Journal of
Aerospace Engineering & Technology
https://journals.stmjournals.com/joaet

ISSN: 2231-038X (Online)
ISSN: 2348-7887 (Print)
Volume 15, Issue 1, 2025
January–April
DOI (Journal): 10.37591/JoAET

Review JoAET

Future Fibers for the Airport Engineering: A Review

Ryan Nadar[1,]*, Akshay Gharat[2]

Abstract

This paper explores the use of advanced fibers in drone technology, with a specific focus on textiles for drone body structures. As drones continue to evolve, selecting materials that enhance performance, durability, and sustainability has become increasingly critical. Traditionally, drone components rely on resin-based composites for strength and rigidity. However, recent advancements demonstrate that certain fibers can achieve exceptional structural performance without the need for resin. The study emphasizes materials such as Kevlar and carbon fiber, which, when used without resin, provide a lightweight yet highly durable solution for drone manufacturing. These fibers significantly reduce the overall weight of drones, improving flight efficiency, battery performance, and payload capacity. Additionally, eliminating resin simplifies the production process, reduces material waste, and offers environmental benefits by facilitating easier recycling. This article investigates the molecular structure of these fibers, showcasing how their intrinsic properties like high tensile strength and impact resistance can support advanced drone designs. Beyond Kevlar and carbon fiber, the study introduces newly discovered materials emerging from ongoing innovations in fiber technology, broadening the scope of possibilities for drone applications. The findings reveal that blending these advanced fibers can yield composite materials that are both lightweight and high performing, making them ideal for the next generation of drone components. This review lays the groundwork for the development of more efficient, sustainable, and cutting-edge aerial systems, demonstrating the transformative potential of advanced fibers in revolutionizing drone technology.

Keywords: Drone material, textile fibers, next-generation drones, Kevlar, carbon fiber, resin-free materials

INTRODUCTION

The use of advanced fibers in drone technology is an emerging field that has the potential to revolutionize drone design and manufacturing. As drones continue to evolve, material selection becomes a key factor in improving performance, durability, and sustainability. Traditional drone components often rely on resin-based composites for structural strength and rigidity. However, recent advancements suggest that certain fibers, such as Kevlar [1] and carbon fiber [2], can provide exceptional structural performance without the need for resin, offering a range of advantages in drone manufacturing.

***Author for Correspondence**
Ryan Nadar
E-mail: ryannadarinventor@gmail.com

[1]Researcher, Department of Aerospace Engineering, Ajeenkya DY Patil University, Pune, Maharashtra, India
[2]Assistant Professor, Department of Aerospace Engineering, Ajeenkya DY Patil University, Pune, Maharashtra, India

Receiving Date: January 02, 2025
Accepted Date: January 17, 2025
Published Date: January 22, 2025

Citation: Ryan Nadar, Akshay Gharat. Future Fibers for the Airport Engineering: A Review. Journal of Aerospace Engineering & Technology. 2025; 15(1): 14–18p.

METHODOLOGY

This study examines the molecular structure and intrinsic properties of advanced fibers, specifically Kevlar and carbon fiber, that enable them to perform at a high level without resin. Also here the idea is full of abstract only: The review investigates how these fibers can be applied in drone body structures and explores the potential of newly discovered fibers that are emerging through ongoing innovations in material science. The approach includes experimental testing of these materials in drone prototypes, along with an analysis of performance metrics like flight efficiency, battery performance, and payload capacity.

LITERATURE REVIEW

Research on fiber-based composites has highlighted the importance of material properties such as high tensile strength, impact resistance, and lightweight characteristics in the design of drones. Traditional resin-based composites have been widely used due to their strength and rigidity, but they also introduce challenges in production and recycling. Studies have explored the potential of fibers like Kevlar and carbon fiber in various industries, including aerospace, demonstrating their ability to replace resin-based [3] materials in certain applications. Resin in fiber increases weight which result in more weightage in this process [4]. The literature also emphasizes the environmental benefits of resin-free materials, which reduce waste and promote sustainability through easier recycling.

RESEARCHER OVERVIEW

The idea of creating resin-free materials for carbon and Kevlar makes them much lighter in weight because the process focuses on molding due to temperature and pressure. Both processes require a specific temperature to remove unnecessary elements during manufacturing. For example, during the process of making carbon fiber, the temperature is applied to eliminate elements that are not needed.

Carbon Molding and Carbonization

Molding PAN (Polyacrylonitrile)

PAN can be molded into various shapes during its precursor stage (before carbonization). Typically, PAN is in a polymeric form that can be processed into fibers, films, or other structures. Molding [5] at this stage allows the material to take the desired shape, offering flexibility in design and application. This process is similar to molding other polymeric materials before they undergo curing or hardening [6].

Carbonization Process

Once the molded PAN has taken the desired shape, it is heated to temperatures around 2000°C in an inert atmosphere (such as nitrogen or argon). This leads to the thermal decomposition of PAN, driving off most non-carbon atoms (hydrogen, nitrogen, and oxygen). The result is a network of carbon atoms forming carbon fibers or carbonized structures with high thermal stability, mechanical strength, and electrical conductivity.

Potential Advantage

The carbonized material retains the shape it was molded into, eliminating the need for resin to bind fibers together. Traditional carbon fiber production involves resins or binders to hold fiber strands together, but the carbonization of PAN directly into its desired shape could bypass this step, potentially reducing production complexity and costs.

Kevlar

The material are molded into specific shapes and heated to 600°C. The high temperature drives off most non-nitrogen atoms, leaving behind a nitrogen-carbon structure that retains the molded shape, thus eliminating the need for resin to bond the fibers. This process could lead to a new class of technical textiles with enhanced strength, durability, and heat resistance, ideal for high-performance applications such as protective clothing, aerospace components, and military gear. The resulting material would retain the lightweight and high-strength properties of Kevlar, while also offering improved environmental sustainability by removing the need for traditional resin-based bonding. This approach offers potential advantages, including increased material longevity, customizability, and greater manufacturing efficiency. However, challenges related to the high-temperature treatment process, energy consumption, and ensuring consistency in the final product's performance must be addressed. Future research should focus on optimizing the molding and heating processes, improving thermal stability, and exploring energy-efficient methods to make this process scalable and cost-effective. This novel approach could significantly advance the development of technical textiles, providing industries with more sustainable, high-performance materials.

Carbon and Kevlar Mixture

Combining carbon and Kevlar into a single material would create a new and innovative solution. The combination of polyacrylonitrile (PAN) and para-aramid fibers, molded together during the process, would result in a material that is both lightweight and strong. Upon heating the mold to 2000°C, the PAN undergoes carbonization, which eliminates most non-carbon and non-nitrogen atoms, leaving behind pure carbon strands along with nitrogen and trace elements. This results in a carbonized material that retains the shape of the original object, eliminating the need for resin. The fusion of PAN and para-aramid offers a potential alternative to traditional resin-bound composites, providing a lightweight, strong, and heat-resistant material with enhanced structural integrity.

Objective

The Advanced Fiber Drone Body is a lightweight, highly durable drone body structure designed using cutting-edge fiber technology. It leverages the intrinsic properties of materials like Kevlar and carbon fiber without the use of resin, enabling superior structural performance. This innovative body design enhances flight efficiency, battery life, and payload capacity, while also contributing to sustainability through simpler production and recyclability.

- *Material composition:* High-tensile-strength material (e.g., Kevlar, carbon material) without resin. Potential integration of newly discovered material to enhance performance.
- *Lightweight design:* Reduced overall weight improves flight efficiency and extends battery performance.
- *Impact resistance:* Exceptional durability and resistance to external impacts, ensuring longevity and reliability.
- *Environmental sustainability:* Resin-free construction facilitates easier recycling and reduces material waste. It simplified manufacturing process minimizes production complexity.
- *Customizable composite blends:* Blending advanced fibers to create optimized material solutions for specific drone applications.

Applications

Aerial drones for surveillance, delivery, and research purposes [7]. Military-grade drones requiring enhanced impact resistance [8]. Lightweight drones for extended flight times and higher payload capacities.

Innovation Potential

The Advanced Fiber Drone Body represents a transformative leap in drone manufacturing, shifting from traditional resin-based composites to eco-friendly, high-performance fiber-based solutions. This object encapsulates the next generation of aerial technology, merging efficiency, durability, and sustainability.

DISCUSSION

The exploration of advanced fibers for next-generation drones presents exciting opportunities to enhance drone performance, sustainability, and manufacturing processes. The use of fibers like Kevlar and carbon fiber without resin offers substantial advantages in terms of reduced weight, increased durability, and improved efficiency. This study highlights how these fibers can perform at high levels due to their intrinsic properties such as high tensile strength, impact resistance, and lightweight characteristics. One of the most notable findings is the potential for eliminating the need for resin in drone body structures. Traditional resin-based composites have been widely used for their strength and rigidity, but they also present challenges, including complicated production processes and difficulties in recycling. The resin-free approach offers a more sustainable alternative by reducing waste and simplifying the manufacturing process. The incorporation of advanced fibers like Kevlar and carbon fiber directly into the drone structure without resin could result in a lighter, more energy-efficient drone capable of higher payload capacity and extended battery life. Furthermore, the potential for blending these fibers with emerging materials provides exciting new possibilities. The combination of carbon and Kevlar fibers in a single material could create a composite that balances the strength and impact resistance of Kevlar with the lightweight and heat-resistant properties of carbon fiber. This could lead to the development of even more advanced drones that are not only efficient but also environmentally friendly. However, the process of molding and carbonizing materials like PAN and para-aramid fibers comes with its own set of challenges, including high temperature treatments and energy consumption. Optimizing these processes to reduce energy usage and improve consistency in material properties will be essential for scaling these technologies for commercial production. Furthermore, ensuring the thermal stability of the final product will be crucial for the performance and longevity of drones using these materials.

COMPARATIVE ADVANTAGES OF RESIN-FREE ADVANCED FIBERS IN DRONE TECHNOLOGY

Drone design increasingly demands materials that balance performance, cost-effectiveness, and scalability. While traditional drone components rely heavily on resin-based composites for structural strength and rigidity, recent advancements in fiber technology reveal promising resin-free alternatives such as Kevlar and carbon fiber. This exploration highlights key comparative advantages in terms of cost, scalability, and application-specific performance.

Cost Efficiency

The elimination of resin significantly reduces production costs. Resin-based composites involve labor-intensive processes such as curing and molding [9], which add to manufacturing time and expenses. In contrast, resin-free fibers simplify assembly and minimize processing requirements, allowing manufacturers to allocate resources more effectively. Additionally, the reduced weight of resin-free fibers lowers drone operational costs by improving energy efficiency, particularly in battery-powered systems.

Scalability and Production Feasibility

Resin-free fibers are inherently more adaptable for high-volume production due to their straightforward fabrication processes. Eliminating resin not only cuts down material waste but also mitigates environmental concerns, as these fibers are easier to recycle. Also resin base fiber has a more complex manufacturing process [10], resin free product. This enhances their scalability for commercial drone production, catering to industries such as logistics, agriculture, and surveillance, where demand for lightweight, durable drones is rapidly growing.

Enhanced Material Performance

The intrinsic properties of Kevlar and carbon fiber such as high tensile strength, impact resistance, and thermal stability make them ideal for drone applications even without resin. The molecular structure of these fibers allows them to retain exceptional rigidity and durability while drastically reducing weight. This reduction in mass translations improved flight efficiency and extended battery life, and increased payload capacity.

Broader Material Innovations

Emerging fibers discovered through ongoing research expand the range of applications for resin-free composites. For instance, advanced hybrid fiber blends leverage complementary material strengths, enabling the development of customized solutions for specific drone requirements. As the resin free material of these will be less CO_2 production, these innovations pave the way for highly optimized designs that meet the evolving demands of modern aerial systems.

CONCLUSION

In conclusion, the integration of advanced like Kevlar and carbon fiber into drone manufacturing represents a significant paradigm shift, moving toward lighter, stronger, and more sustainable designs. The elimination of resin not only simplifies production but also offers environmental benefits, such as reducing waste and improving recyclability. This review lays the foundation for the development of next-generation drones that are more efficient, durable, and environmentally friendly. The potential for further innovation, especially through the blending of different fibers and the exploration of new materials, offers exciting prospects for the future of drone technology. While challenges in material processing remain, ongoing advancements in fiber technology and manufacturing techniques will likely pave the way for the widespread adoption of resin-free composites. Future review should focus on optimizing these processes and addressing scalability to ensure that these materials can be used effectively in commercial drone production, thus ushering in a new era of drone technology that combines performance with sustainability.

REFERENCES

1. Molded Fiber. (N.D.). Home. Retrieved November 24, 2024, From Https://Www.Moldedfiber.Com/ S.M. International Composites. (N.D.). Carbon Fiber Molding Process: What Are the Different Types? Retrieved November 24, 2024, From https://www.smicomposites.com/carbon-fibermolding-process-what-are-the-different-types/
2. Benchmark Abrasives. (2021, January 8). What Is Resin Fiber Discs & Its Types? Benchmark Abrasives. Https://Benchmarkabrasives.Com/Blogs/News/What-Isresin-Fiber-Discs-Its-Types
3. Explore Composites. (N.D.). Basic Numbers and Calculations For Composites. Retrieved December 31, 2024, From Https://Explorecomposites.Com/Articles/Design-For-Composites/Basic-Numbers-And-Calculations-For-Composites/
4. Rlz Motorsports. (2023, February 10). Why Is Carbon Fiber Expensive And Why Should We Opt For It? Rlz Motorsports. https://www.rlzmotorsports.com/blogs/news/why-is-carbon-fiver-expensive-and-why-should-we-opt-for-it#:~:text=these%20carbon%20fibers%20are%20then, materials%20like%20steel%20or%20aluminum
5. Jouav. (N.D.). Security & Surveillance. Retrieved December 31, 2024, From https://www.jouav.com/industry/security-surveillance
6. Unmanned Systems Technology. (N.D.). Tactical Drones. Unmanned Systems Technology. Retrieved December 31, 2024, From https://www.unmannedsystemstechnology.com/expo/tactical-drones/
7. NitPro Composites. (2025). The importance of resin selection in Manufacturing Carbon fiber products. [online] NitPro Composites. Available from: https://www.nitprocomposites.com/blog/the-importance-of-resin-selection-in-manufacturing-carbon-fiber-products.
8. StudySmarter UK. (2019). Mass Properties: Density, Mass & Volume. [online] StudySmarter. UK. Available from: https://www.studysmarter.co.uk/explanations/engineering/aerospace-engineering/mass-properties/
9. Zhang S, Gan J, Lv J, Shen C, Xu C, Li F. Environmental Impacts Of Carbon Fiber Production And Decarbonization Performance In Wind Turbine Blades. J Environ Manage. February 2024;351:119893.
10. Stempihar Jj, Souliman Mi, Kaloush Ke. Fiber-Reinforced Asphalt Concrete As Sustainable Paving Material For Airfields. Transp Res Rec. 2012;2266(1):60–8.

