

REVOLUTIONISING AEROSPACE

Wood Composites Elevate Aerospace Innovation

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IN recent years, the aerospace industry has investigated novel materials and manufacturing techniques to improve aircraft performance, minimise environmental impact, and promote sustainability. The re-emergence of wood composites as a viable alternative to traditional materials such as aluminium, titanium, and carbon fibre is at the forefront of these advancements. Contrary to common assumption, wood has unique qualities that make it an appealing alternative for aerospace applications when paired with current technical processes and sophisticated treatments.

Wood composites were employed in aircraft building, notably during the early days of flight. However, because of their greater strength, durability, and weight-saving qualities, modern commercial aeroplanes are predominantly made using sophisticated materials such as aluminium alloys, carbon fibre composites, and titanium. While wood composites have benefits such as being lightweight and having strong thermal and acoustic insulation capabilities, they also pose substantial issues regarding structural integrity, fire resistance, and moisture absorption. Because of these restrictions, wood

composites are less appropriate for use in contemporary aeroplanes, where safety and performance are critical.

However, there have been significant recent breakthroughs in using wood composites in aviation, notably in small general aviation and experimental aircraft. Advanced wood composites, such as Laminated Veneer Lumber (LVL) or wood fibre-reinforced polymer composites, are frequently used in these applications. Compared to standard wood composites, these materials can give greater strength and durability. Furthermore, wood composites are occasionally utilised in non-structural aircraft components, such as cabin interiors, where their aesthetic attributes and insulating capabilities might be advantageous. Wood veneers or wood-based laminates may be used in certain circumstances to produce visually pleasing surfaces. While wood composites have limited utility in current aircraft, they are still being researched and used in specialised situations where their properties are advantageous.

Wood composites, sometimes referred to as wood-based composites or engineered wood products, are substances produced by fusing wood fibres or particles with adhesives, resins, or other binding agents to produce a composite substance with improved mechanical qualities and performance traits. These composites provide a blend of strength, stiffness, cost-effectiveness, and durability, making them appropriate for various applications in the aerospace, building, automotive, and furniture manufacturing sectors.

Due to its distinctive qualities and advantages, wood composites have been investigated and applied in several aircraft applications. Here are a few instances of wood composite use in the aircraft industry:

1. Aircraft interior cabin components, such as wall panels, flooring, seat frames, and overhead compartments, have been made using wood composites. Wood is a good material option for creating a cosy and pleasant cabin atmosphere because of its aesthetic appeal, acoustic qualities, and lightweight attributes.
2. Non-structural aircraft components have been made with wood composites, including fairings, internal walls, and aesthetic features. The adaptability, cheap cost, simplicity of production, and strong vibration dampening capabilities of wood composites make them ideal for these applications.
3. Wood composites are used to construct small-scale and experimental aircraft. Traditional metal buildings can be replaced with lightweight timber that has been strengthened with composite materials. Wood composites are appealing for smaller aircraft designs because they may offer a mix of strength, weight, and affordability.
4. The airframes of UAVs (Unmanned Aerial Vehicles) and drones are made of wood composites. Wood is a feasible material for building lightweight and manoeuvrable UAVs due to its favourable strength-to-weight ratio and simplicity of modification.
5. Wood composites have been considered for the production of rotorcraft parts, including rotor blades and tail fins. Wood's strong strength and stiffness attributes may provide rotorcraft components with exceptional



performance characteristics with the right coatings and treatments.

It's essential to consider that compared to other materials like metals and carbon fibre composites, the usage of wood composites in aircraft is comparatively restricted. However, wood composites are still being researched and developed for aerospace applications because of their unique qualities, environmental sustainability, and possible financial advantages.

Current Trends and Technologies

To lessen its carbon footprint and reliance on petroleum-based products, the aviation industry is increasingly emphasising recyclable and ecologically friendly materials today. New and innovative wood-based composites can be the solution and materials of the future.

- **Natural fibre polymer composites:** are prospective substitutes for the manufacture of aircraft components and, by replacing synthetic composites, aid in “greening” the aerospace sector. Natural fibres from plants and animals have various benefits, including low density, high strength-to-weight ratio, low cost, and the ability to be used in components with intricate geometrical design characteristics, similar to synthetic composites.

The development of natural fibre-based, ecologically friendly aeroplane interiors has received attention in the aviation sector. Using NFPC (Natural Fibre Polymer Composites) for the interior component increases fuel efficiency. It reduces carbon emissions, possibly due to weight reduction, while replacing non-renewable resources and dangerous materials like glass fibres, phenolic resins, etc.

The current interior components of aircraft depend entirely on improved conventional composite materials like CFRP (Carbon-Fibre-Reinforced Polymer) and GFRP (Glass-Fiber-Reinforced Polymer), which are challenging to recycle. Their goal is to develop a fully recyclable aircraft cabin interior. A study inferred that the advancement of NFPC has shown a positive impact on automotive parts and compartments. Still, it needs

additional work for aeronautical uses, such as fire resistance and reduced smoke and toxicity produced when set alight. Another example of potential uses of NFPC is the use of natural flax fibre in hybrid composite materials on Airbus Helicopters' X3 high-speed demonstrator. Red (2012-2022) noted in his study that one of the NFPC's possible applications is to manufacture aeroplane seats, allowing for the adoption of thinner seat designs for greater volume and seat density. Cotton fibre and Polyurethane (PU) matrix (obtained from castor bean oil) were used in a study by Eloy *et al.* (2015) to demonstrate the potential applicability of NFPC for aerospace interior components.

- **Nanocellulose-based products:** nanocellulose are cellulose molecules with at least one dimension in the nanoscale (1–100 nm). Development in the emerging field of nanotechnology has made nanocellulose a more attractive research subject than its cellulose counterpart. Due to its biodegradable nature, impressive optical properties, anisotropic shape, high mechanical strength, excellent biocompatibility, and tailorable surface chemistry, nanocellulose development has generated significant interest in various applications relevant to material engineering and biomedical fields.

Due to their high surface area and nanoparticle aspect ratio, nanocellulose composites exhibit better characteristics than other biopolymers. CNFs (Cellulose Nanofibres) are now being developed as reinforcement materials in aircraft structural composites to improve adhesion, thermal stability, and mechanical stability. Utilising CNF can drastically reduce aircraft weight, which lowers fuel consumption. Additionally, nanocellulose's small fibre diameter, like other sophisticated fibre architectures, enables the insertion of sensors like the Fibre Bragg Grating (FBG).

By retrieving data close to the sensor, anyone can detect object damage using this method. As a result, nanocellulose aerogels may be a creative substitute for composite structures in the aerospace industry. Also, cellulose that has been microfibrillated can have extremely high strength. By expanding the surface area of the fibrils, the MFC can undoubtedly be advantageous in constructing strong composites. Evidently, tailored, lightweight MFC composites are in demand in the aircraft sector for windows and sensors.

Challenges

Natural fibres have benefits when used in composites but can have disadvantages in processing, performance, and behaviour in polymeric matrix systems. To begin with, natural fibres cannot offer an annual pattern of physical attributes that are constant across all harvesting seasons and/or all harvesting regions due to variable sun, rain, and soil conditions.

The incompatibility of natural fibres with various polymeric matrices is another significant drawback. As a result, the matrix's fibres may not be distributed uniformly. Due to the fact that most polymers, particularly thermoplastics, are nonpolar (also known as "hydrophobic") substances and

incompatible with polar (also known as "hydrophilic") wood fibres, there may be poor adhesion between the polymer and fibre. Their extreme sensitivity to moisture causes severe mechanical property loss and delamination. Low microbiological resistance and susceptibility to rotting can also be limiting considerations, especially regarding shipping, long-term storage, and composite manufacturing. Another major disadvantage is the low processing temperature necessary for fibre processing (poor thermal stability). Above this limit, the fibres start to deteriorate and shrink, which lowers the composite's performance. The allowed temperature is up to 200°C. Depolymerisation, hydrolysis, oxidation, dehydration, decarboxylation, and recrystallisation are the most common physical and chemical structural changes that occur when fibres are heated, limiting the range of resins they can be blended with.

Despite their numerous advantages, nanocellulose composites have several limitations, such as (i) poor dispersion of nanocellulose in the polymer matrix, which results in non-uniform strength properties; (ii) Surface chemical treatments are required to enhance the compatibility of nanocellulose and polymer; (iii) Hydrophilic nature of cellulose composites. All these drawbacks make the processing of nanocellulose composites a difficult task, thus limiting their use in various applications.

Possible Solutions to the Challenges

Mixing batches of fibres from several harvests is one way to solve the issue of natural fibres' inconsistent physical qualities. Fibre blending offers protection from the unpredictability of any single fibre crop. Additionally, the possibility of genetically modified varieties ensuring consistently high-quality products is presented to the market. Chemical "coupling" or "compatibilising" agents must be used to increase the affinity and adhesion between reinforcements (natural fibres) and thermoplastic matrices during production. Chemical coupling agents are chemicals, usually polymers, applied sparingly to a surface to promote the interaction between the treated surface and other surfaces. The temperature range and processing duration must be restricted to prevent the thermal deterioration of fibres during processing.

Numerous pre-treatment (mechanical and chemical) and surface modification approaches can be used to address the problems of poor dispersion and incompatibility of nanocellulose in the polymer matrix. Reduced wood absorption and polarity can be achieved by acetylation, which involves changing the hydrophilic groups of nanocellulose to hydrophobic ones. Without altering the structure of nanocellulose, coupling agents like 3-aminopropyltriethoxysilane and 3-(glycidoxypyl) trimethoxysilane can be employed to substitute hydrophilic groups for hydrophobic ones.

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