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A Review On Research Progress, Processing Techniques, Characterization And Future Prospects On Natural Fiber Composites.

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Abstract: As we know more research is going on to have natural and biodegradable materials in order to upgrade for next upcoming generation on composite applications. Many of the organizations are concerned towards the green resources. Increase in using natural composites has minimized the greenhouse gases. As increase in use of natural fiber has bought some of the problems like poor compactablity between matrix and natural reinforcement and more moisture absorption between the natural fibers and the matrix. Natural fibers can be suits as the alternative source for the petroleum-based products. Moreover, before this the issues need to be solved, including the adhesion between the matrix and the green fibers, poor fire resistance, low impact strength and low durability. The research has led to certain customization on natural fibers and resin. To identify in demand of use of eco-friendly materials in different types of applications on green fibers and the resin type and the resources customization and process techniques, mechanical behaviours and the applications and other properties of natural composite is essential to provide more efficient behavior of natural composite.

Index Terms - Natural fiber composite, Composites, Fiber, Particle, Mechanical Properties, Thermal Properties.

I. INTRODUCTION

Natural fibers reinforced hybrid green composites have gained more importance in many industrial applications like automotive, aerospace, construction, and furnitures .The availability to natural fibers are easy, and also its processing ability makes them a suitable replacement for unconventional fibers that are possibly harmful. Natural fibers have more benefits over unconventional synthetic fibers, like renewability, being eco-friendly, low cost, lightweight, and high specific mechanical characteristics. These benefits of Green fibers has certain limitations like low durability, poor fiber matrix bonding etc. Fibers are readily available, contains high rigidity, exhibit fire-resistant properties, and are sustainable for all the applications as of now. Among natural fibers, banana fiber plays a important role in composite manufacturing due to its highest strength and good adhesion compared with all other forms of matrices.Banana fiber is well known as a huge bio-waste and is environmentally friendly too.Kenaf fibers are fully biodegradable and used in making bio-based composites. These fibers have tensile strength and their high specific strength characteristic too.Sisal composite has a mild wear rate and a low Co-efficient of friction, for smoother relative motion. Coir composite presented the highest wear rate.Thermal conductivity is higher in cotton composite and is lowest at coir composite.

I. NATURAL FIBER COMPOSITES

NFC materials created by combination of natural fibers with a polymer matrix aiming to the strengths of natural fibers while limitations of traditional synthetic composites. Natural fiber composites (NFC) are bio-based composites with a natural fiber reinforcement and matrix.

Types of Natural Fibers Used:-

- Bast Fibers: Flax, hemp, jute, kenaf.
- Leaf Fibers: Sisal, banana, pineapple leaf.
- Seed Fibers: Cotton.
- Fruit Fibers: coconut.
- Wood Fibers: Softwood, hardwood.

Types of Matrix Materials:-

- Polymers: Polyester, epoxy resin.
- Biomass-derived matrices: These are increased being used to improve the biodegradability of the composite.

Applications:-

- Hemp Reinforced Composites: Used in automotive parts, building materials, and packaging.
- Jute Composites: Used in packaging, textiles, and construction.
- Sisal Composites: Used in construction, automotive, and packaging.
- Bamboo Composites: Used in construction, furniture, and packaging.

II. LITERATURE REVIEW

(a) Mechanical, thermal conductivity, and water absorption properties of bio-silica and palm kernel fiber reinforced epoxy composite rebar for building materials.

S. Sasirekha et.all [1] investigated into composite materials reinforced with bio-silica filler extracted from proso millet, which revealed substantial enhancements across various mechanical, thermal, water absorption, and microstructural properties. The tensile, flexural, compression, and hardness properties of the composites showed significant improvements with the incorporation of bio-silica filler up to 4 volume %. Water absorption values has increased with the addition of bio-silica filler. The addition of bio-silica filler led to a reduction in thermal conductivity, highlighting improved thermal insulation properties.

(b) Agave-jute fiber–reinforced hybrid composite for lightweight applications: effect of hybridization

Rittin Abraham Kurien et.all [2] performed an experimental study of agave-jute–reinforced hybrid epoxy composites were conducted to illustrate mechanical, tribo logical, machinability and morphological properties. Agave jute fibers constitutethe best material couple to obtain a bio composite that is renewable and high performing. Although the use of Sodium Hydroxide (NaOH) increases the corresponding environmental impact, the chemical treatment generally improves fiber matrix adhesion further. Result :- Sodium Hydroxide (NaOH) treatment, it remains one of the most interesting matrixes for the development of high- performance biocomposites.

(c) Determination of significant factors for sugarcane fiber extraction as potential dielectric composite material

Norazwina Zainol et.all [3] conduced study to aim that to achieve by using sugarcane waste as a base substance to produce dielectric material and employing Full Factorial Design (FFD) to determine significant factors affecting sugarcane waste extraction. Full Factorial Design was utilized in the experiment to determine the optimal cellulose concentration and permittivity value. The use of FFD in this study was beneficial for factor screening, range selection, and selecting relevant factors. All tested variables were shown to affect the cellulose content and permittivity remarkably.

(d) Evaluation and Analysis of Elastic and Mechanical Characteristics of Hybrid Composite Incorporating Banana Fiber, Kenaf Fiber, and Nano- CaCO3

V. K. Chawla [4] has investigated on to composite materials consisting of banana–kenaf fiber incorporated with nano-calcium carbonate and an epoxy resin is simulated with the help of ANSYS APDL. The composite is subjected to analysis concerning elastic attributes which shows, such as longitudinal stiffness, transverse stiffness, longitudinal Poisson's ratio, and longitudinal shear stiffness by employing M–TA, GS-C, and M-HT, and authenticated through the outcomes of the simulation and research done by the article.

(e) Characterization of Silane Treated Opuntia Short Fiber and Bagasse Bio-silica Toughened Epoxy Resin Composite

P. Neopolean et.all [5] have performed this study in the composite material, which is opuntia fiber and biosilica toughened epoxy resin hybrid composites that were fabricated and tested in this research study. The composites were prepared using hand lay-up method followed by tested according to the ASTM standards.

Results:- The opuntia short fibers were successfully silane-treated using the aqueous solution method. The mechanical properties showed an increase in tensile, flexural, impact toughness for the composite made using biosilica particle and opuntia natural fiber. However adding more nanoparticles decreased the load bearing effect. The micro-hardness and thermal properties of bio-silica dispersed fiber-epoxy resin composite shows highest value.

(f) Exploring wood as a sustainable solution for water f illitration: nanoparticle removal, size exclusion and molecular adsorption

Jennifer Guerrero Parra [6] has conducted a study that shows the highlight of potential of wood filters in particle removal, size exclusion, and molecular adsorption, offering valuable insights into their performance under various conditions and directional orientations. The wood filters exhibited superior particle removal capabilities in the radial and tangential direction, attributed to their extended residence time and intricate microstructure. This study reveals that the degree of size exclusion achieved through wood filtration varies based on tracer nature.

(g) Free vibration and buckling analysis of polymeric composite beams reinforced by functionally graded bamboo fibers.

H. M. Feizabad ell.all [7] has investigated on to the free vibration and buckling responses of bamboo-reinforced composite beams on the elastic foundation and under various boundary conditions are investigated. The elastic properties of the composite are determined via the rule of mixture. By employing Hamilton's law, the governing equations of motion are obtained. Analysing the outcomes results in the deduction to the natural frequencies as well as buckling loads that vary with the change in fiber volume fractions and distributions, the elastic foundation stiffness coefficients, and boundary conditions.

(h) Comparative analysis of tamarind shell biomass powder and roasted chickpeas powder in kenaf fiber reinforced vinyl ester composite

S. Hanish Anand et.all [8] had performed this study presenting the comparative investigation of the mechanical, wear, thermal conductivity, and water absorption properties of Kenaf fiber reinforced vinylester composites containing tamarind shell powder and roasted chickpeas-powder fillers. Both tamarind shell powder and roasted chickpeas powder contributed to enhancing the wear resistance in the composites.

Result:- They indicate significant improvement in mechanical properties with the inclusion of tamarind shell powder. Overall, the findings indicate the efficacy of tamarind shell powder as a promising filler material for enhancing the mechanical, wear, and thermal properties of Kenaf fiber reinforced vinyl ester composites. Further research focusing on optimising filler content and processing parameters could lead to the development of composite materials with even more enhanced performance characteristics.

(i) Development of silane-treated corn husk fiber and agro-waste bio-filler-reinforced epoxy composite: effects on wear, mechanical, thermal, and water absorption properties

L. Narayanan ell.all [9] as conducted an investigation into the mechanical and thermal properties of composite specimens containing silane- treated coconut shell powder (CHCE) and silane- treated areca husk powder (CHAE) revealing significant improvements compared to their respective baseline composites (CHCE0 and CHAE0). Specimens with CHAE demonstrated superior tensile and flexural strengths compared to CHCE specimens.

Result:- Their study shows the limitations include a narrow focus on mechanical and thermal properties, overlooking environmental impact and long-term durability. Fixed filler and fiber combinations limit insights; exploring varied ratios or materials could enhance understanding. Processing parameter effects on composite characteristics were overlooked. They found the imply the potential of silane-treated areca husk powder to significantly enhance mechanical and thermal properties, applicable in automotive, construction, and aerospace sectors.

(j) Preparation and Characterization of Amino-Silanized Opuntia Cladode Fiber and Fumed Silica Toughened Epoxy Composite.

M. P. Sudeshkumar et.all [10] as performed study, through this research, an epoxy composite toughened using silane-treated fumed silica and reinforced with optunita cladode short fibers which was fabricated and analysedby them. Their investigation was focused on the material’s mechanical, wear, and electrical characteristics.

Results:- Further, the addition of silane-treated fumed silica, however, boosts the wear resistance of composites designated as specimen 1, specimen 2, specimen 3, and specimen 4. Finally, for composites with the specimen 4 shows the maximum dielectric constant and dielectric loss are observed while testing of the material. With the help of Scanning Electron Microscopy (SEM), they revealed that silane treatment strengthens the fiber-matrix bonding and improves the interlocking mechanism. A composite with these improved mechanical properties, as well as wear resistance, could be used in potential applications such as industrial and automotive components, household appliances, defense, and spacecraft.

(k) Enhancement of tribology behaviour by the addition of different fiber length of pineapple fiber reinforced polyester composite

S. Krishnakumar et.all [11] have done investigation of a study, which discusses about the influence of treated pineapple fiber length on tribological characteristics of the polyester composite, which was analyzed by a reciprocating wear tester with varied load and sliding speed. The 16 mm pineapple fiber length identified experimental wear.

Results:- On the developed composite has a minimum wear rate and similarly, the coefficient of friction value was increased marginally and has found.

III. Conclusion

Natural fiber composites (NFCs) have gained significant attention due to their sustainability, lightweight nature, and cost-effectiveness. Over the years, research has focused on improving their mechanical, thermal, and durability properties through various processing techniques such as compression molding, injection molding, and resin transfer molding. Surface modifications and hybridization with synthetic fibers have further enhanced their performance.

These advancements, challenges such as moisture absorption, limited mechanical strength compared to synthetic composites, and long-term degradation remain key areas for improvement. Future research should focus on developing innovative treatments, hybrid composite structures, and biodegradable resin systems to enhance their overall properties and expand their applications in industries such as automotive, aerospace, and construction.

With ongoing advancements in material science and processing technology, NFCs are expected to play a crucial role in sustainable material solutions, reducing environmental impact while meeting industrial demands.

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