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A Comparative Analysis Review of Plant Fibres in Advanced Bio-based Material for Sustainable Drone Construction

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ABSTRACT

As researchers' awareness of ecological impact and climate change increases, several solutions were proposed to help reduce carbon emissions and promote the circularity of materials. Drones technology can help monitor the environment since it can cover a large area, collect real-time images and data, and operate in dangerous environments. Also, the drone's ecological factor could be further increased by its construction itself. Thus, many researchers are trying to develop a sustainable drone using plant fibres to reduce carbon emissions and ensure the circularity of materials. This review mainly compares the drones made from plant fibres and traditional materials such as plastics and synthetic fibres. This review also includes the introduction of material circularity, the drone's role in helping ensure material circularity and environment safety, and the advantages and disadvantages of the drone materials. The review will also compare the drone performances made from different bio-based materials with conventional ones. Plant fibres' role in drone construction significantly contributes to reducing carbon emissions and ensuring the circularity of materials. With drone construction paving the way for other critical structural applications, there is a possibility that plant fibres will soon become the most significant raw material for sustainable products.

Keywords: Drone construction, material circularity, plant fibres, sustainable drone

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INTRODUCTION

Unmanned aerial vehicles (UAVs), commonly known as drones, have a rich history dating back to the 18th century. The materials used in the construction of drones have evolved and are influenced by technological advancements and military needs. In the 18th century, the Montgolfier

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brothers in France experimented with unmanned balloons, marking the early use of UAVs. The Montgolfier brothers' balloon, which made the first manned flight in 1783, was made of cotton canvas with paper glued onto both sides (Tretkoff, 2006). After that, the material was replaced with aluminium. The first use of aluminium for UAVs can be traced back to the early 20th century. In June 1919, the Junkers F.13, the first all-metal airliner, used 2017-T4 aluminium alloy as the body material, marking a significant milestone in using aluminium in aircraft construction (Haomei Aluminium, 2023). This development laid the foundation for using aluminium in the aviation industry, including manufacturing UAVs.

Therefore, it can be inferred that aluminium was first used for UAVs around the same time, during the early 20th century. During World War II, there was a surge in plastic production, which spread to UAVs (Rangel-Buitrago & Neal, 2023). After that, in the late 20^{th} century, carbon fibre was used in high-performance applications from aeroplanes to automobiles and satellites to sporting goods (Zhang et al., 2023). The use of carbon fibre in UAVs has become widespread, primarily due to its lightweight and high-strength properties, contributing to improved aircraft performance and fuel efficiency (Parveez et al., 2022). From there, fibre-reinforced polymer composites adoption in aerospace and aviation industries gained momentum in the 1980s and 1990s (Geoff Poulton, 2017). Fibre-reinforced polymer composites are a combination of fibres, such as carbon or glass, and a polymer matrix, such as epoxy or polyester resin. These materials offer high strength-to-weight ratios, corrosion resistance, and design flexibility, making them ideal for UAV manufacturing (Rajak et al., 2019).

In recent years, synthetic fibres have been replaced with natural fibres to make UAVs due to environmental considerations and the desire for more sustainable materials. Natural fibre composites are considered more environmentally friendly than synthetic fibre materials, as they are biodegradable, derived from renewable sources, and offer advantages such as abundance, availability, and low cost (Thyavihalli Girijappa et al., 2019). The increased awareness of the environmental impact of synthetic materials has led to a growing interest in developing eco-friendly materials, including natural fibre-based composites, for various industrial sectors, including aerospace engineering. Additionally, natural fibres are introduced to make the composites lighter. While they may have some disadvantages, such as poor resistance to moisture, their overall sustainability and environmental benefits make them an attractive alternative to synthetic fibres in UAV manufacturing. Previous research stated that kenaf and PALF can be used as alternative composite materials, particularly for multifunctional applications (Rahman & Ariffin, 2022). Figure 1 summarises the evolution of the drone materials.

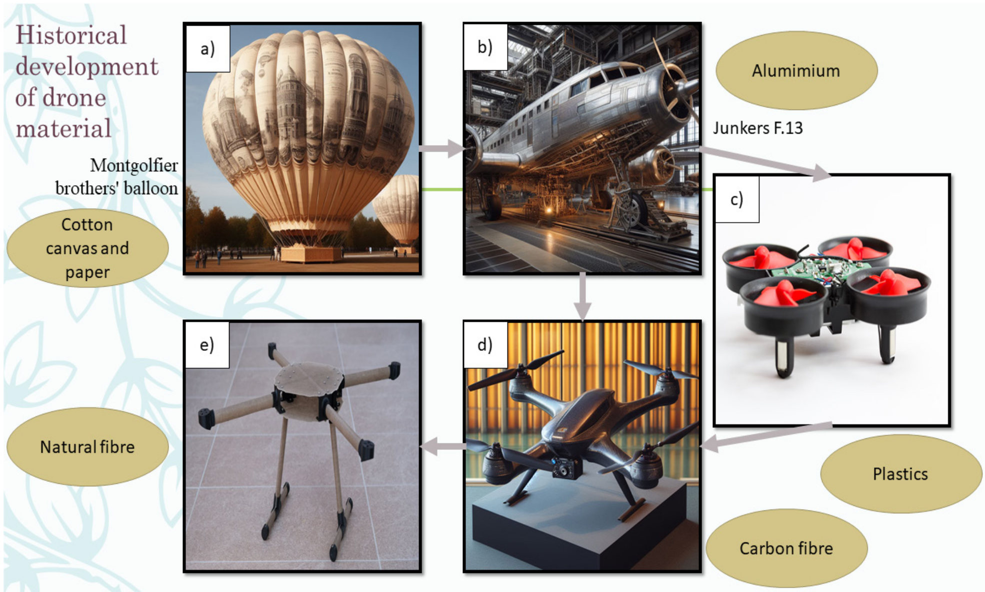

Figure 1. Historical development of drone materials

Source: Authors' work, all images are AI-generated from: a) https://www.bing.com/images/create?FORM=GENILP, b) https://www.bing.com/images/create?FORM=GENILP, c) https://pixabay.com/photos/mini-drone-radio-control-flying-2199857/, d) https://www.bing.com/images/create?FORM=GENILP, e) https://www.thingiverse.com/thing:4800248

The history of drone materials reflects the continuous evolution of technology and the adaptation of materials to meet the changing needs of UAVs, from their early use in warfare to their modern applications in various fields, including photography (Patil et al., 2023), filming (Patil et al., 2023), and goods delivery (Chi et al., 2023). Drones are being used to revolutionise sustainability and the circular economy. They have transformed supply chain management by optimising the distribution and logistics processes, reducing the need for traditional, fuel-dependent transportation methods (Rejeb et al., 2023). Drones are also used for waste management and recycling, and they can produce high-resolution 3D models of landfills to monitor changes over time (Sliusar et al., 2022). In addition, drones are instrumental in environmental monitoring and protection, as they can survey and assess remote and inaccessible areas, enabling rapid response to illegal logging, poaching, and environmental disasters (Bollard et al., 2022). The circular economy offers a framework to improve the sustainability of drones by designing out waste and pollution in all phases, making more durable products to extend the use phase, including drone construction (Mitchell et al., 2022).

Using natural composites in drones can positively impact sustainability and the circular economy. Composite materials play a crucial role in reducing the weight of aerospace materials, which in turn helps to reduce fuel, energy, and emissions (Parveez et al., 2022). Replacing traditional materials with composites can make drone airframes lighter and more efficient, reducing waste and optimising resources in the circular economy (Mitchell et al., 2022). However, there are challenges related to using composites in drones, such as manufacturing processes and difficulties with recycling, as most drone airframes are not currently designed with disassembly, recovery, or reuse of materials in mind. Despite these challenges, natural composites are gaining increasing demand for various applications and can be an environmentally friendly alternative to synthetic composites, aligning with the principles of the circular economy. Figure 2 shows some drone applications developed due to the advancement of drone materials.

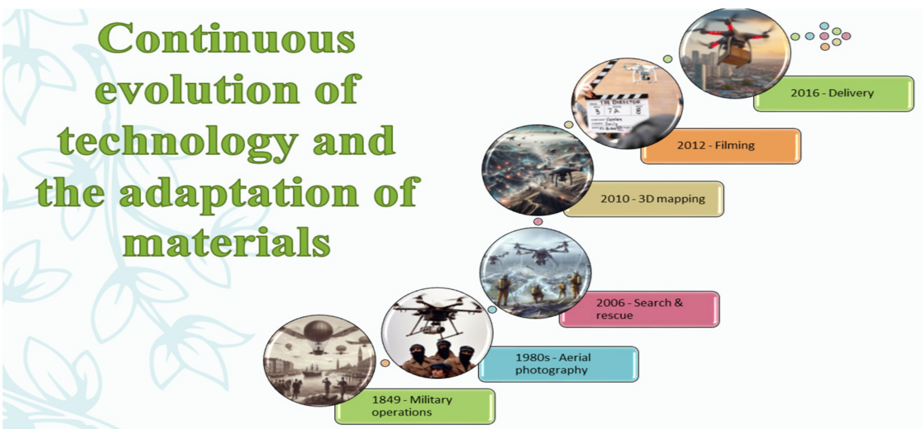

Figure 2. Innovations of drone applications due to continuous adaptation of materials

Source: Authors' work, all images are AI-generated from https://www.bing.com/images/create?FORM=GENILP

Various factors influence the market demand for drone natural composites. The unmanned composites market is expected to reach a value of 3.8 USD billion by 2027, with a projected CAGR of 16.8%, and is currently led by carbon fibre-reinforced polymer composites (Reports and Data, 2020). Due to their stability and durability, the increasing demand for lightweight and electric conductive composites drives the market growth. Additionally, the requirement for composite materials for weight reduction is a significant factor driving the market for unmanned composites in European countries.

PLANT FIBER'S ROLE IN THE CIRCULARITY OF MATERIALS

The circularity of materials refers to maintaining the value of products, materials, and resources for as long as possible by returning them to the product cycle, thereby reducing waste and reliance on finite virgin resources (Kirchherr et al., 2023). In a linear economy, materials are taken from nature, used to make products, and disposed of, leading to waste and resource depletion. In contrast, a circular economy promotes the continuous use of materials to reduce waste and environmental impact. It involves using materials through reuse, repair, remanufacturing, and recycling or safely returning biodegradable materials to the earth. The circular economy aims to eliminate waste and pollution, circulate products and materials at their highest value, and regenerate nature. It involves exploring alternative materials, revamping existing infrastructure, and improving material management to capture the economic value of resources before they become waste (Jacobs et al., 2022). The circularity of materials is measured using indicators such as the Material Circularity Indicator (MCI) and the circularity rate, which represents the share of material resources used that came from recycled waste materials, thus reducing the environmental impacts of extracting primary materials (Moraga et al., 2021). By shifting from a linear to a circular economy, the focus moves from extraction to circulation, contributing to sustainability and resource optimisation.

The circularity of materials is an essential concept in drone construction as it promotes the efficient use of resources and waste reduction. The circular economy offers a framework to improve the sustainability of drones by designing out waste and pollution in all phases, making more durable products to extend the use phase (Mitchell et al., 2022). Plant fibres, such as kenaf, hemp, and flax, offer sustainable and biodegradable alternatives to traditional materials, contributing to the principles of the circular economy. Plant fibres play a crucial role in the circularity of materials due to their renewable and biodegradable nature. There are various plant fibres abundantly available in Malaysia, such as oil palm, kenaf, and screw pine.

Oil palm fibre (OPF) is an excellent raw material for biocomposites due to its high cellulose content, making it suitable for various applications (Shinoj et al., 2011). The fibre is non-hazardous, biodegradable, and abundantly available in Malaysia. The potential of oil palm fibre has been explored in various studies, highlighting its significant mechanical properties and potential as a functional food ingredient. Fibre has shown promise as an excellent antioxidant and a source of dietary fibre, with potential health benefits such as managing and lowering the risk of diabetes, colon cancer, and heart disease. The use of oil palm fibre aligns with the principles of the circular economy, promoting the efficient use of resources and waste reduction.

Kenaf fibre is a natural fibre with various advantageous properties and high potential as a reinforcement in composite materials (Kiron, 2021). It is a non-woody annual plant with a short life cycle of 100–130 days, making it a highly sustainable fibre due to its rapid growth and replenishment ability. Kenaf cultivation and processing require minimal water, fertiliser, and pesticides, contributing to its sustainability. The fibre is obtained from the bast and core of the plant, with the bast constituting 40% of the plant and the core constituting 60%. The individual fibre cells are about 2–6 mm long and slender, with a thick cell wall.

The fibre is also known for its natural absorbency and fire-retardant abilities, making it a valuable raw material in the textile industry.

Screw pine fibre is a natural fibre that is extracted from the leaves of the screw pine (*Pandanus amaryllifolius*). The fibre is in the form of long fibres, which have higher mechanical properties than short fibres like rice husk (Abral et al., 2012). Screw pine fibre has been used as a reinforcement in polymer matrix composites. Some of its unique properties include high strength, light weight, biodegradability, and environmental friendliness. Additionally, screw pine fibre has been used as reinforcement material in composites, exhibiting promising mechanical properties when combined with polyester and vinyl ester resins. The fibre can be treated with aqueous NaOH solution to reduce its hydrophilic nature, making it compatible with hydrophobic materials (Naik et al., 2021). In addition to its industrial applications, screw pine fibre is also used in traditional Malaysian weaving, a thriving artisan activity in the country (Zainol et al., 2016). The art of weaving takes years, and sometimes decades, to learn and master and is considered a piece of Malaysian cultural heritage at risk of disappearing.

Additionally, plant fibres such as hemp, flax, and pineapple leaves have a long history of use in textiles, cordage, and, more recently, in technical applications in composite materials, contributing to the sustainability of these products (Elfaleh et al., 2023). The versatility of cellulosic fibres derived from plants like cotton, flax, and timber is being further explored to mitigate the need for virgin natural resources, emphasising circularity and agricultural waste in the global fibre industry (Lawson et al., 2022). Plant fibres play a significant role in promoting circularity by offering sustainable and biodegradable alternatives to traditional materials, contributing to the principles of the circular economy.

MATERIALS FOR DRONE STRUCTURE

The process of drone production involves several stages, which start with conceptualisation and design. In this stage, the purpose and specification of the drone will be defined by considering factors such as payload capacity, flight range, endurance, and intended applications. By determining these factors at an early stage, suitable materials can be selected to optimise the performance of the flying drone. Suitable materials were chosen to develop the drone's frame, body, and components based on weight, strength, durability, and cost. Common materials include carbon fibre, aluminium alloys, composite materials, and 3D-printed plastics. Next, the drone components such as frame, arms, propellers, landing gear, and electronics housings will be fabricated by using various manufacturing techniques such as CNC machining (for precise shaping of metal and plastic parts), injection moulding (for mass production of plastic components), and 3D printing (for rapid prototyping and customisation of complex geometries). In this stage, dimensional accuracy and surface finish must also be ensured to meet the design specifications. Once the components have been fabricated, they will be assembled and integrated with the electronic components. The drone will then be tested and calibrated to verify the operation of all systems and components. This stage ensures the optimisation and stability of the drone's performance while flying. Finally, the drone will undergo flight tests in controlled environments to evaluate the drone's flight characteristics, stability, and control responsiveness. The flight test complexity will gradually increase, and its performance under various conditions, such as different weather conditions and payload configurations, will be assessed. Table 1 shows some of the recent research conducted on drone production.

Table 1
Recent research on drone development

Aim	Method	Application	References
Designing a compact ducted drone with a co-axial propeller	Computational model and FEA analysis of UAV made from various alloys, carbon fibre-reinforced composites and glass fibre-reinforced composites	High altitude surveillance	Jayakumar et al. (2024)
Optimising drone routes	Comparative analysis of computational simulation on a case study of the Beirut Port Explosion in Lebanon using a greedy constructive heuristic (GCH) and adaptive large neighbourhood search (ALNS)	Post-disaster management	Almeida Coco et al. (2024)
Developing thermoformed composites by TiO_2 modified aramid fibre reinforcement	Experimental study of the proposed material through physico-mechanical testing	Encapsulation of electronic parts	Pelin et al. (2024)
Design and modelling of a versatile, reconfigurable multi-rotor UAV	Computational validation of PULSAR efficacy on UAV	Forest and wildfire management	Perikleous et al. (2024)
Designing a hexacopter for a 3 kg payload	Computational simulation and analysis were used to perform a structural analysis of the UAV design using different materials	Lightweight drone	Raut et al. (2024)

Out of all the production stages, the material selection stage directly impacts the drone's performance and durability the most. The choice of materials directly impacts the weight and strength of the drone. Lightweight materials, such as carbon fibre or high-strength polymers, help reduce overall weight, which is critical for achieving longer flight times, higher payloads, and better manoeuvrability. At the same time, the materials must provide sufficient strength and durability to withstand the stresses of flight and potential impacts. The aerodynamic properties of the materials used to construct the drone's frame, wings, and other components affect its flight performance. Smooth surfaces and streamlined shapes reduce drag and improve efficiency, allowing the drone to fly faster and consume less power. Drones are also often used in demanding environments and are subjected to harsh conditions, including high winds, temperature variations, and mechanical stresses. Choosing materials with excellent durability and resistance to wear, corrosion, and fatigue ensures that the drone can withstand prolonged use without compromising performance or safety. Material selection also influences the cost of production, which is a significant consideration for manufacturers and consumers alike. Balancing performance requirements with material costs helps optimise the overall value proposition of the drone, ensuring that it delivers the desired capabilities at a competitive price point. As sustainability becomes increasingly important, choosing eco-friendly materials derived from renewable sources or recycled materials can help minimise the environmental footprint of drone production. It includes considerations such as resource depletion, energy consumption, and waste generation throughout the lifecycle of the drone.

Drone parts are made of lightweight materials such as plastic or carbon fibre to keep the drone's weight as low as possible (Anand & Mishra, 2022). Carbon fibre is one of the most commonly used materials in drone manufacturing because of its strength and lightness. Almost all drone structures are made from carbon fibre composites, in contrast to piloted aviation, where a large percentage of the structure is made from aluminium and titanium in addition to carbon fibre composites (Hexcel, 2023).

Natural fibres have been increasingly used as reinforcing materials for the construction of drones. These fibres offer an alternative to traditional synthetic materials like carbon fibre, providing potential benefits such as biodegradability and reduced environmental impact. For instance, there are examples of drones made from bio-degradable natural fibre composite materials, such as those using PLA and linen fibres as an alternative to oil-based solutions (Breznik, 2021). Using natural fibres in drone construction aligns with the growing interest in boosting drone performance and addressing environmental concerns. As drone technology advances, the selection of materials becomes more complex, requiring careful consideration of the performance of multiple components.

Conventional vs Bio-based Materials

Using conventional materials, such as carbon fibre, for drone construction offers lightweight, high-strength solutions at a relatively low cost. These materials are widely used in drone technologies due to their excellent strength-to-weight ratios and suitability for many drone components. However, as drone technology advances and the demand for more significant strength increases, light alloys like aluminium, magnesium, and titanium are also being used for their high strength and low weight, mainly in large-sized drones (Anand & Mishra, 2022; Parveez et al., 2022; Siengchin, 2023).

On the other hand, natural fibre composites are gaining attention as an alternative to conventional materials for drone construction. Research has shown that natural fibres, such as kenaf, PALF, eggshell, bagasse, and styrofoam, can be used as alternative composite materials for drone airframes, offering potential environmental benefits (Perdana et al., 2017). While conventional materials offer high performance and cost-effectiveness, using natural fibre composites aligns with the growing interest in sustainability and reducing the environmental impact of drone technology. However, there are still challenges in conducting sustainability assessments of drone materials, and more research is needed to address the end-of-life impact of composite materials, including the potential for bio-based composites to replace traditional materials.

The mechanical properties of drone materials vary depending on the material used. Some common materials used in drone manufacturing include composites, metals, and plastics. Synthetic composites like carbon fibre are known for their high strength and stiffness, making them popular for drone frames (Parveez et al., 2022). Metals like aluminium, steel, and titanium are also used in drone manufacturing, with aluminium being a common choice due to its malleability and ductility (Raj et al., 2021). Plastics like nylon are often used in cost-sensitive applications where rigidity is not as critical. However, none of these materials are environmentally friendly.

In contrast, natural fibre composites are gaining attention as an alternative to conventional materials for drone construction. The mechanical properties of these natural fibre composites, including their strength, stiffness, and durability, are essential considerations in their application for drone construction. Additionally, the mechanical design of drones involves considerations of strength, weight, aerodynamic resistance, and load-lifting ability, highlighting the significance of material properties in ensuring drones' structural integrity and performance. Table 2 compares various synthetic fibres, plastics, and natural fibres.

Most natural fibre composites' densities are comparable to plastics (Table 2). However, the water absorption of natural fibre composites is higher than that of synthetic composites and plastics. Other than that, natural composites' tensile strength and tensile modulus are comparable to those of synthetic composites and plastics, which shows that using natural

Table 2
Comparison of different material's physical, mechanical and thermal properties

Fibre	Matrix	Density (g/cm^3)	Water absorption (%)	Tensile strength (MPa)	Young's modulus (GPa)	References
Carbon	Epoxy	1.15–2.25	0.0500–3.90	0.917–3790	2.62–520.00	MatWeb (2023b)
Aramid	Epoxy	1.24	-	524.00	30.00	MatWeb (2023f)
-	ABS	0.882–3.50	0.0250–2.30	2.60–73.10	0.78–21.20	MatWeb (2023a)
-	Polycarbonate	1.01–1.51	0.0150–0.700	30.00–105.00	1.80–6.00	MatWeb (2023d)
-	Polyamide/Nylon	1.40–1.58	0.200–0.600	62.10–122.00	3.03–5.52	MatWeb (2023c)
-	Polypropylene	0.880–2.40	0.000–0.800	9.00–80.00	0.008–8.25	MatWeb (2023e)
Sugarcane bagasse	Epoxy	1.12–1.14	6.00–14.00	17.49–29.23	0.72–16.81	Abdullahi (2020); Dev et al. (2022); Prasad et al. (2020); Siddique et al. (2021)
Jute	Epoxy	1.5	0.84–40.00	393.00–773.00	0.10–0.30	Ferreira et al. (2016); Masoodi and Pillai (2012); Sujon et al. (2020)
Screwpine	Polyester	1.41	-	12.40–14.70	3.41–41.00	Abral et al. (2012); Gerald Arul Selvan et al. (2023)
Oil palm	Polyester	1.26	1.57	20.00–30.90	0.88–8.50	Rozi et al. (2021); Sahari and Maleque (2016)
PALF	Polyester	1.53	7.4–19.18	29.80–42.30	0.98–1.34	Agung et al. (2018); Siregar et al. (2014)
Kenaf	Polyester	1.13	9.46	21.44–76.56	2.42–3.18	Fajrin et al. (2022); Yahaya et al. (2016)

composites to construct drones is possible. However, the problem of high water absorption needs to be addressed before it can fully replace conventional materials. Several studies have addressed this problem by enhancing water resistivity through fibre treatment. Table 3 shows the study of treated plant fibres and the processing method used.

Table 3
Previous research conducted for water resistivity enhancement

Fibres	Chemicals	Processing method	Results	References
Sisal	Sodium bicarbonate	Alkaline treatment and barrier coating	The mechanical strength increased, and the water absorption capacity was reduced by 30%	Sahu and Gupta (2020)
Hemp	Sodium hydroxide and 3-Aminopropyl-triethoxy silane solution	Alkaline and hydrophobic treatment	Fibre treated with both alkali and silane has the lowest water absorption rate and high mechanical strength	Alao et al. (2021)
Coir	Sodium hydroxide	Alkaline treatment	Treated fibre has a lower water absorption rate compared to untreated fibre	Yew et al. (2019)
Straw	double-[γ-(triethoxysilicon) propyl] tetrasulfide, deionised water, and lipase	Silane, hydrothermal, and lipase treatment	Compatibility with resin increased and improved the mechanical properties	Zhou et al. (2022)
Pine, eucalyptus, and sugarcane bagasse	sodium hydroxide	Alkaline treatment and corona discharge	Corona discharge treatment decreased water absorption of composites and enhanced the mechanical properties of the composites	Mesquita et al. (2017)

From Table 3, most of the fibres treated chemically have an increase in water resistivity. Chemical treatments can make fibres more hydrophobic, meaning they repel water. It is often achieved by coating the fibres with hydrophobic substances such as silicone or fluoropolymers. When water comes into contact with hydrophobic fibres, it forms droplets that roll off rather than being absorbed. Chemical treatments will also introduce cross-links between polymer chains in the fibres. Cross-linking increases the stability and strength of the fibres, making them less likely to swell or absorb water. A barrier will also be created, preventing water from penetrating the fibre structure. It can involve attaching functional groups to the fibre surface that repel water molecules.

In summary, the mechanical properties of drone materials, including strength, stiffness, durability, and weight, play a critical role in selecting materials for drone construction, whether conventional materials or natural fibre composites. These properties directly impact drones' performance, safety, and efficiency in various applications.

Advantages of Drone Materials

Drone materials are mainly made from synthetic composites or plastics, with the current addition of natural composites. These three primary materials offer several advantages, some of which are similar.

The advantages of synthetic composite materials in drones are significant and contribute to their overall performance and efficiency. Synthetic composite materials, such as carbon fibre composites, offer high strength-to-weight ratios, providing structural performance with low mass (Harussani et al., 2022). It reduces the drone's overall weight, improving flight efficiency and endurance. Synthetic composite materials exhibit good corrosion resistance, ensuring the durability and reliability of drone structures, especially in various environmental conditions (Maiti et al., 2022). Synthetic composites can be tuned to absorb specific electromagnetic frequencies and pass other frequencies, contributing to drones' efficient and reliable communication systems (Sahoo et al., 2023). These materials also allow for greater design flexibility, innovation, and the integration of components into the drone structure, leading to improved overall performance (Mishra et al., 2022). Finally, synthetic composite materials benefit from various manufacturing technologies, such as tooling, automated manufacturing, direct processing, and additive manufacturing, which can significantly reduce product development and manufacturing costs.

Plastic materials used in drones also share common benefits with synthetic composites. Drones made from plastics offer several advantages, including lightweight construction, cost-effectiveness, adaptability to complex designs, and resistance to UV rays (Habib, 2023). Engineering plastics such as PEEK and Ultem provide acceptable rigidity at lower weights, enabling the creation of more complex aerodynamic shapes with higher efficiency (Jonckers et al., 2022). Additionally, plastic materials are weatherable, neutrally buoyant, optically clear, durable, and suitable for marine environments, making them ideal for various drone applications, including marine remotely operated vehicles (ROVs) (Curbell Plastics, 2023). Furthermore, plastic materials are integral in the fight against ocean plastic, as AI-powered drones equipped with plastic recognition algorithms are being used to combat plastic pollution in oceans (Harris, 2020). The plastic's weight reduction also improves flight efficiency and endurance. Plastics can increase the durability and reliability of drones by reducing the risk of corrosion, fatigue, or damage. It is crucial for the overall performance and longevity of drone components.

The advantages of natural composite materials in drones are not as widely discussed as those of synthetic composites. However, natural composite materials, such as those derived from plant fibres or other renewable sources, offer potential advantages for drone applications. Natural composite materials can provide lightweight structures, improving flight efficiency and endurance (Parveez et al., 2022). The combination of natural composites and 3D printing offers several advantages for drone design and development, such as weight reduction, durability, reliability, innovation, and the integration of components. Since these materials are derived from renewable sources, they offer potential environmental benefits compared to traditional composites. Some natural composite materials exhibit good corrosion resistance, which is essential for drone operation in various environmental conditions (Azman et al., 2021). Furthermore, depending on the specific properties of the natural fibres used, these composites may offer good impact resistance, contributing to the durability of drone components (Ahmed et al., 2021). Finally, natural composite materials may offer flexibility and potential advantages for aerodynamic performance, contributing to overall flight efficiency.

Disadvantages of Drone Materials

Synthetic fibre composites have several disadvantages, including low hydrophilicity, which affects their processing during wet treatments (Vigneswaran et al., 2014). Additionally, some synthetic fibres are not environmentally friendly and can damage the environment due to exposure to harsh processes. Moreover, certain synthetic fibres can be prone to electrostatic charging when rubbed against other materials and may not always be friendly to the skin (Tahir et al., 2022). Lastly, compared to other fibres, the high cost of some synthetic fibres, such as boron fibre, is also a disadvantage (Rajak et al., 2022).

As for plastics, there are several disadvantages. One of them is that plastic components may have lower durability than composite materials like carbon fibre, making them more susceptible to damage in a crash. While plastics are lightweight, they may not offer the same level of strength as other materials like carbon fibre, which can affect the overall structural integrity of the drone (Shortland, 2023). Plastics are less environmentally friendly than natural fibre composites.

Meanwhile, one of the disadvantages of natural fibre composites is that natural fibres have relatively high moisture absorption, which can lead to chemical degradation of the fibres and weak fibre-matrix interfacial adhesion (Mohammed et al., 2023). Natural fibres also have poor compatibility with many polymer matrices, which can affect the overall performance and durability of the composite material (Elfaleh et al., 2023). In addition, with the current technology, natural fibre composites can be relatively expensive compared to plastics, impacting the overall cost-effectiveness of drone construction. While natural fibre composites are lightweight and have a high strength-to-weight ratio, they may have issues with technical properties such as impact strength.

CONCLUSION

From this review, several points can be concluded. First and foremost, it was found from the review that the drone's material keeps on evolving. Not only is the material getting lighter, but it is also becoming stronger, sustainable, and cost-effective. As the material advances, the potential of drone application widens in various industries. Now, with the addition of plant fibres, the circularity of materials can also be ensured in various stages of the drone construction. Current research shows that Kenaf and PALF can be used as alternative materials for drone construction. This addition makes procuring raw materials needed for construction, repair, and maintenance more manageable.

Furthermore, using plant fibres as drone material creates a circular economy within the country. The review also found some similarities between conventional drones and bio-based drones. These similarities are their lightweight and design flexibility. Despite this, drones made from conventional and bio-based materials also show their differences in eco-friendliness. Natural fibre allows the drone to biodegrade once it is disposed of, and it does not need to use any chemicals to obtain the raw materials.

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