

STUDY OF GREEN COMPOSITE FOR APPLICATION OF PASSENGER AIRCRAFT INTERIOR

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ABSTRACT

The increasing consumption of composites has raised environmental concerns related unsustainable production processes of both synthetic reinforcing fibres and polymers, also to their limited recyclability. The perceived scale of the problem has led to stringent legislations, end-of-life vehicle directive. A potential solution with a view to alleviating environmental issues associated with the use of synthetic fibres in composites is represented by a return to natural materials to replace both the matrix and the fibrous reinforcement. Interest in bio composites reinforced with plant fibres was therefore rising over the last years.

Keyword: - Chemical Properties¹, Composites², Synthetic Reinforcing Fibres³, polymers⁴ and fibrous reinforcement⁵.

1. INTRODUCTION

Materials of various types are required in our day-to-day life for diverse applications. In the development of any technology, the development of materials with specific properties happens to be a basic requirement [1]. Material science or development of target materials has therefore taken the center stage in contemporary research. One way of achieving a target material with specific properties is by fabrication of composites. A composite is a material made from two or more constituent materials having significantly different physical or chemical properties that, when combined, produce a material with characteristics different from the individual components [2].

1.1 Natural Composites

Natural composites exist in both animals and plants. For example, wood and bone are actually composites. Wood contains long cellulose fibers held together by lignin, a much weaker substance [3]. The two weak substances, cellulose and lignin, together form a much stronger one. [4]The bone in human body is made from a hard but brittle material called hydroxyapatite (which is mainly calcium phosphate) and a soft and flexible material called collagen, which is a protein.

1.2 A Few Examples of Composites Made in Early Times

The benefits of composites were known to people from very early days. People prepared composites by mixing mud with straw for construction purpose as they knew that such mixing increased the strength of mud. Gypsum mortar and lime mortar were used in ancient days for construction which were substituted by concrete. Concrete is a mix of stone chips, cement, sand and water. It has good compressive strength. On adding metal rods or wires to the concrete, bending strength of concrete increases. Concrete containing such rods or wires is called reinforced concrete or more commonly as reinforced cement concrete (RCC). Another example of early man-made composite is plywood prepared by gluing wood strips.

2. MODERN COMPOSITES

Modern composites are classified into three types based on the type of matrix used. They are Metal matrix composites,

Ceramic matrix composites and
Polymer matrix composites.

2.1 Metal matrix composites

Metal matrix composites are mostly used in airplanes, rockets and space vehicles due to their high-temperature resistance and low coefficient of thermal expansion. In making metal matrix composites inorganic or ceramic fiber or particulate phase is embedded into light-weight metals. Addition of SiC fibers to metal matrix like aluminum produces a composite which has coefficient of thermal expansion lower than the metal matrix itself. Addition of carbon fiber to aluminum provides a composite with much higher modulus than the metal. Carbon reinforced copper, SiC reinforced copper, Al₂O₃ reinforced aluminum and SiC reinforced aluminum are some of the metal matrix composites that are used in manufacturing various parts of spacecraft's. The antenna boom on the Hubble Space Telescope is made of a graphite-aluminum composite.

1.4.2 Ceramic matrix composites

Ceramic matrix composites consist of ceramic fibers like SiC embedded in ceramic matrix. Ceramic matrix composites are lighter than metal matrix composites, can withstand much higher temperatures and can also be made as strong as metal. Usually ceramic matrix composites are made by combining oxide fibers with oxide matrices and non-oxide fibers with non-oxide matrices. Thus, the main types of Ceramic Matrix composites are Carbon Fibers in Carbon Matrix (C/C), carbon fibers in SiC matrix (C/SiC), SiC Fibers in SiC Matrix (SiC/SiC) and Oxide Fibers in Oxide Matrix (Ox/Ox). Some of oxides used as matrices and also for making ceramic fibers are Alumina, Zirconia and Silica. Ceramic Matrix composites are used in many High Temperature processes. For example, hot gas valves used to control gas flow in gas fired high temperature furnaces are manufactured from Ox/Ox composites. Due to high wear resistance and the favorable friction properties of ceramic matrix composites, they find applications as brakes and clutch-plates of passenger cars.

2.2 Polymer matrix composites

Although the metallic components and components made from metal matrix composites that are used in aircrafts, spacecraft's and automobiles did the job in terms of mechanical properties, the heavy weight of such components was prohibitive. If the weight of the aircraft itself higher, less cargo its engines could carry. Moreover, higher the weight, the fuel consumption becomes high. Same rule applies in automobiles also. Naturally, manufacturers were looking for high strength and lightweight materials. This is where chemists came to the rescue. A revolution occurred in chemistry during latter half of 18th century due to synthesis of polymers in solid/amorphous state. Polymerization enabled new synthetic resins to be transformed from a liquid to solid state in a cross-linked molecular structure. Polymers themselves were not good materials and their reinforcement to provide strength and toughness was an equally important innovation.

In a polymer matrix composite, the polymer matrix provides the platform and supports the formation of the composite by holding the reinforcing component. Numerous synthetic polymers are being employed all over the globe for this purpose. When the reinforcing component, let us say fiber, is added to the base matrix, it plays a vital role in binding the fibers and when the load is applied to the composite material it helps in transferring the load to the fibers. The matrix presents itself as a barrier in the event of adversity and to protect the fiber and surface from mechanical abrasion by trying to hold the fibers in place so as to prevent further abrasion and new surface cracks and damages. The credit of the matrix lies in its ability to deform easily under the applied stress, transfer the stress to the fibers thereby distributing the stress evenly throughout the entire portion of the composite. The two types of polymers used as matrices in the fabrication of composites are thermoplastics and thermosets.

Thermoplastics are often formed by addition polymerization reaction leading to long linear chain polymers with no cross-links. Thermoplastics soften on heating readily and hence can be reshaped and reused. Thermoplastics are generally soft, less brittle and soluble in suitable solvents. Polystyrene (PS) is an important example of commercial thermoplastic. Other major examples are Polyethylene (PE), Polypropylene (PP), Polyvinyl Chloride (PVC), Polycarbonate (PC), Polymethyl Methacrylate (PMMA), Styrene Acrylonitrile (SAN), etc. Thermosets are formed, on the other hand, by Condensation Polymerization reaction leading to three dimensional network structures. Thermosets do not soften on heating and hence cannot be reshaped and reused. Thermosets are usually hard, strong, more brittle and insoluble in almost all organic solvents. Principal examples of thermosets include Epoxy, Phenol Formaldehyde resin (Bakelite), melamine resin and unsaturated polyesters.

2.3 Synthetic fiber reinforced polymer composites (SFRC)

The early polymer matrix composites were prepared by using synthetic fibers. The first synthetic fiber used for reinforcement was glass fiber. In 1942 the first fiberglass laminates made from PPG CR-38 and CR-39 resins were produced. Fiberglass is also called by the names glass reinforced plastic (GRP) and glass fiber reinforced plastic (GFRP). Fiberglass is a strong lightweight material and is used for many products. Its bulk strength and weight are better than many metals, and it can be more readily molded into complex shapes. Applications of fiberglass include

aircraft, boat hulls, automobiles, sports items, etc. The other synthetic fibers used for reinforcement are carbon and aramid. Aramids belong to the nylon family of polymers. Their key structural features are aromatic rings, basically benzene rings, linked by amide groups. Some advanced composites are now made using carbon fibers instead of glass. These materials are lighter and stronger than fiberglass but more expensive to produce. They are used in aircraft structures.

Polymer composites were superior materials in terms specific strength due to comparatively lower weight than the traditional metallic counterpart and attention has been paid always to synthesize newer composite materials which could meet the demand of the industry keeping in view the economic aspect. Despite having several superior properties, these materials are now facing challenges due to issues related with health hazard and biodegradability. The synthetic fibers like glass and carbon can cause acute irritation of the skin and upper respiratory tract. Also it was suspected that the exposure to these fibers for longer period of time might cause lung scarring and cancer. These fibers are not easily degradable and may be responsible for serious environmental hazards. Thus the charm of using synthetic fibers in polymer composites started fading because they are expensive, non-biodegradable and pollute the environment.

2.4 Natural fiber reinforced polymer composites (NFRC)

As highlighted above, the issues of health hazard, environmental pollution and high cost associated with synthetic fibers led the scientists and researchers to focus more on the application of natural fibers and plant based resources towards the development of NFRCs. The primary advantages of natural fibers over synthetic fibers have been their low cost, light weight, high specific strength, renewability, and biodegradability. Therefore, in this thesis the focus is on NFRCs. Depending upon the type of reinforcing fiber, composites are classified as (i) fiber composites, (ii) particle composites and (iii) laminate composites. In fiber composites, fibers of varying lengths are used for reinforcement. Moreover, fibers are laid in different orientations including random orientation. In particle composites, fibers are powdered and sieved, and then particles of different size are used for reinforcement. In laminate composites, fiber mats are prepared and these mats are laid layer by layer for reinforcement with, of course, the polymer matrix being filled in between the mat layers. Fibers may also be laid layer by layer without making prior mats. The polymer matrices used in this case are the same as in the case of SFRCs. They are thermoplastics like PS, PE, PP, PVC, PC, PMMA and Polylactic Acid (PLA) or thermosets like Epoxy, Phenol Formaldehyde Resin (Bakelite), Melamine Resin and Unsaturated Polyesters.

3. NATURAL FIBERS

Nature has abundant natural fibers and only a few of them have been harnessed for the purpose of reinforcement. Natural fibers are grouped into three types, viz. Seed Hair, Bast Fibers, and Leaf Fibers, depending upon the source. Examples are Cotton (Seed Hairs), jute (Bast Fibers), Flax (Bast fibers), Sisal (Leaf Fibers) and Pineapple (Leaf Fibers). The major constituents of natural fibers are cellulose, hemicellulose and lignin. Cellulose is the major component and the relative amounts of these three components vary from fiber to fiber. Some of the structures of cellulose, hemicellulose and lignin are shown in Figures 1.1 and 1.4.

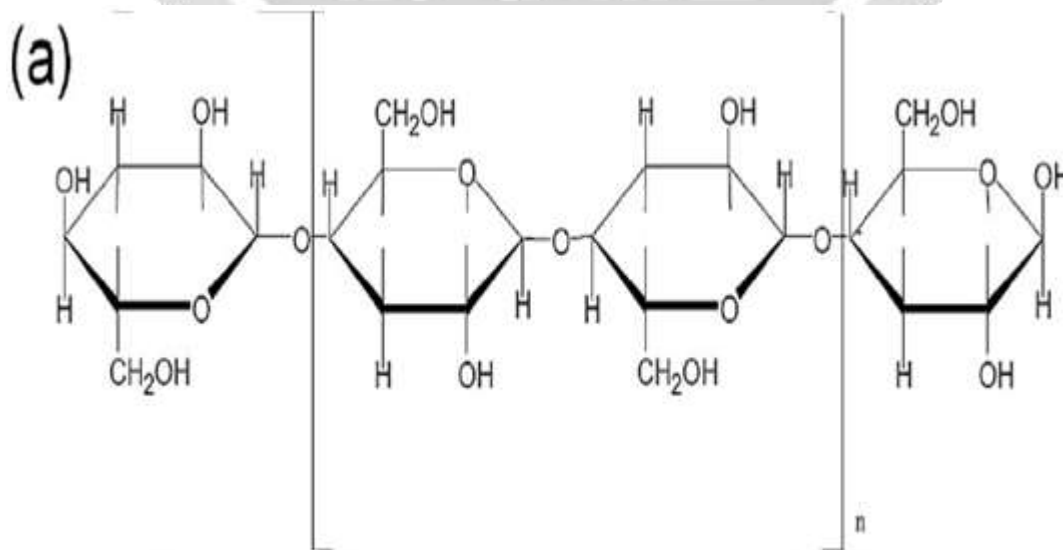


Figure 1.1: Structure of cellulose

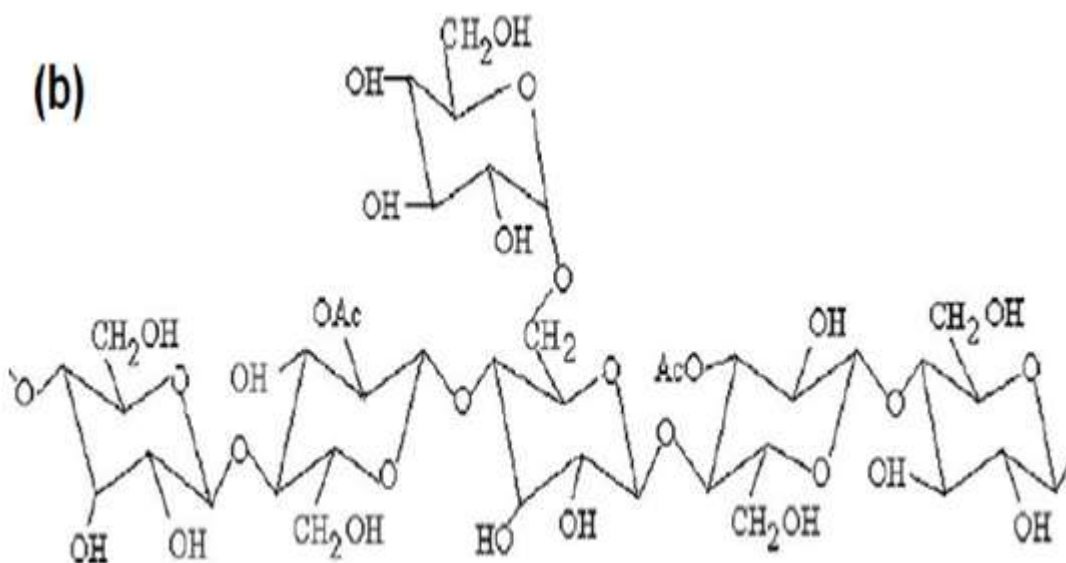


Figure 1.2: Structure of cellulose

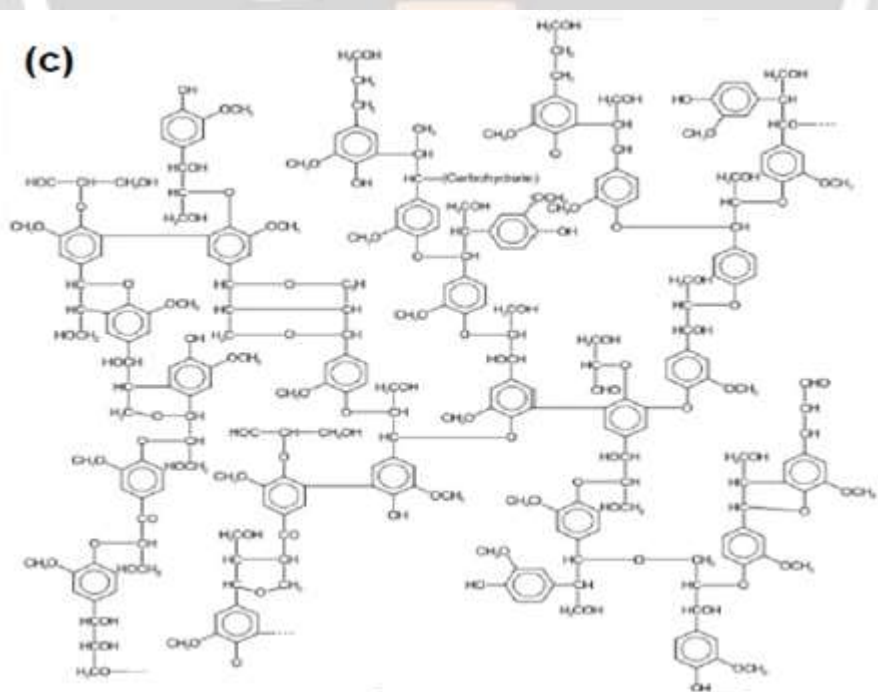


Figure 1.3: Structure of lignin

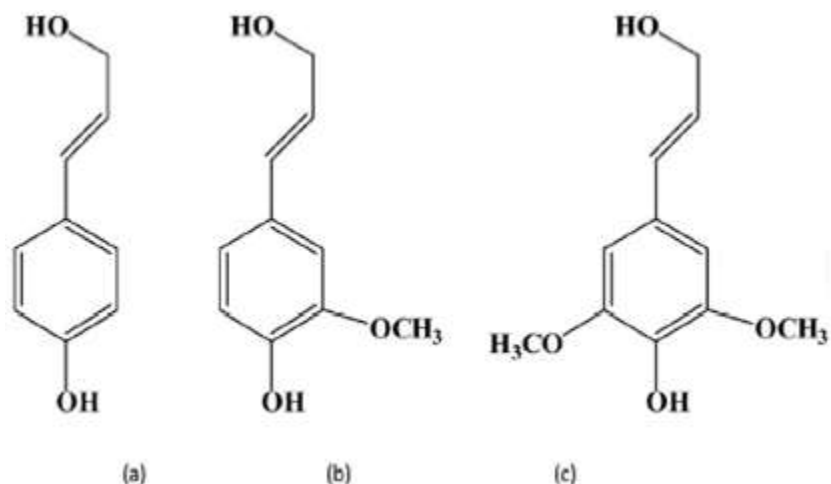


Figure 1.4.: The three common Monolignols: (a) Paracoumaryl Alcohol, (b) Coniferyl Alcohol and (c) Sinapyl Alcohol.

From these structures it is clear that natural fibers, also known as lignocellulose fibers, contain large number of -OH groups which lead to hydrogen bonding and hence natural fibers have hydrophilic surfaces. Due to the hydrophilic surface, natural fibers have the tendency to absorb water. The hydrophilic and water absorbing nature of natural fibers is not a favorable feature for composite formation. Moreover, since the mechanical properties of a fiber depends on its morphology, the properties of NFRC are expected to be dependent on the morphology of fibers. Therefore, surface treatment of the natural fibers is considered to be very important for improving the quality of NFRCs.

3.1 Surface treatment/modification of natural fibers

Surface modification is done by physical methods as well as chemical methods.⁴⁻⁷ Physical methods involve stretching of fiber, thermo treatment of fiber,⁸ calendaring of fiber,⁹ electric discharge on fiber, etc., which modify the surface properties of fibers and improve the binding with the polymer matrix to certain extent. The chemical treatment of fibers exposes more reactive groups on the fiber surface and thus facilitate efficient coupling with the matrix thereby resulting in better mechanical and thermal properties of the composites.¹⁰ Different chemical treatments are done using Silane,¹¹ Alkali,^{12,13} Acrylation,¹⁴ Benzoylation,¹⁵ Maleated coupling Agents,¹⁶ Permanganate,¹⁷ Acrylonitrile and Acetylation grafting,¹⁸ Stearic Acid,¹⁹ etc. The Alkali Treatment of fibers with NaOH is one of the most common methods applied to modify the fiber surface and this treatment is also known as mercerization. The scanning electron micrographs of alkali treated fiber surface reveal more roughness on the surface. The treatment disrupts the hydrogen bonds that connect the cellulose chains providing a rough surface to the fibers. NaOH reacts with OH groups of cellulose to reduce hydrophobicity of the fiber surface and alkali also removes some impurities from the fiber surface. Such action by alkali on the fiber surface results in much better fiber-matrix binding. This in turn improves the mechanical properties of the composites. In the Silane treatment, Silane coupling agent (for e.g., 3-Aminopropyltriethoxysilane) act as a surface coating which penetrates into the pores and develop mechanically interlocked coating on their surface. Similarly, Acetylation (using acetic acid and acetic anhydride), Benzoylation (using benzoyl chloride), and peroxide treatment improve the quality of fiber and the fiber-matrix binding.

4. CONCLUSIONS

Natural fibers are biodegradable, easily available, and low cost and provide an opportunity for the utilization agricultural product. It also helps to develop rural industry. Natural fibers are non-abrasive and hence tool wear cost. Composites plates manufactured from hemp, Hemp/Kenaf hybrid composites molded to plates and used as aircraft interior, and hence petroleum exploitation can be reduced to some extent.

Performance tests of the real world components are to be carried out so that possible replacement of the existing component at low cost using natural fibers can be done.

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