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A Review on Natural Fiber Composite Materials in Automotive Applications

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Abstract: *Researchers from academia and business have lately been interested in natural fibers because of their accessibility, environmental friendliness, and biodegradability. After two decades of intensive study, natural plant-based fibers—including jute, sisal, banana, flax, hemp, coir, kenaf, and many more—are becoming more and more popular than synthetic fibers. Superior thermal and acoustic insulating properties, great fracture resistance, and exceptional strength and stiffness are all shown by natural fiber composite materials. In automotive applications, natural fiber reinforced composites may reduce material waste and component costs. Over the last ten years, European automakers have used more natural fiber composite materials in automotive applications because to the growing need for lighter, safer, and more fuel-efficient vehicles. This study explores the latest developments in the use of composite materials based on natural fibers in the automotive industry.*

Keywords: Environmental Impact, Composite Manufacturing, Mechanical Properties

I. INTRODUCTION

Researchers have been inspired by sustainability and heightened ecological consciousness to create innovative and efficient materials in the automobile industry by using natural resources. Researchers and automakers are increasingly looking at using natural fiber reinforced composites (NFRC) in a sustainable, lightweight manner.[1] In the last fifty years, the automobile industry has required increasingly complex, innovative materials that provide more usefulness and protection. Globally, regulations aimed at lowering CO2 emissions are increasingly becoming required, which presents a significant obstacle for automakers. Reducing the overall weight of automobiles is the main answer. Vehicle components will be manufactured using composite materials, which are becoming more and more popular. Plant-based fibers are a major contributor to this environmentally beneficial endeavor. It has been observed that there is a significant trend toward the inclusion of naturally occurring components in the field of composite materials. Because of growing consumer demand for sustainable products and technological advancements, natural fibers are becoming more important for use in automotive, aerospace, and biomedical applications.[2]

A great deal of thought has gone into determining the physical, mechanical, and thermal properties of materials based on natural fibers. Many other types of fibers are being employed, including banana, kenaf, hemp, jute, flax, coir, and sisal. In order to meet the market's need for natural fibers rather than synthetic ones, it is essential to make use of the resources presently in stock while also looking for novel plant fibers that can be extracted using simple, inexpensive techniques without compromising the qualities of the fibers. The cost of the materials may be decreased in this way.

When compared to single fiber composite materials, composites made of two or more fibers have superior mechanical, thermal, and damping properties. Natural fibers are often used in a traditional way to prepare goods like tablecloths, wall hangings, handbags, purses, and ropes, mats, and yarns. Plants such as pineapple, banana, and cotton also provide fibers that are used in the paper industry and in the production of textiles.[4] It has been documented that composite material was initially used to create walls 6000 years ago. Over the last century, concrete has essentially taken the role of this construction material.

Composites are often employed in many different sectors, such as the construction, automotive, and aerospace industries, in addition to being used in home and medical applications.[5] Because natural fibers are ecologically beneficial and biodegradable, they have replaced synthetic fibers in the past 20 years. In comparison to synthetic fibers,

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they also provide excellent strength, high stiffness, low density, and cheap cost.[6] Over the last ten years, European automakers and suppliers have been using plant-based fiber composites with polymers for dashboards, door panels, headliners, seat backs, and package trays. Over the last 20 years, there has been a growing trend in research attention towards materials based on natural fibers. The majority of research on these natural fibers is focused on creating novel materials for use in automotive applications.[7] The fact that there are more and more papers appearing in respectable journals is exciting to see. Composite materials made of natural fibers have greater strength and stiffness, which makes them appropriate for use in automotive applications.

Using natural fiber composite materials has many advantages, including low density, high strength-to-weight ratio, resistance to breaking during manufacture, low energy content, and recyclability.[8] Natural fibers are high in hydroxyl groups, and they include cellulose, hemicelluloses, pectin, and lignin. These fibers' primary constituent is cellulose. Plant-to-plant variations exist in the amounts of cellulose, hemicellulose, pectin, and lignin. While manufactured polymers are polar and have a significant hydrophobic impact, natural fibers seem to be extremely polar and hydrophilic materials. Compatibility issues between matrix materials and fibers are serious because of the weakness in the interfacial adhesion. While nature offers a wide variety of plant fibers, only a select handful are thought to be appropriate for use in automobile applications.[10,9] The possibility to replace a significant portion of the glass and mineral fillers in various car exterior and interior components exists with the use of lightweight, inexpensive distinctive natural fibers.One of the things that draws natural fiber-based composites for automotive applications is their low weight [11]. It is feasible to lower an automobile's weight by up to 34% by using composites made of natural fibers in different areas of the vehicle. It was stated in 2008 that automotive weight may be decreased by 32 kg by using components composed of bio-sustainable materials.[12] Companies in many nations are now compelled by regulatory laws and ecological interest to manage product recovery at the conclusion of the product life cycle as well as issues pertaining to the product life cycle.

Natural fibers - properties & automobile applications

Properties of natural fibers

Natural fibers come from minerals, plants, and animals. Compared to animal-based fibers, plant-based cellulosic natural fibers are more affordable. Moreover, these fibers don't pose a health risk, in contrast to those made of minerals. When thinking about the automotive use, the NFRCs derived from plant-based cellulosic fibers are the main emphasis.[14] Natural fibers are derived from the leaves, stems, and roots of trees and plants.[15] Natural fibers are abundant and need less money to harvest. The risks associated with synthetic fibers, the challenges associated with recycling, and the presence of hazardous byproducts are the main factors that led to the development and use of bio- composites. Cars use bio-composites because they are non-toxic and non-abrasive, and they have properties similar to synthetic fiber composites.[16]

The strength of the composite is determined by the bonding contact and the chemical structure of the reinforcing fiber. The chemical makeup of plant fiber is determined by the geographic and environmental factors in which the tree or plant is cultivated. Additionally, it is dependent on the part of the plant from which the fiber originates.[17] The cellulose concentration and micro-fibrillary angle are what determine a natural fiber's strength. The fiber will be stronger the higher the cellulose content.

Lower the value of micro-fibrillary angle provides higher strength to fiber.[18]

Research on non-fibrous resin composites (NFRCs) has shown that when natural and synthetic fiber-based composites are combined, the resultant polymer has better qualities. Hybrid composites provide superior qualities compared to single fiber composites. Every every fiber provides the best resistance it can under loading situations. In order to realistically suit natural fibers and improve the qualities of natural fiber composites, they are treated with water. The kinds of fibers employed determine how the surface treatment procedure affects the mechanical characteristics and interfacial bonding.[19]

Recently, synthetic fibers have been replaced by woven natural fibers in the manufacturing of vehicle components. Composites made from woven fibers are more mechanically advanced and flexible due to their weaving structure. Table 1 lists the typical mechanical characteristics of a number of glass and natural fibers. Because of their greater

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strength qualities, flax, hemp, and kenaf are the most promising fibers that are often employed for value-added applications. Because kenaf fibers are lightweight and inexpensive to produce, they have a great deal of promise as a replacement for man-made synthetic fibers, especially in the automobile and aerospace industries. The table makes it clear that, when compared to synthetic fibers, natural fibers exhibit better qualities that make them more suitable for use in the production of vehicle components.[20]

Studies based on natural fibers for automobile applications

Considerable investigation has already been carried out to enhance the functionality of NFRCs and their uses. Recent natural fiber-based research with an eye on automotive applications is covered in this section. A research details the structural planning and assessment of the car bonnet composed of a bio composite material based on flax plant fibers. The results of the impact test demonstrate that these fibers are suitable for use in the manufacture of bonnets. Better compression qualities and reduced weight components are also produced by these fibers.[22]

Specimens on seven natural fibers (jute, coir, kenaf, flax, abaca, sisal, and hemp) were treated to different moisture conditions for the purpose of mechanical testing. The outcomes derived from these fibers indicate a very bright future for the automotive industry. Further research reveals that fiber alkalization may reduce fiber strength and result in subpar mechanical qualities.[23] Better mechanical qualities of the material are shown by the study on Caryota fiber properties, making it suitable for application in the manufacture of automobile components.[24]

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

Leucas Aspera (LA) plant fiber reinforced epoxy composite material treated with silane is an excellent example of how mechanical (tensile and flexural) and thermal characteristics have improved. When compared to untreated fibers, silane-treated LA/epoxy composite, which is used to produce brake pads, exhibits better shear strength. Consequently, silane-treated LA fibers may be used in applications where lightweight and high performance are important factors.[25]

Manimaran et al. examine the physical and chemical characteristics of fiber made from the bark of the Azadirachta indica plant. The findings show that these fibers are a good fit for composite materials, particularly for use in the automobile sector.[26] Using commercial analytical tools, a structural examination of an automotive hood made of natural flax fiber indicates that the composite material is fairly safe, stable, and lightweight. Mechanical testing on a hybrid composite consisting of carbon fiber reinforced with epoxy resin and coir indicates that the concept of using two or more fibers is appropriate when fabricating automobile floors, roofs, and bike helmet covers.[27]

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Owing to its scarcity and expensive cost, a number of entrepreneurs are trying to combine leather with natural fibers. According to a research, using banana fibers and leather together has positive effects for usage in automotive applications. Making textiles from natural fibers will thus benefit the company as it develops new ideas.[28] According to a study by Nayak et al., AS/PVC composite might be a suitable replacement material for dashboard panels made of automobiles. The study used treated Areca sheath (AS) fiber in a polyvinyl chloride (PVC) matrix by injection molding technique.[29] In order to reduce weight, achieve fast speed, low power consumption, and reduced inertia, jute fibers are used instead of glass fibers in the construction of an automobile's front bonnet.[30]

Kim et al. investigate emissions of volatile organic compounds using cassava and pineapple flour fortified with polybutylene succinate (PBS) and polylactic acid (PLA). Polypropylene and Polyethylene polymers are used to compare the outcomes. According to the findings, odor emissions from pineapple, cassava/PLA, and PBS-based composites are significantly reduced; this feature makes them ideal for use in the design of interior car components.[31] According to a research, a vehicle bonnet made of a composite material reinforced with flax fiber and vinyl ester matrix weighs 30% less than a steel bonnet. According to a research, hemp, sisal, and flax fibers are used to create natural fiber hybrid polymers (NFHP), which are then used to make interior and automotive dashboards. Flax and sisal fibers are used by luxury automaker Audi to make door trim.

Calotropis procera fibers have been tested and shown to be a useful reinforcing material for sports equipment and car interiors. Car frames, dashboard designs, headliners, decking, box racks, pallets, spare tire covers, seat backs, and other automotive components are suitable for Saccharum bengalense grass fibers.[32] The results of a research using fiber-reinforced polymer composites covered with coconut flowers to create the eco-friendly material seem to be in line with the testing results, so it might be suggested as a substitute material, especially for the automotive industry.[33] Additional research on the hybridization of hemp and glass fiber showed superior hardness and impact strength, which makes them more appropriate for use in automotive applications.[34]

When creating composite materials, kenaf fibers are used while accounting for factors including the order in which the layers are stacked, the volume ratio of the fibers to the matrix, the orientation of the fibers, and the chemical modification of the fiber surface to enhance adhesion to the matrix. The findings imply that dash boards, door interiors, and underfloor components may be made of composite materials based on kenaf.[35]

Among the natural fibers on the market, abaca fiber has been a major competitor in the creation of natural fiber composites. Numerous automotive industries have found use for the enhanced properties of the resulting composites.[36] According to Marichelvam's study, materials made of palm sheath and sugarcane bagasse fibers combined with epoxy resin may be used for dashboard applications in cars because of their excellent mechanical qualities.[37] Desmostachya bipinnata fibers treated with silane are used to create composite materials for applications involving medium-load and low-weight automobile components.[38] In an effort to develop a unique composite material, the effects of combining fibers from milkweed, kusha grass, sisal, bananas, and hay with polypropylene are investigated. It has been shown that these composites are appropriate for use in automobiles.[39] For a lightweight automotive application, a hybrid composite reinforced with epoxy matrix hybrid composite (HC) is created with sisal/kenaf fiber.

When compared to individual fiber composites, the study on the water absorption of HC material reveals a higher moisture absorption capability. Natural fibers are being used by the automotive industry to produce environmentally friendly technologies in the production of automobiles. The automotive sector is seeing a surge in business prospects due to the sustainability movement. These fibers might thus be used as a biofiber in products that are ecologically friendly.[40] Table 2 lists natural fibers with suggested uses in automobiles based on research findings that have been published in respectable publications.

Automobile companies adopting natural fibers

History of natural fibers in automobile industry

Ford is the first automaker to use straw and flax in soy-based panels. In the 1990s, interior automobile components were made of coconut shell fibers and wood floors. Mercedes-Benz's R&D department began using jute-reinforced polymers for the door panes of its E-Class automobiles in 1994. With the use of sisal/flax fibers in the interior design, the vehicle's overall weight was reduced by 20%. In a similar manner, Benz used natural fibers to produce parts for the

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Travego bus, Setra Top-class vehicles, and Evobus. In 1999, 35% of the semi-rigid Baypreg elastomer from Beyer and 65% of a blend of flax, hemp, and sissal fibers made up Mercedes Benz. According to a 1996 Ford Montero study, kenaf fiber-based composites were commonly employed in automobile interiors.[41]

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, andhay fibres	Automobile application	[39]
20	Sisal/kenaf fiber	Automobile application	[40]

Natural fiber composites

Current trends in automobiles The capacity of glass fiber-based composites to satisfy the structural and reliability requirements of automotive exterior and interior elements has been shown. Excellent mechanical qualities have encouraged the use of fiber-glass-built-up polymers in the automotive industry.Glass-fiber-based polymers, however, have drawbacks such as relatively thick fibers, machining difficulties, poor reuse qualities, and health problems associated with these fibers. Due to government regulations, automakers are concentrating on how a vehicle's whole life cycle affects the environment. The use of natural fiber is rising not just in the automotive industry but also in the construction, aerospace, and marine industries. In 2006, European Union law established a standard that accelerated the use of bio fiber reinforced plastic in automobiles; by 2015, 85% of a car should be recyclable or reusable, up from 80% in 2006. By 2005, 88% of cars in Japan had to be recyclable; by 2015, that percentage had increased to 95%. European businesses including Rieter Automotive (Switzerland), Dieffenbacher (Germany), and BASF (Germany) have been at the forefront of the manufacture of natural fiber composites. In the car industry, the eco-friendly movement is opening up new trade prospects.[42]

German automakers typically utilize natural fibers with polymer bases to build door panels, seat covers, rear parcel shelves, and dampening and insulation pieces, among other components. Toyota also makes interior elements out of composites derived from sugar cane. DaimlerChrysler is a part of a technology transfer program that uses environmentally friendly materials to promote sustainability. In order to promote global sustainability, the company concentrated on using natural resources rather than fossil fuels. Specifically, it developed a natural fiber-based automotive supply chain that would assist farmers in producing natural fibers for the automotive sector. A other research said that natural fibers were used in railroads to make floor/roof panels, berths, dividers, and modular restrooms.[43] Table 3 outlines the natural fibers that are often utilized in the automobile industry to produce different components.

The Mercedes-Benz A-Class model (2018) uses recycled plastic and renewable raw materials to get a high level of material usage. The traditional sheet steel reinforcement frame of the sliding sunroof is replaced with a natural fiber mat and a thermosetting bonding agent. This substitute uses less material and weighs almost half as much. The first European carmaker to use natural fiber composite components in Mercedes-Benz automobiles is DaimlerChrysler (Fig. 1).[49] Jute fiber reinforced composites are used for the door panels on this model, while flax is used for the engine and gearbox covers. Other fibers used in the construction of the underbody panels, pillar inners, head liner, rear cargo shelf, trunk components, and thermal insulation include abaca, hemp, sisal, and wool.[50]

In 2019, the sports car manufacturer Porsche said that its 718 Cayman GT4 Club sport racer was the first vehicle in the world to include external components composed of natural fiber-reinforced composites of hemp and flax. The potential uses of non-fiber reinforced composites (NFRCs) in automotive applications has been broadened by recent research. For example, kenaf/epoxy composites for spall liners, hemp/polypropelene composites that resist weathering for interior and decking components, and flax/vinyl ester composites for hoods are just a few examples.

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, seatback 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. Reproducedwith the permission form [49]. Copyright@Scientific Electronic Library Online.

The dashboard and other interior parts of BMW's E-class and 7-series cars are made of bio-composite material. Polyurethane and a mixture of flax and sisal fibers are used to make the door trim panels of the Audi A2. Toyota wants to be the best brand by using sustainable and easily obtainable materials, including 100% bioplastics.[51] At the 46th Motor Show in 2019, a group from Kyoto University showcased a remarkable and agile wood-fiber Nano Cellulose Vehicle (NCV). This program aims to guarantee a 10% weight reduction in cars by 2020 so that CO2 emissions may be decreased without sacrificing strength. The "ultimate zero CO2 material vehicle," or NCV, is made up of many body and interior components made of Nano-Fibrillated Cellulose (NFC), a material of the future that weighs one-fifth as much as steel but is five times stronger.[52]

Environmental impact

Natural fibers are now widely used in vehicles by automakers for a number of technical, financial, and environmental reasons. Chemicals indirectly lessen negative environmental effects, whereas the recyclable nature of natural fibers reduces environmental impact by doing away with the need for a set manufacturing time. In addition, they are inexpensive, recyclable, biodegradable, and ecologically beneficial goods. The ability of natural fibers to absorb sound comes from a variety of plants.[53] A variety of sectors may reduce noise by using sound-absorbing materials. The air's permeability and sound absorption coefficient are significantly impacted by the fiber mixture's ratio. As the ratio of increasing fiber in the blend of polyester, cotton, and bi components rises, the rate of sound absorption lowers.[54] In a similar vein, multilayer nonwoven fibers prevent airflow more effectively than single-layer nonwoven fibers. The possibility of producing natural fiber-based sound-absorbing textiles is made possible by the health dangers connected to glass and mineral-based fiber products. Affordable and durable soundproofing materials for cars, household appliances, and architecture might be made from natural fibers with non-abrasive, porous, strong insulating, and hygroscopic qualities. Natural fibers like jute, sisal, and kenaf may be harvested twice or three times a year, although they are often harvested yearly.[55]

Figure 2 presents a schematic representation of the sustainable attributes and prospective applications of natural fiber composites in the automobile industry. The noise, heat, and electrostatic charges produced by engines, exhaust systems, gears, and wheels may also be relieved by using natural fibers. Natural fibers are a suitable option for protection since they are not as abrasive as glass fibers and do not develop sharp edges when distorted. Many wealthy countries have moved toward manufacturing natural fibers, which has reduced environmental dangers and created jobs. There has been a recent trend in natural fiber degradation testing. By calculating the percentage weight of fiber reinforcement, researchers have shown that the rate of deterioration may be improved via experiments on natural fibers. Natural fibers' capacity to biodegrade is seen to be one of their most important and intriguing properties when it comes to using them in polymeric materials. Techniques for using biomaterials composites in automobile components are being developed as a result of the development of improved lightweight materials that may replace metals or traditional synthetic structures. The car's fuel efficiency and carbon dioxide emissions may be significantly reduced by designing a combination of strong, lightweight composite panel construction. Lastly, since they are lightweight and environmentally friendly, they may enhance societal well-being and find widespread use in the creation of urban electric cars.

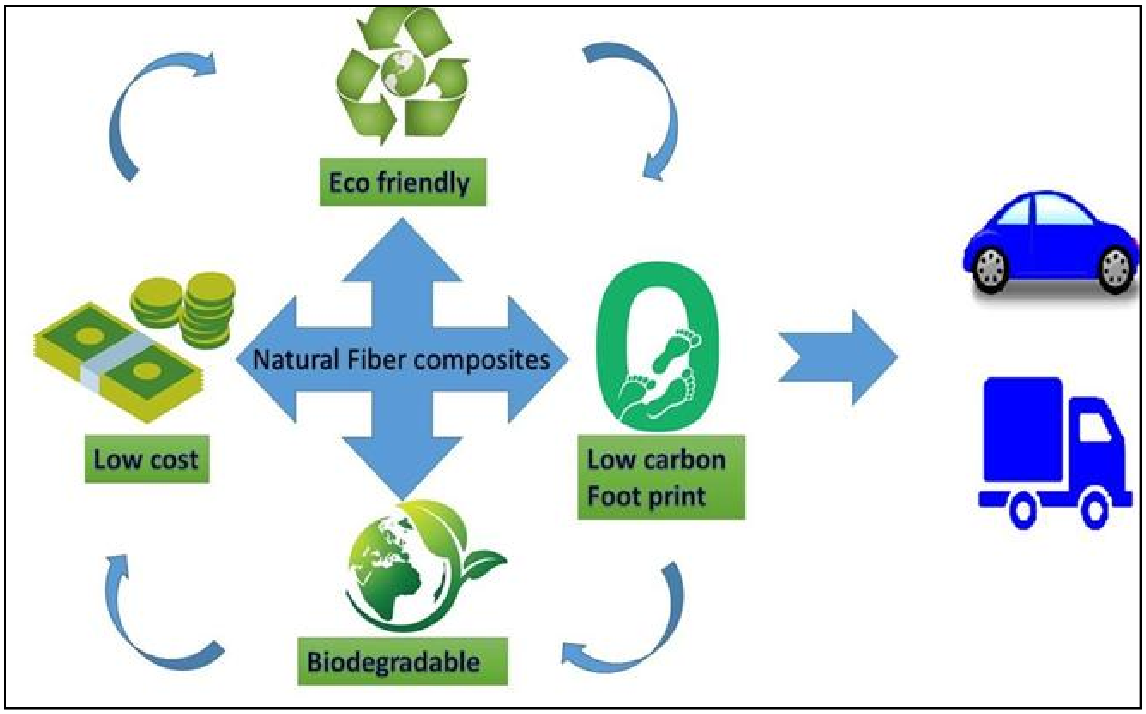

Fig. 2 Sustainable features and potentiality of natural fiber composites in automotive sector.

Bio composites are used in the automobile industry for a variety of purposes, including the body shells of microcars, e-bikes, fully electric cars, automotive interiors, and structural frame sections.[56]

The car sector stands to benefit greatly from natural fiber composites as demand for eco-friendly and lightweight materials rises. According to studies, using natural fiber composites may result in a 20% cost savings and a 30% weight reduction for the vehicle component. Research has shown that automobiles with lightweight components use less gasoline, have more potential for recycling, and produce less noise.[57]

Challenges in using natural fibers

There are many issues with natural fiber utilization in composite materials, such as poor interfacial fiber/matrix adhesion, moisture absorption, and durability. When exposed to the external climate, these materials must contend with the critical obstacle of deterioration. There are many types of degradation that are recognized, such as fire, mechanical, climatic, and chemical degradation. This lowers the material's strength and produces a weak fiber/matrix interaction. Enzyme reactions and oxidation lead to biodegradation. Natural fibers absorb moisture from their surroundings since they are hydrophilic by nature. It is governed by the amount of non-crystalline particles and the void content of natural fibers. The principal moisture-producing elements are rain, snow, dew, and ice. The usage of NFPCs outdoors is restricted by their natural fibers' ability to absorb moisture. Their low fire resistance is a major deterrent to the use of natural fibers in many structural applications. Natural fibers' mechanical qualities may sometimes be impacted by color, smell, and the impacts of heat deterioration. Another key worry is the composite's fiber quality and uniformity. Furthermore, the fiber's diameter varies throughout its length and is often not perfectly round. Low impact strength and high fiber concentration in natural fibers lead to flaws in the composite. One of the main problems with natural fiber-based composites is a poor fiber/matrix interaction. A significant quantity of chemical treatment may be used to improve the low durability caused by fiber breakdown during the composite production process. The primary part of the fiber that takes in moisture is hemicellulose. As a result, the fiber swells and often shrinks throughout the drying process.[58]

In order to increase interfacial fiber/matrix adhesion and solve some of the stated problems, fibers need to undergo several treatments. In order to provide new solutions, scientific and technological activities have been recognized to promote the technical and economic improvement of crop quality and fiber performance. In an effort to improve the effectiveness of NFRCs and their applications, a great deal of work has lately been done to address these problems. Adhesive application surface treatment techniques, recycling and deboning, and ecologically acceptable and sustainable chemicals that permit bio-derived adhesives are some of the challenges facing the adhesives industry. What distinguishes composite materials from other materials is their capacity to be tailored to a specific purpose. Composite biomaterials are superior to traditional metallic and polymeric biomaterials in a number of ways, including their physical, electrical, and chemical capabilities.[59]

II. CONCLUSION

The car industry has lately shown interest in natural fiber-based composite materials for a number of reasons, including increased vehicle fuel economy, more affordable and dependable construction materials, and a rising public interest in ecological sustainability. Emerging technologies are now exploring new composite architectures, which have the potential to completely transform the area of biomaterial engineering and research. However, employing natural fibers raises a number of issues that need to be addressed, including poor fiber-matrix adhesion, moisture absorption, and durability. Furthermore, by generating jobs in rural and underdeveloped areas, the use of natural fibers will contribute to the nation's efforts to eradicate poverty, advance sustainable industrialization, build sustainable cities and societies, and practice responsible material production and consumption.

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