An Ample survey on Characterization and Analysis on Nano-Hybrid Composite Structures

[1] T. Malyadri , [2] Dr. J. Suresh Kumar

[1] Research Scholar,Department Mechanical Engineering, Jawaharlal Nehru Technological University (JNTU), Hyderabad-500085, Telangana. India
[2] Professor,Department Mechanical Engineering, Jawaharlal Nehru Technological University (JNTU), Hyderabad - 500085, Telangana. India

Abstract : Material requirements are highly personalized due to customized products. Resale values almost scrap rate due to lack of standard products. Even a cell phone cover does not available in the market after a period. Use and throw kind products are widely accepted recently by society, and they are produced large in quantity and push into the market. Such use and throw products are live in the market with many competitors. In this situation, reliability and durability are essential factors for the customer's choice in buying the products. The cost-effective, durable material can be developed by utilizing waste materials, natural fibers, etc., to meet such requirements and satisfy the customers' needs is the core concept of this investigation. The contribution of nanotechnology in improving the conventional composite and produce the new material or alter the properties as per our requirement the nanocomposites are highly supportive. This paper focuses on such feasibility studies to meet the material needs today. This comprehensive survey analyzed the feasibilities in various aspects like characterization, structures, mechanisms, materials compatibility etc. this investigation focuses on how material properties are augmented by utilizing nanotechnology.

Keywords: **Nanocomposite, Natural fibers, Characterization, Mechanical Properties, Microstructural Characterization.**

1. INTRODUCTION

The Polymer Composite applications are broad, and their scope and role are very vast. The performance and characters are decided by the inherent specialties of fiber, filer, matrix, hybrid fiber and method of synthesizing etc., and interfacial reaction or bonding among the materials. Hence it is clear that the performance of a polymer composite depends not only on the selection of its components but also on the interface between them. Nowadays, materials are designed to meet specific requirements, so the matrix to be often modified with appropriate filler and reinforcement. The use of natural fibers is utilizing the waste and unused natural resources. Nowadays, engineering proves that all five natural elements can be utilized to fabricate new materials. The philosophy is that what we see around us in nature is made up of various combinations of five elements in various proportions. So the natural fibers and natural materials can be utilized to create new materials for meeting the specific requirements. The available synthetic fibers are also employed in the creation of new materials. Figure 1 explores the fibers which are majorly contributing to the polymer composite. The natural fibers are classified as bio fiber (animal fiber), Lignocelluloses/celluloses, and mineral fibers. Synthetic fibers are classified as organic and inorganic types.

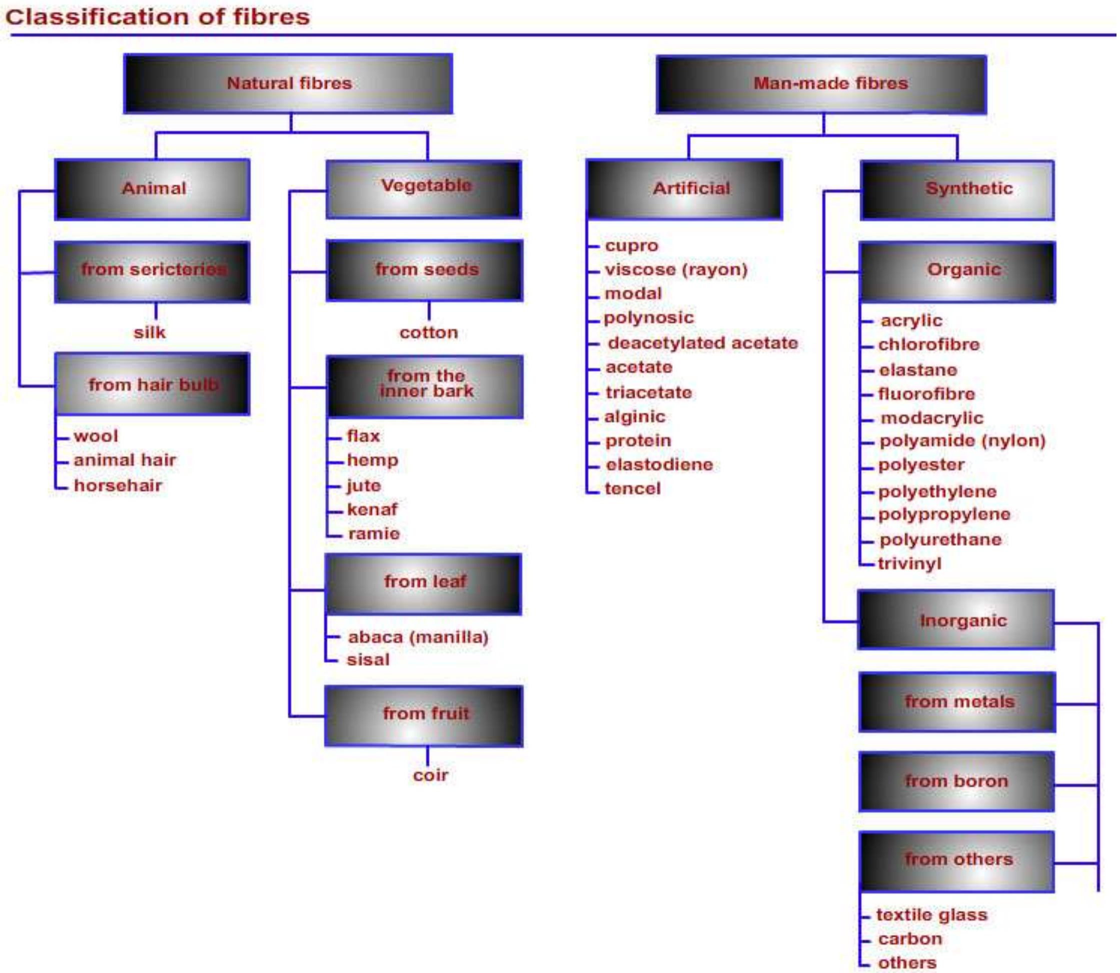

Figure 1 Fibers utilize in the polymer Composite

II. Why Natural Fibers is preferred in this research?

- Sustainable option of material supply can be ensured by utilizing the waste to some useful forms.
- Natural fiber properties can be augmented or altered by selecting the appropriate method, matrix material, filler material, and hybrid fiber.
- The pre-treated natural fibers are compatible for obtaining materials with desirable properties.
- The uses of natural fibers are cost-effective.
- Natural fiber-based Nanocomposites applications are vast, especially automobile, construction, electronics, aerospace, and biotechnology industries.
- Natural fiber-based composites are eco-friendly.
- Hybrid composite with natural composites with suitable reinforcement pair plays a vital role in meeting the material requirements and meeting the properties of environmental care.
- The strength and other properties of the natural fiber-based nanocomposites shall be altered suitably by altering the Nanofillers, fiber type, fiber length, fiber orientation, matrix material, pre-treatment of natural fibers, and interfacial bonding mechanism and method of manufacturing.

Issues and solutions in the use of Natural fiber

The interfacial bonding and its strength is a challenging issue in the use of natural fibers, particularly applications that demand high performance. That can be overcome by including suitable pre-treatment and appropriate nanofillers (which improves the interfacial bonding significantly). Some cases are: Different % of NaOH treatments have been applied to sisal fibers in order to enhance their adhesion in composites materials [1-11] preferred maleated polyethylene, and maleated polypropylene used for treating the sisal fibers.

III. Need for this survey

A sample of hybrid nanocomposite structures is depicted in figure 2. A significant importance use of nanotechnology in material development. The followings are silent features.

- Nanotechnology supports improving the conventional composite materials, and this study helps to concentrate on improving the conventional composite to close the existing complaints on them.
- Natural fibers are good alternatives with nanofiller association to meet the material requirements of various applications, notably railway coaches, wind turbine blades, smart memory, aerospace, prosthetics, consumer products, bridge construction, partition boards, military, ship structures, ceiling paneling, automobiles, building, packaging, etc.
- Many are reported that the natural fiber nano reinforced composite is widely increased in both industrial and domestic applications and also fundamental research. They are renewable, cheap, completely or partially recyclable, biodegradable, and nonhazardous material [12].
- Industrial waste like aluminum oxide and silicon oxide are potentially harmful, and they can be used as nonofillers in the composites and preserve the environment.
- Eco-friendly materials-related research is a worldwide recognizing and hot area that is fast to act and indispensable research. So this study adds some valuable information to enhancing or inventing new materials.
- It was also a common and proven fact that nanofiller-used composites alter the mechanical properties, thermal properties, and chemical stability. So nanofiller-based composite synthesizing attracts the researchers as a magnet.

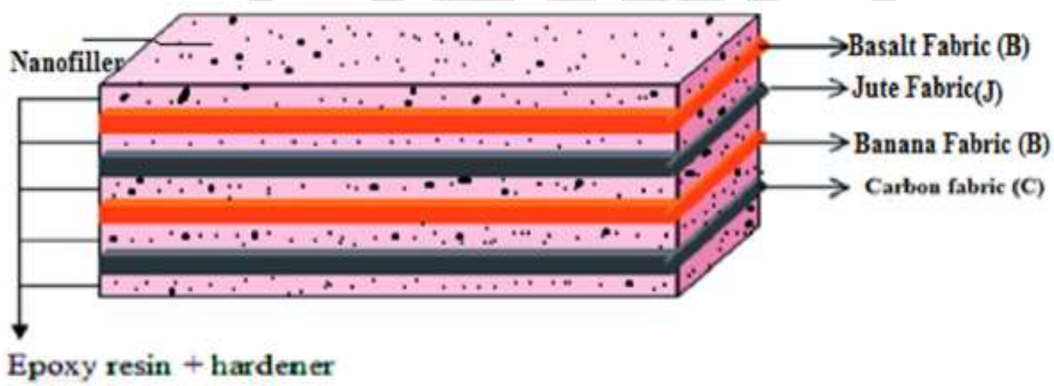

Figure 2 Structure of nanocomposite [12]

IV. Nano-fillers

The properties of polymer composite materials like Epoxy, vinyl ester, polyesters can be enhanced by reinforcing them with nanofillers. It was experimentally proved that polymer with filler is stronger than its pure form. That is, the filler materials and their sizes (Macro to Nano) are influencing in improving the recital of the polymer composites. Based on the size of a particle of filler material, the composite is termed a nanocomposite. The specific classification implied that its significance than other sized filler particles. The decrease of the size of particles to nanoscale increases the vast extent of contact with polymers cause by the nanosize effect. The mechanism of nanofiller improving a property is depicted in Figure 3.

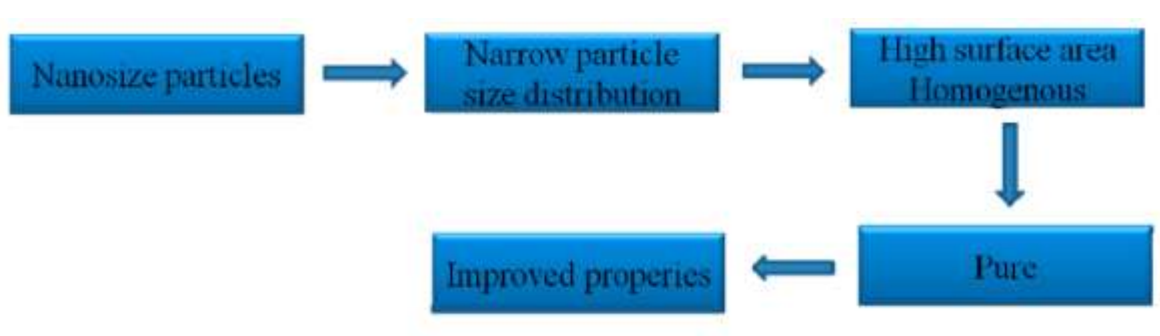

Figure 3. Mechanism of nano-filler augmenting properties [13]

Contribution of Nanoclay Fillers

Nano clay contribution recently popular in the hybrid composites [14] utilized the nano clay fillers by mixing (vol% is 45) with polyester resin and prepared the vakka fiber polyester composite and reported that bending strength and tensile strength improved by the nanoclay contribution in the matrix are 55 percent and 21.2 percent, respectively. Ansal et al. suggested the E-glass/epoxy with filler of nano clay composite for wind turbine blades [15]. The fabricated blade sample was tested experimentally for mechanical characterization and validated numerical investigations. The prepared sample exhibited the required properties for the wind turbine blades. Canan et al. utilized the nanoclay filler in the basalt fiber/cement composites and enhanced the durability [16]. Feng et al. utilized nanoclay with molybdic acid in the polyester composited to composite the fibers from the banana fruit bunch was used [17]. The empty fruit bunch is waste material and utilized 38% mass fraction to manufacture a new material. Deepak et al. used the nanoclay fillers in the coir fiber polyester composite and compared with the coir/glass polyester composite and found that the nano clay composite with coir polyester gives equivalent strength to the hybrid composite of coir/glass/ polyester composite [18]. The authors remarked as the nanoclay is a low-cost substitute. And the mechanical properties are found augmented significantly due to the inculcation of nanoclay on the matrix phase. The mechanical properties are enhanced outstandingly by including the 4 percent nanoclay with polyester to prepare Wild Cane Grass/ polyester/nanoclay composite. The thermal conductivity and thermal diffusivity are disturbed by adding more fiber in the composite matrix (that is, decreasing the thermal conductivity and the thermal diffusivity with an increase in the quantity of fiber). The same issues by increasing the nanoclay content in the matrix of the composite [19]. The nanoclay inclusion, along with the hollow glass microspheres, included the glass /epoxy polymer composite and reported that the nanoclay fillers and hollow glass microspheres augmented impact strength. The material weight is less compared to the strength, so the materials are suggested for the low weight construction. Koricho et al. included the nanoclay in the epoxy resin matrix with glass fiber with the mass fraction of 1% to 5% and found that increase the quantity of nanoclay improves the impact strength significantly [20]. Also designed a bio-composite for wound healing purposes with Iranian Gum Tragacanth (bio fiber), polyvinyl alcohol, along with a little percentage of nanoclay powder. the research finding was an increase of nanoclay content increases the mechanical as well as chemical stability. The higher percentage of 3% nanoclay (which is considered as maximum in their composite matrix) contained composites (Various proportions of Iranian Gum Tragacanth (bio fiber), polyvinyl alcohol) outperformed when compared to without nanoclay composites. Sivasaravanan et al. reported that the nanoclay in association with multiwall carbon nanotube improves the inter-laminar fracture toughness significantly in the glass/epoxy composite laminates, and the same was ensured by the mode I and II and mixed-mode tests [21]. Amiri et al. reported that the clay content in the composite materials has the property of increasing the inter-laminar fracture toughness. The same was proved by including the organoclay in the carbon fiber/ maleic anhydride-modified polypropylene oligomer composite. The findings reported that the 3% inclusion of organoclay improves the thermal and mechanical properties significantly [22-24]. Mohan et al. utilized the nanoclay to treat the banana fibers. Yes, the nanoclay is infused in the short banana fibers, including epoxy matrix to prepare a composite that doubles the compressive yield stress, modulus, and 43% higher compressive strength than NaOH treated banana fiber-based composite [25]. The composites were prepared as cylinders and investigated tensile, fracture toughness, and compressive strengths and found significant improvement in all aspects. Bhuvaneshwaran et al. certified after experimentation by synthesis and characterization that nanoclay filler improves impact, bending, tensile and compressive strengths in the composite [26]. In particular, wt% of 3% outperforms in the composite made up of treated medicinal plant fiber 'Coccinia indicate fiber' with epoxy resin. They ensured such properties enhancement in addition to the mechanical testing that Fourier Transform Infrared Spectroscopy analysis (for ensuring the chemical structure in the composite) and Scanning Electron Microscopy (identifying the pull-out fibers on broken specimens). The nanoclay proved its compatibility with many fiber and resin varieties; furthermore, the natural silk fiber in high-density polyethylene matrix with nanoclay as filler. The composite is designed for material with high wear resistance. Trupti et al. observed that little percentages like 0.5% to 1% mass fraction offered high wear resistance [27]. Nanoclay extended its contribution in preparing natural rubber and jute-based composite in the nanoclay based modification of stearic acid as a matrix. The excellent interfacial bonding through interaction was ensured by Dynamic mechanical analysis. The nanoclay based modification of stearic acid in the composite augmented the tensile strength and the cure rate index (CRI) of the composite material, and its hydrophobic nature was revealed in the Fourier transform infrared investigation [28-29].

Nano SiO_2

The contribution of SiO_2 is widely applicable investigates its nonoform in cementitious composites [30]. The NS, along with polyvinyl alcohol fiber, decreased workability, limited other unnecessary mechanical properties, and added good strength and life to the cementitious composites. Oinghua et al. utilized the NS in the carbon fibers/nylon-6 composites for improving the transverse fibers bundle strength. Oinghua et al. also used the NS to alter the properties of cementitious composites and investigated several special effects of nano-SiO2 in the cementitious composite like flowability, flexural strength, deformability, and toughness [30]. Yibing et al. used the ultrafine composite to augment the combustion temperature at the beginning and reduce the heat release rate [31]. The composite is made up of polyethylene terephthalate and lauric acid, where the NS is filler. Also, many worked on improving with NS for the tribological properties of short carbon fiber/epoxy hybrid composites enriched with NS. The fabricated composite exhibit good quality of lubrication and wear properties.

The Uniform dispersion of NS in the Epikote 828 epoxy polymer is illustrated at various proportions by using Transmission Electron Microscopy images with 2 different magnification [13] refer Figure 4 demonstrates the Nano silica dispersion (The 5 wt%) in the Epikote 828 epoxy polymer Figure 4 (a) is 22500x magnification and the Figure 4 (b) is 4 115000x magnification [31]

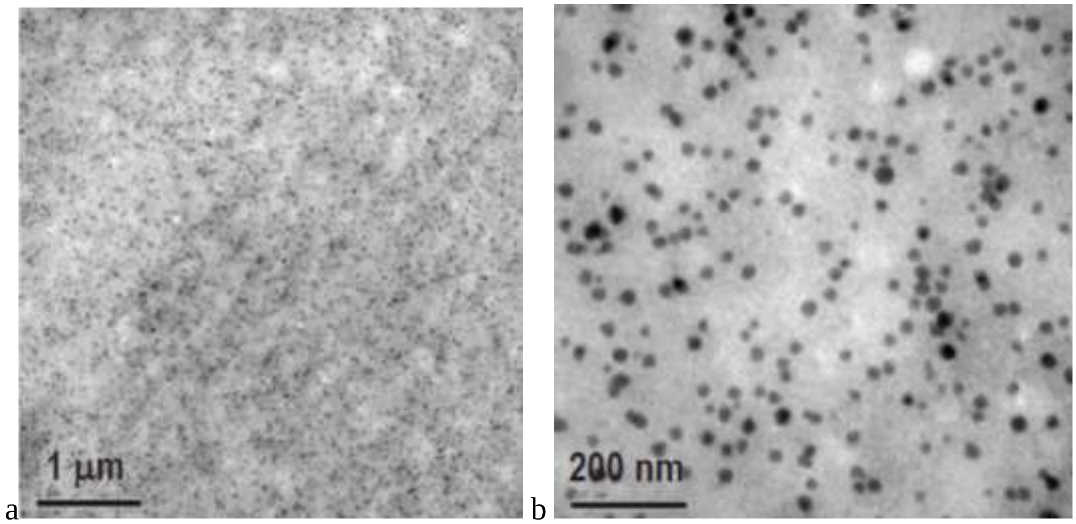

Figure 4. Nano silica dispersion (The 5 wt%) in the Epikote 828 epoxy polymer (a) 22500x (b) 115000x [32]

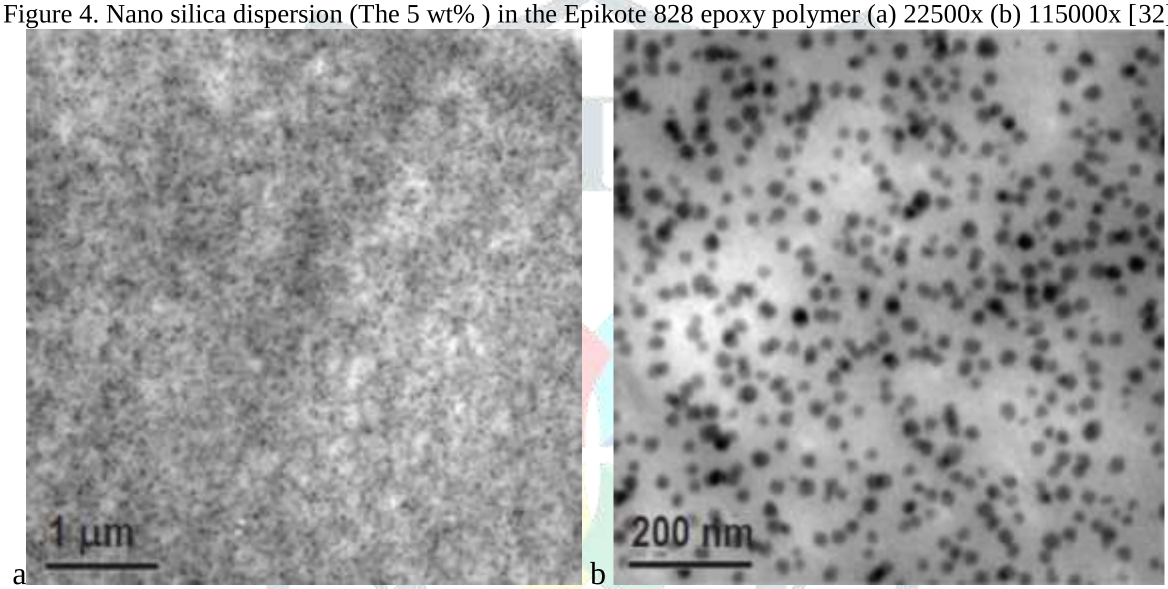

Figure. 5. Nano silica dispersion (The 13 wt%) in the Epikote 828 epoxy polymer (a) 22500x (b) 115000x [32]

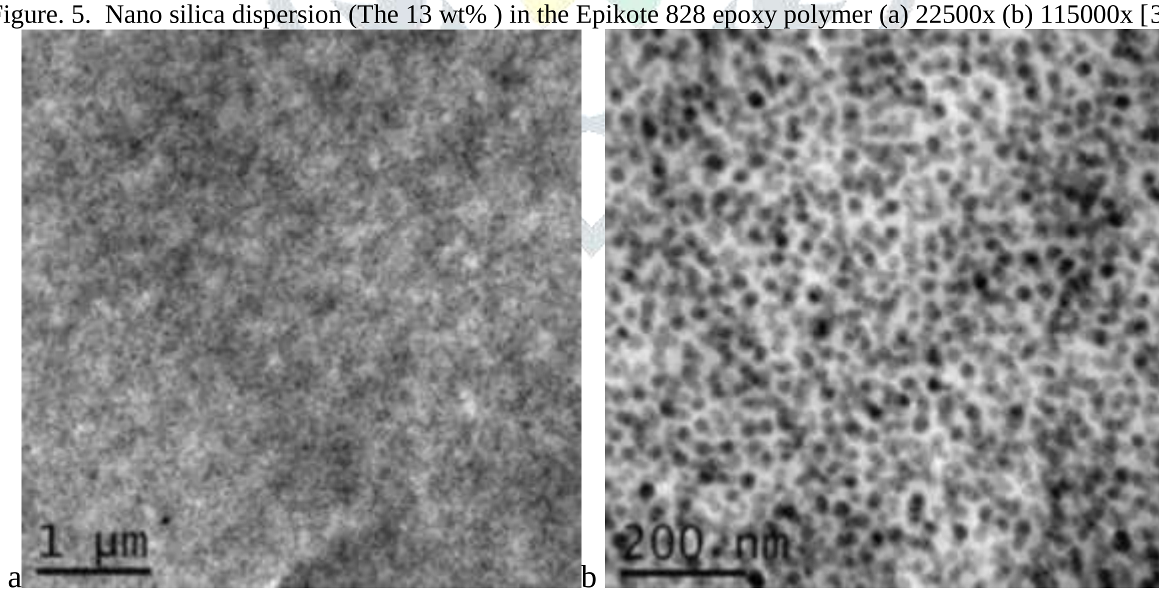

Figure 6. Nano silica dispersion (The 25 wt%) in the Epikote 828 epoxy polymer (a) 22500x (b) 115000x [32]

Figure 5 demonstrates the Nano silica dispersion (The 13 wt%) in the Epikote 828 epoxy polymer Figure 5 (a) is 22500x magnification, and Figure 5 (b) is 4 115000x magnification. Figure 6 emonstrates the Nano silica dispersion (The 25 wt%) in the Epikote 828 epoxy polymer Figure 6 (a) is 22500x magnification and the Figure 6 (b) is 4 115000x magnification [32]

Nano- Titanium dioxide

The Nano-Titanium dioxide or NT or nanoTiO2 inclusion in the polymer composite also yielded better outcomes. Vishnu et al. worked on Nano Titanium dioxide in the epoxy matrix where the flax fiber was employed as a reinforcement element in the composite matrix [33]. From both kinds of mode bending tests, it was found that 52% and 73% of fracture toughness improved, and the better fracture toughness was achieved with the weight fraction Nano Titanium dioxide of 0.4 wt% and 0.5 wt%, respectively. Later those authors utilized the NaOH treated natural flax fiber woven mats for composite with the same matrix and found that 6% inclusion in the matrix simultaneously improved the hardness by 16%, flexural strength by 25%, and fracture toughness by 24% when compared with untreated fibers in the composite matrix [34]. Vishnu et al. worked to a reduced, and standard size of nano Titanium dioxide particle of 50 nano-meters utilized t in the untreated flax fiber epoxy composite, the nano Titanium dioxide particle included in the epoxy matrix through mechanical stirring and sonication process, the fabrication technique changed from hand layup to compression molding [35]. The optimal value of 0.7% inclusion of nano Titanium dioxide particles gives 11% extra tensile strength, 19% additional interlaminar shear strength, 20% improved flexural strength, augmented fracture toughness by 10.45%, and 31% decreased the water diffusion coefficient.

Further, the authors [36] reduced nano Titanium dioxide particle size to 15 nanometers, utilized NaOH treated flax fiber in the epoxy matrix, and presented their investigation. They used two different NaOH concentrations as 5% and 10%. Vishnu et al. mixed the nano-TiO2 as filler in the high-density polyethylene matrix and utilized bamboo fiber and found that thermo-oxidative aging of composites are found decreased, and thermal stability improved [37].

Nano-Al_2O_3

Alumina is a widely available industrial waste that can be utilized to prepare new materials effectively. Peng et al. added nano-alumina particles in the epoxy matrix where coconut bunch fiber was a reinforcement agent for improving mechanical strengths [38]. The alumina nano-fillers performance was evaluated in glass/epoxy composite and reported that the thermal stability, flexural strength was enhanced [39]. The weight fraction was 0.1 percent included alumina nanoparticles in glass/epoxy composite for improving the interlaminar shear strength [40]. Ramesh et al. contained the alumina nanoparticles in the carbon epoxy matrix and obtain a good scatter of fatigue lives utilized the alumina nanoparticles along with rice husk ash in the lightweight geopolymer concretes improved 20% durability [41-42]. Ehsan et al. included nano-Al_2O_3 particles (0.1 wt%) and obtained the inter-laminar shear strength by 12% [43].

Nano-SiC

Ramesh et al. included the SiC nanoparticles as filler to augment mechanical properties in banana/epoxy composite [44]. Prakash et al. included the SiC in the carbon epoxy matrix and obtained a good scatter of fatigue lives. SiCp based nanocomposite in the polymer classification [45].

Nano-Graphene

It was found that the mechanical properties of different fibers were by using graphene nanoparticle prepared using hot pressing method glass fiber reinforced composite, carbon fiber reinforced composite, aramid fiber reinforced polymer was produced in addition 0.1%,0.2%,0.3% graphene nanoplates were used. The addition of 0.2wt% graphene nanoparticle to aramid fiber reinforced polymer composites don't have any effect on tensile strength, but it increased the tensile strength [46].

With the immersion of GNP, the distribution of CNT in Epoxy increased. They have improved flexural properties and decreased the threshold of epoxy composites' electrical percolation with 8:2 CNT and GNP ratio [47]. The three-dimensional CNT and graphene oxide was constructed by pie-sequence interaction between the CNT's and the multiple aromatic areas of the GO (Graphene Oxide) sheets combined [48]. By mixing graphene and CNT in a 9:1 ratio, they improved the mechanical properties [49].

Nano-CNT

The polymer composites are found to be tough by varying their composition of CNT. Fibers are Glass fiber and Kevlar, and unmodified epoxy resin with k6 hardener as Epoxy, the composites made up of carbon and glass were prepared and shown in six ways. The addition of CNT to the epoxy matrix varied from 0 to 2%. The increment in carbon fiber percentage improves composite rigidity. The suggested addition of CNT is restricted to 1wt.%. The hybrid composite properties with different shapes in the individual case of CNT reinforcement differed between carbon composite and glass composite [50]. By performing tensile tests and Impact tests. Where Bamboo is a fiber and Epoxy is a resin and varying % of CNT. They concluded that by increasing the percentage of CNT, the tensile strength and tensile load of the specimens increase [51].

By performing flexural and tensile stress on kenaf/Glass fibers where Epoxy as resin-filled along with carbon nanotubes and investigated that, Flexural modulus and flexural strength of kenaf/glass fibers hybrid reinforced epoxy composites with different percentages of CNT modified Epoxy were compared. It shows that the flexural strength decreases with increasing CNT wt.%. The flexural modulus increases with increasing CNT wt.%. Adding 0.5 and 0.75 wt.% of CNT reduces the tensile strength by about 20% and 5%, respectively. However, the tensile strength increases when 1.0wt.% CNT was added to the hybrid system. Finally, CNT was used to investigate the tensile and flexural properties of kenaf/glass fiber hybrid reinforced epoxy. Both flexural and tensile modulus increase as the strength of the material increases [52].

V. Discussion

The advantage of nanotechnology permits us to utilize agricultural and industrial waste to develop and synthesize the best alternate materials with cost-effectiveness. The use of natural fibers increases biodegradability. The use of natural fibers and synthetic fibers with nanofillers offers the best, strong, and durable material. The nanofillers and natural fibers help to alter the properties suitably for the appropriate use. The disadvantage of poor interfacial bonding strength in the natural fibers could be enhanced with low-cost pre-treatment processes. Huge varsities of natural fibers are available and abundant also, hence the sustainable supply of materials at a low price can be assured. The use of natural fibers, including waste bio-fibers, cleans the environment. The composite technology is a magic method that converts the useless to useful. The use of natural fibers, preventing the generation of pollution. Some of them can be recyclable too. So better material balance can be achieved by giving more importance to the use of natural fibers and natural waste like clay and industrial waste like aluminum in association with synthetic fibers.

VI. Challenges and Future opportunities

In the case of nanocomposites, the homogeneous distribution of nanofiller in matric composites plays an important role. It also includes mixing methods, mixing agents, time, temperature etc. The major challenge is the prepration of nanoparticle composites uniformly in the entire area of the polymer. Secondly, the measuring method is vital in studying nanofiller reinforced nanocomposites' mechanical and thermomechanical properties [53-58].

VII. Conclusion

The ample survey on characterization and analysis of nano-hybrid composite structures is presented in this research article. The cost-effective new material production or the cost-effective improving the excising composites are highly feasible with nanocomposite technology. Filler materials like nano clay are widely utilized for improving material's property. The nanofillers like nanoclay proved their compatibility with many kinds of composite matrix, including hybrid polymer and polymeric Composites. The nanofillers like carbon nanotubes are costly nanofillers where materials like aluminum oxide are industrial waste, nanoclay are cheap and widely available. Hence, using natural fibers with cheap pre-treatments like NaOH and utilizing cheap and freely available nono fillers and wise design of composite matrix will lead to developing the cheap and best alternative materials for many applications.

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