MPa) and tensile modulus (18.61 GPa) but the surface hardness was slightly lower than unfilled composites. Zaretsky et al.52 investigated the dynamic response of woven GFs-reinforced epoxy composite subjected to impact loading through fiber direction and the impact velocities ranging from 60 to 280 m/s. The free surface velocity versus time curve shows that the impact strength increased with increase of the shock wave velocity, the unloading wave speed was higher than compression wave speed and the wave speed decreased with decrease of the pressure. Godara et al.36 investigated the tensile behaviourof GF-

JNAO Vol. 13, Issue. 2: 2022

reinforced epoxy composite with the different woven fibers orientations like [0], [x0005 45] and [90]. The 35 wt% of short borosilicate GFsreinforced with multilayered cross woven composite with epoxy matrix. The stress versus stain curve reported that the tensile strength was strongly depend on the fiber alignment to the external load, [0/90] laminate composites had the maximum failure strength (355MPa), low ductility and low strain failure (1.65%) than [x0005 45]. Karakuzu et al.53 investigated the mechanical behaviour of woven mat GF-reinforced vinyl ester matrix composites with circular hole and 63% fiber Vf, the different distance from free edge of plate (E) to diameter of hole (D) ratios are 1, 2, 3, 4 and 5. During the experiment the load is applied to longitudinal direction of specimen, the tension mode experimental result showed that the young's modulus was found 20,769 MPa. The shear modulus (G12) was found using following Equation (1), where, r, ti and c were density, dimensions of specimen, from the above equation, the shear strength were found for 75 MPa. Dandekar et al.54 investigated the compression and release response behaviour of a woven mat S2 GF-reinforced polyester composites under shock loading applied up to 20 GPa. The stress and particle velocity properties were described the shock response, the plate reverberation and shock and re-shock experimental result showed that the Hugoniot elastic limit (HEL) of composites ranging from 1.3 GPa to 3.7 GPa. LeBlanc et al.55 investigated the compressive strengthbehaviour of woven mat S-2 GF-reinforced Epoxy/Vinyl ester composites with four different areal weights like 93, 98, 100 and 190 oz/yd2 and the composite specimen subjected to shock loading on experimentally, two different pressure applied on compressive specimen such as 2.58 and 4.79MPa. Compressive strength versus pressure curve in weft direction result showed 100 and 98 oz composites was obtained maximum strength but the warp direction 93, 98 and 190 oz composites are maximum strength and nearly equal under each pressure level.

Table 3. Mechanical properties of glass therewinforced polynumics (GMM) comp

606 3 2 " 11 ĩ CONTA QUANT 112 82 ÷ i 23039 (T) 22394 (I) 22394 (I) 0638 (T) ID NOT O MAY e ŝ 66 50 8 W 2 2 9 3 9 5 9

Vibration characteristics of GFRP matrix composites Erden et al.4 investigated vibrational properties of glass/polyester composites via matrix modification technique. To achieve this, polyester unsaturated was modified by incorporation of oligomeric siloxane in the concentration range of 1-3 wt%. Modified matrix composites reinforced with woven roving glass fabric compared with untreated were glass/polyester in terms of mechanical and interlaminar properties by conducting tensile, flexure and short-beam shear tests. Furthermore, vibrational properties of the composites were investigated while incorporating oligomeric siloxane. From the experiment it was found that the natural frequencies of the composites were found to increase with increasing siloxane concentration. Sridhar et al.12 investigated the damping behaviourof woven fabric GFRP composites under saline water treatment with various fiber volumes like 20, 25, 30, 35 and 40

JNAO Vol. 13, Issue. 2: 2022

and various time period using the logarithmic decrement method. The damping factor value of specimen damping and untreated stiffness with increase in fiber increased volume percentage. Maximum decrease in the damping values was observed for 40% fiber volume specimen. Yuvaraja et al.56 investigated the vibration characteristics of a flexible GFRP composite with shape memory alloy (SMA) and piezoelectric actuators. In first case, the smart beam consists of a GFRP beam modelled in cantilevered configuration with externally sists of a GFRP beam with surface-bonded lead zirconate titanate (PZT) patches.

To study the behaviour of the smart beam a mathematical model is developed. Using ANSYS the vibration suppression of smart beam was investigated. The experimental work is carried out for both cases in order to evaluate the vibration control of flexible beam for first mode, also to find the effectiveness of the proposed actuators. As a result of the vibrational characteristic, GFRP beam is more effective when SMA is used as an actuator. SMA actuator was more efficient than the PZT actuator because very less voltage is required for actuation of SMA. Bledzki et al.57 investigated the elastic constants of unidirectional E-glass-reinforced epoxy matrix composite by the vibration testing of plates with two different fibers-surface treatments. The first type was treated by epoxy dispersion with aminosilane to promote fiber/ matrix adhesion and the second type was sized with polyethylene to prevent fiber/matrix adhesion.

Elastic properties were good for epoxy dispersion with aminosilane composite and poor for polyethylene composites. Mishra58 investigated the vibration analysis of unidirectional GFreinforced resol/vac-ehacomposites (with varying Vf of GFs). Resol solution was blended with vinyl acetate-2-ethylhexyl acrylate (vac-eha) resin in an aqueous medium. The role of fiber/matrix interactions in GFs-reinforced composites were investigated to predict the stiffness and damping properties. Damping properties decreased after blending Vac-ehacopolymer content with resol,

Table 3. Continued

plate increases the damping properties. Ref 8 * 35 23 nterlaminar strength (MPa) 18.99 41.46 shear ï strength .840()) mpact modulus Flexural T: Tensile test. F. Flexural test, I: Impact test, S: Shear test, Joc. Jatropha oil cake; Na-MMT: sodium montmonillonite; MWCNT: Multiwalled carbon nanotube. (MPa) Flexural strength 297.82 (MPa) × 1 at break (%) Bongation 0.032 .65 80 modulus Tensile 18610 43700 (MPa) 6700 Strength Tensile 784.98 (MPa) 179.4 E 355 ASTM D 3039-76 (T). ASTM D 2344 (S) (T) 9605 D MT2A ASTM D3039 (T) ASTM D 256 (I) **Festing Standard** 0.73 0.55 0.60 0.5 ž 11 Curing agent Epoxy (6 wt% joc) Epoxy (0.5 wt% poxy (10 wt% MWCNTs) S Epoxy Epoxy Resin Woven + (35 wc% borosilicate) Unidirectional ype of glass onented Randomly Woven Woven

JNAO Vol. 13, Issue. 2: 2022

Due to incorporation of GFs in the matrix, the tensile, stiffness and damping properties were increased. Colakoglu et al.13 investigated the damping and vibration analysis of polyethylene fiber composite under various temperatures ranging from 10C to 60C. A damping monitoring method was used to experimentally measure the frequency response and the frequency was obtained numerically using a finite element program. The damping properties, in terms of the damping factor, were determined by the halfpower bandwidth technique. The experimental result showed that the natural frequency and elastic modulus decreased with increase in temperature. Naghipour et al.14 investigated the vibration damping of glued laminated beams reinforced with various lay ups of E-GFreinforced epoxy matrix composites by using different methods such as, Hilbert transform, logarithmic decrement, moving block and half band power methods. Half band power method improves the accuracy when considering the vibration damping of composite materials possessing relatively high level of damping. Furthermore, their experimental results indicated that the addition of GRP-reinforcement in the bottom surface of cantilever beams could significantly improve their stiffness and strength characteristics.

Environmental behaviours of GFRP matrix composites Araujo et al.30 investigated the water absorption behaviour of fiber glass wastesreinforced polyester composites with different fiber wastes like 20, 30 and 40%. The test specimen immersed in distilled water at different time interval up to 600 h and time versus water absorption curve was plotted. It resulted that the water sorption decreased with increase of fiber content in composite and the minimum water absorption was found for polyester/fiberglass wastes (40%) composite. Abdullah et al.59 investigated the effects of weathering condition on mechanical properties of GF-reinforced thermoset plastic composites. The mechanical properties decreased with various weathering were conditions such as humidity, temperature and ultraviolet radiation and pollutant. Botelho et al.60

607 while increasing the GF content in composite investigated the environmental behaviour of woven mat GF-reinforced poly etherimide thermoplastic matrix composites. The testing was conducted with varying temperature at relative humidity of 90% for 60 days under sea water. The moisture absorption behaviour was mostly dependent on temperature and relative humidity. The moisture absorption curve reported that the weight gain was initially increased linearly with respect to time. The maximum moisture absorption of 0.18% was found after 25 days. Chhibber et al.61 investigated the environmental degradation of GFRP composite with different temperature such as 45C and 55C.

This testing was conducted in normal water and sodium hydroxide (NaOH) bath after a time of 1 and 2 months. The percentage weight gain increased with increase of bath time and temperature, NaOH bath found larger weight gain compared with that of water bath. Renaud et al.62 investigated the environmental behaviour of E-GF-reinforced isophtalic polyester composites with different GFs such as boro-silicate and boron-free at different environmental conditions such as strong acids, cement extract, salt water, tap water and deionized water. The test was conducted at 60C for lifetime of 50 years; the boron-free E-GF composite increased the resistance of moisture absorption in all environmental conditions. Kajorncheappunngam et al.20 investigated the effect of aging environment on degradation of woven fabric Eglass-reinforced epoxy with four different liquid media such as distilled water, saturated salt solution, 5-molar NaOH solution and 1-molar hydrochloric acid solution. Water immersion had the lower damage than Sathishkumar et al. 1269 Downloaded from jrp.sagepub.com by guest on June 20, 2014acid or alkali soaking and lower immersion did not affect the mechanical properties. Agarwal et al. 63 investigated the environmental effects of randomly oriented E-GFreinforced polyester composites with different environmental conditions such as brine, acid solution, ganga water, freezing conditions and kerosene oil.

JNAO Vol. 13, Issue. 2: 2022

The test conducted at different interval of time such as 64 h, 128 h and 256 h. The percentage reduction in tensile strength decreased after every interval of time, the maximum percentage reduction was found on NaOH solution and minimum percentage reduction was found on freezer condition. Ellyin et al.64 investigated the moisture absorption behaviour of E-glassreinforced fiber epoxy composite tubes. They were immersed in distilled water at two different temperatures such as 20C and 50C. The test was conducted in distilled water for 4 months. The time versus moisture absorption curve reported that 0.23% weight gain was found at 20C and 0.29% weight gain was found at 50C. Abbasi et al.65 investigated the environmental behaviour of GFRP composites with different combinations such as GF/isophthalic polyester, GF/vinyl ester and GF/urethane-modified vinyl ester. The test was conducted at different temperatures from 20C to 120C for 30 days, 120 days and 240 days under normal water and alkaline environments.

The GF composites strength and modulus were decreased in alkali environment at higher temperatures. Visco et al.10 investigated the mechanical properties of GF-reinforced polyester composites before and after immersion in seawater. Two different types of polyester resins, such as isophthalic and orthophthalic, and two different types of laminates were used for composites preparation. One laminate contained five layers of reinforcement with isophthalic polyester resin and another was obtained by laminating four layers of reinforcement with orthophthalic resin and one external layer with isophthalic. The experimental result showed that flexural modulus, flexural strength and shear modulus decreased with increase in immersion time. Isophthalic resin was better bonding with GFs, which was resisting the seawater absorption compared to orthophthalic resin

Thermal properties of GFRP matrix compositesHusic et al.27 investigated the thermal properties of Eglass-reinforced soy-based polyurethane composites with two different types of polyurethane such as soybean oil and petrochemical polyol Jeffol. Soy-based polyurethanes had better thermal stability than petrochemical polyol Jeffol-based polyurathene. Hameed et al.11 investigated the thermal behaviourof chopped strand E-GF-reinforced modified epoxy composites with different Vf of fibers such as 10%, 20%, 30%, 40%, 50% and 60%. The test was conducted in nitrogen atmosphere at the temperature range from 30C to 900C.

The thermogravimetric analysis (TGA) showed that 60% Vf of composites had higher thermal stability and its degradation temperature was shifted from 357C to 390C. Budai et al.66 investigated the thermal behaviourof chopped strand mat E-GF-reinforced unsaturated polyester composite with different number of glass mat layers such as 4, 6 and 11 layers and different GF such as viapal and aropol using TGA and heat distortion temperature (HDT) analysis. The test was conducted between 30C and 700C in purging nitrogen and between 30C and 550C in purging oxygen. Increasing GF content in composite delayed the thermo-oxidative decomposition. Lopez et al.3 investigated the thermo-analysis of E-GF waste polyester composite without filler. The TGA/differential thermogravimetric (DTG) curve showed that the degradation temperature shifted from 209.8C to 448.7C and mass loss shifted from 1.8 wt% to 4.4 wt%.

Tribological behaviours of GFRP matrix compositesEl-Tayeb et al.67 investigated the worn surfaces of chopped GF-reinforced unsaturated polyester composites of parallel/anti-parallel (P/AP) chopped GF orientations with various sliding velocities such as 2.8, 3.52, 3.9 m/s and various load of 30, 60, 90 N at ambient temperature. The experimental result showed that sliding in P-orientation had lower friction coefficient at lower load and higher speed compared to AP-orientation. Sliding in APorientation had lower friction coefficient at higher load, speed and distance compared to Porientation. AP-orientation exhibited less mass loss (16%) compared to the P-orientation. El-Tayeb et al.16 investigated the multipass twobody

JNAO Vol. 13, Issue. 2: 2022

abrasive wear behaviour of CGRP composites with various sliding velocities such as 0.157 and 0.314 m/s and the applied normal loads of ranging from 5 N to 25 N. The test was conducted with sliding against water-proof SiC abrasive paper under dry contact condition. Wear rate decreased with increasing load and decreasing rotational speed. AP-orientation enhanced the abrasive resistance of CGRP composite. They concluded that AP-orientation had lowest wear rate than other orientations and scanning electron microscope (SEM) result indicated AP-orientation had no fiber damage.haviour of GF-reinforced polyester composites with loading range from 60 to 300 N at a constant speed of 10 mm/s under dry conditions. The SEM observations showed that parallel orientation had lower friction than transverse orientation.

Mathew et al.2 investigated the tribological properties of E-GF-reinforced polyester composites with various directly oriented warp knit fibers such as biaxial, biaxial non-woven, triaxial and quad-axial fabric with various thermoset resins like polyester, vinyl ester and epoxy resin. Biaxial non-woven-reinforced vinyl ester composite had better performance than other combinations.

Kishore et al.15 investigated the effects of velocity and load on the sliding wear behaviour of plain weave bi-directional E-glass fabricreinforced epoxy composites with different fillers such as oxide particle and rubber particle under the sliding velocity between 0.5 and 1.5 m/s at three different loads of 42, 140 and 190 N. Block on roller test result showed that the oxide particlefilled composite had better wear resistance compared to rubber particles at low load conditions. But during higher load condition, rubber particles had better wear resistance than oxide particles. Yousif et al.69 investigated the friction and interface temperaturebehaviour of chopped strand mat GFreinforced unsaturated composites polyester with various sliding velocities such as 2.8, 3.52 and 3.9 m/s and various loads 30, 60 and 90 N under dry contact sliding against smooth stainless steel. Parallel and

anti-parallel chopped GF orientations were measured at ambient temperature. The APorientation had more friction coefficients (0.5-0.6) and interface temperature (29to 50C) compared to P-orientation. Chand et al.70 investigated three-body the abrasive wearbehaviour of short E-GF-reinforced polyester composites with and without filler at various sliding speed, abrasive particle size and applied load. Increasing the weight fraction of fiber in composite decreased the volume loss of composite. They have concluded that higher GF content had less wear loss. Suresha et al.21 investigated the role of fillers in wear and friction behaviour of woven mat GF-reinforced epoxy composites with varying load and sliding velocities under dry sliding conditions. Two different inorganic fillers were added such as SiC particles (5 wt%) and graphite (5 wt%). The SEM observation reported that graphite-filled composites have lower coefficient of friction than unfilled SiC-filled composites and SiC- filled composite exhibited the maximum wear resistance. Sampathkumaran et al.71 investigated the wear behaviour of GF-reinforced epoxy composite under dry sliding condition. The varying test parameters were applied load (20-60 N), velocity (2-4 m/s) and sliding distance (0.5-6)km). Pin on disc experimental result showed that increasing the load and velocity increased the weight loss. The debris rate was lower for smaller distance and higher for larger distance. Yousif et al.72 investigated the wear and friction behaviour of chopped strand mat GF polyester composites with various loads (30 N to 100 N) under wet contact condition using two different test techniques such as pin-on-disc and block-on-ring. This was conducted with two different fiber orientations like parallel and anti-parallel. From the experiment, they concluded that presence of water content increased the roughness value in orientations. Moreover. anti-parallel both orientation had more wear and frictional resistance than parallel orientation. Suresha et al.73 investigated the friction and wear behaviour of E-GF (woven mat)-reinforced epoxy composites with and without SiC particles. The result showed that (5 wt%) SiC particles-filled

JNAO Vol. 13, Issue. 2: 2022

composite had higher coefficient of friction and higher resistance to wear at sliding distance ranging from 2000 m to 4000 m compared to without SiC-filled composites.

Pihtili et al.74 investigated the wear behaviour of ECGRP composite with the sliding distances of 235.5 mm, 471 mm, 706.5 mm, 942 mm, 1177.5 mm, 1413 mm, 1648.5 mm and 1884 mm. When the sliding distance exceeds 942 mm weight loss of the plain polyester was increased. The result showed that GF-reinforced polyester matrix composite was more wear resistant than the plain polyester. Mohan et al.23 investigated the sliding wear behaviour of Jatropha oil cake-filled woven fabric E-GF-reinforced epoxy composites with different loads (10 and 20 N). The pin on disc setup result showed that the wear loss increased with increase of sliding distance. Wear loss was observed at 2000 m sliding distance at 10 N applied load. The jatropha oil cake-filled glass epoxy composite had good wear resistance and high coefficient of friction at various sliding distances.

Suresha et al.22 investigated the three-body abrasive wear behaviour of woven E-GFreinforced vinyl ester composites with particulatefilled like SiC and graphite fillers. The test was conducted at different loads such as 22 and 32 N under the sliding distance ranging from 270 to 1080 m. The experimental resultshowed that the graphite and silicon-filled composites had more abrasion resistance and lower specific wear rate (1.95 1011m3 /(Nm)) than unfilled composites. Patnaik et al.33 investigated the wear behaviourof randomly E-GF-reinforced oriented epoxy composites with particulate-filled like Al2O3, SiC and pine bark dust. The different compositions of specimens prepared using were GF (50)wt%)/Epoxy (50 wt%), GF (50 wt%)/Epoxy (40 wt%)/Alumina (10 wt%), GF (50 wt%)/Epoxy (40 wt%)/Pine bark dust (10 wt%), GF (50 wt%)/Epoxy (40 wt%)/SiC (10 wt%).

The experimental tests were conducted at different loads like 50 and 75 N and the sliding distance ranging from 200 m to 600 m. They have concluded that GF (50 wt%)/Epoxy (40)wt%)/Pine bark dust (10 wt%) composite had better wear resistance (0.000881- 0.001365 mm3 /(N-m)) for all sliding distance. Chauhan et al.75 investigated the friction and wear behaviour of bidirectional woven fabric S-GFreinforced vinyl ester composites with 65 wt% of fiber and the resin mixed with different co-monomer such as methyl acrylate and butyl acrylate. Three different compositions of specimens were prepared such as GF + (vinyl ester + styrene), GF + (vinyl ester +methyl crylate) and GF + (vinyl ester + butyl acrylate). The test were conducted at various sliding velocities like 1, 2, 3 and 4 m/s and various loads like 10, 20, 30 and 40 N under dry sliding condition. GF + (vinyl ester + butyl acrylate) composite had higher specific wear rate and lower co-efficient of friction at lower sliding speed.

Application

. Electronics: GRP has been widely used for circuit board manufacture (PCB's), TVs, radios, computers, cell phones, electrical motor covers etc. . Home and furniture: Roof sheets, bathtub furniture, windows, sun shade, show racks, book racks, tea tables, spa tubs etc. . Aviation and aerospace: GRP has been extensively used in aviation and aerospace though it is not widely used for primary airframe construction, as there are alternative materials which better suit the applications. Typical GRP applications are engine cowlings, luggage racks, instrument enclosures, bulkheads, ducting, storage bins and antenna enclosures. It is also widely used in groundhandling equipment. .

Boats and marine: Its properties are ideally suited to boat construction. Although there were problems with water absorption, the modern resins are more resilient and they are used to make the simple type of boats. In fact, GRP is lower weight materials compared to other materials like wood and metals. Medical: Because of its low porosity, non-staining and hard wearing finish, GRP is widely suited to medical applications. From instrument enclosures to X-ray beds (where X-ray transparency is important) are made up of GRP.

JNAO Vol. 13, Issue. 2: 2022

Automobiles: GRP has been extensively used for automobile parts like body panels, seat cover plates, door panels, bumpers and engine cover. However, GRP has been widely used for replacing the present metal and non-metal parts in the various applications and tooling costs are relatively low as compared with metal assemblies.

CONCLUSION

The mechanical, dynamics, tribological, thermal and water absorption properties of GFRP composites have been discussed. The important application of these composites has highlighted. . The various preparation technologies were used for preparing the GRP composites with various environmental conditions. . Ultimate tensile strength and flexural strength of the fiber glass polyester composite increased with increase in the fiber glass Vf of fiber weight fractions. . The elastic strain of the composite increased with the fiber glass Vf up to 0.25, and then subsequently decreased with further increase in fiber glass Vf. . The Young's modulus of elasticity of the composite increased with the fiber glass Vf. . The damping properties of GRP were improved by increasing the GF content in composite and the natural frequency was measured for all conditions. . The water absorption was analyzed for various environmental conditions with different time period. The water absorption decreased the mechanical properties of the composites. .The coefficient of friction at various sliding distances and loading condition were analyzed with various fiber orientations like random, woven mat, longitudinal, P/AP chopped GF. The lower wear was found for more fiber incorporated in the polymers. improving the composites For properties, the fibers were treated with various chemicals and matrix blend with suitable chemical for making the GRP composites. This may improve the mechanical, thermal, tribological properties of the GRP composites.Funding This research received no specific grant from any funding agency in the public, commercial, or notfor-profit sectors. Conflict of interest None declared.

612

REFERENCES

1. Aramide FO, Atanda PO and Olorunniwo OO. Mechanical properties of a polyester fiber glass composite. Int J Compos Mater 2012; 2: 147–151. 2. Mathew MT, Naveen Padaki V, Rocha LA, et al. Tribological properties of the directionally oriented warp knit GFRP composites. Wear 2007;

263: 930–938.3. Lopez FA, Martin MA, Alguacil FJ, et al.

Thermolysis of fibreglass polyester composite and reutilisation of the glass fibre residue to obtain a glass ceramic material. J Anal Appl Pyrolysis 2012; 93: 104–112.

4. Erden S, Sever K, Seki Y, et al. Enhancement of the mechanical properties of glass/polyester composites via matrix modification glass/polyester composite siloxane matrix modification. Fibers Polym2010; 11: 732–737.

5. Awan GH, Ali L, Ghauri KM, et al. Effect of various forms of glass fiber reinforcements on tensile properties of polyester matrix composite. J Faculty Eng techno 2009; 16: 33–39.

6. Alam S, Habib F, Irfan M, et al. Effect of orientation of glass fiber on mechanical properties of GRP composites. J Chem Soc Pak 2010; 32: 265–269.

7. Gupta N, Balrajsinghbrar and Eyassuwoldesenbet. Effect of filler addition on the compressive and impact properties of glass fibre reinforced epoxy. Bull Mater Sci 2001; 24: 219–223.

8. Faizal MA, Beng YK and Dalimin MN. Tensile property of hand lay-up plain-weave woven e glass/polyester composite: curing pressure and ply arrangement effect. Borneo Sci 2006; 19: 27–34.

9. Leonard LWH, Wong KJ, Low KO, et al. Fracture behavior of glass fiber reinforced polyester composite. J Mater Design App Part L 2009; 223: 83–89.

10. Visco AM, Calabrese L and Cianciafara P. Modification of polyester resin based composites induced by seawater absorption. Compos Part A 2008; 39: 805–814.

11. Hameed N, Sreekumar PA, Francis B, et al. Morphology, dynamic mechanical and thermal studies on poly (styrene-co-acrylonitrile) modified epoxyresin/glass fibrecomposites. Compos Part A 2007; 38: 2422–2432.

JNAO Vol. 13, Issue. 2: 2022

12. Sridhar I and Venkatesha CS. Variation of damping property of polymer composite under saline water treatment. IJIET 2013; 2: 420–423.

13. Colakoglu M. Damping and vibration analysis of polyethylene fiber composite under varied temperature. Turkish J Eng Env Sci 2006; 30: 351–357.

14. Kumar, A. K., Laxmaiah, G., & Babu, P. R. Process Parameters Optimization And Characterization Of RTM Manufacturing Process For High Performance Composites..

15. Kishore, Sampathkumaran P, Seetharamu S, et al. SEM observations of the effects of velocity and load on the sliding wear characteristics of glass fabric–epoxy composites with different fillers. Wear 2000; 237: 20–27.