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A Review on Natural Fiber Composite Materials in Automotive Applications

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Abstract

Natural fibers have recently caught the attention of academic and industry researchers due to their ease of availability, environmental friendliness, and biodegradability. Natural fibers derived from plants, such as jute, sisal, banana, flax, hemp, coir, kenaf, and many more, have been extensively researched over the last two decades and are gaining prominence over synthetic fibers. Natural fiber composite materials exhibit excellent strength and stiffness, high fracture resistance, as well as superior thermal and acoustic insulation qualities. Natural fiber reinforced composites have the potential to minimize component cost and material waste in automotive applications. The rising need for lighter, safer, and more fuel-efficient automobiles has led to the increased use of natural fiber composite materials in automotive applications by European automakers over the last decade. This paper investigates recent advancements in the usage of natural fiber-based composite materials in the automobile sector.

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1. Introduction

Sustainability and increased ecological awareness have encouraged researchers to develop effective and novel materials by exploiting natural sources in the automotive sector. Lightweight, eco-friendly, and sustainable use of natural fiber reinforced composites (NFRC) is increasingly considered by automakers and researchers.[1] Over the past five decades, the need for sophisticated advanced materials with more functionality and protection has increased in the automotive industry. Regulation on the reduction of CO_2 emissions are also becoming mandatory across the globe, and this poses a major challenge for vehicle manufacturers. The primary solution is to reduce the total weight of automotive vehicles. Composite manufacturing is emerging rapidly and will replace conventional methods for the making of vehicle parts. Plant based fibers are playing a great measure in this eco-friendly effort. In the area of composite materials, it was witnessed that there is a strong tendency toward the incorporation of naturally available materials. Customer interest for sustainable goods and advances in innovation has expanded because of which the usage of natural fibers are assuming indispensable part in utilization of aviation, automobile, and bio medical applications.[2] Great measure of consideration has been coordinated on the use of natural fiber based materials to discover physical, mechanical, and thermal attributes. A broad range of fibers being used are bamboo, kenaf, hemp, jute, flax, coir, sisal, banana *etc*. Satisfying the need for natural fibers over synthetic fibers in today's market, it is necessary to use currently available materials and search for new plant fibers to facilitate the simple and low-cost extraction methods without damaging the properties of fibers. In this manner the cost of the materials can be reduced.[3] Composites prepared by two or more fibers offer better mechanical, thermal and damping performances compared with single fiber composite materials. Natural fibers are generally used in traditional manner for making ropes, mats, and yarns as well as in the preparation of items like table sheets, handbags, purses, and wall hangings. Fibers extracted from plants like pineapple, banana, and cotton are additionally utilized for making fabric as well as being utilized in the paper industry.[4]

The first use of composite material was reported 6000 years ago as a building material for constructing walls. Concrete has largely replaced this building material in the last century. In general, composites are used in a variety of industries, including building, automotive, and aeronautical, as well as medical and household applications.[5] In the last

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two decades natural fibers are substituting man-made fibers due to their biodegradability, and environmentally friendly nature. They also offer good strength, high stiffness, low density and low cost when compared with manmade fibers.[6] In the previous decade, plant-based fiber composites with polymers have been incorporated by European vehicle makers and providers for dashboards, door panels, headliners, seat backs, and package trays. There is an increasing trend of research interest towards natural fiber-based materials over the last two decades. Most of the studies on these natural fibers are based on the development of innovative materials for the automobile applications.[7] It's fascinating to note that the number of publications published in reputable journals is steadily growing. Natural fiber based composite materials show higher strength and stiffness, making them suitable for automobile applications. Low density, high strength-to-weight ratio, resistance to breakage during manufacturing, low energy content, and recyclability are all benefits of using natural fiber composite materials.[8] Natural fibers, including cellulose, hemicelluloses, pectin, and lignin, are rich in hydroxyl groups. The cellulose is the main components of these fibers. However, the proportion of cellulose, hemicellulose, pectin and lignin ranges from plant to plant. Natural fibers appear to be strongly polar and hydrophilic materials, whereas synthetic polymers are polar and have an enormous hydrophobic effect. Due to weakness in the interfacial adhesion, there are significant problems associated with compatibility between fibers and matrix materials. Although there are various plant fibers available in nature, only a few plant fibers are considered to be suitable for automotive applications.[9,10] The utilization of lightweight, low cost characteristic natural fibers offers the likelihood to override a huge segment of the glass and mineral fillers in different vehicle exterior and interior parts.[11]

Light weight is one of the factors which attracts the natural fiber-based composites in automotive applications. With the use of natural fibers-based composites in various parts of an automobile it is possible to reduce vehicle weight by up to 34%. In the year 2008 it was reported that the weight of a car can be reduced by 32 kg by utilizing components made up of bio-sustainable materials.[12] Ecological interest, as well as regulatory legislation, have prompted companies in many countries to address problems related to the product life cycle and to handle product recovery at the end of the product life cycle.[13]

2. Natural fibers - properties & automobile applications

2.1 Properties of natural fibers

Natural fibers are derived from plants, animals, and minerals. Plant-based cellulosic natural fibers are more cost-effective than animal-based fibers. Furthermore, unlike mineral-based fibers, these are not harmful to one's health. As a result, the NFRCs made from plant-based cellulosic fibers are the primary focus while considering the automobile application.[14] Natural fibers come from various parts of the tree or plant, including the leaves, stems, and roots.[15] Natural fibers are plentiful and have less harvesting costs. The biggest contributing reasons in the discovery and application of bio-composites are the hazards of synthetic fibers, recycling difficulties, and toxic byproducts. Bio-composites are non-abrasive and non-toxic, with characteristics equivalent to synthetic fiber composites and are employed in automobiles.[16]

The chemical structure of the reinforcing fiber and the bonding interface determine the composite's strength. The geographical and environmental conditions under which the tree or plant is grown decide the chemical composition of the plant fiber. It also depends on which portion of the plant the fiber is derived from.[17] The cellulose content and micro-fibrillary angle are the deciding factors of strength for a natural fiber. Higher the cellulose content, stronger the fiber will be. Lower the value of micro-fibrillary angle provides higher strength to fiber.[18]

Studies on NFRCs have demonstrated that as both human-made and natural fiber-based composites are mixed, the resulting polymer has superior properties. Composites in their hybrid form exhibit better properties over single fiber composite. When it is subjected to loading conditions, each individual fiber offers its best possible resistance. Natural fibers are treated with water to make them practically suitable with benefits for improving the properties of natural fiber composites. The effect of surface treatment method on the mechanical properties and interfacial bonding depends on the types of fibers used.[19]

Natural fibers in woven form have recently been utilized to replace synthetic fibers in the production of automotive parts. Because of their weaving structure, composites produced from woven fibers are flexible and have higher mechanical characteristics. Typical mechanical properties of several natural fibers and glass fibers are listed in Table 1. Most promising fibers widely used for value added applications are flax, hemp and kenaf due to their higher strength properties. Kenaf fibers reinforced composites have potential and huge possibility as an alternative to the man-made synthetic fibers particularly in the automotive and aerospace due to its lightweight property and low cost of manufacturing. It can be understood from the table that the natural fibers are showing superior properties well suited for automotive component manufacturing in comparison with the synthetic fibers.[20]

2.2 Studies based on natural fibers for automobile applications

Significant research has already been conducted in order to improve the performance of NFRCs and their applications. This section discusses recent research based on natural fibers aimed towards automotive applications. A study reports on structural design and evaluation of the vehicle bonnet made of flax plant fiber-based bio composite material. The impact test results reveal the suitability of these fibers in the bonnet manufacturing. In addition, these fibers result in low weight components and better compression properties.[22] Mechanical experiments were performed on specimens subjected to

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Table 1. Mechanical properties of typical natural fibers and glass fibers.[21]

Sl. No.	Type of fiber	Density (g/cm^3)	Tensile strength (MPa)	Elongation (%)	Elastic modulus (GPa)
1	Kenaf	0.6–1.5	223–1191	1.6–4.3	11–60
2	Sisal	1.3-1.5	400-700	1.4-2.1	9-55
3	Flax	1.3-1.6	340-1600	1.9-12	8.5–40
4	Hemp	1.1-1.6	285–1735	0.8–4	14.4–70
5	Banana	0.5–1.5	711–789	2.4–3.5	4–32.7
6	Jute	1.3–1.5	385-850	1.1–3.3	25-81
7	Cotton	1.5–1.6	200–800	2.1–12	5.5–15.1
8	Bamboo	1.2–1.5	500–575	1.9–3.2	27–40
9	Coir	1.15–1.6	131–593	14–40	3–7
10	Ramie	1.4–1.55	200–1000	1.2–4	41–130
11	Sugarcane bagasse	1.1–1.6	170–350	6.3–7.9	5.1–6.2
12	Abaca	1.5	430–815	1.2–1.5	31.1–33.6
13	Pineapple	1.56	150–1627	2.4	11-82
14	E-Glass	2.5–2.55	2000–3500	0.5–3	70–73
15	S-Glass	2.5	4570	2.8	86
16	Carbon	1.4–1.78	3400–4800	1.4–1.8	230–425

varying moisture conditions on seven natural fibers (jute, coir, kenaf, flax, abaca, sisal, hemp). The results obtained from these fibers show distinctly promising potential in the automobile application. The investigation further uncovers that alkalization of fibers can harm the fiber strength and results poor mechanical properties.[23] The research carried out on the Caryota fiber properties reveals better mechanical properties of the material so it can be used in the production of automotive components.[24]

Silane treated Leucas Aspera (LA) plant fiber reinforced epoxy composite material exemplifies the improvement in mechanical (tensile and flexural) and thermal properties. Silane treated LA/epoxy composite used in the preparation of brake pads shows higher shear strength compared to un-treated fibers. Thus, silane treated LA fibers can be utilized in applications where good performance and lightweight is prominent.[25] Manimaran *et al*. study fiber derived from Azadirachta indica plant bark and evaluate the physical and chemical properties. The results reveal that these fibers are well suited for the composite materials especially for the application in automotive industries.[26] Structural analysis conducted on automobile hood based on natural flax fiber using commercial analysis software confirms that the composite material is reasonably safe, stable, and light weight. Mechanical tests conducted on the hybrid composite made up of coir and carbon fiber reinforced with epoxy resin show the idea of using two or more fibers are reasonable for the fabrication of the bike helmet cover, car floors and roofs.[27]

Due to scarcity and high cost of leather, several industrialists are attempting to use the combination of leather with natural fibers. A study done on the combination of banana fibers with leather shows good results to use them in automotive applications. Thus, it is advantageous to create natural fiber-based fabrics to help the business in developing new designs.[28] A work published by Nayak *et. al*. using treated Areca sheath (AS) fiber in polyvinyl chloride (PVC) matrix by injection molding method shows that AS/PVC composite can be appropriate substitute material for production of automobile dashboard panel.[29] Jute fibers are used to fabricate front bonnet of a car to replace glass fibers to achieve weight reduction, high speed, low power consumption, and lesser inertia.[30]

Kim *et al*. use pineapple and cassava flour reinforced with poly lactic acid (PLA) and polybutylene succinate (PBS) to study volatile organic compound emissions. The results are compared with polypropylene and polyethylene polymers. The results reveal significant reduction in odor emissions with pineapple, cassava/PLA, PBS-based composites, and this property is well suited for designing automotive interior parts.[31] A study carried out on the design and analysis of a vehicle bonnet using flax fiber reinforced with vinyl ester matrix composite material shows 30% less weight compared to steel bonnet. A study reports the use of natural fiber hybrid plastics (NFHP) in the manufacturing of car dashboards and indoor panes using flax, sisal, and hemp fibers. Luxury car brand Audi is making use of flax and sisal fibers for the making of door trim. Tests conducted on calotropis procera fibers showed that it can be good reinforcement for the fabrication of automobile interiors, and sports equipment. Saccharum bengalense grass fibers are suited for car frames, dashboard design, headliners, decking, box racks, pallets, spare tyre covers, seat backs, and other automobile parts.[32] The findings of a study based on coconut flower covered fiber-reinforced polymer composites for making the eco-friendly material appear to be consistent with the experimental data and so may be recommended as an alternative material, particularly in the automobile sector.[33] Another study into the hybridization of glass fiber with hemp fiber reveals excellent

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impact strength and hardness, making them more suitable for automotive applications.[34] Kenaf fibers are utilized in the fabrication of composite materials while taking into account aspects such as stacking sequence (layer by layer), volume ratio of fibers to matrix, angular orientation of fibers, and chemical modification of fiber surface to improve adhesion to matrix. The results suggest that kenaf-based composites may be used in automobile components such as dash boards, door interiors, and underfloor components.[35]

Abaca fibre has been a prominent contender in the production of natural fiber composites among the natural fibers available on the market. The improved characteristics of the resultant composites have led to applications in a wide variety of automotive sectors.[36] Marichelvam's research on the development of a new hybrid composite from palm sheath and sugarcane bagasse fibers with epoxy resin shows these materials to be acceptable for vehicle dashboard applications with superior mechanical properties.[37] Treated with silane, desmostachya bipinnata fibers are used to make composite materials for low-weight and medium-load automotive component applications.[38] An attempt is made to investigate the effect of milkweed, kusha grass, sisal, banana, and hay fibers combined with polypropylene to create a novel composite material. These composites are proved to be suitable for automotive applications.[39] A hybrid composite is developed for a light weight automobile application using sisal/kenaf fiber reinforced with epoxy matrix hybrid composite (HC). Study of water absorption of HC material finds to have better moisture absorption capacity in comparison with individual fiber composites. Automotive industry is taking advantages of natural fibers to achieve an eco-friendly technology in automobile manufacturing. The sustainability movement is also creating new business opportunities in the automobile industry. As a result, these fibers may be used as a bio fiber in environmentally sustainable materials.[40] Natural fibers with recommended automotive applications are included in Table 2 based on studies published in reputable journals.

3. Automobile companies adopting natural fibers

3.1 History of natural fibers in automobile industry

Ford is the first car manufacturer incorporated flax and straw into soy based panels. During 1990s wood floor and coconut shell fibers were used in the car interior parts. In 1994 R&D section of Mercedes Benz started using jute reinforced polymers for door panes in their E-Class car models. The interior was designed with sisal/flax fibers resulted 20% weight reduction of total vehicle. Same way Benz utilized

Table 2. Various studies published on natural fibers focusing on automobile applications.

Sl. No.	Natural fibres used in the study	Recommended Applications	References
1	Flax plant fiber	Vehicle bonnet	[22]
2	Jute, coir, kenaf, flax, abaca, sisal, hemp	Automobile application	[23]
3	Caryota fiber	Automotive components	[24]
4	Leucas Aspera	Brake pads	[25]
5	Azadirachta indica	Automobile application	[26]
6	Flax	Automobile hood	[27]
7	Banana fibers with leather	Automobile application	[28]
8	Areca sheath	Automobile dashboard panel	[29]
9	Jute fibers	Frontal bonnet of a vehicle	[30]
10	Pineapple and cassava flour	Automotive interior parts	[31]
11	Flax fiber	Vehicle bonnet	[32]
12	Calotropis Procera	Automobile interiors, and sports equipment	[32]
13	Coconut flower cover fiber	Automobile application	[33]
14	Glass fibre with hemp fibre	Automobile application	[34]
15	Kenaf fibres	Automobile components such as dash boards, door interiors, and underfloor components	[35]
16	Abaca fibre	Automobile application	[36]
17	Palm sheath and sugarcane bagasse fibres	Vehicle dashboard applications	[37]
18	Demostachya Bipinnata Fibers	Automotive component applications	[38]
19	Milkweed, kusha grass, sisal, banana, and hay fibres	Automobile application	[39]
20	Sisal/kenaf fiber	Automobile application	[40]

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natural fibers in the preparation of components for Evobus, Setra Top-class cars and Travego Busses. In 1999, Mercedes Benz constituted 65% mixture of flax, hemp and sissal fibers and 35% Baypreg semi-rigid elastomer from Beyer. Kenaf fiber-based composites were widely used in the car interiors as reported by Ford Montero in 1996.[41]

3.2 Natural fiber composites: recent automotive trends

Glass fiber-based composites have shown their ability to meet the structural and reliability requirements of vehicle exterior and interior parts. Great mechanical properties have supported in the inclusion of fiber glass-built up plastics inside the car business. However, glass-fiber based plastics show deficiencies like their moderately high fiber thickness, trouble in machining, and poor reusing properties, and health issues with these fibers. As a result of strict rules set by government, automobile manufacturers are focusing on the environmental impact of a vehicle's entire life cycle. Along with the automobile sector other sectors such as construction, aerospace and marine are also experiencing the increasing in the natural fiber usage. European Union legislation set the benchmark in 2006 that has expedited bio fiber reinforced plastic automotive insertion; by 2006, 80% of an automobile must be recycled or reusable and by 2015 it should be 85%. Japan mandated 88% of a vehicle to be recyclable by 2005, rising to 95% by 2015. Natural fiber composite manufacturing has been pioneered by European companies such as BASF (Germany), Dieffenbacher (Germany), and Rieter Automotive (Switzerland). The eco-friendly drive is creating new trade opportunities in the automotive sector.[42]

Polymer based natural fibers are predominantly used by German automakers to produce various components such as door panels, seat coverings, rear parcel shelf and damping & insulation parts *etc*. Toyota also uses sugar cane-based composites for their interior parts. DaimlerChrysler is involved in technology transfer initiative towards sustainability using green materials. The business focused on the use of natural resources over fossil fuels to foster global sustainability, where the production of a natural fiber-based automotive supply chain will help farmers produce natural fibers in the automotive industry. Another study reported the use of natural fibers in railways for making berths, partitions, floor/roof panels and modular toilets.[43] Table 3 enlists widely used natural fibers in automotive industry in the productions of various components.

Renewable raw materials and recycled plastic materials are employed in the Mercedes-Benz A-Class model (2018) to achieve a high degree of material utilization. A natural fiber mat, together with a thermosetting bonding agent is used in the reinforcing frame of the sliding sunroof to replace the conventional sheet steel frame. This replacement saves resources and reduces weight by nearly half. DaimlerChrysler is the leading European manufacturer to incorporate natural fiber composite parts (Fig. 1) in their Mercedes-Benz vehicles.[49] For this model, jute fiber reinforced composites are used in door panels, flax for engine and gearbox covers, and other fibers such as abaca, hemp, sisal, and wool are utilized for underbody panels, pillar inners, head liner, rear cargo shelf, trunk components, and thermal insulation.[50]

Sports car manufacturer Porsche claimed in 2019 that the 718 Cayman GT4 Club sport racer was the world's first car to have exterior parts made of hemp and flax natural fiber–reinforced composites. Recent investigations on NFRCs have expanded the potential automotive applications of NFRCs, such as flax/vinyl ester composites for hoods, kenaf/epoxy composites for spall liners, maple and pine flour reinforced nylon with thermal stability for under hood parts, and hemp/polypropelene composites resisting weathering for

Table 3. Natural fibers in automobile applications.[44-48]

Natural fibers	Components in automobile
Flax	Door panel cover, covered, instrument panels, covered inserts, arm rests, seat back panels,
Hemp	Door panels, seat back panels, dashboard
Abaca	Body panel, floor panel
Banana	Wrapping paper
Jute	Door panels, Dashboard
Coir	Seat covers, Seat mattresses, mats,
Cotton	Insulation material, sound proofing, trunk panel
Sisal/Flax	Door linings, interior panels
Wood Flour	door panels, arm rest,
Wool	Upholstery, rear seat covers
Wood	Foamed instrument panels, seat back panels, fiber in the seatback cushions, covered inserts and components, inserts,

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Fig. 1 New Mercedes-Benz A-Class and its parts made of natural fiber composites. Adapted from Daimler AG, 2018. Reproduced with the permission form [49]. Copyright@Scientific Electronic Library Online.

interior and decking components and small parts. Bio-composites are employed in BMW's E-class and 7-series vehicles in the interior components including the dashboard. In the Audi A2 model, door trim panels are made of a blend of sisal/flax fibres and polyurethane. Toyota aims to become the number one brand by employing naturally accessible and sustainable products such as 100 percent bioplastics.[51] A team from Kyoto University has demonstrated an outstanding and sporty Nano Cellulose Vehicle (NCV) made of wood fibre at the 46th Motor Show in 2019. This initiative attempts to ensure a 10% weight reduction in automobiles by 2020 in order to reduce CO_2 emissions while retaining strength. An NCV is the 'ultimate zero CO_2 material vehicle' with a number of body and interior parts constructed of Nano-Fibrillated Cellulose (NFC), a future generation material that is one-fifth the weight of steel while being five times stronger than steel.[52]

4. Environmental impact

Vehicle companies have decided to make widespread use of natural fibers for a variety of technological, economic, and environmental reasons. Natural fibers recyclable property decreases environmental impact by eliminating the need for a specific production period, and chemicals indirectly mitigate adverse environmental impacts. They are also low-cost, biodegradable, recyclable and environmentally friendly products. Natural fibers have the property of sound absorption that can be derived from different plants.[53] Noise reduction is possible using sound absorbing materials in various industries. The ratio of the fiber mixture has a significant effect on the sound absorption coefficient and the permeability of the air. The rate of sound absorption decreases as the percentage of increased fiber in the polyester-cotton-bi component mixture increases.[54] Similarly, multi-layer non-woven fiber resist airflow better than single-layer fiber non-woven. Health risks associated with glass and mineral-based fiber goods open the door to the production of natural fiber-based sound absorbing fabrics. Natural fibers with non-abrasive, porous, sturdy insulating, and hygroscopic properties could be used to make inexpensive and long-lasting soundproofing fabrics for automobile, home appliances, and architectural applications. Natural fibers such as kenaf, sisal and jute are usually harvested annually and can be harvested two to three times a year.[55]

A schematic illustration of the sustainable features and potentiality of natural fiber composites in automotive sector presented in Fig. 2. Natural fibers also provide a cure for the discomfort caused by engines, exhaust systems, gears and wheels generated in the form of noise, heat, and electrostatic charges. The non-abrasive properties of natural fibers make them a good choice in terms of protection, as natural fibers do not produce sharp edges when deformed like glass fibers. Natural fibers have been manufactured in many developed nations, paving the way for employment, and reducing environmental hazards. Degradation testing on natural fibers is a recent trend. Researchers have experimented on natural fibers to calculate the rate of degradation and have discovered that the percentage weight of fiber reinforcement improves the rate of degradation. Biodegradability of natural fibers is considered to be the most significant and fascinating aspects of their use in polymeric materials. The development of advanced lightweight biomaterials composites that can replace conventional synthetic structures or metals leads to techniques being proposed to be used in automotive components. Designing a mixture of lightweight and powerful heavy-duty composite panel construction can greatly affect the car's fuel consumption and decrease carbon dioxide emissions. Finally,

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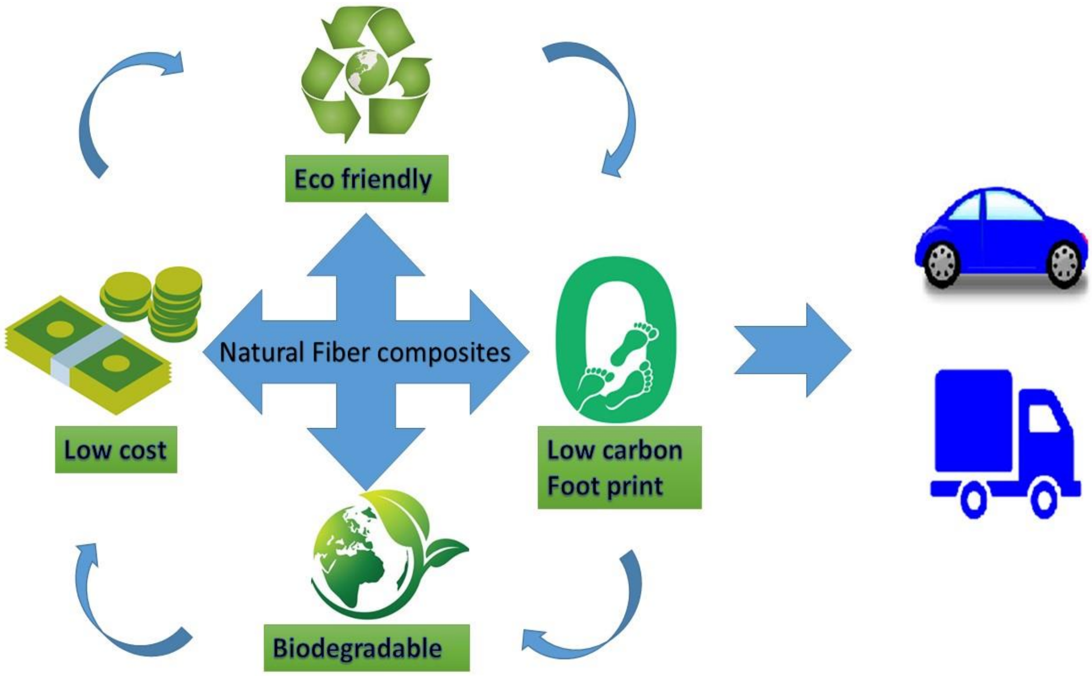

Fig. 2 Sustainable features and potentiality of natural fiber composites in automotive sector.

they may contribute to an improvement in societal well-being and become widely used in the development of urban electric vehicles because they are light and ecological. Bio composites find various types of applications in the automotive sector, such as micro-car body shells, e-bikes, full-electric vehicles, automotive interiors, structural frame parts.[56]

Natural fiber composites have tremendous potential for the automotive industry as the market for lightweight and environmentally sustainable materials becomes higher. Studies suggest that natural fiber composites can lead to a cost reduction of 20 per cent and a weight reduction of 30 per cent of the vehicle component. Studies have proved that the light weight components in automobile results in lower fuel consumption, more recycling potential, and less noise.[57]

5. Challenges in using natural fibers

The use of natural fibers in composite materials includes a variety of problems related to moisture absorption, durability, weak interfacial fiber/matrix adhesion. These materials face the vital challenge of degradation when exposed to the outdoor atmosphere. Various forms of degradation known include chemical, mechanical, climatic, and fire degradation. This results in weak fiber/matrix interface and reduces the strength of the material. Bio degradation is caused by oxidation and enzyme-reaction. As natural fibers are hydrophilic in nature, they absorb moisture in the surrounding environment. It is controlled by the void content of natural fibers and the content of non-crystalline pieces. Rain, snow, dew, and ice are the main sources of moisture. The moisture absorption activity of natural fibers limits the outdoor use of NFPCs. Another significant barrier to the use of natural fibers in various structural applications is their poor fire resistance. Color, odor and thermal degradation effects sometimes affect the mechanical properties of natural fibers. Fiber consistency and quality in the composite is also a major concern. Also, the fiber diameter is not constant over its length, and often it is not fully circular. Natural fibers have a low impact strength and a high fiber concentration causes defects in the composite. Poor fiber/matrix interface is a big difficulty for natural fiber-based composites. Fiber deterioration during composite manufacturing leads to a poor durability, which can be increased with up to a substantial amount of chemical treatment. Hemicellulose is the main component of the fiber that absorbs moisture. Because of this, the fiber swells and often shrinks as it dries.[58]

Fibers require several treatments to address some of the shortcomings listed, including the improvement of interfacial fiber/matrix adhesion. Scientific and technological efforts have been identified to support the technical and economic advancement of crop quality and fiber performance, with the goal of providing new solutions. A lot of work has recently been done to solve these issues in order to increase the efficiency of NFRCs and their applications. Challenges in the adhesives industry, including sustainable and environmentally friendly chemicals that allow bio-derived adhesives, recycling and deboning, and adhesive application surface treatment approaches. The ability to adapt composite materials to particular use is what sets them apart from other materials. In terms of physical, electronic, and chemical properties, composite biomaterials have several advantages over conventional metallic and polymeric biomaterials.[59]

6. Conclusion

Natural fiber-based composite materials have recently caught the interest of the automotive industry for a variety of reasons, including greater fuel efficiency in automobiles, cheaper and

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more reliable building materials, and a growing national interest in ecological sustainability. New composite structures are now being investigated in emerging technologies, and this has the tendency to revolutionize the field of bio-material research and engineering. However, several concerns must be addressed when using natural fibers, such as moisture absorption, durability, and poor fiber-matrix adhesion. Furthermore, the use of natural fibers will help achieve the countries sustainable development goals of eradicating poverty, promoting sustainable industrialization, developing sustainable cities and societies, and responsible production and consumption of material by creating job opportunities in rural and less developed areas.

Conflict of interest

There are no conflicts to declare.

Supporting information

Applicable.

References

[1] H. Sreenivas, N. Krishnamurthy, G. Arpitha, *International Journal of Lightweight Materials and Manufacture*, 2020, **3**, 328–337, doi: 10.1016/j.ijlmm.2020.05.003.

[2] S. Subramanian, R. Rajkumar, T. Ramkumar, *Journal of Natural Fibers*, 2021, **18**, 343-354, doi: 10.1080/15440478.2019.1623744.

[3] Y. Singh, J. Singh, S. Sharma, T. Lam, D. Nguyen, *Journal of Materials Research and Technology*, 2020, **9**, 15593-15603, doi: 10.1016/j.jmrt.2020.11.023.

[4] S. Singaraj, K. Aaron, K. Kaliappa, K. Kattaiya, M. Ranganathan, *Journal of Natural Fibers*, 2021, **18**, 1618-1628, doi: 10.1080/15440478.2019.1697982.

[5] M. Egbo, *Journal of King Saud University-Engineering Sciences*, 2021, 557-568, doi: 10.1016/j.jksues.2020.07.007.

[6] L. Afolabia, P. Melor, M. Yusoff, Z. Ariff, M. Hamizol, *Journal of Materials Research and Technology*, 2019, **8**, 3102–3113, doi: 10.1016/j.jmrt.2017.05.021

[7] R. Ramasubbu, S. Madasamy, *Journal of Natural Fibers*, 2020, **8**, 1544-0478, doi: 10.1080/15440478.2020.1761927.

[8] B. Yousif, A. Shalwan, C. Chin, K. Ming, *Materials & Design*, 2012, **40**, 378-385, doi: 10.1016/j.matdes.2012.04.017.

[9] F. M. Al-Oqla, S. M. Sapuan, *Journal of Cleaner Production*, 2014, **66**, 347-354, doi: 10.1016/j.jclepro.2013.10.050.

[10] K. Reddy, R. Reddy, M. Ramesh, D. Krishnudu, B. Reddy, H. Rao, *Journal of Natural Fibers*, 2021, **18**, 378-389, doi: 10.1080/15440478.2019.1623747.

[11] S. Nayak, S. Khuntia, S. Mohanty, J. Mohapatra, *Journal of Natural Fibers*, 2022, **19**, 450-462, doi: 10.1080/15440478.2020.1745124.

[12] N. Fantuzzi, M. Bacciocchi, D. Benedetti, J. Agnelli, *Composites Part C*, 2021, **4**, 100096, doi: 10.1016/j.jcomc.2020.100096.

[13] M. Li, Y. Pu, V. Thomas, C. Yoo, S. Ozcan, Y. Deng, K. Nelson, A. Ragauskas, *Composites Part B: Engineering*, 2020, **200**, 108254, doi: 10.1016/j.compositesb.2020.108254.

[14] M. Syduzzaman, M. Faruque, K. Bilisik, M. Naebe, *Coatings*, 2020, **10**, 1-34. doi: 10.3390/coatings10100973.

[15] R. Vijay, D. Singaravelu, A. Vinod, I. Raj, M. Sanjay, S. Siengchin, *Journal of Natural Fibers*, 2020, **17**, 1739-1747, doi: 10.1080/15440478.2019.1598914.

[16] M. Zwawi, *Molecules*, 2021, **26**, 404, doi: 10.3390/molecules26020404.

[17] K. Yoganandam, P. Ganeshan, B. NagarajaGanesh, K. Raja, *Journal of Natural Fibers*, 2020, **17**, 1706-1718, doi: 10.1080/15440478.2019.1588831.

[18] R. Vinayagamoorthy, *Journal of Natural Fibers*, 2020, **17**, 1757-1774, doi: 10.1080/15440478.2019.1598916.

[19] D. Cho, J. Seo, H. Lee, C. Cho, S. Han, W. Park, *Advanced Composite Materials*, 2007, **16**, 299-314, doi: 10.1163/156855107782325249.

[20] H. Aisyah, M. Paridah, S. Sapuan, R. Ilyas, A. Khalina, N. Nurazzi, S. Lee, C. Lee, *Polymers*, 2021, **13**, 471, doi: 10.3390/polym13030471.

[21] G. Parka, H. Park, *Composite Structures*, 2018, **184**, 800–806, doi: 10.1016/j.compstruct.2017.10.068.

[22] R. Kumar, M. Haq, A. Raina, A. Anand, *International Journal of Sustainable Engineering*, 2009, **12**, 212-220, doi: 10.1080/19397038.2018.1538267.

[23] M. Symington, W. Banks, O. West, R. Pethrick, *Journal of Composite Materials*, 2009, **43**, 1083-1108, doi: 10.1177/0021998308097740.

[24] S. Vijayakumar, K. Palanikumar, *Journal of Materials Research and Technology*, 2020, **9**, 7915–7925, doi: 10.1016/j.jmrt.2020.05.005.

[25] R. Vijay, S. Manoharan, S. Arjun, A. Vinod, D. Lenin Singaravelu, *Journal of Natural Fibers*, 2020, **18**, 1957-1973 doi: 10.1080/15440478.2019.1710651.

[26] P. Manimaran, P. Senthamaraikannan, K. Murugananthan, M. Sanjay, *Journal of Natural Fibers*, 2018, **15**, 29-38, doi: 10.1080/15440478.2017.1302388.

[27] C. Kong, H. Lee, H. Park, *Composites Part B: Engineering*, 2016, **91**, 18-26, doi: 10.1016/j.compositesb.2015.12.033.

[28] D. Puglia, J. Biagiotti, J. Kenny, *Journal of Natural Fibers*, 2005, **1**, 23-65, doi: 10.1300/j395v01n03_03.

[29] S. Nayak, J. Mohanty, P. Samal, B. Nanda, *Journal of Natural Fibers*, 2020, **17**, 781-792, doi: 10.1080/15440478.2018.1534186.

[30] C. Alves, P. Ferrão, A. Silva, L. Reis, M. Freitas, L. Rodrigues, D. E. Alves, *Journal of Cleaner Production*, 2010, **18**, 313-327, doi: 10.1016/j.jclepro.2009.10.022.

[31] K. Kim, B. Lee, S. Kim, H. Kim, J. Yun, S. Yoo, J. Sohn, *Journal of Hazardous Materials*, 2011, **187**, 37-43, doi: 10.1016/j.jhazmat.2010.07.075.

[32] P. Peças, H. Carvalho, H. Salman, M. Leite, *Journal of Composites Science*, 2018, **2**, 66, doi: 10.3390/jcs2040066.

[33] K. Kumar, D. Keshavan, E. Natarajan, A. Narayan, K. Kumar, M. Deepak, L. Freitas, *Plastics and Recycling Technology*, 2021, **37**, 3-18, doi: 10.1177/1477760619895011.

[34] N. Nachippan, M. Alphonse, V. Bupesh Raja, S. Shasidhar,

 © Engineered Science Publisher LLC 2022

G. Teja, R. Reddy, *Materials Today: Proceedings*, 2021, **44**, 3666-3672, doi: 10.1016/j.matpr.2020.10.798.

[35] H. Sreenivas, N. Krishnamurthy, G. Arpitha, *International Journal of Lightweight Materials and Manufacture*, 2020, **3**, 328-337, doi: 10.1016/j.ijlmm.2020.05.003.

[36] B. Barba, J. F. Madrid, D. Penaloza Jr, *Journal of the Chilean Chemical Society*, 2020, **65**, 4919-4924, doi: 10.4067/s0717-97072020000204919.

[37] M. Marichelvam, P. Manimaran, A. Verma, M. Sanjay, S. Siengchin, K. Kandakodeeswaran, M. Geetha, *Polymer Composites*, 2021, **42**, 512-521, doi: 10.1002/pc.25843.

[38] G. Krishnan, J. Kumar, G. Shanmugasundar, M. Vanitha, N. Sivashanmugam, *Materials Today: Proceedings*, 2021, **43**, 828-831, doi: 10.1016/j.matpr.2020.06.530.

[39] K. Hariprasad, K. Ravichandran, V. Jayaseelan, T. Muthuramalingam, *Journal of Materials Research and Technology*, 2020, **9**, 14029-14035, doi: 10.1016/j.jmrt.2020.09.112.

[40] R. Ramasubbu, S. Madasamy, *Journal of Natural Fibers*, 2020, 1-11, doi: 10.1080/15440478.2020.1761927.

[41] D. Bajwa, S. Bhattacharjee, *Journal of Natural Fibers*, 2016, **13**, 660-669, doi: 10.1080/15440478.2015.1102790.

[42] H. Sreenivas, N. Krishnamurthy, G. Arpitha, *International Journal of Lightweight Materials and Manufacture*, 2020, **3**, 328-337, doi: 10.1016/j.ijlmm.2020.05.003.

[43] M. Haq, A. Raina, R. Kumar, A. Anand, *International Journal of Sustainable Engineering*, 2019, **12**, 212-220, doi: 10.1080/19397038.2018.1538267.

[44] S. Witayakran, W. Smitthipong, R. Wangpradid, R. Chollakup, P. Clouston, *Materials Science and Engineering*, 2017, 166-174, doi: 10.1016/B978-0-12-803581-8.04180-1.

[45] J. Holbery, D. Houston, *JOM*, 2006, **58**, 80-86, doi: 10.1007/s11837-006-0234-2.

[46] A. Ramdhonee, P. Jeetah, *Journal of Environmental Chemical Engineering*, 2017, **5**, 4298-4306, doi: 10.1016/j.jece.2017.08.011.

[47] Food and Agriculture Organization of the United Nations. Unlocking the Commercial Potential of Natural Fibers;Food and Agriculture Organization of the United Nations: Rome, Italy, 2012.

[48] Food and Agriculture Organization of the United Nations. Common Fund for Commodities. In Proceedings of the Symposium on Natural Fibers, 2008.

[49] B. Barba, J. Madrid, P. Penaloza, *Journal of the Chilean Chemical Society*, 2020, **65**, doi: 10.4067/s0717-97072020000204919.

[50] A. G. Daimler, New Mercedes-Benz A-class: Environmental Certificate for the A-class (2018)

[51] M. Li, Y. Pu, V. Thomas, C. Yoo, S. Ozcan, Y. Deng, K. Nelson, A. Ragauskas, *Composites Part B: Engineering*, 2020, **200**, 108254, doi: 10.1016/j.compositesb.2020.108254.

[52] S. M. Sapuan and R. A. Ilyas, Biocomposite and Synthetic Composites for Automotive Applications, *Woodhead Publishing Series in Composites Science and Engineering*, 2020

[53] N. Ramli, N. Mazlan, Y. Ando, Z. Leman, K. Abdan, A. Aziz, N. Sairy, *Materials Science and Engineering*, 2018, **368**, 012012, doi: 10.1088/1757-899x/368/1/012012.

[54] L. Amelia, D. Wahab, C. Haron, N. Muhamad, C. Azhari, *Journal of Cleaner Production*, 2009, **17**, 1572-1579, doi: 10.1016/j.jclepro.2009.06.011.

[55] K. Hariprasada, K. Ravichandranb, V. Jayaseelanc, T. Muthuramalingamd, *Journal of Materials Research and Technology*, 2020, **9**, 14029–14035, doi: 10.1016/j.jmrt.2020.09.112.

[56] R. Song, M. Murphy, C. Li, K. Ting, C. Soo, Z. Zheng, *Drug Design, Development and Therapy*, 2018, **12**, 3117-3145, doi: 10.2147/dDDT.s165440.

[57] M. Huda, L. Drzal, D. Ray, A. Mohanty, M. Mishra, *Woodhead Publishing: Oxford*, UK, 2008, ISBN 9781845692674.

[58] J. Ighalo, C. Adeyanju, S. Ogunniyi, A. Adeniyi, S. Abdulkareem, *Composite Interfaces*, 2020, 1-36, doi: 10.1080/09276440.2020.1826274.

[59] Z. Azwa, B. Yousif, A. Manalo, W. Karunasena, *Materials & Design*, 2013, **47**, 424-442, doi: 10.1016/j.matdes.2012.11.025.

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