Published by :
http://www.ijert.org

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Volume 13, Issue 03 March 2024

A Brief Overview of Natural Fiber Reinforced Composite Materials for Product Design

Siddharth Hanswal, Dr. Chitaranjan Agrawal, Dr. N.L Panwar, Dr. Trilok Gupta
Student M.Tech (CAD/CAM), Associate Professor at Maharana Pratap University of Agricuture & Technology, Professor & Head MPUAT, Associate Professor & Head MPUAT.

Abstract-

Natural fibers as composite reinforcements have gained increasing attention in recent years due to their environmentally friendly and sustainable characteristics. This review will highlight the key aspects of using natural fibers in composites, discussing their properties, advantages, challenges, applications and how well it works in product design.

***Keywords*- Natural fibers, manufacturing, applications**

INTRODUCTION

In the manufacturing sector, natural fiber materials are becoming more and more common, and numerous researchers have examined them. There are three groups into which natural fibers are classified: cellulose-based, protein-based, and mineral-based. As stated , natural fibers are sustainable materials found in nature that offer various benefits. Cellulose, hemicellulose, and lignin make up the three primary parts of the constitution of natural fibers. The chemical makeup of natural fibers , where the chemical makeup and cell architectures vary depending on the portion of the plant and its origin. The lignocellulosic fibers' mechanical, chemical, and physical properties depend on the cellulose crystallinity. This combination is made up of the reinforcing phase, which can take the shape of fibers, fragments, or particles , embedded in the matrix phase of various materials. While the matrix phase distributes the load among the fibers and acts as a binder for the reinforcing material, reinforcement bears weight. The matrix serves as a material barrier to prevent damage to the fiber material before, during, and after composite production. New materials with superior qualities to the component ingredients can be created by this combination.

ADVANTAGES-

1. Lightweight: Natural fibers, such as jute, flax, hemp, and kenaf, are inherently lightweight, contributing to the overall weight reduction of composites.
2. Renewable: Being derived from plants, natural fibers are renewable resources, making them an eco-friendly alternative to synthetic reinforcements.
3. Biodegradability: Natural fibers may naturally break down, lessening the impact of disposal, making them environmentally friendly
4. Absorbency: Natural fibers are comfortable to wear, especially in warm, humid conditions because of their capacity to absorb moisture and subsequently release it.
5. Specific Properties: Natural fibers have great tensile strength, flexibility, and abrasion resistance, depending on the kind and grade of the fiber.

SOURCE OF HARVESTING:

Fibers From Plant:
Seed Fibers: fibers are derived from the seeds of different plants.
Leaf fibers: Taken from the leaves of certain plants; examples of these include banana and pineapple leaf fibers.
Fruit Fibers: Made from fruit pieces (e.g., fiber from coconuts).
Stalk Fibers: Derived from plant stalks, such as barley, rice, bamboo, and wheat straws.
Jute, flax, industrial hemp, and ramie fibers are a few examples of bast fibers, which are derived from the outer layer of plant stems.

Fibers from Animals:
Silk: Made by silkworms; various species produce different kinds of silk.
Sinew: In some animals, it joins muscles to bones.
Wool: Produced by shearing certain sheep breeds' fur.
Mohair: Angora goat hair is used to create mohair.

PROPERTIES-

1. Environmental Sustainability: The use of natural fibers aligns with the growing demand for eco-friendly materials, reducing the reliance on non-renewable resources and minimizing the environmental impact of composites.
2. Cost-Effectiveness: In many cases, natural fibers are more cost-effective than synthetic alternatives, contributing to the economic viability of composite materials.
3. Good Specific Strength and Stiffness: Natural fibers can provide good specific strength and stiffness properties, making them suitable for various applications, especially in automotive and construction industries.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Volume 13, Issue 03 March 2024

4. Renewability and Environmental friendliness: Since natural fibers originate from regenerative plants and animals, they are renewable resources. As a result of their low energy requirement during production, they emit less CO2 than synthetic materials.
5. Electrical Resistance: Natural fibers have a high electrical resistance, which qualifies them for some uses.
6. Biodegradability: Natural fibers decompose naturally, in contrast to synthetic materials. The environment is not harmed or exposed to pollutants as a result of their breakdown.
7. Natural fibers have thermal insulation properties that keep you comfortable in cold weather. Additionally, they are breathable, which makes them comfortable to wear in a variety of temperatures.
8. Skin-Friendly: Natural fibers are perfect for textiles and apparel since they don't irritate the skin or trigger allergic reactions.

CHALLENGES-

1. Moisture Absorption: Natural fibers have a tendency to absorb moisture, which can lead to dimensional instability and a reduction in mechanical properties. Proper surface treatment and coating are required to mitigate this issue.
2. Non-Uniformity and Variability: Natural fibers (such as coir, jute, flax, and hemp) exhibit non-uniformity along their length. This results in variable diameters and cross-sectional areas. Additionally, factors like gauge length, fiber species, origin, strain rate, extraction method, porosity, and pore size distribution influence the tensile strength of these fibers. This variability can limit their consistent performance in composites.
3. Inconsistent Tensile Properties: Different authors have reported varying tensile strengths for the same type of natural fiber (e.g., coir). In the case of coir, an average tensile strength of approximately 120.97 ± 42.30 MPa has been observed from various reports. However, inconsistencies arise due to factors like fiber diameter variations and inadequate sample sizes for testing.
4. Poor Interfacial Bonding: Natural fibers tend to be hydrophilic, leading to challenges in achieving strong interfacial bonding with polymer matrices. Proper adhesion between fibers and matrix is crucial for composite performance.
5. Limited Processing Temperature: Natural fibers have a processing temperature limit of around 200°C. Beyond this temperature, they may degrade or lose strength.
6. Low Thermal Stability: Natural fiber composites exhibit lower thermal stability compared to synthetic counterparts. This limits their use in high-temperature applications.

APPLICATIONS-

1. Automotive Industry: Natural fiber composites are increasingly being used in automotive interiors, door panels, and non-structural components to reduce weight and enhance sustainability.
2. Construction: Natural fiber composites find applications in construction materials such as panels, boards, and reinforcements for their lightweight and insulation properties.
3. Packaging: Biodegradable and lightweight natural fiber composites are explored for packaging materials, reducing the environmental impact of disposable packaging.
4. Interior Applications:

- Passenger Cars: Door panels, seat covers, and headliners are just a few of the interior components made of natural fibers in automobiles.
- False ceiling panels and partitions both support environmentally efficient home design. Natural fibers improve the appearance and acoustics of partition boards.
- Roof Tiles: Roofing materials include coir fibers1.

5. Applications for Furniture: Natural fibers are woven into mats, cushions, and upholstery for furniture.
6. Insulating Materials: Natural fibers serve as insulation in low-energy homes, controlling temperature and consuming less energy.
7. Enhancement of Barrier Properties: Materials can benefit from the incorporation of natural fibers to improve their barrier qualities, such as moisture resistance.

NATURAL FIBERS FOR PRODUCT DESIGN-

In the field of product production engineering, natural fiber composites have gained attention as eco-friendly materials. For building purposes, the first composite material employed by the ancient Egyptians was straw-reinforced clay, which they used starting 3000 years ago. Natural fibers have been successfully used as reinforcements in the composites sector, as demonstrated by research and development, in applications such as construction, building, aircraft, and interior components. The fact that natural fiber composites are less expensive than synthetic ones, biodegradable, widely accessible, renewable, and lightweight are further benefits.

The initial stage of the manufacturing process is design, during which a number of crucial choices that will have an impact on the final product must be made. Consequently, a number of factors need to be taken into account, including production, assembly, cost, sales, maintenance, and disposal and recycling at the outset of the design phase. Additionally, early in the design phase is when 70% of the costs associated with manufacturing a product are decided. The same methodology used for other product design processes is applied when designing with natural fiber composites.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Volume 13, Issue 03 March 2024

Product designers will employ factors such as suitability for purpose, convenience of use, cost, materials, and quantity of constituent parts to evaluate the formal attributes of items made by industry.

To finish the design process, which includes choosing design concepts, materials, and production processes, design and manufacture must essentially proceed in tandem. Every issue must be handled in accordance with the expertise that it represents. While some experts may concentrate on design principles, others will concentrate on the materials to be used. Using computer-aided drawing (CAD) and finite element analysis (FEA), design concepts and materials can be merged. TRIZ method could be applied in development of product.

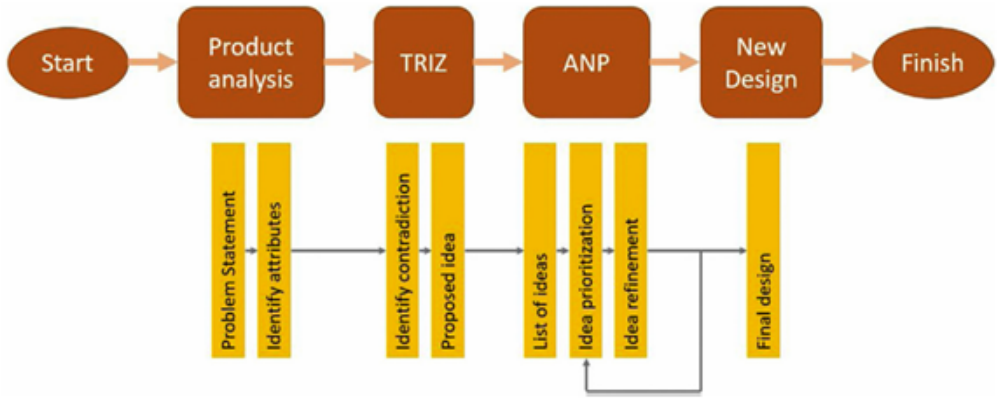

Fig. 1 The application of TRIZ in the concurrent engineering conceptual design framework to develop the product (Ref. 26).

CONCLUSION-

Natural fibers as composite reinforcements offer a promising avenue for developing sustainable materials with a reduced environmental footprint. While challenges exist, ongoing research and technological advancements in processing and treatment methods are addressing these issues, paving the way for wider adoption in various industries. The combination of eco-friendliness, cost-effectiveness, and acceptable mechanical properties positions natural fiber composites as valuable alternatives in the pursuit of sustainable material solutions.

REFERENCES-

1. Hanan, F.; Jawaid, M.; Tahir, P.M. Mechanical performance of oil palm/kenaf fiber-reinforced epoxy-based bilayer hybrid composites. J. Nat. Fibers 2018, 17, 155–167. [CrossRef]
2. Alsubari, S.; Zuhri, M.Y.M.; Sapuan, S.M.; Ishak, M.R.; Ilyas, R.A.; Asyraf, M.R.M. Potential of Natural Fiber Reinforced Polymer Composites in Sandwich Structures: A Review on Its Mechanical Properties. Polymers 2021, 13, 423. [CrossRef]

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Volume 13, Issue 03 March 2024

3. Sapuan, S.; Hemapriya, G.; Ilyas, R.; Atikah, M.; Asyraf, M.; Mansor, M.R. Implementation of design for sustainability in developing trophy plaque using green kenaf polymer composites. In Design for Sustainability; Elsevier: Amsterdam, The Netherlands, 2021; pp. 85–103
4. Elanchezhian, C.; Ramnath, B.; Ramakrishnan, G.; Rajendrakumar, M.; Naveenkumar, V.; Saravanakumar, M. Review on mechanical properties of natural fiber composites. Mater. Today Proc. 2018, 5, 1785–1790. [CrossRef]
5. Bakar, N.H.; Hyie, K.M.; Ramlan, A.S.; Hassan, M.K.; Jumahat, A. Mechanical Properties of Kevlar Reinforcement in Kenaf Composites. Appl. Mech. Mater. 2013, 465-466, 847–851. [CrossRef]
6. Asyraf, M.R.M.; Rafidah, M.; Azrina, A.; Razman, M.R. Dynamic mechanical behaviour of kenaf cellulosic fibre biocomposites: A comprehensive review on chemical treatments. Cellulose 2021, 28, 2675–2695. [CrossRef]
7. Omran,A.A.B.; Mohammed, A.A.B.A.; Sapuan, S.M.; Ilyas, R.A.; Asyraf, M.R.M.; Koloor, S.S.R.; Petr˚ u, M. Micro- and Nanocellu lose in Polymer Composite Materials: A Review. Polymers 2021, 13, 231. [CrossRef] [PubMed]
8. Nurazzi, N.; Asyraf, M.; Khalina, A.; Abdullah, N.; Aisyah, H.; Rafiqah, S.; Sabaruddin, F.; Kamarudin, S.; Norrrahim, M.; Ilyas, R.; et al. A Review on Natural Fiber Reinforced Polymer Composite for Bullet Proof and Ballistic Applications. Polymers 2021, 13, 646. [CrossRef]
9. Maleque, M.A.; Belal, F.Y.; Sapuan, S.M. Mechanical properties study of pseudo-stem banana fiber reinforced epoxy composite. Arab. J. Sci. Eng. 2007, 32, 359–364.
10. Sapuan, S.; Maleque, A. Design and fabrication of natural woven fabric reinforced epoxy composite for household telephone stand. Mater. Des. 2005, 26, 65–71. [CrossRef]
11. Ilyas, R.A.; Sapuan, S.M.; Atiqah, A.; Ibrahim, R.; Abral, H.; Ishak, M.R.; Zainudin, E.S.; Nurazzi, N.M.; Atikah, M.S.N.; Ansari, M.N.M.; et al. Sugar palm (Arenga pinnata [Wurmb.] Merr) starch films containing sugar palm nanofibrillated cellulose as reinforcement: Water barrier properties. Polym. Compos. 2019, 41, 459–467. [CrossRef]
12. Ilyas, R.; Sapuan, S.; Atikah, M.; Asyraf, M.; Rafiqah, S.A.; Aisyah, H.; Nurazzi, N.M.; Norrrahim, M. Effect of hydrolysis time on the morphological, physical, chemical, and thermal behavior of sugar palm nanocrystalline cellulose (Arenga pinnata (Wurmb.) Merr). Text. Res. J. 2021, 91, 152–167. [CrossRef]
13. Huda,M.S.; Drzal, L.T.; Ray, D.; Mohanty, A.K.; Mishra, M. Natural-fiber composites in the automotive sector. In Properties and Performance of Natural-Fibre Composites; Elsevier: Amsterdam, The Netherlands, 2008; pp. 221–268.
14. Girijappa, Y.G.T.; Rangappa, S.M.; Parameswaranpillai, J.; Siengchin, S. Natural Fibers as Sustainable and Renewable Resource for Development of Eco-Friendly Composites: A Comprehensive Review. Front. Mater. 2019, 6, 1–14. [CrossRef]
15. Arpitha, G.; Sanjay, M.; Senthamaraikannan, P.; Barile, C.; Yogesha, B. Hybridization Effect of Sisal/Glass/Epoxy/Filler Based Woven Fabric Reinforced Composites. Exp. Tech. 2017, 41, 577–584. [CrossRef]
16. Madhu, P.; Sanjay, M.R.; Senthamaraikannan, P.; Pradeep, S.; Saravanakumar, S.S.; Yogesha, B. A review on synthesis and characterization of commercially available natural fibers: Part-I. J. Nat. Fibers 2018, 11, 25–36.
17. Chandra, C.S.J.; George, N.; Narayanankutty, S.K. Isolation and characterization of cellulose nanofibrils from arecanut husk fibre. Carbohydr. Polym. 2016, 142, 158–166.
18. Jonoobi, M.; Khazaeian, A.; Tahir, P.M.; Azry, S.S.; Oksman, K. Characteristics of cellulose nanofibers isolated from rubberwood and empty fruit bunches of oil palm using chemo-mechanical process. Cellulose 2011, 18, 1085–1095. [CrossRef]
19. Cherian, B.M.; Leão, A.L.; de Souza, S.F.; Thomas, S.; Pothan, L.A.; Kottaisamy, M. Isolation of nanocellulose from pineapple leaf f ibres by steam explosion. Carbohydr. Polym. 2010, 81, 720–725. [CrossRef]
20. Teixeira, E.D.M.; Bondancia, T.; Teodoro, K.B.R.; Corrêa, A.C.; Marconcini, J.M.; Mattoso, L.H.C. Sugarcane bagasse whiskers: Extraction and characterizations. Ind. Crop. Prod. 2011, 33, 63–66. [CrossRef]
21. Alemdar, A.; Sain, M. Biocomposites from wheat straw nanofibers: Morphology, thermal and mechanical properties. Compos. Sci. Technol. 2008, 68, 557–565. [CrossRef]
22. Wang, F.; Xie, Z.; Liang, J.; Fang, B.; Piao, Y.; Hao, M.; Wang, Z. Tourmaline-Modified FeMnTiOx Catalysts for Improved Low-Temperature NH3-SCR Performance. Environ. Sci. Technol. 2019, 53, 6989–6996. [CrossRef]
23. Suriani, M.; Zainudin, H.; Ilyas, R.; Petr˚u, M.; Sapuan, S.; Ruzaidi, C.; Mustapha, R. Kenaf Fiber/Pet Yarn Reinforced Epoxy Hybrid Polymer Composites: Morphological, Tensile, and Flammability Properties. Polymers 2021, 13, 1532. [CrossRef]
24. Asrofi, M.; Sujito, S.; Syafri, E.; Sapuan, S.; Ilyas, R. Improvement of Biocomposite Properties Based Tapioca Starch and Sugarcane Bagasse Cellulose Nanofibers. Key Eng. Mater. 2020, 849, 96–101. [CrossRef]
25. Asrofi, M.; Sapuan, S.; Ilyas, R.; Ramesh, M. Characteristic of composite bioplastics from tapioca starch and sugarcane bagasse f iber: Effect of time duration of ultrasonication (Bath-Type). Mater. Today Proc. 2020. [CrossRef]
26. Azman, M. A., Asyraf, M. R. M., Khalina, A., Petrů, M., Ruzaidi, C. M., Sapuan, S. M., ... & Suriani, M. J. (2021). Natural fiber reinforced composite material for product design: A short review. Polymers, 13(12), 1917.