
Research Article


# A Research Review on Metals Used in the Manufacturing of Drones Using Bibliometrics Analysis Software

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**KEY WORDS:**
Unmanned Aerial Vehicles
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Magnesium

**Abstract:** The rapid advancement regarding the technology of Unmanned Aerial Vehicles (UAVs) in military, civilian, along with commercial domains has heightened the emphasis on materials engineering as vital facilitator related to performance improvements. The presented work offers an extensive bibliometric analysis for mapping the thematic evolution, intellectual structure and significant contributors in metallic materials for the manufacturing of drones. The presented research utilizes a structured search regarding academic databases and uses scientific mapping and performance analysis tools for revealing publication patterns, collaborative networks, along with significant co-word clusters. A second thematic review integrates such bibliometric findings with in-depth examination of the applications, properties, and production methods of notable metallic materials, like titanium, aluminum, and magnesium alloys. The analysis shows that lightweight aluminum alloys are still the most popular choice because of their machinability and cost-efficiency. It shows that magnesium and titanium alloys are becoming more popular for specialty as well as high-performance uses. The study identifies Additive Manufacturing (AM) as transformative technology used to produce complex geometries from such metals as well as explores the emerging research frontiers, such as the development of multi-functional alloys, sustainable manufacturing practices, and hybrid metal-composite structures. Furthermore, the study provides a foundational understanding regarding the current study as well as identifies critical research gaps and potential directions to guide future corporate and academic endeavors in the field.

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## INTRODUCTION

**Background and Market Context:** Over the past ten years, Unmanned Aerial Vehicles (UAVs) business has changed a lot. Its uses have grown much beyond its original military purposes. The industry of drones has grown to be a major player in several areas, including farming, logistics, urban mobility, along with infrastructure inspection[1]. The worldwide commercial drone industry is expected to rise from approximately $11 billion in the year 2023 to $48 billion by the year 2029. This shows how the economy is changing[1]. This rapid growth is directly related to new developments in various related fields, like propulsion systems, materials science, and artificial intelligence[1]. The transition from specialized military applications to widespread civil and commercial tool has imposed pressing and new requirements on materials engineering for the purpose of providing solutions which are both economically viable and high-performing.

**The Foundational Role of Materials Engineering:** The ratio of strength-to-weight is considered to be the most important factor in how well aerial systems perform, whether it is unmanned or manned. This is particularly true for drones, which are limited by the power sources they use, majorly batteries. In such case, every gram saved in airframe means more payload capacity, longer flight times, and better overall operational efficiency[7]. Advanced composite materials, such as Carbon Fiber Reinforced Polymer (CFRP) have become more popular because of their great properties, metallic alloys are still the best choice for various important functional and structural parts. This is because they are impact resistant, robust, more resistant to heat, more durable, and machinable, which are all important for flights and operating drones[4]. Choosing the right metallic materials is thus very important for the progress of drone technology.

**Aims and Scope of the Review:** This research review aims to provide a structured, data-driven overview of the scientific literature regarding using metals in drone manufacturing. The main goals are threefold: first, using bibliometric analysis for quantitatively mapping research environment, which will help us evaluate the intellectual contributions, find major thematic trends, along with visualizing the collaborative networks in the field[13]. Second, to synthesize material-specific knowledge by conducting thorough research of applications, properties, along with manufacturing techniques of key metallic alloys, with a specific focus on aluminum, titanium, and magnesium. Third, to identify critical research gaps and emerging trends that are poised to shape the future of drone materials science and engineering. The presented study aims to be a basic resource for academics as well as professionals, giving them a clear understanding regarding where the field is now and where it is going in future.

## MATERIALS AND METHODS

**Bibliometric Analysis Methodology:** The presented work is based on systematic bibliometric analysis, which is considered as a quantitative method which uses statistics for analyzing scientific literature and identifying trends, patterns, and the effects of research in certain topic[13]. There are two main steps to the analysis: collecting data and analyzing it.

**Data Collection and Search Strategy:** The initial step was collecting the data in a structured way. A thorough search has been done on major academic databases, such as Google Scholar and Scopus for ensuring that the mechanical engineering field has been well covered[16]. Using more than one database is considered to be an important way for avoiding possible biases that come with searching only one database and include a wider spectrum of scholarly work[19]. A thorough search query has been made by combining a number of terms that were linked to the topic. The main query comprised the words "UAV," "drone," "metals," "unmanned aerial vehicle," "aluminum," "alloys," "magnesium," "titanium," "additive manufacturing," and "steel”[15]. This comprehensive method was meant to get a complete data set with regard to analysis; thus, the study isn't confined to certain area of research, yet covers all relevant research.

**Data Analysis and Software:** The collected data underwent a dual analytical methodology utilizing specialist bibliometric software. The analysis utilized both VOSviewer as well as bibliometrix R-package[16]. Bibliometrix software has been chosen because it has complete science mapping procedure which lets you do robust statistical analysis regarding publication as well as citation data[16]. VOS viewer has been used since it is better at making large network structures and bibliometric maps simple to understand, which is important to find connections between collaborators and research areas[16].

**The analytical tools utilized are:**

**Performance Analysis:** This approach examined the impact regarding the research through quantitative metrics, such as annual publishing trends, citation counts, along with identifying the most productive institutions as well as authors[13].

Science Mapping: This approach was used for understanding how the parts of study area connect together through looking at co-authorship and co-word analysis. Co-word analysis identifies clusters of essential words through looking at their co-occurrence. Furthermore, co-authorship analysis, on the other hand, shows how institutions and researchers work together[13].

## RESULTS AND DISCUSSIONS

**Bibliometric Findings: Mapping the Research Landscape**

**Publication Trends and Growth Trajectory:** An analysis of publication trends indicates a significant increase in the scholarly output concerning UAVs as well as their associated technologies, especially since the year

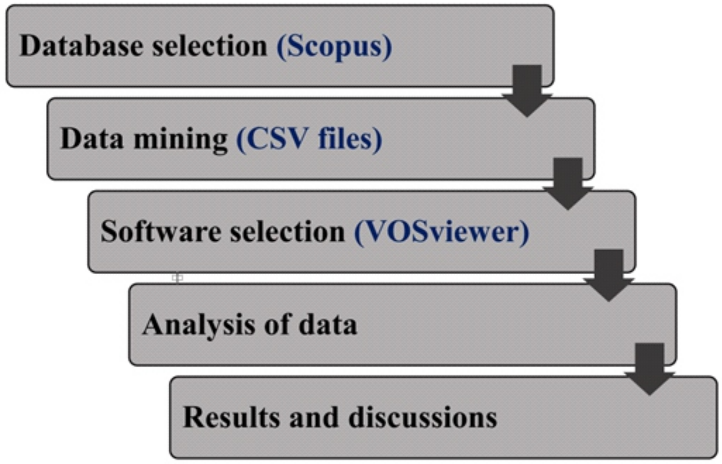


Fig. 1: Scientometric analysis sequence followed in the current study

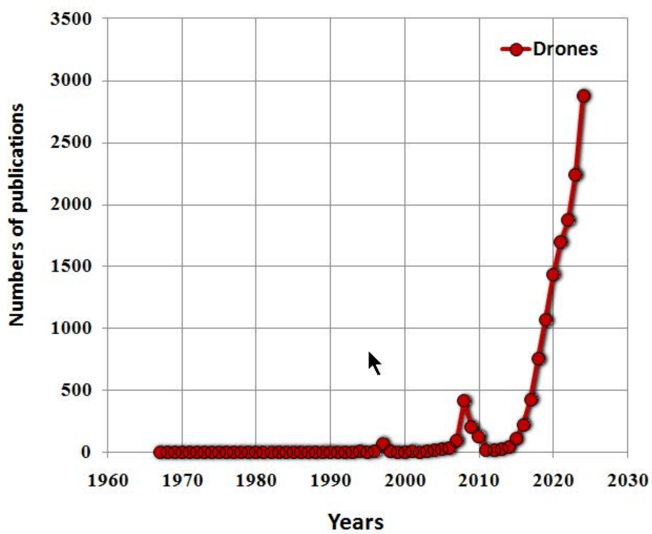


Fig. 2: Yearly publication trend of present study area

2017[21]. This increase is in line with bigger trends in automation in mechanical engineering. Over the past few decades, studies have focused on different areas at different times, however, recently, there has been a steady rise in interest in materials science connected to drones[15]. The indicated rise in publications is not just a measure regarding general academic expansion; it also indicates a time of intense development and research in response to the growing economic viability and widespread use related to the technology of drones. This dynamic suggests a strategic shift from foundational, theoretical research to applied, industry-driven problem-solving aimed at addressing the practical challenges of large-scale manufacturing and diverse operational needs. The growth in publications directly mirrors the industry's need for robust, cost-effective, and performance-optimized materials to support the projected market expansion from 2023 to 2029[1].

**Keywords Co-Occurrence:** Because they identify as well as highlight the key topic of research field, keywords are important tools of research. The top 30 keywords emerging most frequently in articles related to the current topic are displayed in Table 5. The top five most frequently occurring keywords, according to VOS viewer analysis, are fly ash, inorganic polymers, compressive strength, and geopolymers. Keyword networks, their linkages, along with the density related to their co-occurrence are shown in co-occurrence visualization in Figure 4. The dimension regarding keyword circle in Fig. 4(a) indicates its frequency, whereas its position indicates its co-occurrence in articles. Furthermore, the scientific mapping shows that

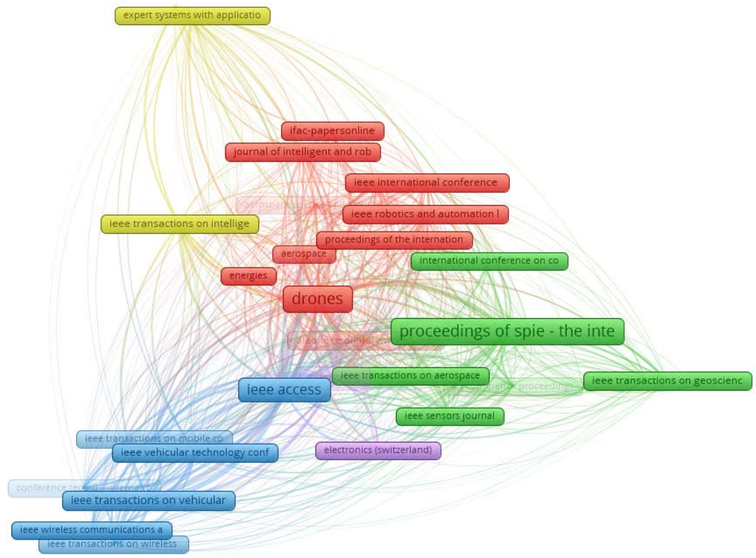


Fig. 3: Network visualization of top publication sources

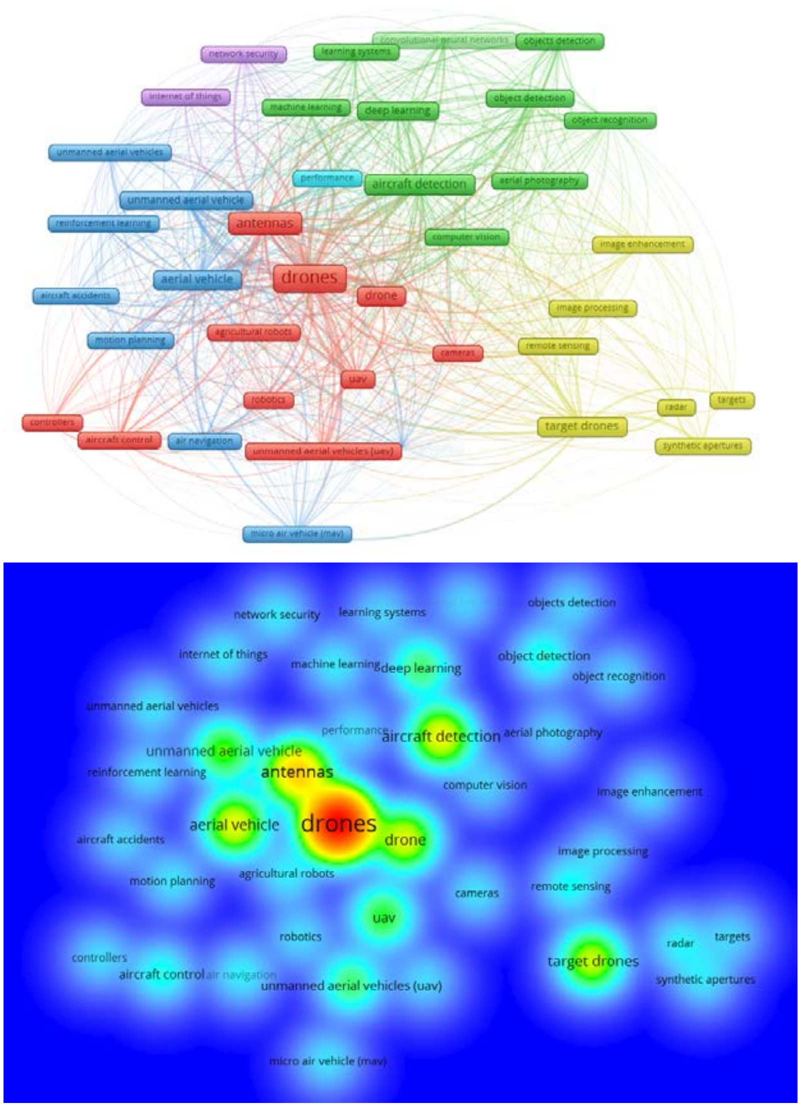


Fig. 4: Co-occurrence of keywords: (a) Network visualization; (b) Density visualization

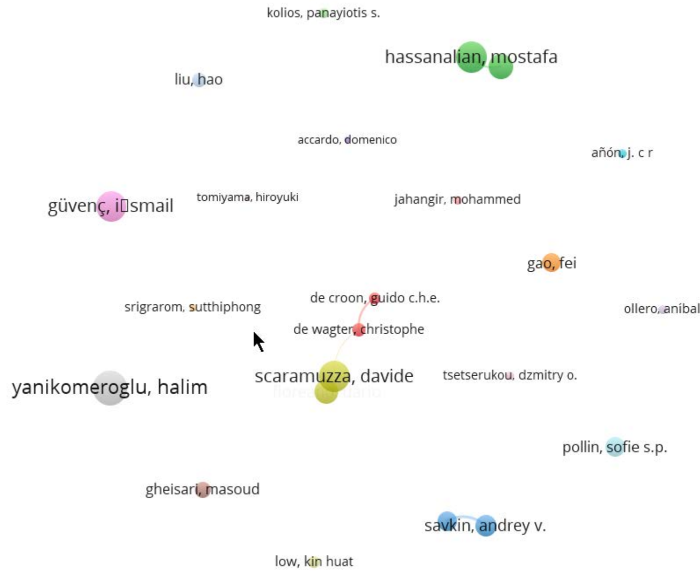


Fig. 5: Science mapping of connected authors based on citations

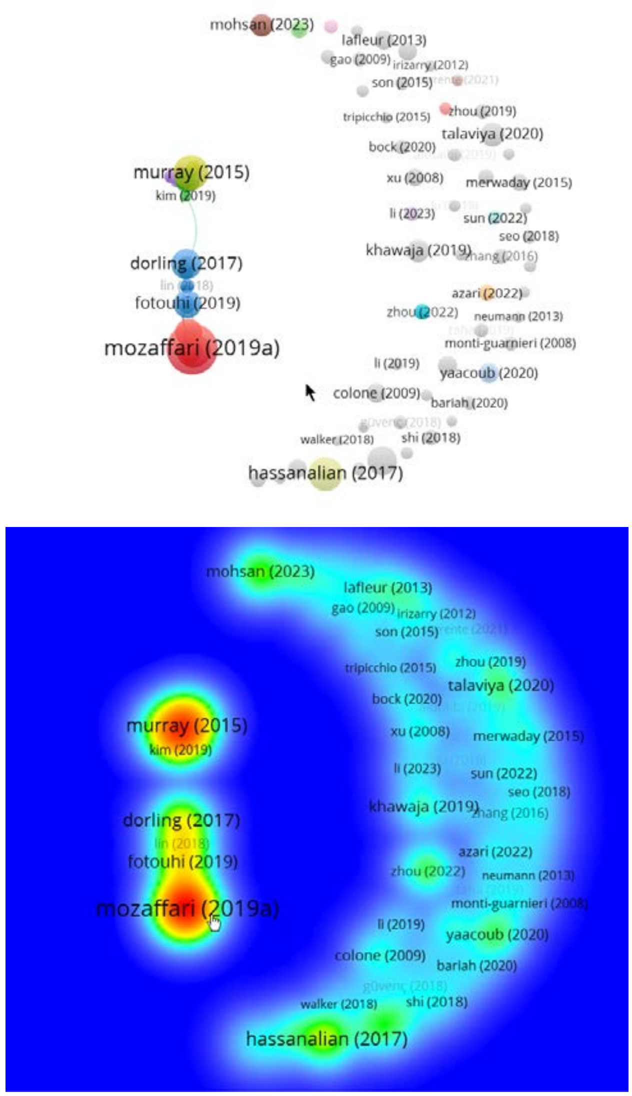


Fig. 6: Science mapping of publications: (a) Network image of linked papers; (b) Density image of linked papers

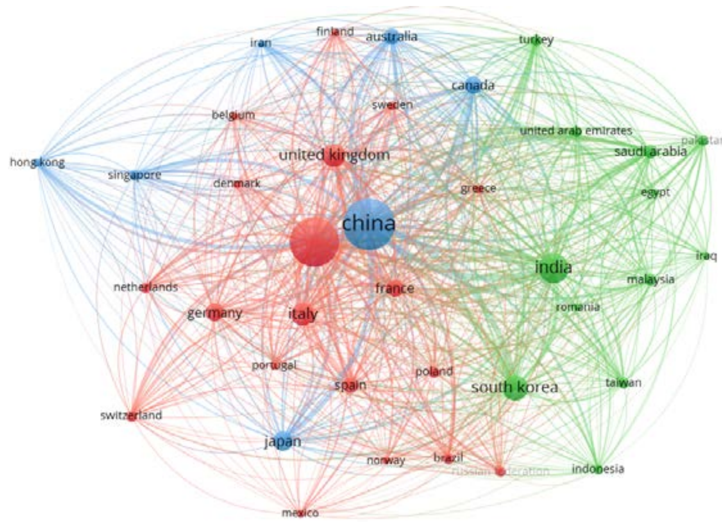


Fig. 7: Visualization of leading participating nations to the present study area

the aforementioned keywords have a larger circle compared to others, suggesting that they are the most valuable keywords in the current field of study. The image's keyword clusters and groups were highlighted differently to indicate their co-occurrence in various publications. Red and green were used to identify five categories.

**Key Thematic Clusters and Co-Word Analysis":** Co-word analysis of collected data reveals numerous significant research clusters characterizing present intellectual landscape. Some important keywords with high co-occurrence are additive manufacturing, unmanned aerial vehicle, aluminum alloys, composite materials, light-weighting, titanium alloys, along with structural integrity[7]. The frequent co-occurrence regarding "additive manufacturing" as well as certain "metallic alloys" suggests a robust symbiotic link between such two fields. There is a precise reason for such association, which is engineering necessity. Machining and forging are two common production methods that can result in a lot of wasted materials and designs that aren't very complicated[23]. The most important need is for lightweight drone parts that are very strong so that the payload capacity and flight endurance of drones are increased. This has rendered such old approaches no longer useful[7]. Additive manufacturing (AM) solves the problem through making it feasible to make topology-optimized, complex geometries as well as internal lattice structures that can't be made with traditional methods. This maximizes material efficiency and makes things lighter[19]. Consequently, the study emphasis on metallic alloys has become progressively integrated with the advancement and utilization of AM, as such production technique facilitates the complete realization regarding such materials' potential in the advanced drone designs. The appearance of specialist review papers dedicated to such certain topic further confirms AM's vital position[24].

**Influential Contributors and Collaborative Networks:** The bibliometric analysis highlights a diverse and globally represented research community. Significant contributions originate from regions such as China, Germany, and the United States, which consistently emerge as leading contributors in the field[15]. The concentration of scholarly output in these specific countries is not a coincidence but reflects a deliberate strategic and economic effort to secure a competitive advantage in the burgeoning drone industry. Control over a mature, in-house drone ecosystem requires mastery of all aspects, from electronics and propulsion to, most crucially, materials science and manufacturing. The rise of specific manufacturing hubs in regions such as India, focusing on local sourcing and processing of drone components, further underscores this nationalistic and strategic approach to building a self-sufficient supply chain[8]. Within these networks, certain authors are noted for their high betweenness centrality, indicating their pivotal role in connecting various researchers and institutions and facilitating the flow of knowledge across different sub-disciplines[15]. This highlights a complex and interconnected academic environment where interdisciplinary collaboration is essential for advancing the field.

**A Review of Metallic Materials in Drone Manufacturing: Aluminum Alloys: The Workhorse of UAV Structures:** Aluminum and its alloys have a long and successful history in aerospace, with their use dating back to the Wright brothers' first manned flight in 1903[29]. Their continued and widespread use in drone manufacturing is a testament to a unique

Table 1: Network Visualization of Key Research Keywords in Drone Materials Science

| Node ID | Keyword | Cluster | Node Size (Relative Frequency) | Connection to AM |
|---|---|---|---|---|
| 1 | Unmanned Aerial Vehicle | Core | Large | High |
| 2 | Additive Manufacturing | Core | Large | N/A |
| 3 | Aluminum Alloys | Metallic Materials | Medium | High |
| 4 | Titanium Alloys | Metallic Materials | Medium | High |
| 5 | Composite Materials | Structural Materials | Medium | High |
| 6 | Lightweighting | Design Principles | Medium | High |
| 7 | Structural Integrity | Design Principles | Medium | Moderate |
| 8 | Magnesium Alloys | Metallic Materials | Small | Moderate |
| 9 | Graphene | Emerging Materials | Small | Low |
| 10 | Sustainability | Future Trends | Small | Low |

Note: The table is a conceptual representation of a VOSviewer network map. Node size represents the frequency of the keyword in the dataset, while "Connection to AM" indicates the co-occurrence frequency, with 'High' signifying a strong research link. This visualization would show 'Additive Manufacturing' as a central hub, linking various material types and design principles.

TABLE (1) Searched keywords and resulting documents from Scopus database as of 14 September 2025

| S/N | Term | Search Within | Article results | results after refine |
|---|---|---|---|---|
| 1 | Drones | Title | 19,239 | 8,210 |
| 2 | Drone | keywords | 32,200 | 16,103 |
| 3 | Drone | Abstract | 44,273 | 18,883 |
| 4 | Drone | Title, keywords,Abstract | 55,286 | 23,912 |

Table 2 Limits/filters applied during data retrieval from Scopus database

| Option | Limit/filter applied |
|---|---|
| Type of document | Article |
| | Review |
| | Conference paper |
| Language | English |
| Source type | Journal |
| | Conference proceeding |
| Subject area | Engineering |
| | Materials Science |

Table 3: Various options selected and constraints applied during VOSviewer analysis

| Analysis type | Option | |
|---|---|---|
| Mapping of publication sources | Analysis type | Bibliographic coupling |
| | Analysis unit | Sources |
| | Minimum publications | 40 |
| Keywords co-occurrenc | Analysis type | Co-occurrence |
| | Analysis unit | All keywords |
| | Minimum co-occurrence | 400 |
| Authors mapping | Analysis type | Co-authorship |
| | Analysis unit | Authors |
| | Minimum publications | 20 |
| Articles mapping | Analysis type | Bibliographic coupling |
| | Analysis unit | Documents |
| | Minimum citations | 400 |
| Countries mapping | Analysis type | Bibliographic coupling |
| | Analysis unit | Countries |
| | Minimum publications | 110 |

Table 4: List of leading 10 sources of publications in the relevant field from 2001 to 2021 (August)

| S/N | Option | Documents | Citations |
|---|---|---|---|
| 1 | Drones | 919 | 14519 |
| 2 | Proceedings of SPIE the International Society for Optical Engineering | 851 | 3605 |
| 3 | IEEE Access | 563 | 16666 |
| 4 | Sensors | 372 | 4456 |
| 5 | IEEE Transactions on Vehicular Technology | 180 | 4608 |
| 6 | Applied Sciences Switzerland | 164 | 2241 |
| 7 | IEEE Robotics and Automation Letters | 148 | 4379 |
| 8 | Sensors Switzerland | 134 | 5772 |
| 9 | IEEE International Conference on Intelligent Robots and Systems | 129 | 2029 |
| 10 | Proceedings IEEE International Conference on Robotics and Automation | 108 | 2009 |

combination of properties: an excellent strength-to-weight ratio, superior corrosion resistance, and affordability[7]. Choosing certain aluminum alloy can be considered as an important design choice combining performance with costs as well as ease of production. The majority of drone frames for military and commercial use are made of grades 7075 and 6061[10]. Alloy 7075 has high content of zinc and tensile strength of about 572 MPa. It also has a fatigue resistance which is as good as steel's[9]. Those qualities

Table 5: Top 25 mostly occurred keywords in literature

| S/N | Keyword | Occurrences |
|---|---|---|
| 1 | drones | 12998 |
| 2 | antennas | 4152 |
| 3 | aircraft detection | 2868 |
| 4 | aerial vehicle | 2773 |
| 5 | drone | 2655 |
| 6 | target drones | 2415 |
| 7 | unmanned aerial vehicle | 1782 |
| 8 | uav | 1552 |
| 9 | deep learning | 1250 |
| 10 | unmanned aerial vehicles (uav) | 1234 |
| 11 | object detection | 791 |
| 12 | aircraft control | 766 |
| 13 | remote sensing | 683 |
| 14 | air navigation | 590 |
| 15 | radar | 569 |
| 16 | agricultural robots | 566 |
| 17 | machine learning | 545 |
| 18 | network security | 542 |
| 19 | internet of things | 524 |
| 20 | unmanned aerial vehicles | 516 |
| 21 | motion planning | 512 |
| 22 | micro air vehicle (mav) | 507 |
| 23 | reinforcement learning | 507 |
| 24 | synthetic apertures | 505 |
| 25 | cameras | 499 |

Table 6: Authors with minimum 20 publications in the present study area

| S/N | Author | Documents | Citations | Average citations |
|---|---|---|---|---|
| 1 | hassanalian, Mostafa | 68 | 2461 | 36 |
| 2 | añón, j. c r | 56 | 265 | 5 |
| 3 | güvenç, i?smail | 45 | 2407 | 53 |
| 4 | floreano, Dario | 38 | 1546 | 41 |
| 5 | savkin, andrey v. | 36 | 1264 | 35 |
| 6 | huang, hailong | 33 | 1112 | 34 |
| 7 | kolios, panayiotis s. | 31 | 318 | 10 |
| 8 | scaramuzza, davide | 31 | 2448 | 79 |
| 9 | abdelkefi, abdessattar | 28 | 1652 | 59 |
| 10 | liu, hao | 27 | 639 | 24 |
| 11 | srigrarom, sutthiphong | 27 | 191 | 7 |
| 12 | tsetserukou, dzmitry o. | 27 | 211 | 8 |
| 13 | ollero, aníbal | 24 | 271 | 11 |
| 14 | low, kin huat | 23 | 420 | 18 |
| 15 | accardo, Domenico | 21 | 140 | 7 |
| 16 | de wagter, Christophe | 21 | 521 | 25 |
| 17 | gao, fei | 21 | 995 | 47 |
| 18 | gheisari, masoud | 21 | 781 | 37 |
| 19 | tomiyama, Hiroyuki | 21 | 79 | 4 |
| 20 | de croon, guido c.h.e. | 20 | 433 | 22 |
| 21 | jahangir, Mohammed | 20 | 281 | 14 |
| 22 | pollin, sofie s.p. | 20 | 1068 | 53 |
| 23 | yanikomeroglu, halim | 20 | 3085 | 154 |

Table 7: Relevant articles with minimum 600 citations

| S/N | Article | Title | Publication year | Citations |
|---|---|---|---|---|
| 1 | Mozaffari, M. [ ] | A Tutorial on UAVs for Wireless Networks: Applications, Challenges, and Open Problems | 2019 | 2246 |
| 2 | Murray, C.C. [ ] | The flying sidekick traveling salesman problem: Optimization of drone-assisted parcel delivery | 2015 | 1264 |
| 3 | Krajewski, R.[ ] | The highD Dataset: A Drone Dataset of Naturalistic Vehicle Trajectories on German Highways for Validation of Highly Automated Driving Systems | 2018 | 1217 |
| 4 | Hassanalian, M. [ ] | Classifications, applications, and design challenges of drones: A review | 2017 | 1199 |
| 5 | Dorling, K. [ ] | Vehicle Routing Problems for Drone Delivery | 2017 | 1013 |
| 6 | Chamola, V. [ ] | A Comprehensive Review of the COVID-19 Pandemic and the Role of IoT, Drones, AI, Blockchain, and 5G in Managing its Impact | 2020 | 957 |
| 7 | Fotouhi, A. [ ] | Survey on UAV Cellular Communications: Practical Aspects, Standardization Advancements, Regulation, and Security Challenges | 2019 | 883 |
| 8 | Alzenad, M [ ] | 3-D Placement of an Unmanned Aerial Vehicle Base Station (UAV-BS) for Energy-Efficient Maximal Coverage | 2017 | 848 |

make it the best selection for military uses when durability and performance are most important, even if it has moderate machinability[10]. Grade 6061 has a tensile strength of about 310 MPa, which makes it a better mix of cost-effectiveness and strength[9]. It's easy to weld and machine, which makes it perfect for mass-produced, light crafts as well as commercial UAVs, in which being efficient in production is considered to be big part of being competitive in the market[7]. Other alloys, such as 2024 and 5052, are also utilized for wings, fuselage, and interior frameworks, each selected for specific attributes like fatigue resistance or formability[29].

**Titanium Alloys: For High-Performance and High-Stress Components:** Titanium alloys are considered to be the next step in the material performance with regard to mission-critical uses, in which durability as well as strength are most important[5]. Even though titanium is heavier in comparison with aluminum, its better strength-to-weight ratio lets you make lighter, thinner parts which work better compared with aluminum parts[7]. Ti-6Al-4V can be defined as very important alloy in the category. It is often utilized in the airframes as well as propulsion systems because it has the best strength-to-weight ratio and is very resistant to heat and corrosion[5]. In comparison with conventional aluminum structures, such alloy could save mass by 30%, meaning that surveillance drones could have flight endurance of between 18 and 22%.5 A tiered material approach is a key design principle in advanced drone engineering, and the selective use regarding titanium shows this. Because titanium is much more expensive and harder to work with in comparison with aluminum, not all parts need its qualities[7]. Therefore, manufacturers strategically reserve titanium for only the most demanding parts, such as high-impact landing gear, high-stress engine mounts, or turbine blades in complex propulsion systems[5]. This approach allows designers to achieve a "best of both worlds" solution, leveraging the cost-efficiency of aluminum for the main frame while ensuring the reliability of critical components with a higher-performance material. This is a practice commonly used in manned aerospace and is now being scaled down to advanced UAVs[6].

**Magnesium Alloys: The Emerging Lightweight Frontier:** Magnesium alloys are gaining significant traction as the next frontier in lightweight structural materials for drones due to their exceptionally low density, which is approximately 50 percent less than that of aluminum.8 The properties of magnesium alloys, such as their excellent castability and machinability, are proving to be major advantages in large-scale production[31]. High-pressure die casting of magnesium alloys is considered superior to that of aluminum for manufacturing large quantities of identical components, primarily due to lower iron solubility, which extends tool life, and approximately 30 percent shorter die filling times due to the material's lower density[30]. These manufacturing advantages are critical for consumer and commercial drone manufacturers who prioritize scaling production and reducing unit cost. Despite its historical susceptibility to corrosion, ongoing research into novel coatings and corrosion protection concepts is successfully mitigating these concerns, positioning magnesium as a viable and economically attractive alternative for the mass market[31]. Real-world examples, such as the DJI Inspire 2 UAV featuring an AZ91 housing and the DJI Mavic Air using AZ91-based brackets, demonstrate the material's successful adoption in commercially available products[30]. The focus of research on these alloys signifies a trajectory that prioritizes manufacturing efficiency alongside material properties.

**Other Critical Metals and Hybrid Materials:** Beyond the primary structural metals, a wide array of other critical minerals plays specialized and indispensable roles in drone manufacturing. For example, beryllium is used in the landing gear alloys for making them very stiff and able to absorb shocks, which makes landings more reliable[4]. Hafnium, nickel, along with copper are employed in advanced drone engines as well as propulsion systems because they can handle high temperatures and work well in them[4]. Also, rare-earth elements like praseodymium, neodymium, along with dysprosium are very important for the powerful, compact electric motors powering the flight systems of drones. These elements make motors more efficient and give them more power[4]. Using hybrid materials as well as structures in designing drones is a new trend that moves away from solutions related to monolithic material. Phantom 4 Pro V2.0 quadcopter, for instance, has titanium-magnesium composite structure to make its airframe as rigid as possible[30]. The widespread utilization regarding composites, such as Glass Fiber Reinforced Polymer (GFRP) and Carbon Fiber Reinforced Polymer (CFRP) for fuselages and wings adds to this[7]. This design concept uses many materials, such as robust metal frame and impact-resistant, lightweight composite parts, to let designers optimize for a wide range of performance parameters. This shows how important it is to use the appropriate material in right place.

Table 8: Top participating nations on the basis of publications and citations

| Country | Documents | Citations | Avarege Citation |
|---|---|---|---|
| China | 3289 | 42818 | 13 |
| India | 1294 | 14949 | 12 |
| South Korea | 973 | 19555 | 20 |
| Italy | 813 | 13982 | 17 |
| Japan | 666 | 5187 | 8 |
| Germany | 575 | 10127 | 18 |
| France | 546 | 11349 | 21 |
| Canada | 523 | 14450 | 28 |
| Australia | 453 | 11939 | 26 |
| Spain | 413 | 8561 | 21 |
| Saudi Arabia | 345 | 7438 | 22 |
| Malaysia | 279 | 4268 | 15 |
| Taiwan | 258 | 3757 | 15 |
| Brazil | 252 | 3153 | 13 |
| Poland | 241 | 2027 | 8 |
| Switzerland | 238 | 6211 | 26 |
| Russia | 231 | 1949 | 8 |
| Netherlands | 227 | 5448 | 24 |
| Singapore | 223 | 4624 | 21 |
| Pakistan | 212 | 5929 | 28 |
| Indonesia | 194 | 1397 | 7 |
| Greece | 163 | 2505 | 15 |
| Hong Kong | 157 | 4110 | 26 |
| Sweden | 157 | 2958 | 19 |
| Denmark | 155 | 3150 | 20 |
| Belgium | 151 | 3445 | 23 |
| Mexico | 138 | 1693 | 12 |
| Portugal | 136 | 3043 | 22 |
| Iran | 135 | 2428 | 18 |
| Norway | 130 | 2239 | 17 |
| Finland | 126 | 5773 | 46 |
| Romania | 118 | 850 | 7 |
| Egypt | 113 | 1167 | 10 |
| Iraq | 113 | 968 | 9 |

Table 9: Comparison of Common Aerospace Aluminum Alloys for Drones

| Alloy Grade | Primary Alloying Element | Tensile Strength (MPa) | Applications and Key Properties |
|---|---|---|---|
| 7075 | Zinc | 572 | High-performance, military platforms; excellent fatigue resistance, high strength-to-weight ratio. |
| 6061 | Magnesium and Silicon | 310 | Consumer and industrial UAVs; easy to machine and weld, cost-effective. |
| 2024 | Copper | 483 | Wings and fuselage; widely used due to high yield strength and excellent fatigue resistance. |
| 5052 | Chromium | 258 | Landing gear, interior structures; high ductility and superior corrosion resistance. |
| 7068 | Zinc | 683 | Military aircraft; one of the strongest alloys on the market with low mass. |

Note: Data derived from multiple sources.9 Tensile strength values are approximate and depend on temper designation.

Table 10: Manufacturing Comparison: Aluminum vs. Magnesium Die Casting

| Metric | Aluminum Alloys | Magnesium Alloys |
|---|---|---|
| Density | 2.70 g/cm³ | 1.6 g/cm³ |
| Die Filling Time | Longer | Approximately 30% shorter |
| Tool and Casting Life | Standard | Significantly longer due to lower iron solubility |
| Relative Cost | Cost-effective | Slightly higher raw material cost but superior manufacturing efficiency in high volume |

**Advanced Manufacturing and Future Trends:**

**Additive Manufacturing of Metallic Drone Components:** Additive Manufacturing (AM), sometimes known as 3D printing, is considered to be a new technique altering the way metal parts for drones are produced as well as designed[19]. AM has a number of important benefits compared with traditional subtractive manufacturing techniques. For example, it could decrease material waste, produce complex geometries, and combine many components into single lightweight one[19]. For example, a titanium landing gear can be additively manufactured layer-by-layer, which greatly reduces material waste compared to cutting it from a solid block[23]. Despite these benefits, the widespread industrial adoption of AM faces significant challenges, particularly in ensuring quality control, dimensional accuracy, and certification[19]. Conventional inspection methods are often insufficient for detecting and preventing defects in real-time, which is a critical limitation for flight-critical components. As a result, the focus of research is shifting towards the development of "smart monitoring systems" that integrate multi-sensor approaches with artificial intelligence and machine learning to detect and correct anomalies during the production process itself[19]. This development signifies that the next wave of innovation in AM is not merely about the printing process but about developing a holistic, data-driven ecosystem that ensures the reliability and integrity of the final product, thereby addressing the critical certification gap that currently limits widespread industrial application[26].

**Identified Research Gaps and Future Outlook:** Based on the synthesis of the bibliometric analysis and the thematic review, several key research gaps and emerging trends are identified that are poised to shape the future of drone materials science. A prominent area of research is the integration of advanced materials such as graphene, which is noted for its exceptional strength and lightweight nature, with potential applications in ultra-lightweight frames and next-generation batteries that promise faster charging and longer flight durations[7]. Another emerging frontier is the development of "smart" and adaptive materials that can respond to their environment by changing shape or even self-healing[7]. This area of research moves beyond passive, static material systems and promises to enable components that can actively monitor their own state, adapt to changing conditions, and reduce maintenance costs[34]. Furthermore, the growing awareness of environmental impact has led to an emerging focus on sustainability, including the development of biodegradable materials for single-use drones in applications such as disaster relief and military operations[7]. This is complemented by research aimed at improving the recyclability of metallic and composite materials[31]. Finally, the field is increasingly exploring the role of artificial intelligence in optimizing every stage of the design and manufacturing process, enabling a paradigm shift from a one-time material selection choice to a continuous process of in-flight optimization and adaptation[1].

## CONCLUSION

The presented work has systematically mapped the landscape regarding metallic materials in the manufacturing of drones, employing bibliometric methodology for the purpose of establishing a quantitative basis for qualitative synthesis. The analysis shows that the field is both well-established in its usage of basic materials and quickly evolving as it looks for more advanced solutions. Aluminum alloys are still a popular choice because they offer the best balance of performance and affordability. Titanium and magnesium, on the other hand, are becoming more popular with regard to high-performance and mass-produced parts, respectively. Research is still being done for finding ways to improve their limits. The research shows that the future regarding metallic materials in drones is not a separate field, yet is closely linked to progress in the artificial intelligence, Additive Manufacturing, and an increasing focus on sustainability. For the purpose of pushing the limits regarding flight duration, overall system reliability, along with cargo capacity, it will be important to move from monolithic materials to multifunctional and hybrid systems and to use data to guide manufacture and design. This review serves as a critical resource, providing a foundational understanding of past achievements and a clear roadmap for future scholarly and industrial endeavors in this dynamic and essential field of mechanical engineering.

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