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Mechanical Properties of Fiber Reinforced Composites: A Review

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Abstract: As a result of their superior eco-friendliness over synthetic-fiber based polymer composites, products made from natural fiber reinforcement have become more popular in a wide range of applications. This paper describes the review of Mechanical Properties of Fiber Reinforced Composites. Renewable resources such as natural fibers have been continually replenished for thousands of years thanks to both nature and human innovation. As a bonus, they don't have any negative impact on the environment due to their carbon footprint. All of these fibers are biodegradable, inexpensive, low-impact, have high specific strength, are not abrasive, and can be replenished quickly. For these reasons, natural fibers have recently gained favor among scientists and researchers as a potential replacement for synthetic fibers in fiber-reinforced composites. This article acted as a survey of fibers and their uses throughout history.

Index Terms **- Fibers, Polymer composite, Mechanical properties.**

I. INTRODUCTION

Two or more physically distinct phases that together yield aggregate properties that differ from those of their constituents make up a composite material system. Because composites are strong, rigid, and light in weight, their strength-to-weight and stiffness-to-weight ratios are significantly higher than those of steel or aluminium. Composites also make it feasible to combine qualities that are not conceivable with metals, ceramics, or polymers alone. Natural fibre reinforced composites have gained popularity in recent years. Due to their better mechanical qualities, natural fibres increasingly predominate in the automotive, construction, and athletic industries. These natural fibres come in a variety of forms, including flax, hemp, jute, sisal, kenaf, and coir. Low density, low cost, low energy inputs, comparable mechanical properties, and better elasticity of polymer composites reinforced with natural fibres are just a few of the benefits of using natural fibres. This is especially true when those fibres are modified with crushed fibres, embroidered fibres, and 3-D weaved fibres. A fibre reinforced polymer called glass fibre reinforced polymer (GFRP) is constructed of a plastic matrix and tiny glass fibres for reinforcement. Due to its exceptional qualities, fibre glass is a lightweight, strong, and sturdy material used in many sectors. Although it is less stiff and has slightly lower strength than carbon fibre, the material is often much less brittle, and the cost of the raw materials is significantly lower. When compared to metals, its bulk strength and weight characteristics are quite favourable, and it can be easily manufactured utilising moulding procedures. Due to their low cost and ease of availability, natural fibres like sisal and jute are now replacing glass and carbon fibres in composite materials. The scope of application for natural fibres is expanding daily, especially in the automobile industry, which has significantly increased their use. Due to its eco-friendly qualities, natural fibre composites are currently gaining more and more attention. Researchers have based a lot of their work on these natural fibres. Natural fibres like jute, sisal, silk, and coir are affordable, plentiful, renewable, lightweight, have a low density, have a high level of tensile strength, and are biodegradable. For applications requiring a high strength-to-weight ratio and additional weight reduction, natural fibres like jute have the potential to be employed in place of conventional reinforcement materials in composites.

II. Areca Nut

Dr.G. Ramachandra Reddy.et.al,[1] determined the mechanical performance of Epoxy composites filled with betel nut(Areca catechu) short fiber(Bn) at different compositions (3,5,10,20 and 30wt%), using the extrusion and hot press moulding technique. Results showed that Bn10:EP90 mixture (Bn EP) was found better performance among the composites prepared. Besides Sansevieria cylindrical (Sc) was hybridized with betel nut short fiber in EP system to achieve superior mechanical performance. Dielectric strength, water sorption capacity, degradation behaviour such as simulating weathering and soil buried test of different composites were also performed.

III. $CaCo_3$

Wasim Akram.et.al,[2] comparative study of the mechanical properties of E glass/Epoxy composite materials with fillers (Al2O3, CaCo3, SiO2 and PbO) to the matrix help improving the mechanically operating properties of a composite. The mechanical characteristics of these composite materials, is examined by Tensile Strength Test by UTM, Torsion Strength Test by Torsion Testing Machine, Hardness Test by Vickers Hardness Testing Machine and Charpy Test by Impact Testing Machine. Results of the various mechanical tests is Lead Oxide as a filler material added in resign and Fibre composites (52% Resin + 13% PbO + 35% Fibre) has a better mechanical tensile properties as compared to others, Silica Oxide (SiO2) as a filler material added in resign and fibre composites (52% Resin + 13% SiO2 + 35% Fibre) has a better mechanical torsion properties and hardness properties as compared to others, resin and fibre composite without filler (65% + 35% Fibre) has a better mechanical energy absorbed properties as compared to others.

Vinay Kumar Patel.et.al,[3] describes the fabrication and physical, mechanical, three-body abrasive wear and water absorption behaviour of Luffa fibre reinforced polyester composites with and without addition of micro fillers of Al2O3, CaCO3 and TiO2. The addition of micro fillers has influenced the physico-mechanical properties of Luffa-fibre based polyester composites in descending order of CaCO3, Al 2O3, and TiO2.

IV. Cao

TimoJ.Lehtonenn.et.al,[4] describes the dissolution behaviour of three silica based resorb able glasses manufactured by an industrial type continuous fibre drawing process yielding fibres with tensile strength of 1800–2300MPa.The results of a long-term in vitro degradation testing of the manufactured high strength bio resorb able glass fibres are presented. The degradation was performed by exposing the glass fibres to SBF and TRIS for 26 weeks at physiological conditions at 37 1C. All fibres showed continuous resorption throughout the study and two of the fibres revealed bioactivity by forming a calcium phosphate (CaP) layer in SBF.

YuyaAsakawaa.et.al,[5] Studied The bond strength between the FRC posts and core build-up resin were measured using the pull-out and micro tensile tests before and after thermal cycling. Four types of experimental FRC posts, combinations of two types of matrix resins (polymethyl methacrylate and urethane dimethacrylate) and two types of fiber glass (E-glass and zirconia-containing glass)were examined. The bond strength is obtained by the test before and after thermal cycling three-way ANOVA and Tukey's multiple comparisons test (po0.05).

Nikoloz M.et.al,[6] The results of an investigation into the production of wind turbine blades manufactured using polymer composites reinforced by hybrid (carbon, basalt, glass) fibers and strengthened by various Nano powders (oxides, carbides, borides) are presented. The hybrid fiber-reinforced composites (HFRC) were manufactured with prepare technology by moulding pre-saturated epoxy-strengthened matrix-reinforced fabric. Performance of the manufactured composites was estimated with values of the coefficient of operating condition (COC) at a moderate and elevated temperature.

V. Coconut shell powder

Sudeep Deshpande.et,al,[7] Investigated on E-glass fiber/jute fiber reinforced epoxy composites filled with varying concentrations of bone and coconut shell powder and fabricated by hand lay-up technique and the mechanical properties such as ultimate tensile strength, flexural strength, inter laminar shear strength ,tensile modulus, impact strength and hardness of the fabricated composites were tested. The test results of these were compared with unfilled HFRP composites. From the results it was found that the mechanical properties of the composites increased with the increase in filler of 15% volume coconut shell powder exhibited maximum flexural strength, inter laminar shear strength, tensile modulus and hardness and Maximum impact strength was achieved by addition of filler (15% Vol.) of bone powder.

B.Venkatesh.et.al,[8] studied the mechanical behaviour and develop a polymer matrix composite (epoxy resin) using coconut shell powder. Studied In polymer industry carbon black is most widely used as reinforcing filler to achieve desirable and strengthen the product service qualities and carbon black is expensive due to its dependence on supply of crude oil. So they have investigated on the alternate source of fillers from renewable source such as bamboo stem, oil palm empty fruit bunches, agricultural waste and coconut shells which are carbonaceous in nature and rich in organic materials. Effective application of coconut shell, from which shell is particularly valuable due to its high contains 70% carbon, 1% ash, 30.1% lignin, 19.8% cellulose and 68.7% hemicellulose.

VI. Al_2O_3

Bernd Wetzela.et.al,[9] Investigated the various amounts of micro- and Nano-scale particles (calcium silicate CaSiO3, 4–15 mm, alumina Al2O3, 13 nm) were systematically introduced for reinforcement purposes. The influence of these particles on the impact energy, flexural strength, dynamic mechanical thermal properties and wear behaviour was investigated. If the nanoparticles were incorporated only, they yield an effective improvement of the epoxy resin at a nanoparticle content of already 1–2 vol. % Al2O3. Choosing the Nano composite with the highest performance as a matrix, conventional CaSiO3 micro particles were further added in order to achieve additional enhancements in the mechanical properties. In fact, synergistic effects were found in the form of a further increase in wear resistance and stiffness. Several reasons to explain these effects in terms of reinforcing mechanisms were discussed..

RafahA.Nasif.et.al,[10] Investigated the effect of ceramic fillers (aluminium oxide Al2O3 and titanium TiO2) and industrial wastes (red mud and copper slag) with weight fraction (10% wt)on the mechanical properties of composite material consist of epoxy reinforced with glass fiber with weight fraction (40/50)%wt .Impact strength, tensile strength and hardness and results have been compared with composite material reinforced only with glass fiber (50/50)%wt . The results show that the composite reinforced with TiO2 had higher value of impact strength and lowest value of tensile strength compared with other composites.The composite material reinforced only with glass fiber had higher value of tensile strength And also all the hybrid composites have hardness values higher than that of composites material reinforced with Al_2O_3.

Bhadrabasol Revappa Raju1.et.al,[11] Studied the mechanical and two-body abrasive wear behaviour of alumina (Al2O3) filled glass fabric reinforced epoxy composites containing 0, 5, 7.5 and 10 wt% were prepared using the hand lay-up technique followed by compression molding. The mechanical properties such as tensile strength, hardness and tensile modulus were investigated in accordance with ASTM standards. Two-body abrasive wear studies were carried out using a pin-on-disc wear tester under multi-pass condition against the water proof silicon carbide abrasive paper. From the experimental investigation, it was found that the presence of Al2O3 filler improved the tensile strength and tensile modulus of the G-E composite. Inclusion of Al2O3 filler reduced the specific wear rate of G-E composite and in abrasion mode, as the filler loading increases the wear volume decreases and increased with increasing abrading distance. The excellent wear resistance was obtained for Al2O3 filled G-E composites. Furthermore, 10 wt% filler loading gave a very less wear loss. Finally, the scanning electron microscopic observations on the wear mechanisms Al2O3 filled G-E composites was discussed.

Ramesh K. Nayak.et.al,[12] developed epoxy matrix by Al2O3, SiO2 and TiO2 micro particles in glass fiber/epoxy composite to improve the mechanical properties. The composites are fabricated by hand lay-up method and It is observed that mechanical properties like flexural strength, flexural modulus and ILSS are more in case of SiO2 modified epoxy composite compare to other micro modifiers. This may be because of smaller particle size of silica compare to others. Alumina modified epoxy composite increases the hardness and impact energy compare to other modifiers. Agglomeration of Al2O3 micro particles in the matrix is observed in SEM. This may be because of bigger particle size of Alumina. SEM analysis clearly indicates the mode of failure is the combination of crack in matrix, matrix/fiber de-bonding and fiber pull out for all types of composites.

Md Nadeem M.et.al,[13] Studied, composite materials required for elevated temperature applications were fabricated using vacuum bagging technique. Epoxy Resin (ER-VP401) was used as the matrix and Glass fibre was used as reinforcement. SiC, Al2O3 and others were used as fillers to bring in elevated temperature resistance. These composites were subjected to mechanical tests like Tensile, Hardness and Impact test. Tribological tests like two body abrasion and Pin on disc (POD) were carried out. Tensile strength, hardness and impact energy were improved with increase in fillers content. Wear resistance also improved with increase in percentage of fillers substantially. SEM micrographs are used to explain the mechanism of the material strengthening at elevated temperatures.

S. Rajesh.et.al,[14] fabricated epoxy and polyester resin composites using aluminium oxide, silicon carbide with different proportion of Al2O3 and SiC along with GFRP. A mixing unit has been fabricated for making reinforcement mixtures. Mechanical testing like tensile, impact hardness shear bi axial are conducted in order to know the properties of fabricated composites. The result shows that composites with epoxy resin shows higher strength as compared to composites with polyester resin.

Iskender Ozsoy.et.al,[15] Investigated the influence of micro- and Nano-filler content on the mechanical properties of epoxy composites was studied. The matrix material is epoxy; the micro-fillers are Al2O3, TiO2 and fly ash added in 10 wt% to 30 wt% by weight ratio; the Nano-fillers are Al2O3, TiO2 and clay added in 2.5 wt% to 10 wt% by weight ratio. Test samples were prepared using an open mould type die. The tensile strength, elastic modulus, elongation at break, flexural strength, flexural modulus, and the hardness of the composite materials were obtained and evaluated and The results show that the tensile strength, flexural strength and elongation at the break values of composites decreased while the tensile modulus and flexural modulus increased with the increasing micro and Nano-filler content ratio.

VII.Fly Ash

Arun kumar Parida.et.al,[16] A attempt has been made to assess the influencing parameters on the machining of GFRP composites. Using Taguchi method, an L9 orthogonal array has been used for experimentation and the experiments were conducted on all geared lathe using carbide tool with three levels of input parameters such as cutting speed, depth of cut and feed rate. A procedure has been developed to assess and optimize the chosen factors to attain minimum surface roughness by incorporating: (i) response table and response graph; (ii) normal probability plot; (iii) analysis of variance (ANOVA) technique. It is found that the feed rate is the most significant parameter followed by the depth of cut for surface roughness.

Vijay Baheti.et.al,[7 The mechanical activation of fly ash was carried out using ball milling to promote adhesion with epoxy. The 5 h of wet pulverized particles of size less than 500 nm. The obtained nanoparticles were incorporated into epoxy to prepare three layered laminated composite of glass fabrics. The results revealed substantial improvement in mechanical properties of Nano composites as compared to neat and unmilled fly ash composites. Moreover, the storage modulus exhibited 85.71, 38.09, 104.76 and 80.95% increment over neat composites for 1, 3, 5 and 10 wt% of activated fly ash at 200 C.

VIII. SIC

C.M. Manjunatha.et.al,[18] Studied thermosetting epoxy polymer was modified by incorporating 10 wt.% of well dispersed silica nanoparticles. The addition of the silica nanoparticles increased the fatigue life by about three to four times and the nanoparticle modified epoxy resins were used to fabricate glass fibre reinforced plastic (GFRP) composite laminates by resin infusion under flexible tooling (RIFT) technique. Tensile fatigue tests were performed on these composites, during which the matrix cracking and stiffness degradation was monitored. The fatigue life of the GFRP composite was increased by about three to four times due to the silica nanoparticles. Suppressed matrix cracking and reduced crack propagation rate in the nanoparticle modified matrix were observed to contribute towards the enhanced fatigue life of the GFRP composite employing silica nanoparticle modified epoxy matrix.

Sandeep Kumar.et.al,[19] This paper focuses on the erosion of fibre reinforced hybrid composites consisting of vinyl ester resin and short E-glass/carbon fiber (1:1) at different fiber weight fractions (from 20 wt.% to 50 wt.%). A investigation of the optimal level of control factors using Taguchi orthogonal arrays design that lead to minimization of erosion rate. The steady state erosion responses of these composites are investigated with respect to impingement angle, impact velocity and erodent size by keeping other factors constant. The dynamic mechanical properties were evaluated to determine possible correlation with erosion rate of these composites. The storage modulus (E0) steadily increases up to 3927 MPa for 40 wt.% fiber, but on further increase in the fiber content, the E0 value decrease to 3321 MPa at 0 C. The maximum storage modulus was obtained at 40 wt.% of fiber contents which may be due to the maximum stress-transfer between the fibers and matrix.

Arpitha G R.et.al,[20] Investigated on Polymer Composites with natural fibers and fillers as a alternative material for some engineering applications, particularly in aerospace applications and automobile applications. Natural fiber composites such as sisal, jute, hemp and coir polymer composites appear more attractive due to their higher specific strength, lightweight and biodegradability and low cost. In this study, sisal/glass/Sic fiber reinforced epoxy composites are prepared and their mechanical properties such as tensile strength, flexural strength and impact strength are evaluated. Composites of silicon carbide filler (without filler, 3, 6 & 9Wt %) sisal fiber and glass fiber are investigated and results show that the composites without filler better results compared to the composites with silicon carbide filler.

Feng-Hua Su.et.al,[21] Nomex fabric composites filled with the particulates of polyfluo150 wax (PFW) and Nano particles of SiO2, respectively, were prepared by dip-coating of Nomex fabric in a phenolic resin containing particulates to be incorporated and the successive curing. The friction and Wear behaviours of the pure and filled Nomex fabric composites sliding against AISI-1045 steel in a pin-on-disk configuration were evaluated on a Xuanwu-III high temperature friction and wear tester. The structure of the composites, and the morphologies of the worn surfaces and of the counterpart steel pins were analyzed by means of scanning

electron microscopy. The adhesion and tensile strength of the unfilled, PFW or nano-SiO2 filled Nomex fabric composites were evaluated with a DY35 universal material tester. The results showed that the addition of PFW and Nano SiO2 significantly improved the wear resistance and decreased the friction coefficient, moreover the PFW as a filler is better than nano-SiO2.
X.F. Yao.et.al,[22] Macro/microscopic fracture characterizations of the SiO2/epoxy Nano composite are studied experimentally. Both the load displacement curve and the static fracture toughness are obtained using a three-point-bending test. Microscopic characterizations of fracture surface in Nano composites are analyzed using the scanning electron microscope (SEM). Distribution of displacement field at the initial edge crack tip in Nano composites is obtained by digital speckle correlation method. Crack propagation characterizations of Nano composites are described using field emission scanning electron microscope (FE-SEM). The influence of nanoparticle contents on fracture behaviour of Nano meter composites is analyzed. The research results will be useful for structure design and fracture properties evaluation of Nano composites.
M. Lai.et.al,[23] Studied the influence of SiO2 nanoparticles and rubber micro-fillers on the mechanical and thermal responses of an epoxy based composite using classical quantitative thermo-mechanical testing (tensile tests, DMTA, TMA), microstructural analysis (Micro-CT, TEM, SEM microscopy) as well as distributed optical sensing in order to determine different residual strain fields generated during processing. The results show that the tensile modulus of the compounds increases with the addition of SiO2 and decreases with the rubber content. The coefficient of thermal expansion appears to be insensitive to the particles content in the temperature range investigated. The residual strains generated during processing are influenced by the rubber content that introduces a strong relief, whereas the silica content tends to increase their level.

IX. SLAG

Goulart.et.al.[24] Natural fibers, compared to glass fibers, exhibit better mechanical properties, such as stiffness, impact strength, flexibility and modulus. However certain drawbacks, such as the incompatibility between fibers and polymer matrices, the tendency to form aggregates during processing and the poor resistance to moisture, reduce the use of these natural fibers as reinforcements in polymers. Several treatments and modifications are being used to improve fibers/matrix compatibility, such as bleaching, acetylation and use coupling agent. In this work, the effect of coupling agent in the palm fibers/ PP composites was evaluated on mechanical behaviour.
N. Vijaya Kumar.et.al,[25] Lot of waste by industries and they are piled up on land which creates land and environmental problem. Therefore industrial waste slag as the reinforcement material in polypropylene composites. Wear resistance of material is an important requirement for many of the industries like automotive, aircraft and aerospace. The effects of variation in sliding velocity and applied load on the wear behavior of polymer composites are studied in the present work. Composite specimens are prepared by injection molding machine with varying particulate weight percentage of 0%, 10%, 20% , 30% & 45%. The pin-on disc wear testing machine has been used to study the friction and wear behavior of the polymer composites. The wear loss and coefficient of friction are plotted against the normal loads and sliding velocities.
Volkan Arikan.et.al.[26] Studied , E-glass fiber reinforced composites have been manufactured with two types of resin, polypropylene and epoxy (Thermoplastic and Thermoset) and they have been subjected to the low velocity single and repeated impacts and effect of resin type on the impact response of composites are investigated. Impact energies were chosen as 20 J, 50 J, 80 J and 110 J for single impact tests while 50 J was chosen for repeated impact tests. Comparisons between the results of 110 J single and 50 J repeated impacted specimens were performed. As a result of the study it is concluded that the resin type is a crucial parameter for the repeated impact response of the composites.

Conclusion

1. Fiber-reinforced composites can be made from a wide variety of materials, including both natural and synthetic fibers. Yet, natural fibers have the advantage of being inexpensive and biodegradable, while synthetic fiber provides higher rigidity. kinder to the planet's ecosystems. Research has shown that hybrid fiber reinforced composite materials work exceptionally well, despite the fact that both types of fibers are effective in important applications.
2. There are a wide variety of methods for creating composites, each of which is best suited to a specific type of composite. Because different materials have varied physical qualities like melting point, stiffness, tensile strength, etc., the efficiency of a manufacturing procedure is reliant on the combination of type and amount of matrix or fiber material utilized. Consequently, production methods are determined by the materials being used.
3.Composites have been used to make stronger and more rigid constructions while drastically cutting down on weight. The composition of the material, the kind of fiber, and the manufacturing technique employed to

produce composites all influence their qualities, including their resistance to impact, wear, corrosion, and chemicals. Composites are used in a wide variety of contexts because their desirable qualities may be tailored to meet a wide range of needs.

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