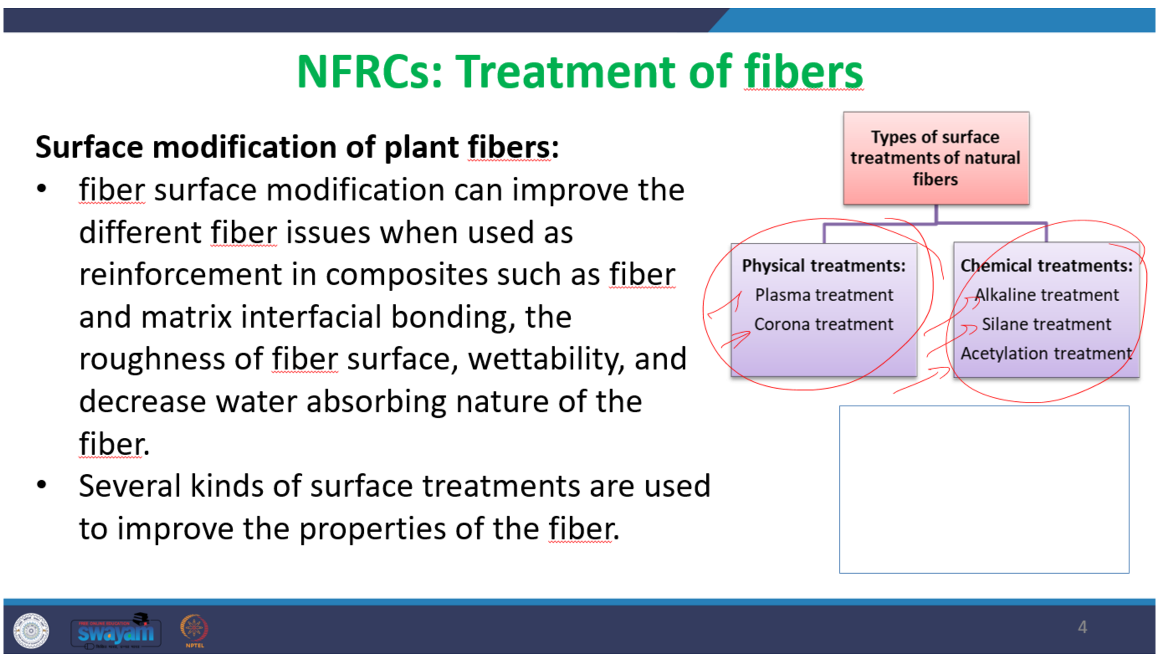
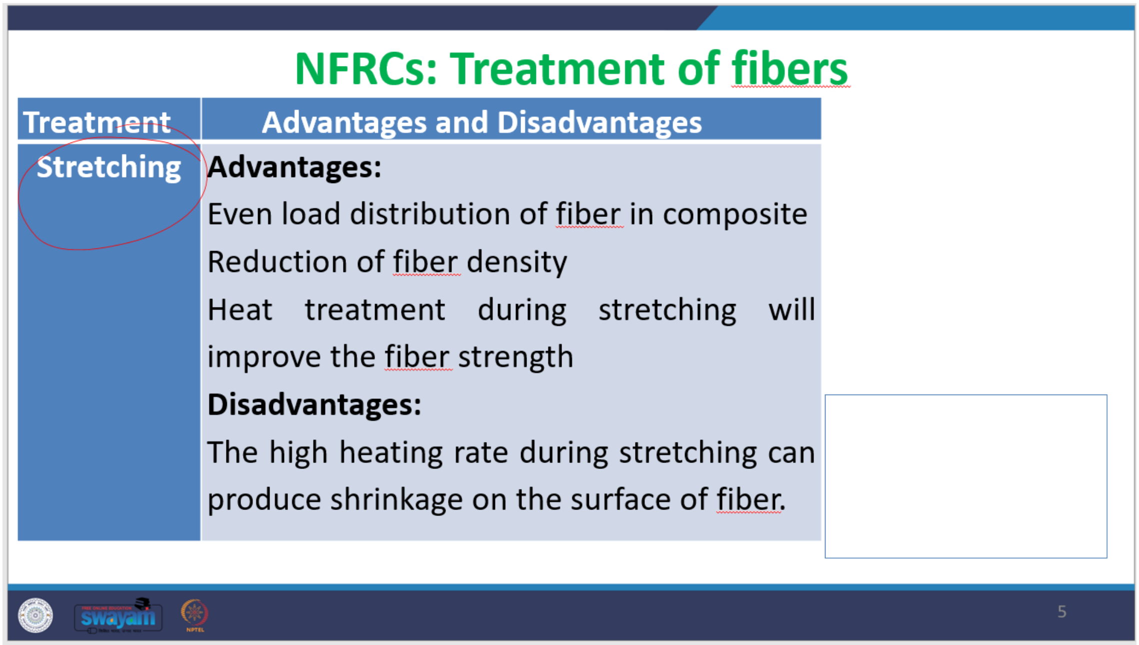
Lecture 55: Natural fiber reinforced composites-II

Hello friends, welcome to the next aspect of Natural Fiber Fiber-Reinforced Composites under the umbrella of Polymer Process Engineering. In the previous lecture, we covered the introduction of natural fiber-reinforced composites, discussed different types of natural fibers, and then classified, applied, and discussed various issues attributed to using natural fiber-reinforced composites. In this particular segment, we will delve into the treatment of fibers because the interface between the fiber and the poly matrix plays a vital role, and sometimes dissociation may occur. That is why treating these fiber matrices is essential for establishing a close bond between the polymer matrix and fibers. Subsequently, we will discuss the various advantages and disadvantages of these treatments. Moving forward, we will explore the utilization of these natural fiber-reinforced composites in different high-end technology sectors.

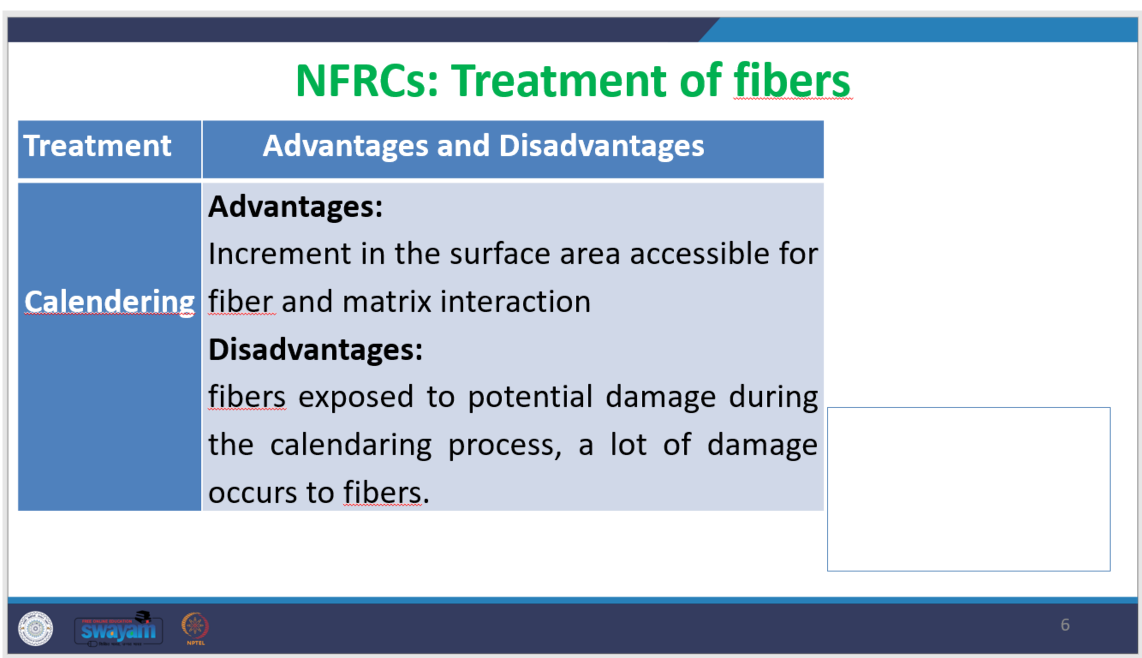
As mentioned earlier, fiber treatment plays a crucial role. The necessity arises from the fact that we cannot alter various other ingredients of these fibers. Therefore, surface modification becomes crucial in these fiber treatments as well.



The ultimate aim is to achieve a closer interface between the polymer matrix and these fibers. Surface modification of these fibers can improve various fiber-related issues when used as a reinforcement in composites, such as fiber and matrix interfacial bonding, the roughness of the fiber surface, wettability, and a decrease in the water-absorbing nature of the fiber. Various types of surface treatments are employed to enhance the properties of the fiber, including physical treatment, plasma treatment, corona treatment, and chemical treatments like alkaline treatment, silane treatment, and acetylation treatment. All these methods contribute to the modification of the surface of these fibers.



Another treatment method is stretching. The advantages include the reduction of fiber density and improved fiber strength through heat treatment during stretching. However, a disadvantage is that the high heating rate during stretching can cause shrinkage on the surface of the fiber.



Calendaring is another approach where the advantage lies in the increased surface area accessible for fiber and matrix interaction. Conversely, the disadvantage is that the fiber is exposed to potential damage during the calendaring process, leading to significant fiber damage.

NFRCs: Treatment of fibers

Treatment	Advantages and Disadvantages
Solvent extraction	Advantages: By solvent extraction process, huge fiber cellulose content is obtained from plants. Disadvantages: By-products from the solvent extraction process are dangerous to the ecosystems.

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Solvent extraction is a process through which substantial amounts of fiber and cellulose content are obtained from plants. However, the downside is that the byproduct from the solvent extraction process can be hazardous to the ecosystem.

NFRCs: Treatment of fibers

Treatment	Advantages and Disadvantages
Corona treatment	**Advantages:** fiber wettability improved. The compatibility between hydrophilic fibers and the hydrophobic matrix can be enhanced by corona treatment. **Disadvantages:** Surface etching can decrease the fiber sustainability

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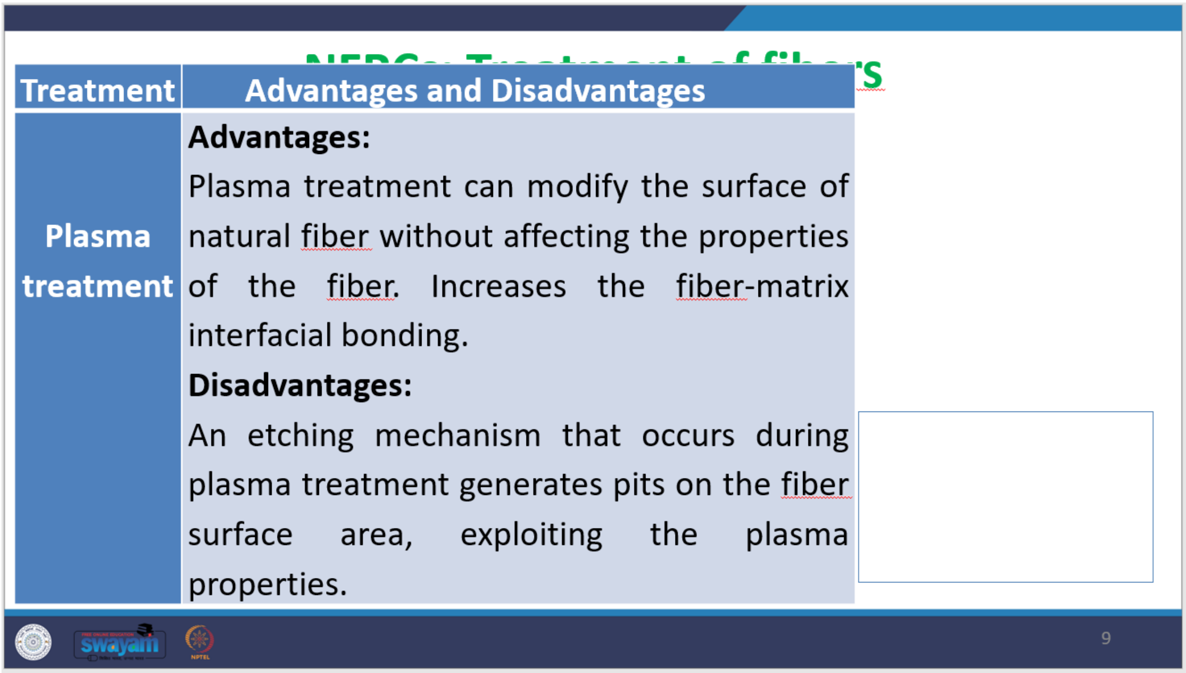
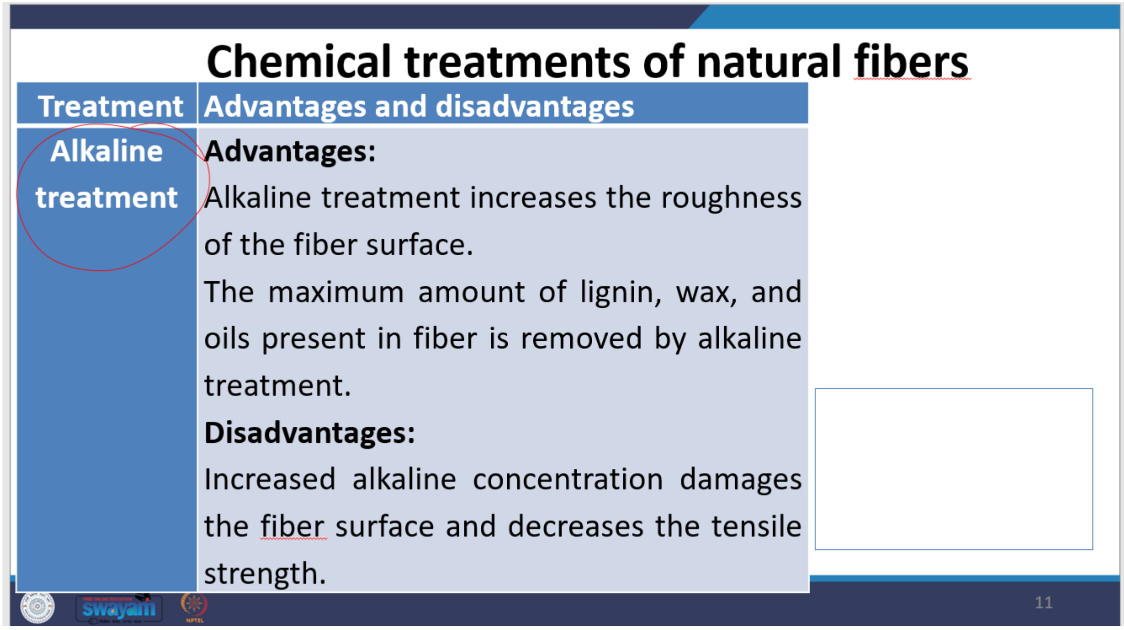
Corona treatment serves to enhance fiber wettability, improving compatibility between hydrophilic fibers and hydrophobic matrices. However, surface etching can decrease fiber sustainability, presenting a serious disadvantage.



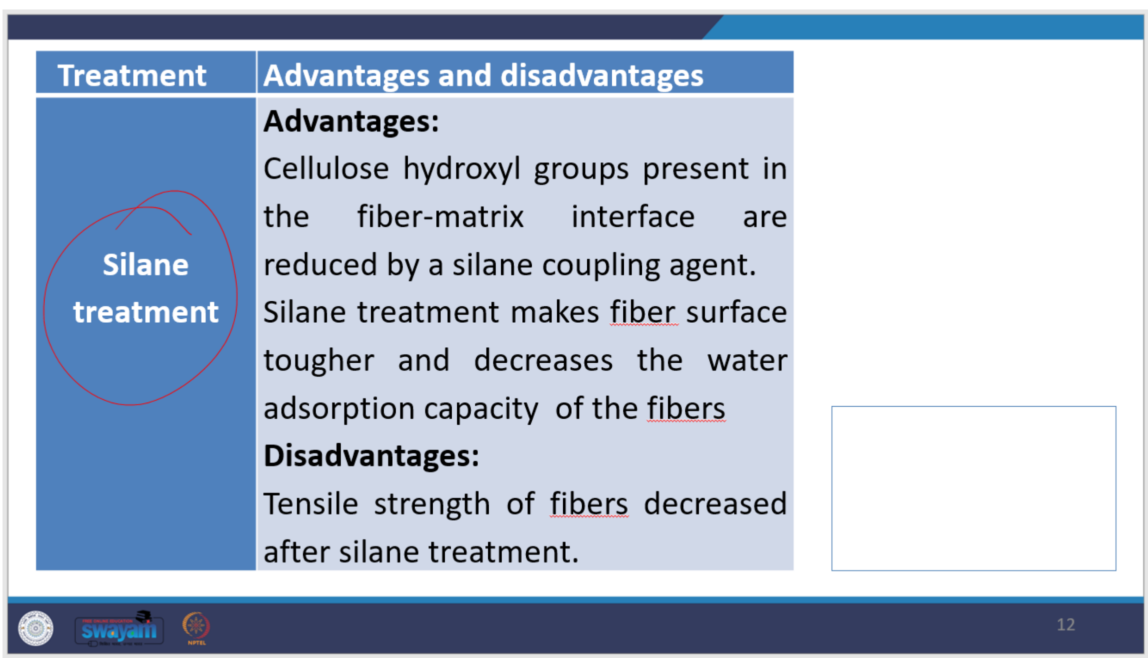
Plasma treatment can modify the surface of natural fiber without affecting the properties of the fiber, and it increases the fiber matrix interfacial bonding. However, a disadvantage of this process is the etching mechanism that occurs during plasma treatment, generating pits on the fiber surface and exploiting the plasma properties.

Now, let's delve into the chemical treatment of natural fiber. Various chemical treatments are utilized to modify the fiber surface, with alkaline, silane, coupling agents, peroxides, and permagnets being among the chemicals employed. These chemical treatments have the dual benefit of enhancing the mechanical properties of natural fiber and removing weak components like hemicellulose and lignin.

Examining specific chemical treatments, alkaline treatment increases the roughness of the fiber surface, effectively removing the maximum amount of lignin, wax, and oil present in the fiber. However, a drawback is associated with the increased alkaline concentration, which damages the fiber surface and reduces tensile strength.

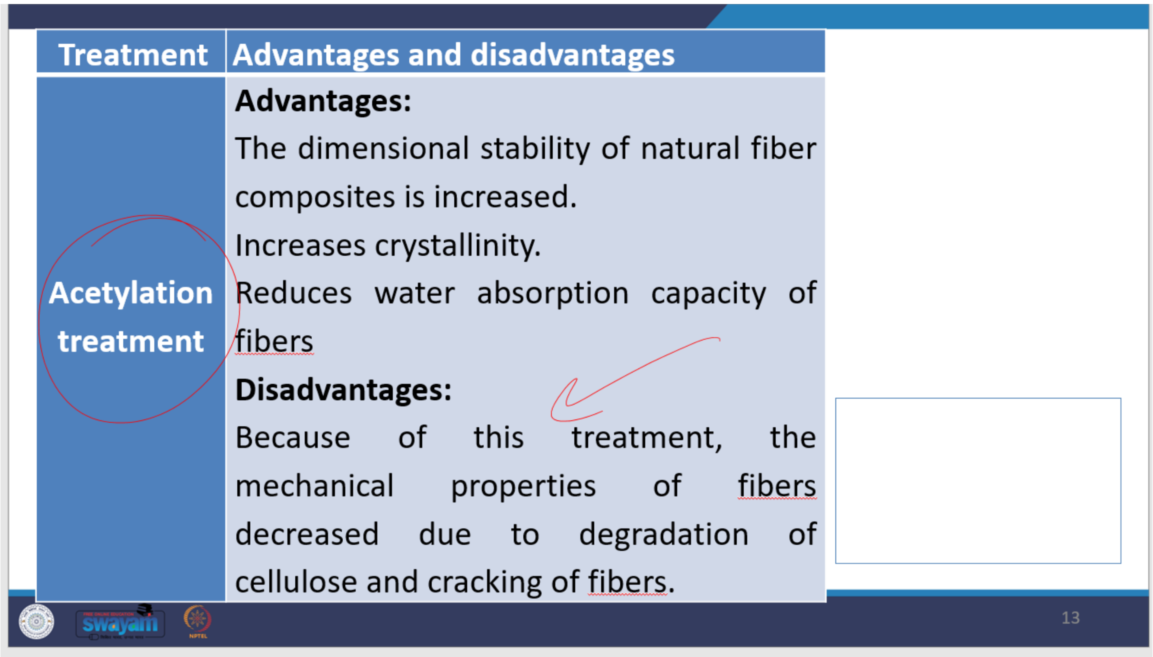


Silane treatment, on the other hand, has advantages attributed to the reduction of cellulose hydroxyl groups in the fiber matrix interface by a silane coupling agent. This makes the fiber surface tougher and decreases its water absorption capacity. Unfortunately, a downside is observed as the tensile strength of the fiber decreases after silane treatment.



In **acetylation treatment**, the advantage lies in the increased dimensional stability of natural fiber composites, leading to enhanced crystallinity and reduced water absorption capacity of the fiber.

One of the drawbacks of acetylation treatment is the degradation of cellulose and cracking of fibers, leading to a decrease in the mechanical properties of the fiber.



Treatment	Advantages and disadvantages
Acetylation treatment	**Advantages:** The dimensional stability of natural fiber composites is increased. Increases crystallinity. Reduces water absorption capacity of fibers **Disadvantages:** Because of this treatment, the mechanical properties of fibers decreased due to degradation of cellulose and cracking of fibers.

Peroxide treatment, conversely, offers advantages such as increased crystallinity and mechanical properties of the fiber. This treatment enhances the interfacial bonding between the fiber matrix and reduces the moisture absorption capacity, thereby improving thermal stability. However, a disadvantage associated with peroxide treatment is its dependence on fiber surface morphology and chemical composition for effective mechanical and chemical bonding.

Treatment	Advantages and disadvantages
Peroxide treatment	**Advantages:** Increases crystallinity and mechanical properties of the fiber. Improves interfacial bonding between fiber-matrix and also reduces the moisture absorption capacity of the fiber. Improves thermal stability. **Disadvantages:** The mechanical and chemical bonding at the fiber surface depends on the fiber's surface morphology and chemical composition.

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Commonly utilized chemical treatments for natural fibers aim to enhance their properties and improve compatibility with polymer matrices. Among these treatments is alkali treatment, also known as mercerization. This involves treating natural fibers with an alkali solution, typically containing sodium hydroxide or potassium hydroxide. The purpose of this treatment is to eliminate impurities such as wax and hemicellulose from the fiber surface. Waxes and hemicellulose form a barrier between the polymer matrix and the fiber, and alkali treatment effectively removes these impediments, facilitating improved interaction between the natural fiber and the polymer matrix.

The alkali treatment, by increasing surface roughness, improves fiber matrix adhesion and enhances moisture resistance. Silane treatment, involving the application of organosilane compounds to the fiber surface, contains functional groups that react with both the fiber surface and the polymer matrix. This reaction promotes better adhesion between the fiber and the matrix, enhancing interfacial bonding, improving mechanical properties, and increasing resistance to moisture and aging.

Acetylation modifies natural fiber by introducing acetyl groups onto the surface, typically using acetic anhydride or acetyl chloride in the presence of a catalyst. Acetylation reduces the hydrophilicity of the fiber surface, improving compatibility with hydrophobic polymer matrices and enhancing resistance to moisture absorption.

Benzoylation treatment introduces benzyl groups to the fiber surface, improving the hydrophobicity of natural fiber. This treatment enhances interfacial bonding with hydrophobic polymer matrices and provides resistance against moisture absorption.

Malleic anhydride treatment consists of reacting malleic anhydride with the hydroxyl groups on natural fiber, forming ester linkages. This treatment serves to enhance the compatibility between the fiber and the polymer matrix, resulting in improved interfacial adhesion and enhanced mechanical properties of the resulting composites.

Grafting, another approach, involves chemically attaching polymer chains to the surface of natural fibers. This method further contributes to modifying the fiber surface, promoting better adhesion with the polymer matrix, and ultimately enhancing the overall mechanical properties of the resulting composite materials. This treatment enhances the compatibility between the fiber and the polymer matrix, this improves the interfacial adhesion and enhances the mechanical properties.

Let's discuss the advantages and disadvantages of natural fiber-reinforced composites.

Advantages:

1. Weight Reduction: Natural fiber-reinforced composites generally exhibit an overall weight reduction of up to 10 to 20 percent.

2. Fuel Consumption: These composites contribute to a substantial reduction in fuel consumption.

3. Health Benefits: During the manufacturing process, natural fiber-reinforced composites emit no toxic compounds, resulting in potential health benefits.

4. Greenhouse Gas Emission: On the positive side, the use of natural fiber composites can contribute to a reduction in greenhouse gas emissions.

5. Manufacturing Cost: The manufacturing cost of natural fiber composites is substantially decreased.

6. Socio-Economic Benefits: The utilization of NFRCs in automotive applications can generate socio-economic benefits by creating new opportunities and dimensions in agriculture, thus contributing to economic growth.

7. Fire Resistance: NFRCs exhibit good fire resistance and high stability during combustion, especially in the case of collagen, providing an advantage in terms of fire safety.

8. Technical Benefits: NFRCs offer technical advantages, including low energy loss, good wear protection, and an extended lifetime of tools.

9. Eco-Friendly Manufacturing: The manufacturing process of NFRCs is eco-friendly, as these composites are derived from renewable resources.

NFRCs: Advantages and Disadvantages

Advantages	Disadvantages
There is an overall weight reduction (up to 10-20%)	The thermal stability of natural fiber composites is minimal.
The fuel consumption is reduced.	They absorbed moisture when exposed to the environment, which results in swelling and cracking of natural fiber composites.

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NFRCs: Advantages and Disadvantages

Advantages	Disadvantages
There are many health benefits as compared to the synthetic fiber during the manufacturing process of composites because of the no emission of toxic compounds.	The strength of natural fiber composites is lesser, especially the impact strength.

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NFRCs: Advantages and Disadvantages

Advantages	Disadvantages
The greenhouse gas emission is reduced.	The durability of natural fiber composites is low compared to synthetic fiber composites.
The manufacturing cost is decreased.	Because of the breaking of fibers during the manufacturing process, the performance of composites decreased.

NFRCs: Advantages and Disadvantages

Advantages	Disadvantages
There are many socio-economic benefits, i.e., utilization of natural fiber composites in automotive applications will create new opportunities in agriculture.	The disintegration of properties of natural fibers is also a limitation of composites.

NFRCs: Advantages and Disadvantages

Advantages	Disadvantages
In case of collisions and burning, natural fiber composites show good accident performance and high stability.	The inhomogeneous mixing of fiber and polymer matrix is also a limitation of natural fiber composites.

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NFRCs: Advantages and Disadvantages

Advantages	Disadvantages
There are many technical benefits, i.e., lower energy loss, good wear protection, and an enlarged lifetime of tools.	-
The manufacturing and degradation are eco-friendly because natural fiber composites are renewable resources	

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Disadvantages:

1. Thermal Stability: The thermal stability of natural fiber composites is minimal.

2. Moisture Absorption: Natural fiber composites tend to absorb moisture when exposed to the environment, leading to swelling and cracking.

3. Strength: The strength of natural fiber composites, especially impact strength, is lower compared to synthetic fibers.

4. Durability: The durability of natural fiber composites is notably lower than that of synthetic fiber components. Additionally, the breaking of fibers during the manufacturing process can decrease the overall performance of the composite.

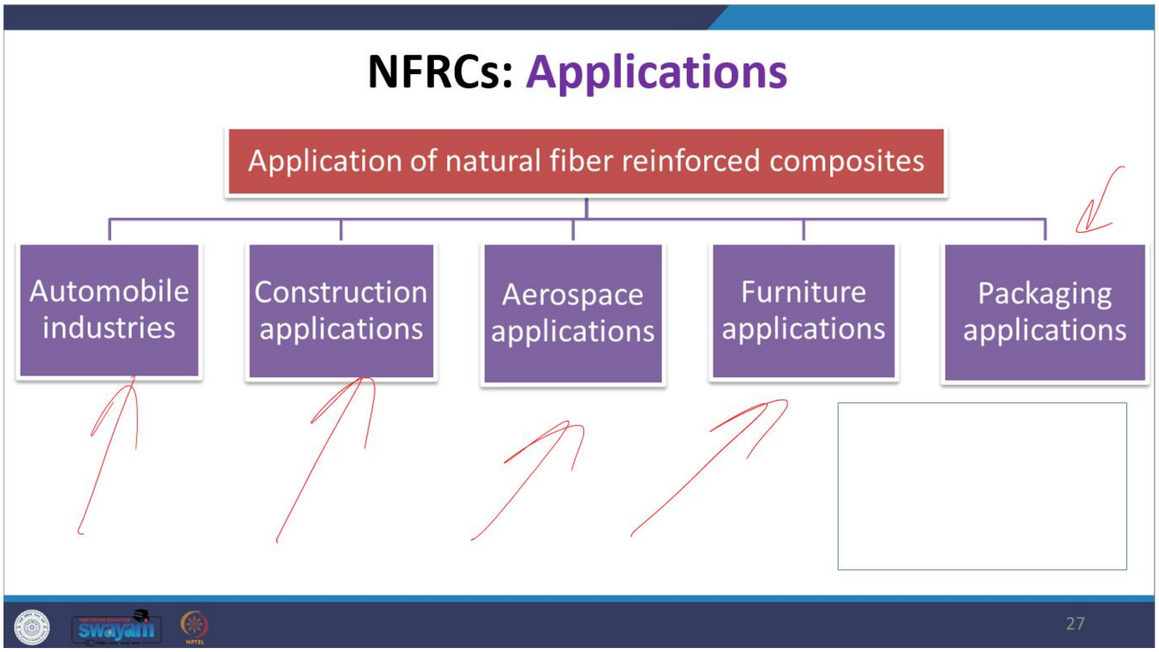
5. Performance: Because of the breaking of fibers during the manufacturing process, the performance of composites decreased.

6. Disintegration Properties: The disintegration properties of natural fibers present a limitation for composites, impacting their overall structural integrity.

7. Inhomogeneous Mixing: Inhomogeneous mixing of fibers and the polymer matrix poses a limitation to the effectiveness of natural fiber composites, affecting their performance.

In summary, while natural fiber-reinforced composites offer benefits such as weight reduction, reduced fuel consumption, health advantages during manufacturing, lower greenhouse gas emissions, and decreased manufacturing costs, they also come with drawbacks like limited thermal stability, moisture absorption, lower strength (especially impact strength), reduced durability, and potential performance issues during the manufacturing process. NFRCs not only provide socio-economic benefits and technical advantages but also exhibit fire resistance and contribute to eco-friendly manufacturing. However, challenges related to disintegration properties and the mixing of fibers with the polymer matrix need to be addressed for optimal performance in various applications.

Natural fiber reinforced composites find diverse applications across various industries, showcasing their versatility and advantageous properties.



1. Automobile Industries:

- In the automotive sector, natural fiber reinforced composites are employed to manufacture lightweight components. This application contributes to improved fuel efficiency and a reduction in greenhouse gas emissions. The utilization of plant fibers like flax, hemp, sisal, and kenaf dates back to 1930 when Henry Ford recommended their use. These fibers are utilized to reinforce plastic body parts and interior components of cars.

2. Construction Applications:

- Natural fiber composites are used in construction applications, where their excellent strength, lightweight nature, non-corrosive properties, and dimensional stability make them suitable for various structural components.

3. Aerospace Applications:

- Aerospace industries benefit from the application of natural fiber reinforced composites due to their lightweight characteristics and strength. These composites are used to manufacture components for aircraft, contributing to overall weight reduction and improved fuel efficiency.

4. Furniture Construction:

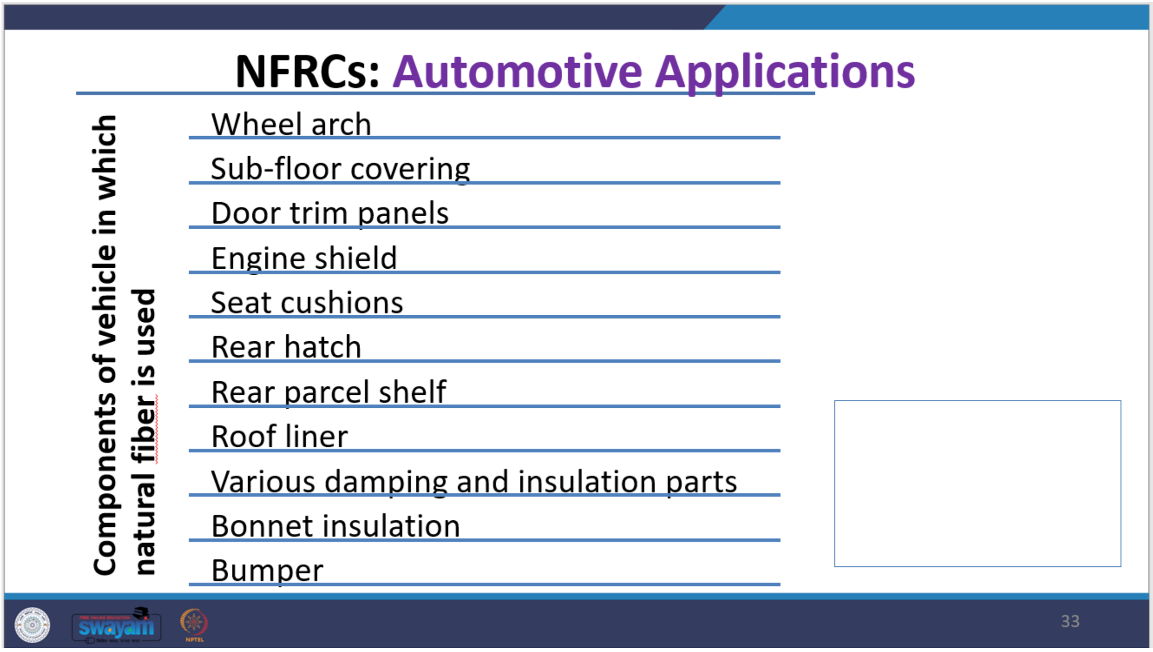
- Natural fiber composites are employed in furniture construction, providing a lightweight and durable alternative for various furniture components. The use of these composites aligns with the demand for sustainable and eco-friendly materials in the furniture industry.

5. Packaging Applications:

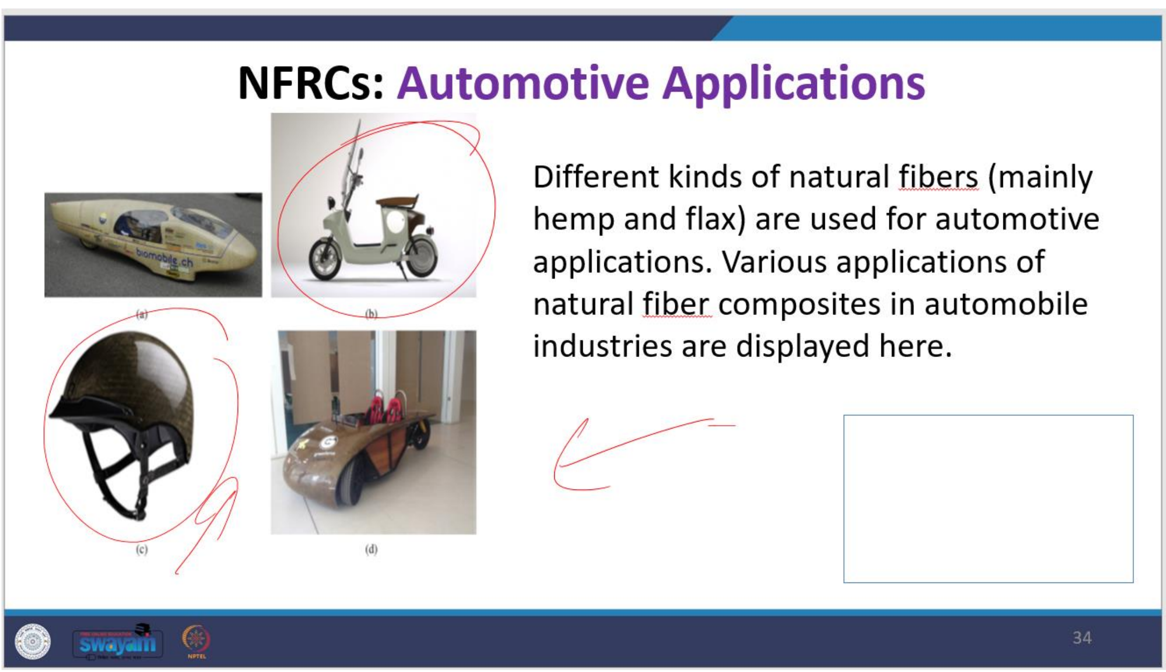
- In packaging, natural fiber reinforced composites offer a lightweight yet sturdy material. This application aligns with the industrial sector's goal of substituting heavy-weight products with lighter alternatives without compromising strength or other essential properties.

The industrial sector's preference for substituting heavy-weight products with lightweight materials without compromising strength has led to the increased use of natural fiber polymer composites. These composites are chosen for their excellent strength, lightweight nature, non-corrosive properties, and dimensional stability. Additionally, the growing emphasis on eco-friendly composite materials has further highlighted the relevance and suitability of bio-based composites, such as natural fiber reinforced composites, in various applications. In 1950, natural fibers were first used in the construction of the East German Trabant. Since then, natural fiber-reinforced components have gained significant traction in the automotive industry due to the increasing demand for lightweight and eco-friendly materials. This trend is driven by the potential to reduce manufacturing costs by approximately 20 percent and achieve an overall weight reduction of automotive parts by up to 30 percent.

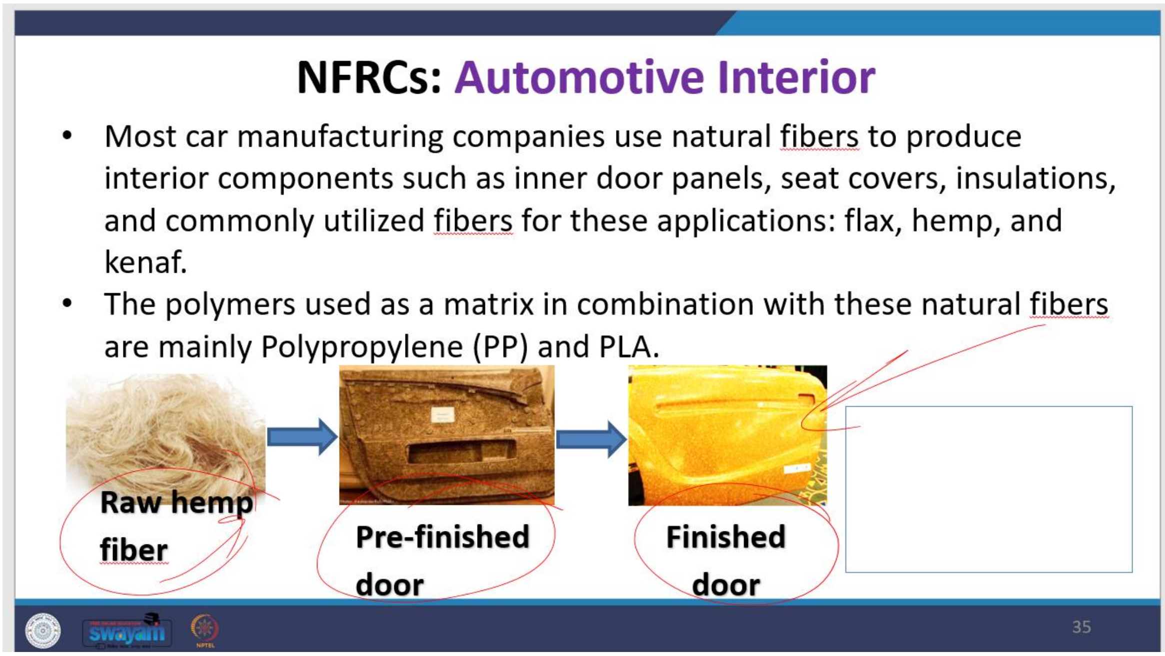
The advantages of using lightweight automotive parts are manifold. Reduced fuel consumption, enhanced recyclability, and a decrease in waste disposal contribute to lower greenhouse gas emissions. Different regions around the world utilize various natural fibers based on availability and regional preferences. European countries predominantly use flax and hemp fibers, while jute and kenaf fibers are imported from Bangladesh and India, respectively. Banana fibers from the Philippines and caesar fibers from South Africa and the United States also find applications. The German automotive industry, for example, primarily utilizes flax fibers.



Natural fibers are incorporated into various components of vehicles, as highlighted in a comparative list. These components include wheel arches, sub-floor coverings, door trim panels, engine shields, seat cushions, rear hatches, rear parcel shelves, roof liners, various damping and insulation parts, bonnet insulation, and bumpers.



The diversity of natural fibers used in automotive applications is showcased, with hemp and flax being prominently featured. Various applications of natural fiber composites in the automobile industry, such as helmets, are also displayed. Many manufacturing companies utilize natural fibers to produce interior components like inner doors, panels, seat covers, and insulators. The commonly used fibers for these applications are hemp and flaxseed, providing lightweight, low-density solutions that contribute to overall vehicle weight reduction. The matrix materials used in combination with these natural fibers are mainly polypropylene and PLA (polylactic acid).



The visual representation of the raw hemp fiber, pre-finished door, and the finished door made of natural fiber-reinforced composite underscores their versatility and application as various interior components, including door panels, seat backs, instrument panels, and trims. The use of natural fibers contributes significantly to achieving lightweight solutions and reducing the overall density of vehicles. Natural fiber-reinforced composites (NFCs) offer several advantages in different automotive interior components, contributing to both functionality and aesthetics:

1. Trunk Liners and Parcel Shelf:

- NFCs are employed in trunk liners and parcel shelves, providing a durable and lightweight solution for cargo storage areas. They offer sufficient strength and rigidity to support items while reducing the overall weight of the vehicle.

2. Headliners:

- Natural fiber composites can be used in headliners, the interior roof lining of vehicles. They provide good thermal and acoustic insulation properties, enhancing comfort and reducing weight compared to traditional materials.

3. Door Panels:

- NFCs find application in door panels, offering advantages such as weight reduction, improved sound absorption, and reduced production costs. Natural fibers provide good impact resistance and dimensional stability, making them suitable for door panel applications.

4. Seat Components:

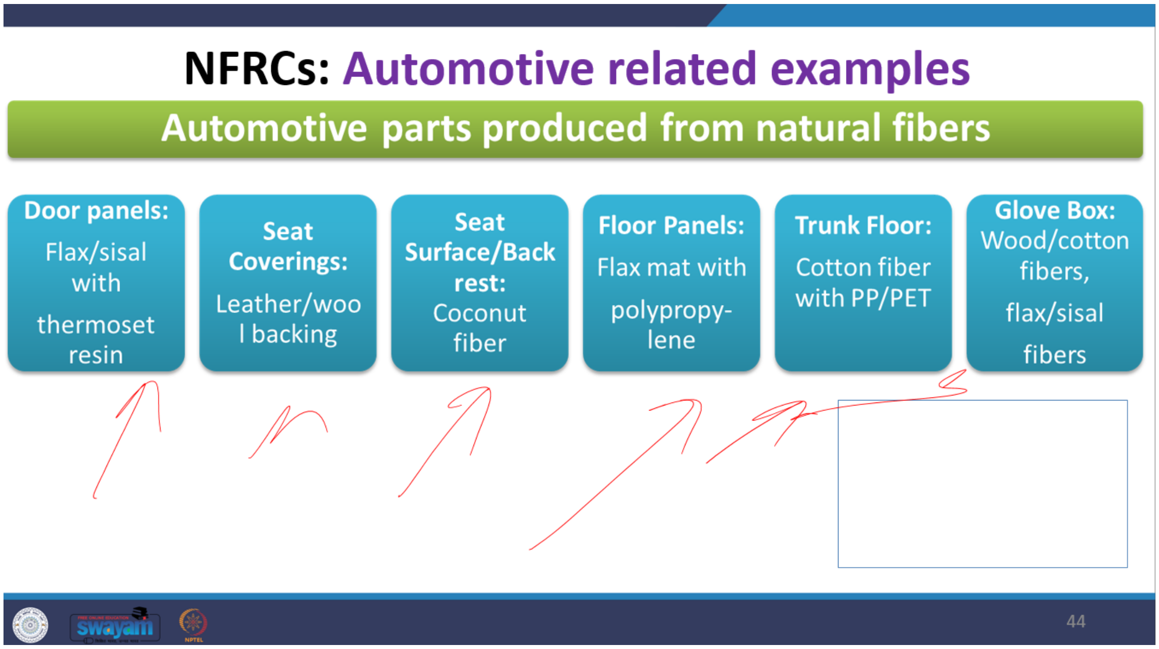
- Natural fiber components are used in various seat components, including seat backs, seat bases, and seat trims. They offer a lightweight alternative to traditional materials while meeting the necessary strength and comfort requirements.

5. Underbody Shields:

- NFCs are utilized in underbody shields, which protect the vehicle's undercarriage from road debris and impacts. These components provide good impact resistance, durability, and weight reduction compared to traditional materials.

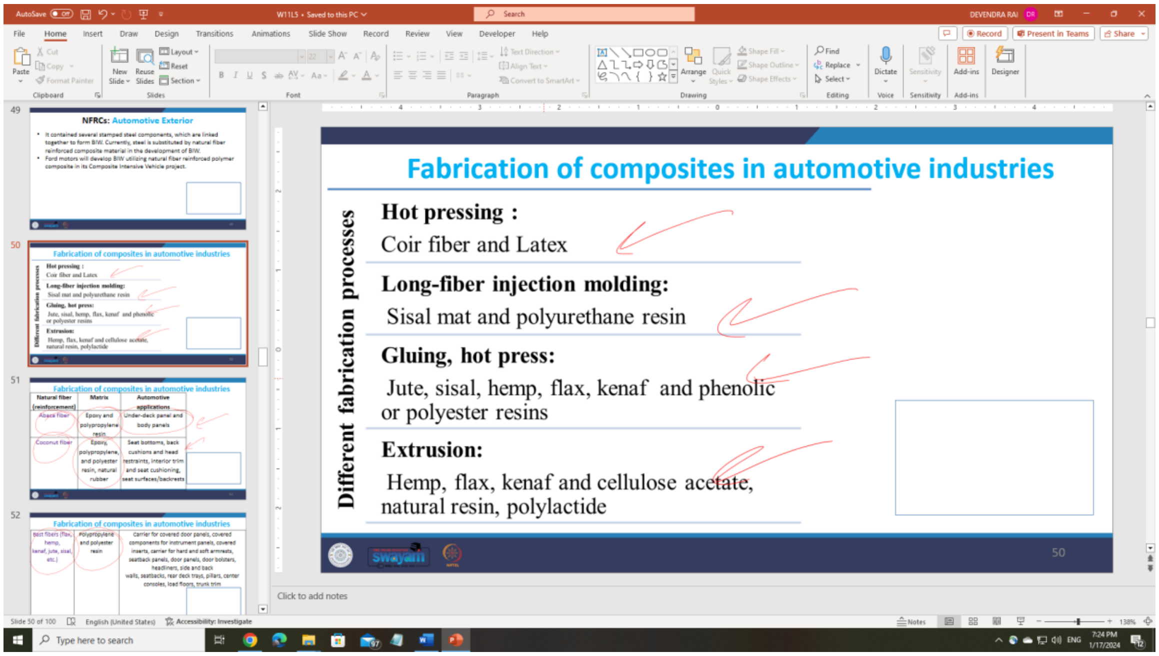
In the manufacturing of natural fiber-polymer composites, both thermosets and thermoplastic polymers are used. Among thermoplastics, polypropylene is the most commonly used for automotive applications, particularly in the manufacturing of non-structural components. The popularity of polypropylene is attributed to its excellent properties, including low density, excellent processability, good mechanical and electrical properties, and dimensional stability. Other thermoplastics, such as polyethylene, polystyrene, polyamides, etc., are also being used in various composites, expanding the range of applications and performance characteristics available in the automotive industry.

The manufacturing of natural fiber thermoplastic composites faces a key limitation in processing temperature, as high temperatures can lead to fiber degradation. In the automotive industry, thermoset resins commonly used in natural fiber-reinforced composites include polyesters, vinyl esters, and epoxy resins. Epoxy resins, in particular, are frequently used due to their high strength, environmental degradation ease, but they have limitations such as long curing times and high monomer costs. Vinyl ester resins are a newer addition to thermosetting resins, offering excellent chemical resistance, good thermal and mechanical properties, and ease of processing. They also exhibit greater resistance to moisture than epoxy resins when cured at room temperature.



Examples of automotive parts produced from natural fibers include door panels, seat coverings, seat surface bags, floor panels, trunk floors, and glove boxes. These natural fibers are commonly utilized in the manufacturing of interior components such as door panels, seat backs, layers inside the seats, and package shelves. Specific natural fibers like coconut fiber find application in various parts of the automobile, including seat bottoms, seat back cushions, and headrest restraints. Abaca fiber is used in underfoot body panels.

However, the application of natural fiber composites in the automotive industry is presently limited primarily to the interior parts of vehicles. The challenge lies in expanding the use of these composites to automotive exteriors, where considerations such as weather resistance, durability, and other external factors come into play. Research and development efforts are ongoing to overcome these challenges and explore the potential for broader applications of natural fiber composites in the automotive sector.



Recent advancements in the field of natural fiber reinforced composites have led to their use in manufacturing exterior components of vehicles. Daimler-Chrysler, for instance, utilizes abaca fiber in the exterior underfloor paneling of the Mercedes A-class. The composite made from abaca fiber demonstrates high elasticity and remarkable tensile strength. Other exterior components, including the front bumper, underfloor panels, and automobile trims, are also being manufactured using natural fiber reinforced composites. These innovations are expected to become more widely accessible in the automotive industry.

Mercedes Benz employs flax fibers in the manufacturing of exterior parts for models like the Travago, showcasing the versatility and applicability of natural fibers in various vehicle components.

A range of exterior parts, including bumpers, wheels, mirrors, housing, lenses, and body structures, are now being manufactured using natural fiber reinforced composites. Bumpers, designed to protect the vehicle during collisions, are mounted on both the front and back ends of the car. They safeguard critical car parts such as headlights, taillights, the hood, fenders, and the exhaust and cooling systems.

The concept of "Body-in-White" (BIW), referring to a group of components that bear static and dynamic loads while providing torsion toughness to the vehicle, has also seen a shift. Traditionally, BIW components were primarily made of stamped steel. However, there is a current trend towards substituting steel with natural fiber reinforced composite materials in the development of BIW. Ford Motors, for example, is actively engaged in the development of BIW using natural fiber reinforced polyurethane composites as part of the Composite Intensive Vehicle Project. This signifies a growing trend toward the adoption of sustainable and lightweight materials in critical vehicle components. Certainly, the fabrication of composites in the automotive industry involves various methods and materials. Here's a tabular summary of different natural fibers, matrix materials, and their applications:

Natural Fiber	**Matrix Materials**	**Applications in Automotive Industry**
Abaca Fiber	Epoxy, Polypropylene Resin	Egg panel, Body panels
Coconut Fiber	Epoxy, Polypropylene, Polyester Resin, Natural Rubbers	Seat bottoms, Back cushion, Head restraints, Interior trims, Seat cushioning, Seat surface
Flax, Hemp, Kenaf, Jute, Sea Cell, etc.	Polypropylene, Polyester Resin	Covered door panels, Component of instrument panel, Cover inserts, Carrier for hard and soft armrest, Seat back panels, Door panels, Door bolsters, Headliners side and back
Banana Fibers	LDP (Low-Density Polyethylene), Polyester Resin	Wrapping paper, Quire fiber, Car seat covers, Mattresses, Door mats, Rugs
Cotton Fiber	Polypropylene, Soundproofing Trunk Panel Insulations	Soundproofing trunk panel insulations, Other applications
Fiber Wood Recycle	Polypropylene Granules	Plastic retainer for the seat back panel
Flax Fiber	Polypropylene, Epoxy Resin	Seat backs covers, Rear parcel shelves, Other interior trims, Floor trays
Flax and Hemp Fiber	Epoxy	Carrier for covered door panels
Flax and Cecil Fiber	Any thermoset resin	Interior door lining, panel doors,
Kenaf Fiber	Polypropylene	Door inner panel
Kenaf and Flax Fiber	Thermoset resin	Packaging, package tray, door panels

Kenaf and Hemp Fiber	Polypropylene, Polyester Resins	Door panels, rear parcel shelves, other interior trims, Lexus package shelves
Wood	Acrylic resin, Synthetic fibers	Carrier for covered door panels, covered foamed instrument panels, covered inserts, components, covered seats
Wood Floor - Matrix: -	Polypropylene, Polyolefin	Applications: Carrier for covered door panels, armrest transportation, covered inserts
Wool	Leather	Upholstery, seat cover

These natural fibers, combined with different matrix materials, are utilized in various automotive applications, contributing to lightweighting, sustainability, and improved performance in specific components of vehicles. **Automobile manufacturers** such as Mercedes-Benz, BMW, Audi, and Daimler-Prestler have been substituting some glass fiber-based components with natural fiber-reinforced components, emphasizing a move towards more sustainable materials in the automotive sector.

Moving on to **aircraft applications**, the foundation of aerospace industries originally involved the use of wood and natural fibers like wire cloth in the manufacturing of aircraft structures. This historical usage underscores the longstanding presence of natural fibers in the aerospace sector. In recent times, there has been a shift in aircraft manufacturing towards utilizing plant fibers as an alternative to synthetic fibers like carbon, glass, and Kevlar. Natural fiber-reinforced composites (NFRCs) bring several advantages, including high strength, light weight, excellent fatigue resistance, and corrosion resistance. Aircraft manufacturers such as Boeing and Airbus have shown interest in and adopted NFRCs, recognizing their potential for weight savings, improved sustainability, and other beneficial properties.

Airplane models	Natural fiber composite applications
A300	Fairings, radome
A310	Rudder, spoilers, air brakes, elevators, VTP box
A320	Flaps, dry HTP box, LG door, engine cowlings
A330/A340	Wet HTP box, ailerons
A340-600	Rear bulkhead, keel beam, J-nose
A380	Center wing box, wing ribs, rear unpress fuselage, cross beams
A400	Upper wing
A350	Wing box, fuselage

Different applications of natural fiber reinforced composites materials in airbus airplane models (Mansor et al., 2019)

While NFRCs are still limited in their use in primary structural components of aircraft, they have found applications in non-structural and secondary components, particularly in the interior.

1. Aircraft Interior Components:

- Cabin Panels, Overhead Bins, Galley Structures: Natural fibers like flax and hemp are utilized in these components, offering a lightweight alternative to traditional materials and contributing to an overall reduction in the aircraft's weight.

2. Seating Components:

- Backrests, Armrests, Tray Tables: Natural fiber composites can be employed in manufacturing seating components, providing a lightweight solution without compromising comfort and durability.

3. Cargo Liners and Dividers:

- These composites find application in cargo liners and dividers, offering a lightweight yet strong solution for cargo compartments in aircraft. They provide good impact resistance and contribute to reducing the overall weight of the cargo compartment.

4. Air Ducts and Ventilation Systems:

- Natural fiber composites are used in air ducts and ventilation systems, providing a lightweight alternative to metal components. They offer good thermal insulation and can be easily shaped to fit the required configuration.

5. Non-Structural Covers and Fairings:

- NFRCs are utilized in non-structural covers and fairings, such as engine covers and access panels. They contribute to weight reduction while providing adequate strength and impact resistance.

The adoption of NFRCs in these applications highlights their potential to enhance aircraft performance, reduce environmental impact, and contribute to the ongoing efforts in the aerospace industry towards sustainability.

In the context of aircraft applications, it's crucial to emphasize that the use of Natural Fiber Reinforced Composites (NFRCs) must adhere to stringent safety and certification standards. Meeting these standards requires extensive testing and validation to ensure the performance, durability, and fire resistance of these materials. Ongoing research and development efforts are directed towards improving the properties of NFRCs and expanding their applications in a wide range of aerospace components.

In Airbus airplane models, various applications of NFRCs can be observed, including fairing random, rudder, slabs, wet HTP box, and more, showcasing the versatility and potential of these materials.

Moving on to **naval applications**, NFRCs are being explored as an alternative solution for manufacturers, aiming to replace synthetic fiber materials and reduce dependence on non-renewable resources. Natural fiber-reinforced polymer composites offer advantages such as low density, good sound absorption ability, excellent impact strength, and stiffness. Sugar palm-reinforced composites are specifically used in many naval applications.

While the use of NFRCs in primary structural components of naval vessels is still limited, they have found applications in non-structural and secondary components. The advantages offered by NFRCs make them attractive for certain naval applications, and ongoing research aims to further enhance their properties and broaden their scope in naval construction. In naval applications, Natural Fiber Reinforced Composites (NFRCs) find versatile use in various components, contributing to both performance and sustainability:

1. Interior Components:

- Applications: Cabin panels, partitions, furniture.

- Benefits: Weight reduction, improved acoustic properties, natural aesthetic appeal. Contributes to overall weight saving of the vessel while maintaining satisfactory strength and durability.

2. Decking and Flooring:

- Applications: Decking and flooring in naval vessels.

- Natural fibers like jute, quire, bamboo reinforced with polymers create durable and lightweight deck coverings.

- Advantages: Improved slip resistance, reduced weight, resistance to corrosion and degradation caused by exposure to seawater.

3. Insulation in Acoustic Panels:

- Applications: Insulation in acoustic panels.

- Provides thermal insulation properties, helping regulate temperature and reduce energy consumption.

- Contributes to improved sound absorption, enhancing acoustic comfort on the vessel.

4. Non-Structural Covers and Enclosures:

- Applications: Non-structural covers and enclosures, e.g., access panels, storage compartments, equipment housing.

- Offers a lightweight alternative to traditional materials, customizable to specific requirements.

- Advantages: Good impact resistance, thermal insulation, resistance to environmental conditions.

These applications showcase the adaptability and advantages of NFRCs in naval construction, providing solutions that enhance performance while aligning with sustainable practices.

In this discussion, we covered the use of natural fiber composites in both naval and aviation sectors, emphasizing their benefits and ongoing research and development efforts. The provided references offer further exploration into this field. Thank you for your attention.