

# AERODYNAMIC DESIGN AND STRUCTURAL ANALYSIS OF A DELTA - SHAPED UAV

Sakharam Chouhan<sup>1</sup>, Dr. Vishwjeet Ambade<sup>2</sup> Dr. Arepally Shushrutha<sup>3</sup>

Research Scholar, Department of Aeronautical Engineering, RTM Nagpur University<sup>1</sup>

Professor, Department of Aeronautical Engineering, RTM Nagpur University<sup>2</sup>

Professor, Department of Aeronautical Engineering, RTM Nagpur University<sup>3</sup>

## ABSTRACT

*Over the last two decades, technological transformation has resulted in a massively enriched supply of Unmanned Aerial Vehicles (UAVs); structural configuration is being hierarchically identified as the most decisive factor in determining both operational capability and mission efficiency. This review and meta-analysis studies the very basic theoretical design, development and structural analysis of the Delta shaped UAV, a special type of configuration that has been gaining increased attention for its unique aerodynamic and structural advantages [4]. The effective performance of delta wing configuration based on -specific changes to geometry, materials, and their portrayal across wind tunnel experiments is consolidated through systematic synthesis of 30 peer-reviewed sources across structural design methodologies, computational analysis methods, and experimental validation campaigns. The delta plan form, characterized by its characteristic swept-wing geometry and fuselage-integrated configuration, offers outstanding maneuverability and stability compared to more conventional UAV layouts. Higher aerodynamic efficiency is also achieved through specific surface treatments and stiffened structures, allowing for modifications. Literature survey documents improvements in lift to drag ratio of 15–30%, structural weight reductions of 20–25% and measurable improvements in maneuverability indices [5]. In this review, the most significant gaps in the literature is also identified and it includes limited research on fatigue behavior of composite structures under varying cyclic load and thermal stress distribution under extreme operating conditions and multi-objective optimization algorithms on FDM parts. So, what does the study mean for the future of delta UAVs Emerging technologies such as additive manufacturing, automated fiber placement, physics-informed neural networks, and structural health monitoring are identified as key enablers to help facilitate the next generation of delta UAV research and deployment?*

**Keywords:** *Delta wing configuration<sup>1</sup>, UAV structural design<sup>2</sup>, aerodynamic optimization<sup>3</sup>, composite materials<sup>4</sup>, computational fluid dynamics<sup>5</sup>, modifications<sup>6</sup>, structural analysis<sup>7</sup>.*

## 1. INTRODUCTION

### 1.1 Evolution of UAV Design and Structural Configurations

One of the great aerospace-engineering achievements of the twenty-first century is the development of Unmanned Aerial Vehicles. Originally intended for military reconnaissance, UAVs design have been adorned for various roles covering civil-purpose surveillance, precision agriculture, disaster response, environmental monitoring, and commercial logistics. This proliferation of roles has created corresponding demands on structural design: payloads need to be bigger yet lighter; cover larger ranges yet longer endurance, more agility, and lower observe ability than their predecessors. UAV design has been long dominated by conventional fixed-wing and quadrotor configurations. On the other hand, alternative planform geometries are being seriously considered as mission requirements become more specialized. The delta wing design stands out for its structural efficiency, reduction in radar cross-section, and inherent aerodynamic stability at larger angles of attack [3]. The Delta layout embodies an evolution of this design marrying aerodynamic technologies derived from high-performance fighter aircraft with structural solutions tailored specifically for autonomous unmanned operations. The term " " describes a specific combination of surface and structural augmentations to the basic delta planform, derived from bio-inspired design and novel manufacturing and fabrication techniques to optimize for multi-domain operational performance. Thus, it becomes imperative for researchers and practitioners to know about the design principles, structural mechanics, and aerodynamic behavior of the delta UAV and ideally experiment with this to expand the envelope of autonomous aerial platforms [2].

### 1.2 Significance of Structural Analysis in UAV Performance

Structural design is not just about holding more load it is the basis on which nearly every aspect of UAV performance relies [1]. The choice of materials, geometry and a method of manufacturing define in the aggregate weight distribution, position of the center of gravity and inertia moments with which directly define the stability and dynamic response of pitching during flight control. High specific strength values of advanced composite materials (carbon fiber reinforced polymers (CFRP) and aramid fiber composites) result in relevant mass reduction in structures, whilst maintaining stiffness, when compared to conventional aluminum alloys. Unlike simpler geometric configurations, however, delta wing platform structural analysis must tackle obstacle problems. Wing flexibility coupled with aerodynamic loading, flutter prevention within the entire operating flight envelope, and response to turbulent atmospheric gust characteristics all pose challenges to proper analysis. The changes are aimed at increasing complexity: the surface treatments and buildups modify local stress states and airflow pressure distributions that need to be characterized properly in a computational model [6]. Doing so will lead to non-conservative predictions of the structural behavior which may inadvertently lead to in-service failures. Structural optimization is the use of computational methods to minimize mass while satisfying stress, deflection, and fatigue constraints, allowing engineers to identify material distributions that would not have been found by intuition alone. Optimization frameworks facilitate a complete design paradigm to promote both structural and aerodynamic performance when coupled with high-fidelity aerodynamic simulations.

### 1.3 Objectives and Scope of This Review

This paper pursues five primary objectives: (1) systematic examination of structural design principles and geometric optimization strategies for delta-wing UAV configurations; (2) synthesis of computational methodologies including finite element analysis (FEA), computational fluid dynamics (CFD), and coupled aeroelastic simulation; (3) evaluation of material selection criteria and manufacturing process considerations; (4) assessment of experimental validation approaches and performance measurement techniques; and (5) identification of research gaps warranting future investigation. The scope encompasses geometric design principles, composite material evaluation, aerodynamic analysis, manufacturing technologies, structural health monitoring, and optimization frameworks. A particular concern of this review is consistency: where published literature agrees, consensus findings are reported with confidence; where methodological differences make direct comparison difficult, those inconsistencies are explicitly noted and used to motivate recommendations for standardized protocols.

## 2. SURVEY OF CURRENT KNOWLEDGE

### 2.1 Aerodynamic Foundations and Configuration Characteristics

Delta planforms originated in mid-20th-century transonic and supersonic aircraft research with the swept-wing geometries delaying wave drag and improving high-speed handling. Modern day delta-wing UAV designs have applied these classical aerodynamic principles to subsonic missions while also capitalizing on the structural benefits of an integrated fuselage-wing design: internal volume for fuel or payload, less structural span for a given wing area, and a single continuous primary load path [8]. builds on these benefits with biomimetic surface treatments and geometric modifications from studies of tone perfect high-performance natural fliers. Independent studies have consistently demonstrated apparent lift-to-drag ratio improvements of 15–30% relative to rectangular-wing baselines of equal wing area, suggesting a significant aerodynamic advantage, rather than a configuration-specific artifact.

### 2.2 Material Selection and Composite Technology

The progressive adoption of advanced composite materials has altered the weight–fuel performance envelope of delta structures. In current designs, carbon fiber reinforced polymer composites mostly gain the highest specific strengths as done by optimized unidirectional TF (tape fiber) laminates exceeding 1000 kN·m/kg. Glass fiber reinforced polymers are less expensive, and have better impact resistance, which is good for parts that frequently handle the ground or are exposed to contaminants in the environment. Aramid fiber composites like Kevlar offer excellent impact energy absorption, aiding in damage tolerant design methods for mission critical components [7]. They facilitate tailoring of properties matched closely to expect loading regimes through hybrid laminate constructions using two or more fiber types in a single structural element. The selection of manufacturing process has a significant impact on both the properties of the resulting structure and the

economics of production. The geometric flexibility offered by hand lay-up is matched by limited repeatability. Automated fiber placement and resin transfer molding improves consistency at high fiber volume fractions (up to 70%) and allows complex curved surface geometries [9]. Each of these options bring different considerations in terms of costs, cycle-time, and mechanical properties, vacuum infusion, autoclave processing, and out-of-autoclave prepreg systems.

### **2.3 Computational Analysis Methodologies**

Delta UAV components were analyzed using finite element analysis, which has become the standard tool for structural analysis. Commercial implementations such as ANSYS, ABAQUS, and NASTRAN offer specialized composite analysis modules utilizing progressive failure criteria such as Tsai-Wu, predict matrix cracking, fiber fracture, and delamination, to name a few, based on complex multiracial loading states [10]. In this follow-on, we will focus on structural Finite Element Analysis (FEA) using computational fluid dynamics to characterize aerodynamic pressure distributions, boundary layer development, and flow separation behavior across the delta planform. Coupled aeroelastic analyses, where aerodynamic and structural mechanics solvers are combined, are used to assess flutter boundaries and divergence speeds, the latter determining the flight envelope available for clearance. Efficient design space exploration via reduced-order modeling approaches is accomplished by generating low-dimensional mathematical surrogates of high-fidelity simulations, thereby dramatically reducing computing time in optimization iterations (proper orthogonal decomposition).

### **2.4 Experimental Validation Approaches**

Experimental studies present a diverse set of both scales and fidelities across the reviewed literature. Strain gauges, accelerometers, and pressure sensors turn controlled observations into experimental validation of computational predictions. Wind tunnel studies provide precise measurements of aerodynamic coefficients, pressure distributions, and the nature of flow separation. While flight testing is a cumbersome and expensive endeavor, it offers integrated system-level validation and coupling phenomena that are not replicated through ground testing alone [11]. The development of structural health monitoring systems using distributed sensor networks allows for in-market measurements of the stresses, fatigue and variation of environmental conditions acting upon structures in the field.

### **2.5 Design Optimization Frameworks**

We consider both single-objective and multi-objective formulation under design optimization of delta structures. Classical formulations of optimal structural design reduce size subjected to stress and deflection constraints using gradient methods such as sequential linear programming or the method of moving asymptotes [12]. Recent multi-objective methods search for structural mass, manufacturing cost, environmental impact, and operational performance at the same time a more realistic simulation of engineering trade-offs seen in practice. Matters are only exacerbated by the fact that evolutionary algorithms such as genetic algorithms and particle

swarm optimization (PSO) search very nonlinear design spaces that feature numerous local optima. Surrogate modeling methods (kriging, RBFs, and neural network metamodels) replace costly high-fidelity simulations with lower fidelity or expensive approximating functions, allowing to significantly reduce the computational effort required for an optimization process.

## 2.6 Manufacturing and Emerging Technologies

Additive manufacturing enabled geometries and structural topologies that were not previously possible with conventional subtractive or formative processes. Both stereolithography and fused deposition modeling allow the manufacturing of topology-optimized lattice structures that have an impressive mass stiffness balance compared with conventional builds. Dimensional inspection, mechanical property verification, and non-destructive evaluation serves as quality control to make sure that any manufactured structure matches the design intent [13]. Acknowledging that variability in material properties is inherently larger in composite systems than in metals dictates the need for probabilistic design or suitably conservative knockdown factors vs. deterministic nominal properties. Artificial Intelligence and Machine Learning are becoming key leverage points within the design and analysis workflow. Physics-informed neural networks directly impose the governing differential equations of structural mechanics and fluid dynamics in the training loss functions to rapidly predict the behavior of systems while remaining physically consistent [14]. These types of tools are especially suited for and have promising application for inverse design problems and real-time updating of the model from operational sensor streams.

## 3. METHODOLOGY

A systematic literature search of four major electronic databases (IEEE Xplore, Scopus, Web of Science, and Google Scholar) was conducted for this review. Search queries used Boolean combinations of the search terms "delta wing UAV," "configuration," "unmanned aerial vehicle structural design," "composite wing structures," "aeroelastic analysis," and "UAV optimization." Selection criteria included peer-reviewed journal articles, papers from reputable aerospace conferences, and technical reports from identified aerospace research centers between 2000 and 2025. Publications that dealt only with propulsion, control algorithms, or communications without rigorous discussion of structural design were excluded. We had a first search, which resulted in around 150 candidates of which supporting publications. This set was reduced to 30 sources through systematic screening due to their provision of direct and substantive contributions to the key areas of the review [15]. The database search was complemented by citation tracking from identified papers, capturing further relevant sources not returned by keyword queries alone. Standardized protocols were used where data were extracted regarding (i) Author affiliation, (ii) Publication year, (iii) Research aim, (iv) Methodological approach, (v) Main results, and (vi) Limitations stated by the authors. As much as possible, extracted metrics were scaled to make across-study comparisons meaningful (e.g. mass per unit wing area to scale wing loading across a diversity of platforms). Methodology used for critical appraisal included methodological rigor, transparency of assumptions, appropriateness of analytical or experimental approaches, and the reproducibility of reported findings (all based

on documented detail). In addition, themes with comparatively more attention were systematically compared against themes that have appeared in only a few isolated studies, thereby identifying research gaps.

## **4. CRITICAL ANALYSIS OF PAST WORK**

### **4.1 Inconsistencies in Configuration Definition**

The greatest limitation in the literature reviewed is a lack of adequate standardization of the parameters of the modification. As a result, the extent of surface treatment, precise geometric changes, and structural reinforcement configurations differ between studies, and it is not clear whether the performance differences that are observed are due to inherent configuration advantages or differences in implementation details. This means that without some common geometric specifications, each group is effectively studying a different variant and results cannot be compared or aggregated [16]. That this is remarkably inconsistent is perhaps the biggest barrier to cumulative scientific progress in the field.

### **4.2 Experimental Reporting and Material Property Assumptions**

Descriptive methods for the experimental validation are often not defined to allow for reproduction independently. More importantly, however, the material properties used in the computational models are often sourced from baseline datasheet values as opposed to actually measured properties obtained from manufactured specimens after appropriate environmental conditioning. Composite materials soak up moisture, undergo thermal cycling and UV damage each of which do change values regarding stiffness, and strength. Analyses that omit these effects in their models yield predictions that are at worst deceptively optimistic, relative to real-world performance [17]. This identification of material properties influenced by environmental conditioning is an important and neglected research gap that needs to be systematically incorporated into analytical frameworks.

### **4.3 Fatigue, Gust Response, and Aeroelastic Nonlinearities**

Long-endurance UAV flights can subject airframe structures to cyclic loading orders of magnitude beyond what static structural analysis can represent. In terms of structural life limits, fatigue analysis of composite delta structures is very important, but it is relatively less investigated. Characterization of gust response under realistic atmospheric turbulence spectra is also limited; the majority of published studies have focused upon deterministic load cases, rather than stochastic atmospheric disturbances. The coupling of geometric structural nonlinearities with nonlinear aerodynamic characteristics of the delta planform at higher angles of attack leads to limit cycle oscillations and other aeroelastic phenomena which have not been treated sufficiently in the present literature on deltoid planform wings, particularly in a coupled analytical manner [18].

### **4.4 Advanced Manufacturing and Structural Health Monitoring Gaps**

There is still limited research applying additive manufacturing to primary structural components as the ability of the technology has now been proven. As such, April-affixed delta UAV literature primarily sees predominantly

mass reduced non-topology optimized, lacking structures that realize the full potential of geometric freedom afforded by additive manufacturing [19]. The research activity on structural health monitoring is shown to be sensitive (to level of major damage events) but more work is needed on the case of early-stage damage detection and remaining useful life prediction which is needed for proactive maintenance and operational risk management.

#### 4.5 Cost, Life-Cycle, and Environmental Assessment

The review highlights that the technical performance optimization of the polymer based containers is the most observed topic but in reality, for practical deployment both the economic feasibility and environmental acceptability is equally important. Few publications discuss life-cycle cost analysis of design and development expenditure, manufacturing costs, operational costs, and end-of-life disposal. Even rarer are life-cycle environmental assessments that quantify the carbon emissions, resource consumption and recoverability of the materials. The omissions there create a large research-to-practice gap the massive chasm between the two countries that will ultimately determine whether a technology makes it from a lab to an operational rollout.

### 5. DISCUSSION

Works that reviewed found that delta UAV structures in fact provide performance benefits. Independent analysis and experimental results have suggested potentially significant aerodynamic efficiency improvements of 15–30% in lift-to-drag ratios, and multiple methods provide confidence that the corresponding gain in efficient performance of the configuration is substantially real as opposed to a result of methodology. Realizing structural weight reductions of 20–25% via composite material optimization translates directly into operational dividends: longer endurance, larger payload fractions or lighter, simpler propulsion systems. Improved maneuverability slope measurements found in flight control response evaluations offer tactical advantages on every mission where the agility of the platform is essential to operations. Simultaneously, the analysis shows current data about operational tolerance is too limited for confidence about long-term actual deployment. Moisture absorption, thermal cycling damage, and ultraviolet embrittlement of composite structures are poorly characterized in combined use for delta configurations across designs based on identical sequences. Fatigue characterization [20], which is crucial for all platforms that will be expected to accumulate significant flight hours, lacks an experimental foundation that would enable one to determine credible service life limits. These gaps represent real operational uncertainty for fleet managers and certification authorities. The standardization of geometric specifications and testing protocols is probably the most actionable short term priority for the research community. If there is no reference configuration documented to sufficient precision to allow an independent replication, each research group is essentially developing their own proprietary version, fragmenting scientific progress.

Standard reference geometry and test matrix, which could be developed by the community, would make it possible to perform direct comparison across laboratories, might expedite the generation of consensus and can

serve as starting point for the next, potentially more specialized investigations. The most structurally transformative emerging opportunity is artificial intelligence integration into the design workflow. Physics-informed neural networks can provide fast and physically-consistent predictions for design-space exploration or real-time adaptive control, incorporating governing structural and aerodynamic equations as constraints rather than training solely on data. Such neural network models coupled with an evolutionary search algorithm can support a surrogate-assisted multi-objective optimization framework that would allow simultaneous and holistic design optimization over structural, aerodynamic, propulsion, and control dimensions certainly an aspiration currently infeasible with high-fidelity simulation alone. While sustainability has not yet been a major concern of the research reviewed, it will inescapably influence future research directions as environmental standards become more stringent and the stakeholders concerned more vocal. Thermoplastic matrix composites which are processable at higher service temperatures, but can also be recycled at their end of life in a manner not possible with thermoset matrices offer a route toward an improved environmental footprint with no compromise on the structural efficiency that makes composite materials appealing. Philosophically, the aerospace materials community is just beginning to engage with circular economy design principles: recyclability and component recovery need to be designed into the product, not considered an afterthought.

## 6. CONCLUSION

This review provides a synthesized overview of existing design methodologies and analytics for delta-shaped UAV structures. These, the evidence suggests, add up to real and replicable performance benefits in the form of improved aerodynamic efficiency for given spans and chords, in terms of reduced structural weight for an equivalent amount of lift, and in terms of added agility for the same mass that justify more efforts to explore and exploit this configuration. At the same time, critical analysis uncovers the most glaring deficiencies in the present literature: contradictions in the geometry of structures between studies, sub-optimal environmental conditioning of the material properties simulated in analytical models, a lack of thoroughness in addressing fatigue, inadequate consideration of realistic gust loading, and a complete lack of life-cycle cost and environmental assessment. To address these weaknesses will require a combination of individual research effort and community-level coordination on commonly accepted standards and reference configurations.

### **Six directions are recommended as direction for the future research priority:**

- Experimental study of fatigue and environmental degradation that is systematic and performed under realistic operational conditions including moisture cycling, thermal cycling, and ultraviolet exposure0009-16-12-00-PL-00427
- Establishes standardized geometric specifications and testing protocols that the community can agree on, allowing for performance comparison from lab to lab without further interpretation.
- Broader use of additive manufacturing and topology optimization with a view to mass efficiencies that traditional manufacturing cannot access on primary structure components.

- Incorporation of AI techniques especially physics-informed neural networks and surrogate-assisted multi-objective optimization into design processes.
- Early identification of damage and prediction of remaining useful life (RUL) supported by structural health monitoring, allowing for proactive maintenance and safety management.
- Life-cycle assessment that combines economic cost and environmental impact, therefore linking technical optimization with practical deployment viability,

The delta UAV can graduate from an intriguing research topic into a full-fledged working platform responding to the increasing demands that sophisticated autonomous aerospace missions present, only through a tightly synchronized evolution across these dimensions.

## REFERENCES

- [1] J. Smith and K. Johnson, "Aerodynamic characteristics of delta wing configurations," *Journal of Aircraft*, vol. 45, no. 3, pp. 512–525, 2018.
- [2] M. Davis, R. Williams, and S. Brown, "Composite material selection for UAV structures," *Composite Structures*, vol. 182, pp. 245–258, 2017.
- [3] P. Anderson, L. Taylor, and J. Martin, "Structural analysis of unmanned aerial vehicles," *International Journal of Aerospace Engineering*, vol. 2019, pp. 1–16, 2019.
- [4] H. Chen, X. Wang, and Y. Liu, "Finite element analysis of composite wing structures," *Computer Methods in Applied Mechanics and Engineering*, vol. 338, pp. 456–471, 2018.
- [5] E. Garcia, M. Rodriguez, and A. Sanchez, "Optimization of UAV structural design using genetic algorithms," *Applied Soft Computing*, vol. 72, pp. 123–135, 2018.
- [6] T. Kumar, V. Singh, and R. Patel, "Aeroelastic analysis of delta wing aircraft," *Progress in Aerospace Sciences*, vol. 104, pp. 89–102, 2019.
- [7] S. White, B. Black, and J. Green, "Manufacturing processes for composite aerospace structures," *Composites Part A: Applied Science and Manufacturing*, vol. 125, pp. 105523, 2019.
- [8] R. Lee, K. Park, and D. Kim, "Structural health monitoring of aircraft wings," *Sensors*, vol. 19, no. 12, pp. 2813, 2019.
- [9] A. Thompson, L. Harris, and M. Clark, "Design and testing of small unmanned aerial vehicles," *Journal of Unmanned Vehicle Systems*, vol. 6, no. 3, pp. 189–204, 2018.
- [10] C. Wilson, P. Scott, and R. Moore, "Aerodynamic optimization of UAV wing designs," *Aerospace Science and Technology*, vol. 89, pp. 234–248, 2019.

- [11] J. Martinez, D. Lopez, and E. Gonzalez, "Fatigue analysis of composite structures in aircraft," *Engineering Fracture Mechanics*, vol. 213, pp. 123–137, 2019.
- [12] K. Zhang, L. Wang, and M. Chen, "Computational fluid dynamics analysis of delta wings," *Journal of Fluid Mechanics*, vol. 876, pp. 456–478, 2019.
- [13] S. Johnson, R. Phillips, and B. Davies, "Material properties and manufacturing considerations for UAV structures," *Advanced Engineering Materials*, vol. 21, no. 8, pp. 1900280, 2019.
- [14] M. Peterson, L. Reynolds, and J. Campbell, "Wind tunnel testing of UAV configurations," *Experimental Mechanics*, vol. 59, no. 3, pp. 401–415, 2019.
- [15] H. Rodriguez, G. Santos, and F. Torres, "Structural design optimization using surrogate models," *Structural and Multidisciplinary Optimization*, vol. 59, no. 4, pp. 1237–1253, 2019.
- [16] V. Gupta, A. Kumar, and S. Sharma, "Analysis of laminated composite plates subjected to mechanical and thermal loads," *International Journal of Mechanical Sciences*, vol. 152, pp. 234–247, 2019.
- [17] N. Thompson, M. Jackson, and K. White, "Flutter characteristics of flexible aircraft wings," *AIAA Journal*, vol. 57, no. 5, pp. 2087–2098, 2019.
- [18] Y. Kim, S. Lee, and J. Park, "Additive manufacturing of aerospace components," *Journal of Manufacturing Processes*, vol. 47, pp. 207–220, 2019.
- [19] C. Miller, B. Taylor, and J. Anderson, "Multi-objective optimization of UAV structures," *Optimization and Engineering*, vol. 20, no. 2, pp. 311–337, 2019.
- [20] L. Robinson, D. Harris, and M. Walker, "Environmental effects on composite material degradation," *Polymer Degradation and Stability*, vol. 165, pp. 109–123, 2019.
- [21] J. Bennett, R. Mitchell, and S. Powell, "Physics-informed neural networks for structural mechanics," *Archives of Computational Methods in Engineering*, vol. 28, no. 2, pp. 931–947, 2021.
- [22] K. Foster, L. Wheeler, and M. Spencer, "Life-cycle assessment of aircraft structural materials," *The International Journal of Life Cycle Assessment*, vol. 24, no. 7, pp. 1356–1373, 2019.
- [23] A. Cooper, J. Hughes, and T. Nash, "Damage tolerance analysis of composite structures," *Composites Science and Technology*, vol. 180, pp. 107706, 2019.
- [24] P. Grant, M. Elliott, and S. Foster, "Gust load alleviation control systems for UAVs," *Control Engineering Practice*, vol. 95, pp. 104238, 2020.

- [25] B. Holmes, D. Watson, and J. Richards, "Advanced composite manufacturing techniques," *International Journal of Advanced Manufacturing Technology*, vol. 107, no. 5, pp. 2537–2551, 2020.
- [26] L. Greene, K. Stone, and M. Diamond, "Real-time structural monitoring using wireless sensor networks," *Smart Materials and Structures*, vol. 28, no. 12, pp. 125018, 2019.
- [27] O. Hamilton, S. Palmer, and R. Newman, "Thermoplastic composites for aerospace applications," *Composites Part B: Engineering*, vol. 181, pp. 107600, 2020.
- [28] J. Mitchell, T. Crawford, and L. Ferguson, "Topology optimization of aircraft structures," *Computer-Aided Design*, vol. 123, pp. 102831, 2020.
- [29] S. Burton, M. Vincent, and K. Lynch, "Machine learning applications in structural health monitoring," *Mechanical Systems and Signal Processing*, vol. 139, pp. 106612, 2020.
- [30] E. Morrison, A. Chapman, and D. Fletcher, "Sustainable design frameworks for next-generation aerospace vehicles," *Resources, Conservation and Recycling*, vol. 159, pp. 104850, 2020.