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BIBLIOMETRIC ANALYSIS OF RESEARCH ON NON-DESTRUCTIVE TESTING IN AEROSPACE

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Abstract:

This study presents a bibliometric analysis of non-destructive testing (NDT) in aerospace, emphasising trends, collaborations, and advancements. Using Scopus data and VOSviewer software, 1,385 publications spanning 2014 to 2025 were analysed. The methodology included keyword co-occurrence, citation analysis, and collaborative network visualisation to identify influential authors, emerging topics, and interdisciplinary connections. Results indicate a steady increase in publications, peaking in 2024, reflecting sustained global interest and advancements in aerospace NDT. Dominant keywords include "non-destructive testing," "structural health monitoring," and "composites," highlighting a primary focus on structural integrity and material evaluation. Recent trends show the integration of artificial intelligence, evidenced by the rise of terms such as "machine learning" and "deep learning," signalling a shift toward digitalised, intelligent NDT systems. Collaboration analysis revealed distinct author clusters and international partnerships, with significant contributions from China, the United States (US), and the United Kingdom (UK), supported by major funding organisations. Integrating engineering, materials science, and emerging technologies like infrared thermography and additive manufacturing underscores the field's interdisciplinary nature. Findings also reveal an evolving focus on lightweight composite materials and advanced defect detection methods, essential for aerospace safety and efficiency. This study concludes that bibliometric analysis is a valuable tool

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for identifying research gaps, fostering interdisciplinary collaboration, and guiding future innovations in aerospace NDT.

Keywords:

Non-Destructive Testing, Aerospace, Bibliometric Analysis, Scopus

Introduction

Non-Destructive Testing (NDT) is an essential component in the aerospace industry, playing a pivotal role in ensuring that materials and components meet stringent safety and reliability standards without incurring damage during inspection. The significance of NDT has been underscored by advancements in materials science, which have led to the development of innovative techniques tailored to meet the unique challenges posed by aerospace applications. Methods such as ultrasonic testing, eddy current testing, and infrared thermography are widely employed to assess the integrity of complex aerospace structures, particularly those made from advanced composite materials and titanium alloys (Ma & Liao, 2012; Taheri & Hassen, 2019; Xie et al., 2020; Zhu et al., 2011).

The aerospace sector is characterised by rigorous safety regulations enforced by organisations such as the Federal Aviation Administration (FAA) and the European Union Aviation Safety Agency (EASA). These regulations necessitate the implementation of effective NDT methods to identify potential defects early in the lifecycle of aerospace components (Oliveira et al., 2023; Saboktakin et al., 2014; Shen, 2023). The growing complexity of aerospace materials, particularly composites, has prompted researchers to explore and innovate NDT techniques that can effectively evaluate these materials without compromising their structural integrity (ORTJOHANN, 2023; Salski et al., 2014; Tonga et al., 2023). As a result, NDT has evolved into a critical aspect of aerospace engineering, ensuring that safety and performance standards are consistently met (Kraljevski et al., 2021; Zheng et al., 2015).

In recent years, bibliometric analysis has emerged as a valuable tool for tracking research trends in NDT and aerospace. This analytical approach quantifies scientific output, allowing researchers to assess productivity, collaboration patterns, and the overall impact of various studies within the field (D'Angelo & Rampone, 2015; Hueber et al., 2018; Ren et al., 2022). Applying bibliometric methods has revealed a significant increase in publication volumes related to NDT in aerospace. This reflects the growing interest in this area as technological advancements continue to reshape the industry (Chaki & Krawczak, 2022; Deane et al., 2019). Furthermore, bibliometric studies have highlighted the interdisciplinary nature of NDT research, as it often intersects with fields such as materials science, engineering, and electronics (Pollock, 2023; Shrifan et al., 2019; Thabet et al., 2018).

The relevance of bibliometric analysis in understanding NDT research in aerospace cannot be overstated. It provides insights into the evolution of research topics, identifies influential works, and highlights shifts in focus over time (Mohseni et al., 2019; MOSKOVCHENKO, 2023). Recent studies have shown that integrating artificial intelligence (AI) and machine learning techniques into NDT practices is gaining traction, reflecting a broader trend towards automation and enhanced data analysis capabilities (Chung et al., 2021; Ibarra-Castanedo,

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2023; Yu, 2023). This trend is particularly pertinent in the context of aerospace, where the need for rapid and accurate inspections is paramount (Braun et al., 2013; Gupta & Khan, 2021).

The growth of NDT research in the aerospace industry is closely associated with the increasing use of advanced composite materials. These materials present unique challenges for inspection due to their complex structures and properties (Chen et al., 2014; Loganathan et al., 2022; Vilaça et al., 2014; Zhao et al., 2018). As the aerospace sector continues to adopt these lightweight and high-strength materials, there has been a surge in demand for effective NDT methods capable of detecting defects such as delamination and impact damage (Saha et al., 2023; Tao et al., 2021; Torbali et al., 2023). As a result, researchers are actively exploring novel NDT techniques, including microwave testing and digital shearography, to tackle these challenges (Alhammad et al., 2021; Guo et al., 2019; Hu et al., 2020).

In summary, the role of NDT in the aerospace sector is complex and becoming increasingly important as the industry evolves. The use of advanced materials and the focus on safety and regulatory compliance require ongoing innovation in NDT methods. Bibliometric analysis is valuable for understanding research trends and interdisciplinary connections within this field. Ultimately, this insight contributes to advancing NDT practices in aerospace applications.

Literature Review

The literature surrounding Non-Destructive Testing (NDT) in aerospace presents an evolving landscape driven by a continual focus on innovation in materials and techniques to ensure structural integrity. Several NDT techniques, including ultrasonic testing, eddy current testing, and infrared thermography, have emerged as standard methods for inspecting aerospace components. Ibarra-Castanedo (2023), Laureti et al. (2019), and Malik et al. (2021) have documented the effectiveness of these approaches, especially in assessing defects in composite materials like carbon fibre-reinforced composites (CFRP) and glass laminate aluminium-reinforced epoxy (GLARE). Advances in machine learning have been crucial for enhancing the accuracy of these inspections, as Niccolai et al. (2021) pointed out, by automating and refining the detection of defects. However, as discussed by Bělský and Kadlec (2019), the complexity of newer composite materials poses persistent challenges that necessitate further development of NDT methodologies.

Bibliometric analysis is a powerful tool for evaluating research outputs and mapping the progress of NDT in aerospace, offering insights into emerging trends and collaboration networks. Barthel and Seidl (2017) established the importance of bibliometrics in understanding scientific progress using citation counts and co-authorship metrics to assess impact and productivity (Doğruer, 2022; Srivastava & Srivastava, 2022). This interdisciplinary approach is vital for tackling complex challenges, such as the evaluation of sandwich structures and additive manufacturing defects in aerospace, which require input from diverse fields to create effective solutions (Bělský & Kadlec, 2019). The ability of bibliometric analysis to reveal the interdisciplinary nature of NDT research emphasises its role in driving innovation by fostering knowledge exchange across traditional boundaries.

A few areas have been identified where further research question (RQ) is developed to establish the current research agenda and future directions as follows:

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RQ 1. What are the trends in NDT according to the year of publication?
RQ 2. What are the trends in NDT according to the subject area?
RQ 3. What are the trends and contributing factors in NDT by country or territory?
RQ 4. What is the most cited article's perspective approach?
RQ 5. What are the popular keywords related to the study, and have they evolved/changed during the last ten years?
RQ 6. What are the co-authorship collaborations in NDT researched?

Finally, the broader application of bibliometric analysis to track interdisciplinary collaborations, as suggested by Henriksen (2016), could help identify under-researched areas and promote targeted research efforts that effectively address these gaps.

Methodology

Bibliometrics refers to the combination, management, and analysis of bibliographic information derived from scientific publications (Verbeek et al., 2002). It includes general descriptive statistics, such as the publishing journals, publication years, and classification of main authors. Additionally, it involves complex techniques like document co-citation analysis. An effective literature review, bibliography building, and the attainment of reliable results require an iterative process of selecting appropriate keywords, conducting literature searches, and analysing the findings (Fahimnia et al., 2015).

The following section discusses the adoption of search terms, the initial screening of search results, and the refinement of those results. Journals that indicate a Scopus impact factor are recognised for their high quality. Thus, this study aims to focus on top-tier publications to enhance the understanding of the theoretical framework surrounding the evolution of the research domain. For this reason, the study relied on the Scopus database for data collection. Furthermore, to ensure the inclusion of top-tier publications, only articles published in rigorously peer-reviewed academic journals were considered, excluding books and conference proceedings.

Data Search Strategy

The study employed a screening process to determine the search terms for article retrieval. It began by querying the Scopus database with the online search string TITLE-ABS-KEY (non AND destructive AND (aerospace OR aircraft)). The search string is detailed in Table 1. This initial search yielded a total of 3,615 articles. From these, 1,385 results were further scrutinised to include only research articles written in English. The final refinement of the search string, focusing specifically on non-destructive testing, resulted in 767 articles used for bibliometric analysis.

Table 1: The Scopus Search String

TITLE-ABS-KEY (non AND destructive AND (aerospace OR aircraft)) AND (LIMIT-TO (DOCTYPE , "ar")) AND (LIMIT-TO (LANGUAGE , "English")) AND (LIMIT-TO (PUBSTAGE , "final")) AND (LIMIT-TO (EXACTKEYWORD , "Nondestructive Examination") OR LIMIT-TO (EXACTKEYWORD , "Non Destructive Testing") OR LIMIT-TO (EXACTKEYWORD , "Ultrasonic Testing") OR LIMIT-TO (EXACTKEYWORD , "Non-destructive Testing") OR LIMIT-TO (EXACTKEYWORD , "Non Destructive Evaluation") OR LIMIT-TO (EXACTKEYWORD , "Aircraft") OR LIMIT-TO (EXACTKEYWORD , "Aerospace Industry") OR LIMIT-TO (EXACTKEYWORD , "Structural Health Monitoring") OR LIMIT-TO (EXACTKEYWORD , "Thermography (imaging)") OR LIMIT-TO (EXACTKEYWORD , "Eddy Current Testing") OR

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LIMIT-TO (EXACTKEYWORD , "Non Destructive Inspection") OR LIMIT-TO (EXACTKEYWORD , "Ultrasonic Applications") OR LIMIT-TO (EXACTKEYWORD , "Aerospace Applications") OR LIMIT-TO (EXACTKEYWORD , "Non-destructive Evaluation") OR LIMIT-TO (EXACTKEYWORD , "Ultrasonics") OR LIMIT-TO (EXACTKEYWORD , "Nondestructive Evaluation") OR LIMIT-TO (EXACTKEYWORD , "Nondestructive Testing") OR LIMIT-TO (EXACTKEYWORD , "Non-destructive Technique") OR LIMIT-TO (EXACTKEYWORD , "NDT") OR LIMIT-TO (EXACTKEYWORD , "Non-destructive Evaluation Techniques") OR LIMIT-TO (EXACTKEYWORD , "Eddy Currents") OR LIMIT-TO (EXACTKEYWORD , "Infrared Thermography") OR LIMIT-TO (EXACTKEYWORD , "Thermography (temperature Measurement)") OR LIMIT-TO (EXACTKEYWORD , "X-ray Computed Tomography") OR LIMIT-TO (EXACTKEYWORD , "Thermography") OR LIMIT-TO (EXACTKEYWORD , "Non-destructive Test") OR LIMIT-TO (EXACTKEYWORD , "Nondestructive Testing Method") OR LIMIT-TO (EXACTKEYWORD , "Non-destructive Testing (NDT)") OR LIMIT-TO (EXACTKEYWORD , "D. Non-destructive Testing") OR LIMIT-TO (EXACTKEYWORD , "Aerospace Structure") OR LIMIT-TO (EXACTKEYWORD , "Non-destructive Testing And Evaluations") OR LIMIT-TO (EXACTKEYWORD , "Pulsed Thermography") OR LIMIT-TO (EXACTKEYWORD , "Acoustic Emission") OR LIMIT-TO (EXACTKEYWORD , "Aircraft Materials") OR LIMIT-TO (EXACTKEYWORD , "Aircraft Structure") OR LIMIT-TO (EXACTKEYWORD , "Aircraft Engines"))

As of November 2024, all articles from the Scopus database related to NDT in the aerospace or aircraft fields were incorporated into the study. The selection criteria can be found in Table 2.

Table 2: Selection Criteria, Inclusion And Exclusion Criteria

Criterion	Inclusion	Exclusion
Language	English	Non-English
Literature type	Journal (Article)	Conference, Book, Review
Publication Stage	Final	In Press
Year	2014-2025	<2013

Data Analysis

Data sets containing various aspects of academic publications, including publication year, title, author names, journal names, citation information, and keywords in PlainText format, were collected from the SCOPUS database. This collection spans a significant period from 2014 to 2025. VOSviewer software, specifically version 1.6.19, was employed to analyse this data comprehensively. VOSviewer is a powerful tool that facilitates the analysis and visualisation of data by applying VOS clustering and mapping techniques. It serves as an alternative to the Multidimensional Scaling (MDS) approach, as discussed by Van Eck et al. (2010). Both methodologies share a common goal: to position items within a low-dimensional space so that the distance between any two items accurately reflects their relatedness and similarity (Appio et al., 2014).

What sets VOSviewer apart from MDS is its unique focus on normalising co-occurrence frequencies. While MDS primarily relies on similarity measures, such as Jaccard indexes and cosine similarity, VOSviewer utilises a more appropriate technique for this normalisation

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process. This approach calculates the association strength (ASij) providing a nuanced understanding of the connections between different items in the dataset (Van Eck & Waltman, 2010, p. 531).

$$\mathrm{AS}_{ij} = \frac{C_{ij}}{w_i w_j}$$

Using this index, VOSviewer organises items into a map by minimising the weighted sum of the squared distances between all item pairs. Appio et al. (2016) noted that the LinLog/modularity normalisation method was applied. Additionally, VOSviewer utilises visualisation techniques to analyse the dataset, revealing patterns based on mathematical relationships. This enables the execution of keyword co-occurrence, citation analysis, and co-citation analysis. Meanwhile, citation analysis helps to pinpoint key research issues, trends, techniques, and the historical significance of a discipline's primary focus. Document co-citation analysis, one of the most used bibliometric methods (Appio et al., 2016; Fahimnia et al., 2015; Liu et al., 2015), relies on network theory to identify relevant structures within the data (Liu et al., 2015).

Results and Discussion

This section presents the findings related to the research questions discussed in the relevant literature. The results section offers a detailed analysis of critical trends and patterns in non-destructive testing (NDT) research within the aerospace sector. Further, it explores these findings to address the research question.

Findings and Discussion for RQ1: Trends in Documents by Year

Figure 1 shows the document by year's trend. Between 2014 and 2016, the number of publications remained relatively steady, starting at around 40 papers and experiencing a minor fluctuation, with a slight decline in 2016. After 2016, there was a significant upward trend until 2019, suggesting a growing interest and increased research activities in this field. The number of documents peaked at around 80 in 2019, showing a sharp increase.

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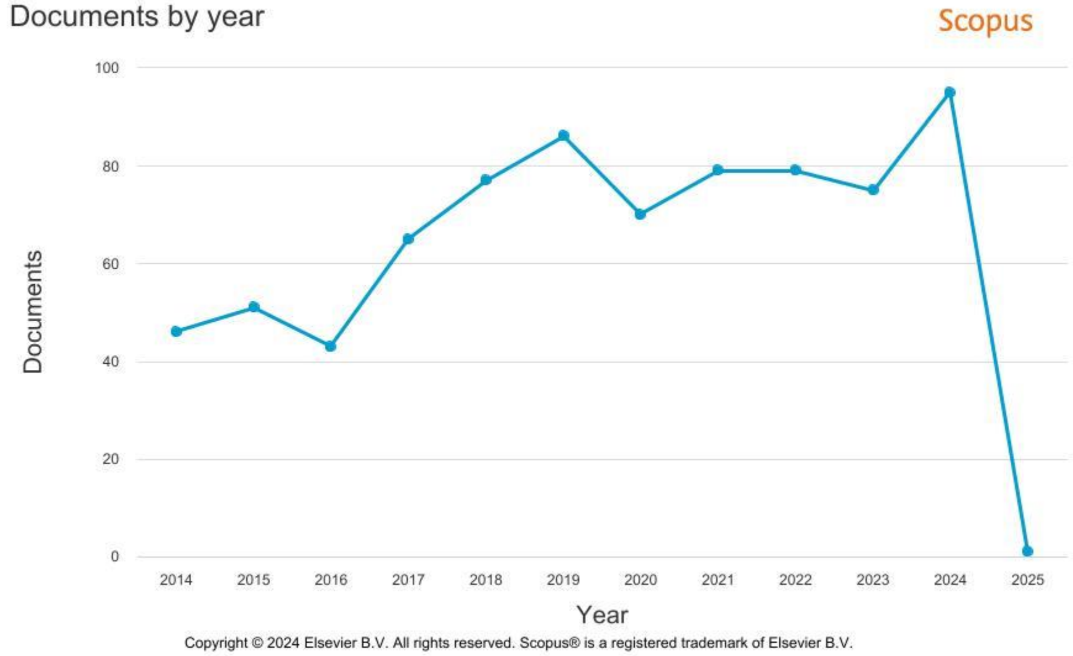

Figure 1: Document by Year

The trend is relatively stable from 2019 to 2023, with minor fluctuations. The publications remained around 70-80, indicating sustained interest and consistent research output. The data shows a notable peak in 2024, reaching 100 documents, reflecting an intensified research focus, increased funding, or emerging advancements within this field during that year.

Interestingly, there is a sharp decline in 2025, with the number of publications dropping to almost zero. This steep drop could be due to incomplete data collection for that year, suggesting that the data might not be fully captured in the Scopus database yet. Alternatively, it might indicate a significant change in research priorities or funding availability, leading to reduced publications. Overall, the data from 2014 to 2024 suggests a growing and steady interest in the field, with potential uncertainty in the data for 2025.

Findings and Discussion for RQ2: Trends in Documents by Subject Area

The pie chart in Figure 2 depicts documents by subject area from the Scopus database, revealing the distribution of research across different disciplines. The field of Engineering dominates with the highest percentage of documents (36.5%), suggesting that the focus of the studies is primarily on the engineering aspects of the topic. This is consistent with the nature of NDT and aerospace studies, which are often engineering-driven, emphasising the design, testing, and implementation of structural health monitoring techniques.

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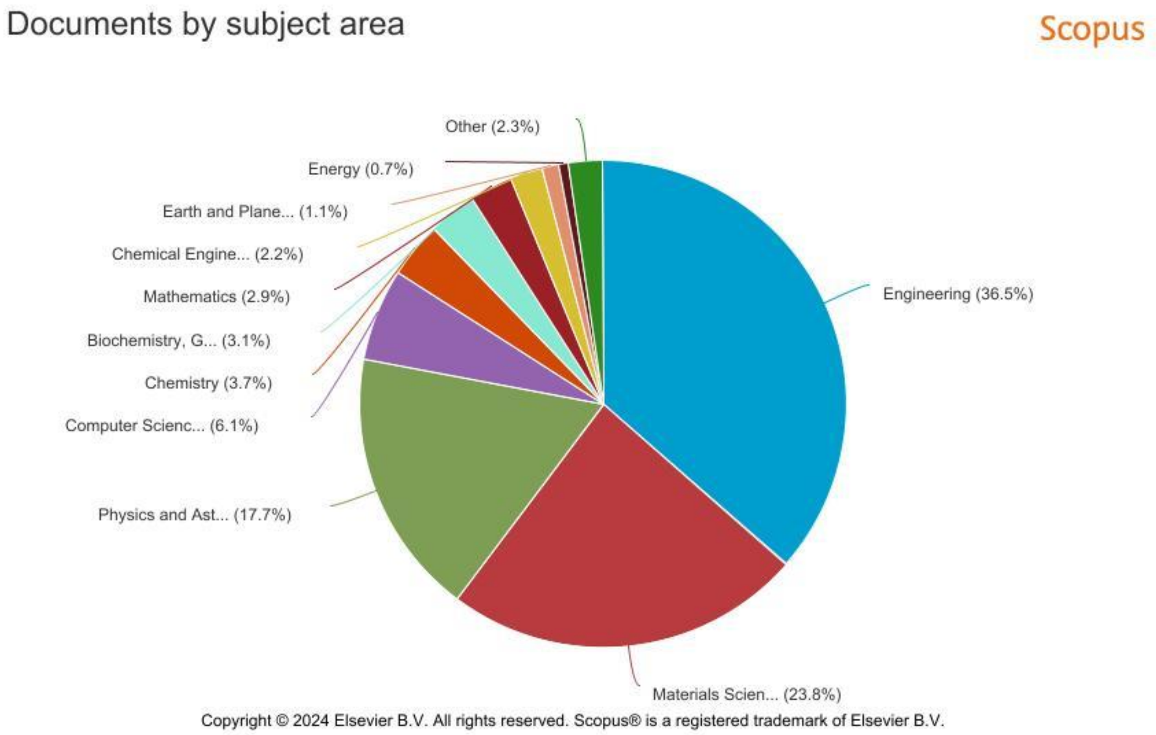

Figure 2: Documents By Subject Area

The second largest category is Materials Science, contributing 23.8% of the documents. This highlights the significant interest in materials characterisation, composite analysis, and the study of material properties—all of which are crucial for understanding how aerospace materials respond to different testing methods. The substantial presence of research in this area demonstrates the intersection of materials science with aerospace engineering, emphasising the importance of analysing the physical properties and defects in various materials used in aerospace applications.

Physics and Astronomy comprise 17.7% of the documents, reflecting the theoretical underpinnings of many NDT techniques, such as wave propagation, thermography, and ultrasonic testing. The inclusion of Computer Science (6.1%) and Chemistry (3.7%) indicates an interdisciplinary approach, where computational modelling, data analysis, and chemical composition also play significant roles in advancing NDT technology. Fields like Biochemistry (3.1%) and Mathematics (2.9%) contribute more niche but essential perspectives, likely focusing on experimental analysis, statistical methods, or biocompatibility considerations. Overall, the chart highlights the interdisciplinary nature of research in NDT and aerospace, with strong contributions from Engineering, Materials Science, and Physics, while also drawing from various other scientific disciplines to advance the field comprehensively.

Findings and Discussion for RQ3: Trends in Documents by Country or Territory

The bar chart in Figure 3 depicts documents by country or territory from the Scopus database. It illustrates the geographical distribution of research activity related to NDT in aerospace. China and the United States are the leading contributors, publishing over 130 documents each. This significant output highlights their strong emphasis on aerospace research and technological development. As two of the largest economies in the world, both countries have

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substantial resources dedicated to aerospace innovation and a strong presence in developing advanced testing techniques for structural health monitoring.

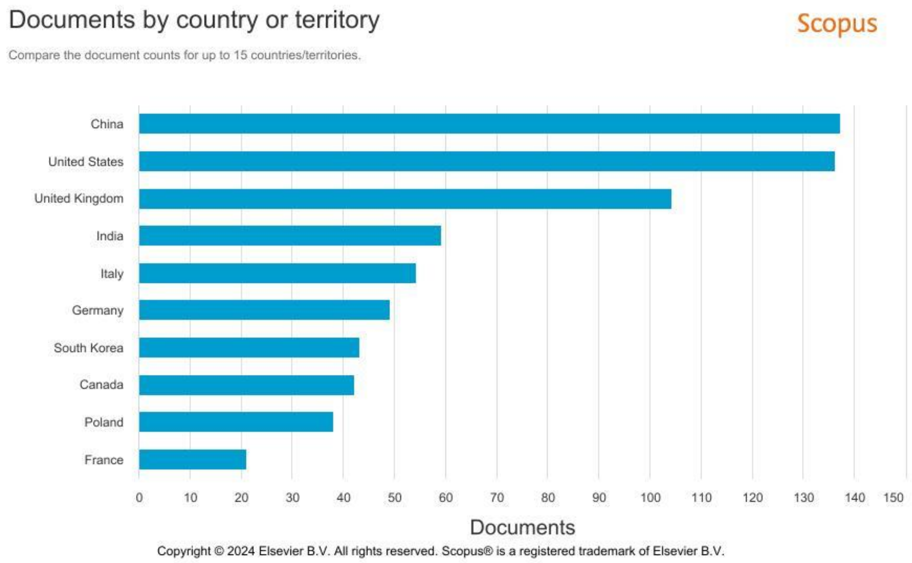

Figure 3: Documents by Country or Territory

The United Kingdom (UK) ranks third, followed by India, indicating a notable level of research engagement from these countries. The UK's position as a significant contributor can be attributed to its well-established aerospace sector and its role in international collaborations on aviation safety and innovation. Similarly, India's involvement in aerospace technology has increased considerably, particularly with its growing domestic aerospace industry and research initiatives. Countries like Italy, Germany, and South Korea are significant contributors, reflecting their focus on technological advancement in aerospace materials and manufacturing.

The presence of Canada, Poland, and France, each with around 40-50 documents, highlights their active participation in aerospace research and NDT development. These countries are highly interested in improving aerospace safety, materials, and manufacturing processes. The wide distribution of research across different countries demonstrates the global interest in aerospace safety and the application of advanced NDT methods. It also underscores the importance of international collaboration, as aerospace research and innovation benefit from countries' diverse expertise and technological capabilities worldwide. Overall, the trend shows that leading economies with established aerospace sectors dominate research activity, while other countries are also making considerable contributions, reflecting a truly international effort in advancing NDT in aerospace.

The trends in documents by country or territory in Figure 3 can be closely related to those in documents by funding sponsor in Figure 4, as countries with leading research output are often supported by prominent national funding organisations.

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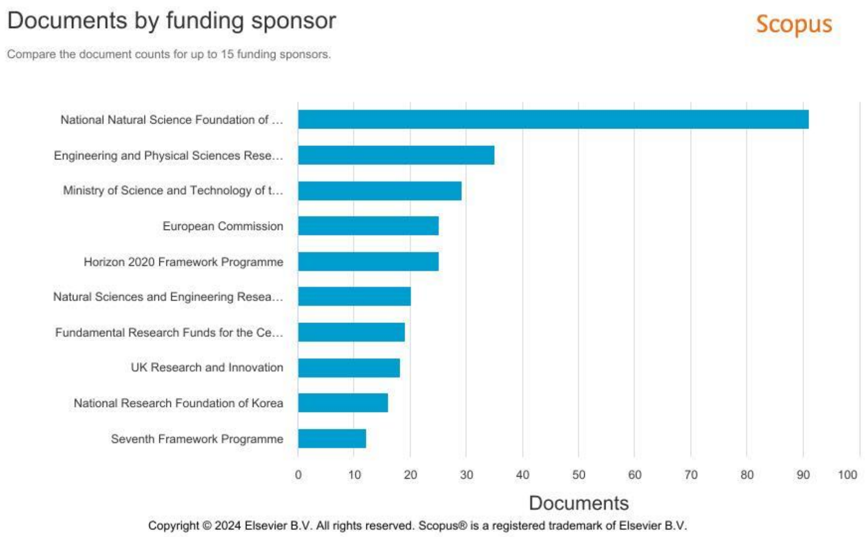

Figure 4: Documents by Funding Sponsor

The National Natural Science Foundation of China is the leading sponsor of aerospace NDT, reflecting China's prominent role in research output. This is supported by the Engineering and Physical Sciences Research Council (EPSRC) in the UK, which aids innovative NDT methods and various federal programs in the US, such as the Department of Defense and NASA. The European Commission and Horizon 2020 also contribute significantly to research funding across several European nations, including the UK, Italy, Germany, and France.

Additionally, the Ministry of Science and Technology of China and the National Research Foundation of Korea illustrate a commitment to advancing aerospace research in their respective countries. Overall, there is a clear correlation between the leading countries in research output and the support from their funding agencies, highlighting the vital role of funding in promoting aerospace technologies and NDT methods on a global scale.

Findings And Discussion for RQ4: Purpose and Perspective Of The Most Cited Article

The articles on NDT in aerospace reflect a variety of methodologies ranging from practical innovations to technical analyses of material properties. For instance, as in Table 3, Kong et al. (2018) introduce a novel sound-based technique for monitoring bolt looseness, emphasising efficient, non-invasive applications in structural health monitoring. Similarly, Janapati et al. (2016) focus on enhancing the sensitivity of acousto-ultrasound-based structural health monitoring techniques, while Bang et al. (2020) integrate artificial intelligence with thermography to improve the accuracy of NDT in composite materials, showcasing a significant trend toward technological advancement in aerospace.

Table 3: Purpose and Perspective of The Most Cited Article

Authors	Title	Purpose	Perspective/Approach
(Kong et al., 2018)	Tapping and listening: A new approach to bolt looseness monitoring	To introduce a new method for monitoring bolt looseness using sound-based tapping techniques.	Practical, emphasising innovative sensor-based solutions in structural health monitoring through non-invasive and efficient methods.

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(Leckey et al., 2014)	Guided waves in anisotropic and quasi-isotropic aerospace composites: Three-dimensional simulation...	To explore guided wave behaviour in aerospace composite materials through simulations and experiments.	Analytical and simulation-based, focusing on the detailed interaction of waves with materials to improve NDT methods for aerospace composites.
(Janapati et al., 2016)	Damage detection sensitivity characterisation of acousto-ultrasound-based structural health monitoring	To characterise the sensitivity of acousto-ultrasound SHM techniques for damage detection.	Experimental, examining specific SHM techniques to advance detection sensitivity for structural health in aerospace applications.
(Williams et al., 2016)	Wire + Arc additive manufacturing	To examine the properties and potential applications of Wire + Arc additive manufacturing (WAAM) in materials science and aerospace.	Technical and materials science-based, focusing on manufacturing processes and structural applications of WAAM, with implications for rapid and cost-effective production.
(Bang et al., 2020)	Defect identification in composite materials via thermography and deep learning techniques	To utilise thermography combined with deep learning for detecting defects in composite materials.	Innovative, integrating AI (deep learning) with thermographic NDT techniques to enhance accuracy in defect detection, particularly in composites.
(Katunin et al., 2015)	Damage identification in aircraft composite structures: A case study using various non-destructive testing techniques	To provide a comparative analysis of multiple NDT techniques for identifying damage in aircraft composites.	This case-study approach examines the effectiveness of multiple NDT methods (e.g., thermography and ultrasonics) on composite materials, offering insights into their relative effectiveness in aerospace applications.
(du Plessis & Beretta, 2020)	Killer notches: The effect of as-built surface roughness on fatigue failure in AlSi10Mg	To assess the impact of surface roughness on the fatigue failure of 3D-printed AlSi10Mg structures.	Material-centric and fatigue analysis perspective, addressing manufacturing limitations and structural integrity implications of 3D-printed materials in industrial applications.
(Gorelik, 2017)	Additive manufacturing in the context of structural integrity	To analyse the implications of additive manufacturing on the structural integrity of	Risk and reliability-focused, discussing the challenges and potential failures associated with additive manufacturing in maintaining high structural

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		components in critical applications.	integrity in safety-critical components.
(Brenner et al., 2015)	Laser-driven X-ray and neutron source development for industrial applications of plasma accelerators	To develop laser-driven x-ray and neutron sources suitable for industrial applications of plasma accelerators.	Technological development perspective, focused on creating advanced radiation sources for industrial use, enabling new applications in imaging, NDT, and material analysis.
(Park et al., 2014)	Visualisation of hidden delamination and debonding in composites through noncontact laser ultrasonic.	To demonstrate the use of laser ultrasonics in visualising hidden delamination and debonding in composite structures.	Diagnostic and visualisation approach: Laser ultrasonic scanning improves the visualisation of internal structural faults in composites, benefiting aerospace and other critical applications where non-invasive inspection is paramount.

Additionally, several studies adopt material-centric and analytical perspectives to address challenges related to additive manufacturing and NDT methods. Williams et al. (2016) examine the properties of Wire + Arc additive manufacturing (WAAM) for rapid production in aerospace, and Du Plessis and Beretta (2020) analyse the effects of surface roughness on fatigue failure in 3D-printed materials. Moreover, researchers like Leckey et al. (2014) and Park et al. (2014) explore wave propagation and laser ultrasonic scanning techniques to enhance defect detection. This diverse array of approaches illustrates NDT research's complexity and multifaceted nature, all aimed at improving safety, reliability, and structural monitoring in aerospace applications.

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Findings And Discussion for RQ5: Popular Keywords

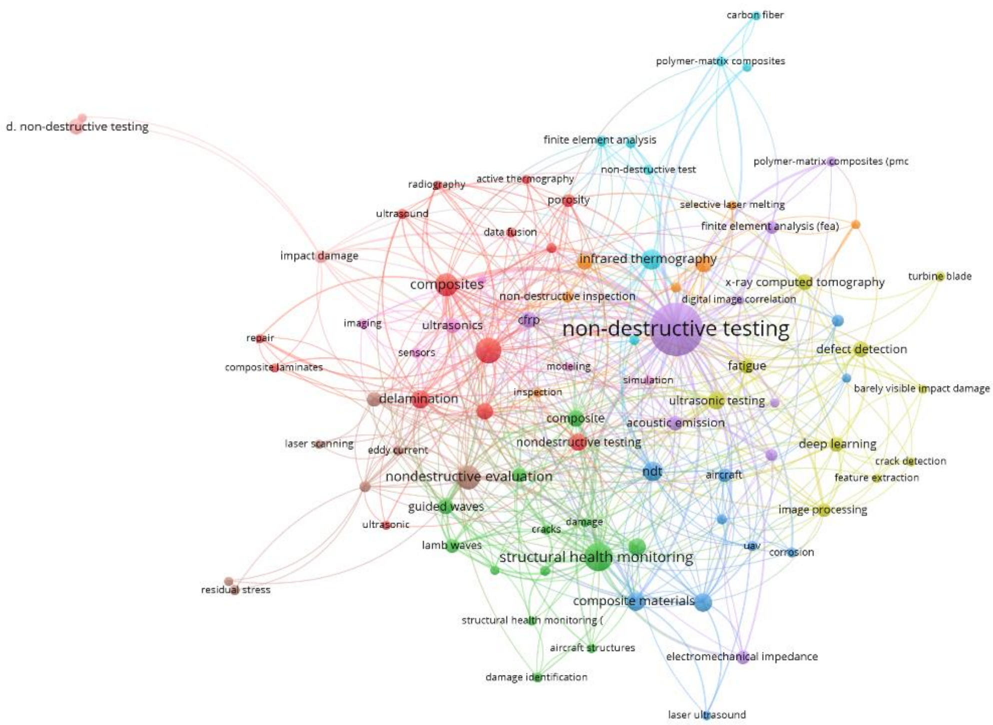

Figure 5: Author Keywords

Based on the VOSviewer co-occurrence analysis of author keywords in Figure 5, several popular keywords related to the study of NDT in aerospace have been identified, and there has been an evolution in their focus over the last ten years. The most frequently occurring keywords include "non-destructive testing" (165 occurrences), "structural health monitoring" (49 occurrences), "non-destructive evaluation" (39 occurrences), and "composites" (33 occurrences). These keywords suggest a continued and primary focus on testing techniques and ensuring the integrity of aerospace structures, mainly through NDT, which has been consistently central to aerospace research.

Keywords such as "infrared thermography" (25 occurrences), "deep learning" (13 occurrences), and "machine learning" (16 occurrences) indicate a recent trend toward integrating advanced technologies into NDT practices. The inclusion of AI-based terms, such as "deep learning" and "machine learning," signifies the growing interest in enhancing detection capabilities using automated and intelligent systems. This shift marks an evolution from traditional NDT techniques to more data-driven and AI-assisted methods, reflecting a broader industry push towards digitalisation and precision in defect detection.

Another notable trend is the focus on materials, as reflected by keywords like "composite materials" (21 occurrences), "carbon fiber" (5 occurrences), and "composites" (33 occurrences). The increased emphasis on composite materials highlights the changing landscape of aerospace structures, with a shift toward lightweight, high-strength materials. Related keywords such as "damage detection" (21 occurrences) and "delamination" (21 occurrences) demonstrate the focus on assessing the integrity and damage in these materials.

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Overall, the keyword analysis shows a progression from traditional NDT approaches towards incorporating more advanced technologies and a growing interest in monitoring newer composite materials in aerospace.

Findings And Discussion for RQ6: Co-Authorship

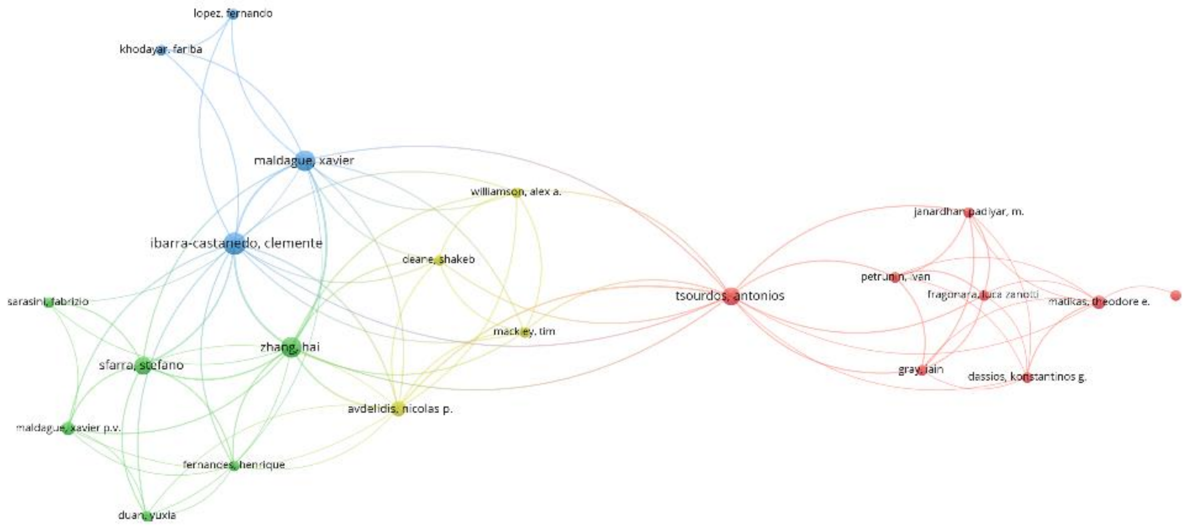

Figure 6: Co-Authorship

The data from the co-authorship analysis in Figure 6 contains information about the selected authors, including their names, the number of documents they authored, and their total link strength, representing their collaborative relationships with other authors.

The co-authorship network visualisation reveals several distinct clusters of collaboration among authors. One notable cluster is led by ", Antonios," which forms a densely connected group, indicating frequent collaboration with co-authors like "Petrucci, Ven," "Fragkoulis, Ilias Zanol," and "Matikas, Theodore E." This group is well-connected internally, suggesting strong research ties and a collaborative network focusing on a specific aerospace or NDT research area.

Another significant cluster is led by "Maldague, Xavier," which includes co-authors such as "Ibarra-Castanedo, Clemente," "Sfarra, Stefano," and "Abidin, Ilham Mukriz Zainal." The links between these authors suggest a well-established collaborative effort, likely focusing on topics related to infrared thermography or non-destructive evaluation methods. This group forms an interconnected network, highlighting a pattern of consistent co-authorship and likely focusing on thermographic inspection techniques and structural health monitoring.

Additionally, the presence of "Zhang, Hai" in the network, connected to authors like "Sfarra, Stefano" and "Avdelidis, Nicolas P.," indicates that these authors bridge multiple clusters. This suggests that their interdisciplinary research covers multiple facets of NDT and potentially brings insights from one subdomain into another.

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Overall, the co-authorship analysis highlights the collaborative nature of research in non-destructive testing, with strong connections within clusters that represent specific research focuses. The existence of bridging authors, such as "Zhang, Hai" and "Abidin, Ilham Mukriz Zainal," also suggests integrating knowledge across different sub-disciplines, which is crucial for advancing aerospace NDT technologies. This type of collaboration fosters the sharing of methods and findings, which could help accelerate innovation in material evaluation techniques and structural health monitoring.

Conclusion

The bibliometric analysis of research on non-destructive testing (NDT) in aerospace reveals a dynamic and evolving field shaped by increasing interest and interdisciplinary contributions. Over the past decade, publications have generally trended upward, reflecting heightened global attention on aerospace safety and advanced inspection techniques. Engineering dominates the subject areas, emphasising the technical focus of NDT studies, followed by materials science, which highlights the importance of understanding aerospace materials' properties and behaviours. Contributions from physics, computer science, and chemistry further underscore the interdisciplinary nature of NDT research, combining theoretical foundations with innovative technologies like AI and additive manufacturing.

Geographically, research outputs are concentrated in countries with strong aerospace sectors, including China, the United States (US), and the United Kingdom (UK), supported by substantial funding from national and international organisations. This alignment of research activity with funding highlights the role of financial resources in advancing innovation. The focus on additive manufacturing, defect detection, and structural health monitoring reflects a clear trend towards integrating advanced materials science, computational tools, and innovative inspection techniques to meet the demands of modern aerospace applications. The diverse range of perspectives—practical, experimental, analytical, and technological—demonstrates the field's commitment to addressing complex challenges through fundamental research and applied solutions.

The bibliometric analysis of NDT in aerospace highlights significant trends in keyword usage and research collaborations. Over the past decade, frequently occurring keywords such as "non-destructive testing," "structural health monitoring," and "non-destructive evaluation" underscore the enduring focus on testing methods and structural integrity in aerospace. Recent additions, including "deep learning," "machine learning," and "infrared thermography," point to a shift towards incorporating artificial intelligence and advanced technologies to enhance defect detection and evaluation processes. Additionally, an increasing emphasis on materials-related terms like "composites," "composite materials," and "damage detection" reflects the rising importance of lightweight, high-strength materials in aerospace structures, marking an evolution in research priorities and technological applications.

The co-authorship and collaboration analysis reveals a robust network of research partnerships, characterised by distinct clusters of authors working on specialised topics. For instance, tightly connected groups indicate focused efforts on specific NDT techniques while bridging authors link multiple clusters, enabling interdisciplinary integration and knowledge transfer. These collaborative dynamics, evident across various sub-disciplines, such as thermographic inspection and structural health monitoring, demonstrate the importance of shared expertise in advancing aerospace NDT technologies. The interconnected nature of these networks

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facilitates innovation and the development of cutting-edge methods to address emerging challenges in aerospace material evaluation and structural analysis.

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