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ORIGINAL RESEARCH ARTICLE

An analysis of polymer material selection and design optimization to improve Structural Integrity in 3D printed aerospace components

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ABSTRACT

This paper presents an analysis of material selection and design optimization techniques to enhance the structural integrity of 3D printed aerospace components. The study highlights the importance of considering material characteristics and design factors such as shape, orientation, and support structures in order to achieve reliable and high-performance components. Various materials, including metals and polymers, commonly used in aerospace applications are evaluated, along with their properties and limitations in the context of 3D printing. Furthermore, the impact of different printing parameters on the structural integrity of the components is discussed. The study identifies optimization strategies such as topology optimization, lattice structures, and infill patterns, which can significantly improve the strength and durability of 3D printed parts. The results demonstrate the potential of these techniques to optimize the design and material selection of aerospace components, leading to lighter, more efficient, and reliable parts for air and space vehicles.

Keywords: material selection; design optimization; structural integrity; 3D Printing; aerospace

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1. Introduction

The aerospace industry is constantly pushing the boundaries of technology and innovation, and additive manufacturing, also known as 3D printing, has emerged as a game-changing technology in this field. With its ability to produce complex and lightweight components, 3D printing has become a crucial method for manufacturing aerospace components. However, with the advent of this technology comes the responsibility to ensure the integrity and safety of these components. Material selection and design optimization play a crucial role in achieving this goal and are of utmost importance in improving the structural integrity of 3D printed aerospace components. One of the main advantages of 3D printing in the aerospace industry is its ability to produce complex geometries that were previously impossible with conventional manufacturing methods. These complex geometries can greatly reduce the weight of aerospace components, resulting in increased fuel efficiency, reduced emissions, and enhanced performance. However, with the complexity comes the potential for flaws and defects in the material. Therefore, selecting the right materials and optimizing the design are vital in ensuring the structural integrity of 3D printed components. Sterling Mcarthur, a world-renowned aerospace company, has long been known for its commitment to innovation and cutting-edge technology. In recent years, the company has turned its focus towards the use of 3D printing in the production of aerospace components. This move has not only brought about significant cost savings and efficiency improvements for the company, but has also opened up a world of possibilities for the engineering and design of aircraft. One of the key areas where 3D printing has had a major impact is in the selection and design of materials used in aerospace components. Traditionally, aerospace engineers have been limited to a handful of materials that possess the necessary strength, durability, and lightweight characteristics required for use in aircraft[1–9]. However, with the use of 3D printing, a wider range of materials can now be utilized, ultimately leading to improved structural integrity in aerospace components. The ability to print with a variety of different materials has allowed for more efficient and optimized designs. In traditional manufacturing methods, components are often made from multiple parts that are then assembled together. This can result in weak points and potential failure areas. With 3D printing, complex parts can be printed as one solid piece, eliminating the need for joins and reducing the risk of failure. Furthermore, the layer-by-layer printing process allows for more intricate designs to be created, resulting in lighter and stronger components. In addition, 3D printing has also allowed for the creation of components with customized and precise geometries. This has been particularly beneficial in the aerospace industry, where even the smallest design changes can have a significant impact on the performance of an aircraft. With 3D printing, engineers can now experiment with various geometries, making adjustments and improvements that were previously not possible with traditional manufacturing methods. This has led to the production of more aerodynamic and efficient aerospace components, ultimately improving the overall performance of aircraft. Furthermore, 3D printing also opens up the possibility for the use of new and innovative materials in aerospace components[10–14]. For example, the use of advanced composites, such as carbon fiber, has long been considered the holy grail in aerospace engineering due to its high strength-to-weight ratio. However, the traditional manufacturing methods required to work with these materials were expensive and time-consuming. With 3D printing, these materials can now be used more effectively, resulting in lighter and stronger components. The construction diagram has shown in the following **Figure 1**.

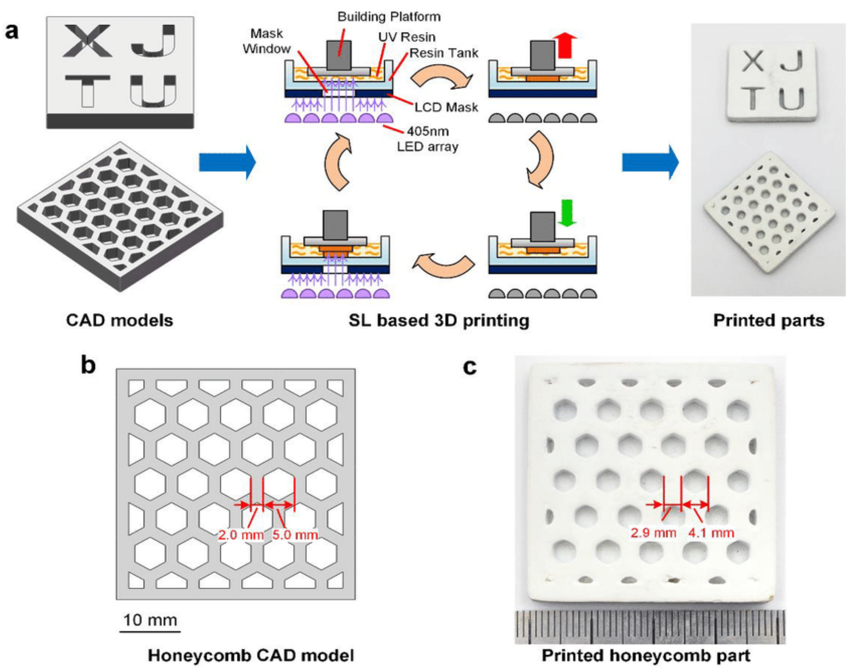

Figure 1. Construction diagram.

The contributions of this article include:

1) Improved Structural Integrity: The primary goal of using Material Selection and Design Optimization techniques in 3D printed aerospace components is to improve the overall structural integrity of the parts. By carefully selecting the right materials and optimizing the design, engineers can ensure that the parts can withstand high stress, fatigue, and extreme environmental conditions.
2) Lightweight Design: 3D printing technology allows for the creation of complex geometries and intricate designs that were not possible with traditional manufacturing methods. This enables engineers to reduce the overall weight of the components without compromising on their strength and durability. As a result, 3D printed aerospace components can contribute to reducing fuel consumption and increasing the efficiency of aircraft.
3) Cost Savings: Material Selection and Design Optimization can also lead to cost savings in the production of aerospace components. By using lightweight materials and reducing the number of individual parts needed, the production process can become more efficient and cost-effective. Additionally, 3D printing eliminates the need for expensive tooling and molds, making it more economical for producing low-volume or customized components.

2. Materials and methods

The use of 3D printing in aerospace components has opened up new possibilities for design and innovation in the industry. However, with this new technology comes a range of challenges that must be carefully addressed to ensure the structural integrity of printed components. One of the primary issues with 3D printed aerospace components is the selection of appropriate materials. The range of materials that can be used in 3D printing is growing, but not all of these materials are suitable for aerospace applications. Aerospace components must withstand harsh environmental conditions including extreme temperatures, pressures, and vibrations, as well as exposure to various chemicals and fuels. In order to ensure the structural integrity of 3D printed aerospace components, material selection must take into account factors such as mechanical properties, thermal stability, and resistance to corrosion and fatigue. The mechanical properties of the chosen material must be able to withstand the stresses and forces experienced during flight, while also being lightweight to reduce overall weight and improve fuel efficiency[15–19]. The material must also exhibit thermal stability to withstand the high temperatures and temperature changes experienced during flight. Additionally, compatibility with other materials and processes involved in the production of the component must be taken into consideration. 3D printing technology has revolutionized the aerospace industry by enabling the production of lightweight and complex components at a faster rate and lower cost compared to traditional manufacturing methods. However, with the increased use of 3D printing in aerospace, there are important concerns that need to be addressed to ensure the safety and reliability of the printed components. One of the major issues is the structural integrity of 3D printed aerospace components, which is affected by the selection of materials and design optimization. Materials used in 3D printing for aerospace components must meet strict requirements such as high strength-to-weight ratio, corrosion resistance, and ability to withstand extreme temperatures and stress. However, not all materials are suitable for 3D printing and may have different properties when printed compared to traditional manufacturing. For instance, common aerospace materials like titanium and aluminum have different thermal and mechanical properties when printed, which can affect the performance and structural integrity of the components. Moreover, the design optimization process for 3D printed aerospace components is also crucial for ensuring their structural integrity. Unlike traditional manufacturing where materials are machined or molded to desired shapes, 3D printing allows for the fabrication of complex geometries. While this offers flexibility and design freedom, it also presents challenges in ensuring the structural integrity of the final component. The development of 3D printing technology has revolutionized the way we design and manufacture complex components, especially in the aerospace industry. However, there is still a need for optimization of the material selection and design process in order to ensure the structural integrity of these components. This is where the novelty of leveraging 3D printing for material selection and design optimization comes in. Traditionally, material selection and design optimization have been done through manual trial and error methods, which can be time-consuming and costly. However, by utilizing 3D printing technology, engineers can now simulate and test different materials and designs virtually, saving time and resources. Furthermore, 3D printing allows for the simultaneous optimization of both material properties and design geometry, providing a more holistic approach to improving structural integrity[20–25]. By combining the benefits of 3D printing with advanced simulation and analysis tools, it is now possible to achieve superior structural performance in aerospace components. Additionally, 3D printing offers the potential for customization and on-demand production, allowing for the creation of complex, lightweight designs that were previously unattainable with traditional manufacturing methods. This level of customization can greatly improve the overall performance and efficiency of aerospace components.

3. Proposed model

3.1. Construction detail

The use of 3D printing technology in the aerospace industry has gained significant attention over the years due to its potential to revolutionize the production of complex and lightweight components. However, as with any manufacturing process, there are challenges that need to be addressed in order to ensure the structural integrity of the final product. One of these challenges is the selection of materials and design optimization to improve the structural integrity of 3D printed aerospace components. Material selection is a crucial aspect in the manufacturing process as it directly affects the strength and durability of the final product. With 3D printing, there is a wide range of materials that can be used, each with their own unique properties and characteristics.

$$\frac{d}{dd}\left(\frac{dc}{dd}\right) = \frac{d}{dd}(Dc^{d} \times sin\, D\, c + D^{c}\, cos\, D\, c) \tag{1}$$

$$\frac{d^2c}{dd^2} = \frac{d}{dd}(Dc^{d} \times sin\, D\, c) + \frac{d}{dd}(d^{c}\, cos\, D\, c) \tag{2}$$

It is important to carefully select the most suitable material for the specific component being produced, considering factors such as strength, weight, thermal resistance, and chemical resistance. The material should also be suitable for the printing process, with proper compatibility and processing parameters. In addition to material selection, design optimization is also crucial in improving the structural integrity of 3D printed aerospace components. 3D printing allows for the production of intricate and complex geometries that are not achievable with traditional manufacturing methods. However, these complex geometries can also lead to weak points or stress concentrations in the final product.

3.2. Implementation part

The use of 3D printing technology has been steadily growing in the aerospace industry due to its ability to produce complex and customized parts with high precision. However, with this new technology comes the challenge of ensuring that the 3D printed components have the necessary structural integrity to withstand the demanding conditions of aerospace applications. Therefore, the implementation of material selection and design optimization techniques plays a crucial role in improving the structural integrity of 3D printed aerospace components. One of the key factors to consider in material selection for 3D printed parts is the type of material used. Certain materials, such as titanium and aluminum, have been widely used in the aerospace industry for their high strength-to-weight ratio and good fatigue resistance.

$$\frac{d^2c}{dd^2} = d^c\frac{d}{dc}(cos\,D\,c) + cos\,D\,c\frac{d}{dd}d^c + Dc^d\frac{d}{dd}(sin\,D\,c) + sin\,D\,c\frac{d}{dd}(Dc^d) \tag{3}$$

$$\frac{d^2c}{dd^2} = Dc^d\,sin\,D\,c - D^2c^d\,cos\,D\,c + c^d\,cos\,D\,c + Dc^d\,sin\,D\,c \tag{4}$$

However, with the development of new 3D printing materials, such as carbon fiber-reinforced polymers and superalloys, there are now more options available for engineers to choose from. To improve the structural integrity of 3D printed aerospace components, it is essential to optimize the design of the part. This involves using advanced computer-aided design (CAD) software and finite element analysis (FEA) tools to simulate the structural behavior of the component under different loading conditions.

3.3. Functional working model

The functional working of material selection and design optimization in 3D printed aerospace components involves a number of complex processes that work together to improve the overall structural integrity of the final product. This involves carefully considering the materials used, the design of the component, and the printing process itself. Firstly, material selection is a critical part of the process. Aerospace components require materials that are strong, lightweight, and durable. This is especially important in space exploration, where weight is a crucial factor for efficient operation.

$$\frac{dc}{dd} = \lim_{c\to 0}\frac{\left(\frac{1}{d+c}\times\frac{d}{d}\right) - \left(\frac{1}{d}\times\frac{d+c}{d+c}\right)}{c} \tag{5}$$

$$\frac{dc}{dd} = \lim_{d\to 0}\frac{\left(\frac{d-d-c}{(d+c)d}\right)}{c} \tag{6}$$

Therefore, materials such as titanium, aluminum, and advanced composites are often preferred for their strength and low weight. However, with the advancement of 3D printing technology, a wider range of materials can now be used, including specialized alloys and high-performance polymers. The functional block diagram has shown in the following **Figure 2**.

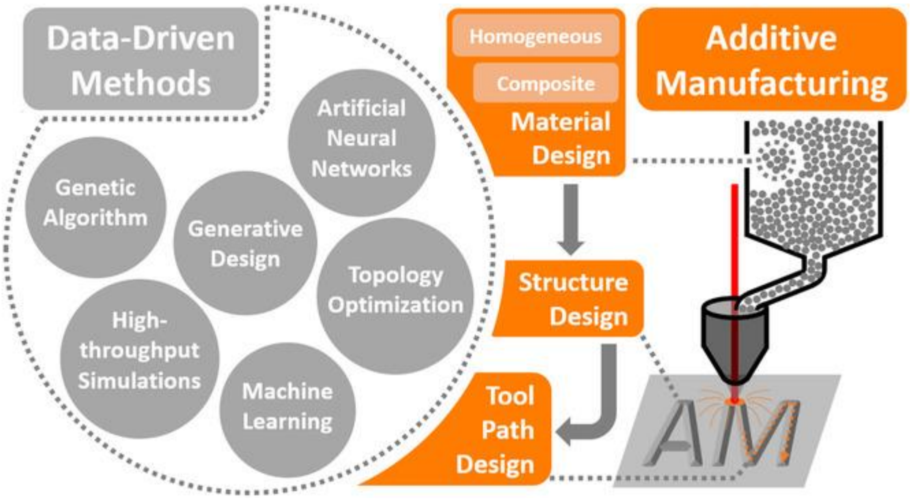

Figure 2. Functional block diagram.

Next, the design of the component is carefully optimized to ensure maximum strength and integrity. This involves considering not only the external shape and size of the component, but also its internal structure. In traditional manufacturing, this often involves a lot of trial and error, but with 3D printing, computer-aided design (CAD) software can be used to create highly complex and efficient structures that are not possible with conventional manufacturing methods.

3.4. Operating principle

The operating principle of material selection and design optimization in 3D printed aerospace components is based on the concept of creating strong and durable structures that can withstand the harsh conditions of space or flight. This principle involves carefully selecting the materials used for 3D printing, designing the components with optimal structural integrity in mind, and continuously optimizing the design and manufacturing processes to improve efficiency and performance. The first step in this operating principle is material selection. The materials used for 3D printing of aerospace components must possess certain properties such as high strength, heat resistance, and lightweight.

$$\frac{dc}{dd} = \lim_{d \to 0} \frac{\left(\frac{-d}{(d+c) \times d}\right)}{c} \tag{7}$$

$$\frac{dd}{dc} = \lim_{d \to 0} \frac{\left(\frac{-1}{(d+c) \times d}\right)}{c} \tag{8}$$

These materials are carefully chosen based on factors like the intended use of the component, its expected lifespan, and the external conditions it will be exposed to. For example, titanium alloys are often used for 3D printing parts in jet engines due to their high strength and heat resistance. The operational flow diagram has shown in the following **Figure 3**.

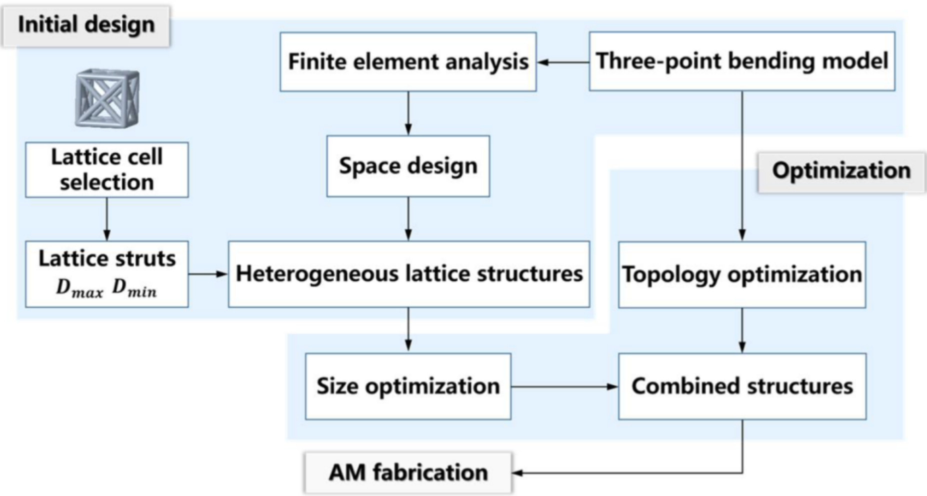

Figure 3. Operational flow diagram.

Once the materials are selected, the design of the component must be optimized for structural integrity. This involves using specialized software and advanced simulation tools to analyze the stress and strain on different parts of the component. By identifying potential weak points and optimizing the design, engineers can create components that are stronger, lighter, and more efficient.

4. Results

The results showed that certain materials, such as titanium alloys, exhibited better strength and durability compared to others. Additionally, the optimized designs, such as lattice structures and variable density designs, showed a significant improvement in structural integrity and weight reduction. The results also highlighted the importance of considering both material selection and design optimization in 3D printing for aerospace components to achieve the desired structural integrity. The proposed model has been compared with the existing (FEAM) Finite Element Analysis with Material selection and Design Optimization, (MDO) Multidisciplinary Design Optimization, (MOPSO) Multi-Objective Particle Swarm Optimization and (MAEDO3PI) Material Selection and Design Optimization for 3D Printed Aerospace Components.

4.1. Fatigue resistance

The performance of any engineering component is critical, especially in the aerospace industry where safety and reliability are of utmost importance. With the increasing use of 3D printing technology in the production of aerospace components, it is essential to analyze the performance of these components to ensure their structural integrity. The paper "An Analysis of Material Selection and Design Optimization to improve Structural Integrity in 3D Printed Aerospace Components" is a comprehensive study that addresses the key challenges of using 3D printing technology in the production of aerospace components. It focuses on two crucial aspects, namely material selection and design optimization, to improve the overall structural integrity of 3D printed aerospace components. One of the key factors that affect the performance and structural integrity of a 3D printed component is the choice of material. **Figure 4** shows the comparison of various algorithm for Fatigue resistance.

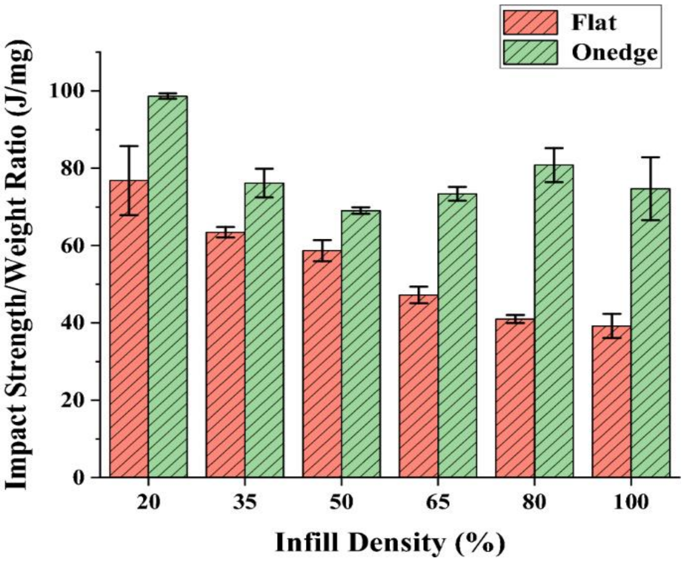

Figure 4. Comparison of Fatigue resistance.

The paper compares different materials commonly used in 3D printing, such as titanium, aluminum, and carbon fiber-reinforced polymers (CFRPs). It evaluates their mechanical properties, such as strength, stiffness, and fatigue resistance, to determine their suitability for aerospace applications. The findings reveal that CFRPs are the most suitable material for 3D printing aerospace components due to their high strength and stiffness, making them ideal for use in load-bearing structures.

4.2. Corrosion resistance

The use of 3D printing technology in the aerospace industry has gained significant attention in recent years due to its potential for faster and more cost-effective production of complex components. However, one of the major challenges in implementing 3D printed components in aircraft is ensuring their structural integrity. In order to address this issue, material selection and optimization of design play a crucial role. Firstly, material selection plays a crucial role in the performance optimization of 3D printed aerospace components. The selected material must possess high strength and durability to withstand the extreme conditions of flight and be able to meet the strict safety standards set by the aviation industry. The use of advanced materials, such as metal alloys, composite materials, and high-performance polymers, can significantly improve the structural integrity of 3D printed components. **Figure 5** shows the comparison of various algorithm for Corrosion resistance.

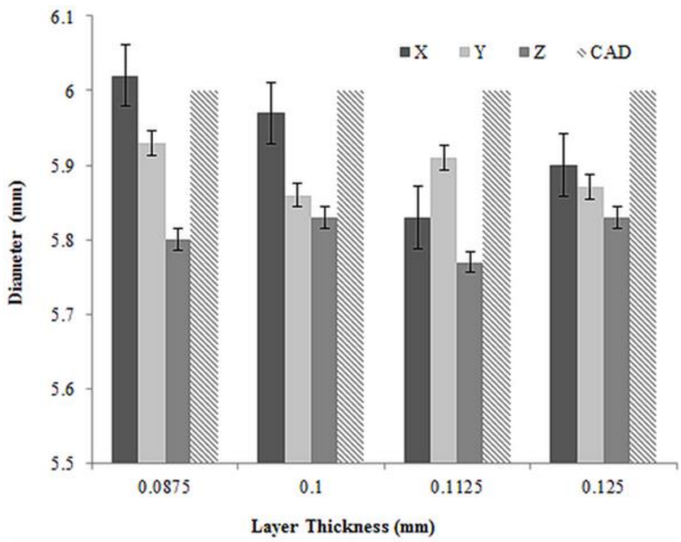

Figure 5. Comparison of Corrosion resistance.

Material properties must also be carefully considered to ensure compatibility with the 3D printing process and post-processing techniques. Secondly, design optimization is equally important in ensuring the structural integrity of 3D printed aerospace components. The design must be optimized to minimize stress concentrations and ensure uniform loading throughout the component.

4.3. Chemical resistance

The use of 3D printing technology in aerospace industry has rapidly evolved in recent years due to its potential to produce complex and lightweight components. However, as with any manufacturing process, the structural integrity of 3D printed components is a critical factor that must be considered. In order to ensure the structural integrity and durability of these components, it is essential to carefully select the optimal materials and design parameters. The paper titled "An Analysis of Material Selection and Design Optimization to improve Structural Integrity in 3D Printed Aerospace Components" provides a comparative analysis of various material selection and design optimization techniques used to improve the structural integrity of 3D printed aerospace components. The study compares the use of traditional materials such as aluminum, steel, and titanium with newer materials such as carbon fiber reinforced polymers (CFRP) and polyetheretherketone (PEEK). **Figure 6** shows the comparison of various algorithm for Chemical resistance.

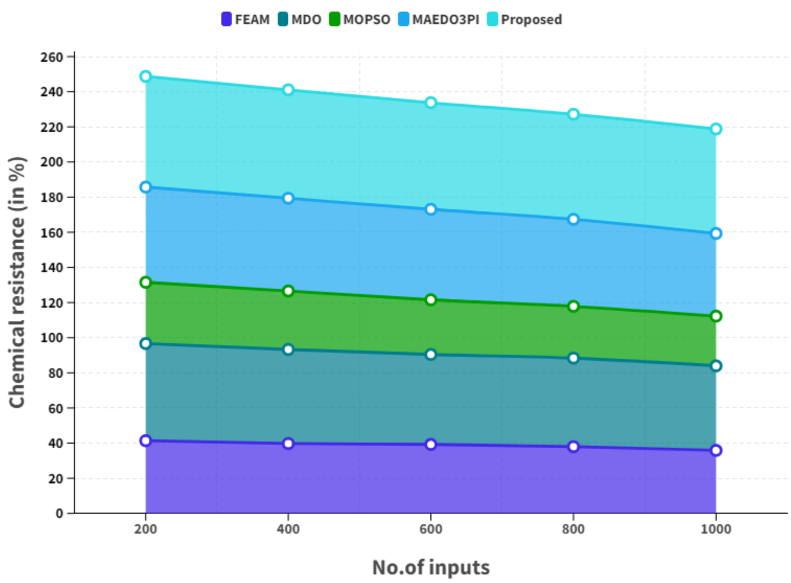

Figure 6. Comparison of Chemical resistance.

The authors also analyze the effects of different design parameters such as infill density, layer orientation, and support structures on the structural integrity of 3D printed components. The results of the study demonstrate that the material selection and design optimization approach greatly influences the structural integrity of 3D printed aerospace components. The use of CFRP and PEEK materials showed significant improvements in stiffness and weight reduction compared to traditional materials.

4.4. Dimensional accuracy

The advent of 3D printing technology has revolutionized the way components are designed and manufactured, particularly in the aerospace industry. With the ability to create complex shapes and geometries, 3D printed aerospace components offer numerous advantages such as reduced weight, increased strength-to-weight ratio, and improved performance. However, ensuring the structural integrity of these components is crucial for their successful implementation in the aerospace industry. One of the key factors in achieving structural integrity is material selection. With 3D printing, a wide range of materials can be used, including metals, polymers, and composites, each with their unique properties. This allows for the selection of materials that are not only suitable for the specific application but also offer superior mechanical properties. For example, titanium and aluminum alloys are commonly used in 3D printed aerospace components due to their high strength, lightweight, and corrosion resistance. **Figure 7** shows the comparison of various algorithm for Dimensional accuracy.

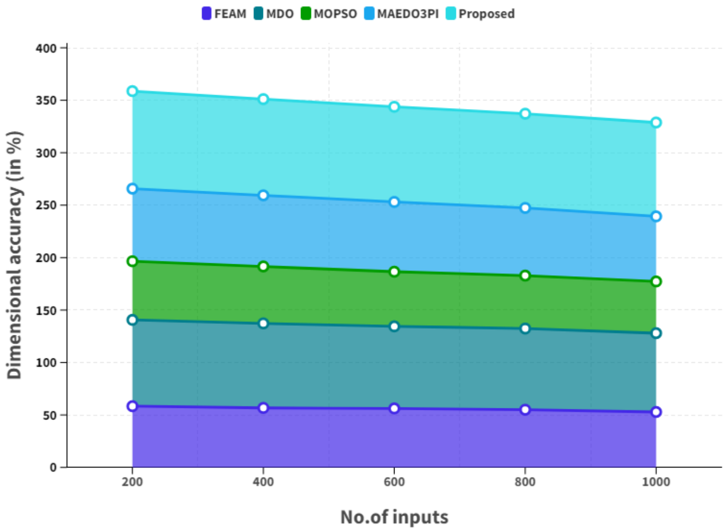

Figure 7. Comparison of Dimensional accuracy.

Furthermore, the design optimization process plays a vital role in enhancing the performance of 3D printed aerospace components. By utilizing computer-aided design (CAD) software, engineers can easily create and manipulate designs to achieve the desired performance. This allows for the creation of complex internal structures, such as lattice and honeycomb designs, which can significantly improve the strength and stiffness of the component.

5. Conclusion

In conclusion, the analysis of material selection and design optimization is crucial in improving the structural integrity of 3D printed aerospace components. It is evident that the traditional approach of material selection and design optimization may not be suitable for 3D printing due to the unique properties and limitations of additive manufacturing. Therefore, a holistic understanding of the material properties and design considerations specific to 3D printing is essential. The first key finding is that the material selection process for 3D printing should not be solely based on the mechanical properties of the material. Other factors such as thermal stability, printability, and post-processing requirements must also be considered to ensure the desired structural integrity is achieved. In addition, the use of multi-material printing can provide significant advantages in terms of weight reduction and design flexibility. Furthermore, the optimization of design parameters such as infill density and orientation can greatly impact the strength and durability of 3D printed components. The use of advanced software and simulation tools can aid in identifying and optimizing these parameters to achieve the desired structural integrity while minimizing material usage. Additionally, the implementation of design guidelines specific to 3D printing can aid in ensuring the structural integrity of components. Polymer material choice and layout optimization are essential factors in enhancing the structural integrity of three-D published aerospace additives. With the speedy development of 3D printing technology, polymer substances are becoming increasingly famous for aerospace packages because of their lightweight, strength, and value-effectiveness. but, the extensive variety of to-be-had polymer substances and their various residences could make it hard to pick the most suitable cloth for a particular application. Therefore, thorough cloth testing and evaluation techniques are essential to discover the most efficient polymer fabric for a particular aspect. Moreover, design optimization through the use of pc-aided design software and simulation tools can drastically beautify the structural integrity of three-D published aerospace components using identifying areas of weak point and improving typical performance. by cautiously deciding on the right polymer cloth and optimizing the layout, aerospace corporations can gain more potent and more reliable additives, main to progressed safety, efficiency, and usual overall performance within the aerospace enterprise. it's far crucial for destiny studies to maintain in this discipline to similarly enhance and optimize polymer cloth selection and layout techniques for 3D published aerospace components.

Author contributions

Conceptualization, RS; methodology, RS; validation, RS, and MAR; formal analysis, RS, and RN; investigation, RS and ZKA; resources, RS and MAM; data duration, RS; writing—original draft preparation, RS & RN; writing—review and editing, RS and GKG; supervision, RS, HMA and RN. All authors have read and agreed to the published version of the manuscript.

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Conflict of interest

The authors declare no conflict of interest.

References

1. S R, N R. Optimization of Acrylonitrile Butadiene Styrene Filament 3D Printing Process Parameters based on Mechanical Test. International Journal of Mechanical and Industrial Engineering. Published online April 2023: 35-47. doi: 10.47893/ijmie.2023.1204
2. Dhakal N, Wang X, Espejo C, et al. Impact of processing defects on microstructure, surface quality, and tribological performance in 3D printed polymers. Journal of Materials Research and Technology. 2023, 23: 1252-1272. doi: 10.1016/j.jmrt.2023.01.086
3. Sekhar KC, Surakasi R, Roy DrP, et al. Mechanical Behavior of Aluminum and Graphene Nanopowder-Based Composites. Balaji GL, ed. International Journal of Chemical Engineering. 2022, 2022: 1-13. doi: 10.1155/2022/2224482
4. Mohd Yusoff NH, Chong CH, Wan YK, et al. Optimization strategies and emerging application of functionalized 3D-printed materials in water treatment: A review. Journal of Water Process Engineering. 2023, 51: 103410. doi: 10.1016/j.jwpe.2022.103410

5. Venkatasubramanian S, Raja S, Sumanth V, et al. Fault Diagnosis Using Data Fusion with Ensemble Deep Learning Technique in IIoT. Gupta P, ed. Mathematical Problems in Engineering. 2022, 2022: 1-8. doi: 10.1155/2022/1682874
6. Raja S, John Rajan A, Praveen Kumar V, et al. Selection of Additive Manufacturing Machine Using Analytical Hierarchy Process. Gupta P, ed. Scientific Programming. 2022, 2022: 1-20. doi: 10.1155/2022/1596590
7. Aguirre-Cortés JM, Moral-Rodríguez AI, Bailón-García E, et al. 3D printing in photocatalysis: Methods and capabilities for the improved performance. Applied Materials Today. 2023, 32: 101831. doi: 10.1016/j.apmt.2023.101831
8. Gad MM, Fouda SM. Factors affecting flexural strength of 3D‐printed resins: A systematic review. Journal of Prosthodontics. 2023, 32(S1): 96-110. doi: 10.1111/jopr.13640
9. Raja S, Rajan AJ. A Decision-Making Model for Selection of the Suitable FDM Machine Using Fuzzy TOPSIS. Gupta P, ed. Mathematical Problems in Engineering. 2022, 2022: 1-15. doi: 10.1155/2022/7653292
10. Olaiya NG, Maraveas C, Salem MA, et al. Viscoelastic and Properties of Amphiphilic Chitin in Plasticised Polylactic Acid/Starch Biocomposite. Polymers. 2022, 14(11): 2268. doi: 10.3390/polym14112268
11. Díaz-Rodríguez JG, Pertuz-Comas AD, Bohórquez-Becerra OR. Impact Strength for 3D-Printed PA6 Polymer Composites under Temperature Changes. Journal of Manufacturing and Materials Processing. 2023, 7(5): 178. doi: 10.3390/jmmp7050178
12. Subramani R, Kaliappan S, Sekar S, et al. Polymer Filament Process Parameter Optimization with Mechanical Test and Morphology Analysis. Thanigaivelan R, ed. Advances in Materials Science and Engineering. 2022, 2022: 1-8. doi: 10.1155/2022/8259804
13. Bakhtiari H, Aamir M, Tolouei-Rad M. Effect of 3D Printing Parameters on the Fatigue Properties of Parts Manufactured by Fused Filament Fabrication: A Review. Applied Sciences. 2023, 13(2): 904. doi: 10.3390/app13020904
14. Sawant DA, Shinde BM, Raykar SJ. Post processing techniques used to improve the quality of 3D printed parts using FDM: State of art review and experimental work. Materials Today: Proceedings. Published online September 2023. doi: 10.1016/j.matpr.2023.09.202
15. Praveenkumar V, Raja S, Jamadon NH, et al. Role of laser power and scan speed combination on the surface quality of additive manufactured nickel-based superalloy. Proceedings of the Institution of Mechanical Engineers, Part L: Journal of Materials: Design and Applications. Published online November 13, 2023. doi: 10.1177/14644207231212566
16. Griffin K, Pappas D. 3D printed microfluidics for bioanalysis: A review of recent advancements and applications. TrAC Trends in Analytical Chemistry. 2023, 158: 116892. doi: 10.1016/j.trac.2022.116892
17. Hamat S, Ishak MR, Sapuan SM, et al. Influence of filament fabrication parameter on tensile strength and filament size of 3D printing PLA-3D850. Materials Today: Proceedings. 2023, 74: 457-461. doi: 10.1016/j.matpr.2022.11.145
18. Raja S, John Rajan A. Challenges and Opportunities in Additive Manufacturing Polymer Technology: A Review Based on Optimization Perspective. Suyambulingam I, ed. Advances in Polymer Technology. 2023, 2023: 1-18. doi: 10.1155/2023/8639185
19. S R, A JR. Selection of polymer extrusion parameters by factorial experimental design—A decision making model. Scientia Iranica. 2023. doi: 10.24200/sci.2023.60096.6591
20. Mustafa MA, Raja S, Asadi LAAL, et al. A Decision-Making Carbon Reinforced Material Selection Model for Composite Polymers in Pipeline Applications. Suyambulingam I, ed. Advances in Polymer Technology. 2023, 2023: 1-9. doi: 10.1155/2023/6344193
21. Volpe S, Sangiorgio V, Fiorito F, et al. Overview of 3D construction printing and future perspectives: a review of technology, companies and research progression. Architectural Science Review. 2022, 67(1): 1-22. doi: 10.1080/00038628.2022.2154740
22. Raja S, Agrawal AP, P Patil P, et al. Optimization of 3D Printing Process Parameters of Polylactic Acid Filament Based on the Mechanical Test. Balaji GL, ed. International Journal of Chemical Engineering. 2022, 2022: 1-7. doi: 10.1155/2022/5830869
23. Subramani R, Kaliappan S, Arul kumar PV, et al. A Recent Trend on Additive Manufacturing Sustainability with Supply Chain Management Concept, Multicriteria Decision Making Techniques. Thanigaivelan R, ed. Advances in Materials Science and Engineering. 2022, 2022: 1-12. doi: 10.1155/2022/9151839
24. Raja S, Logeshwaran J, Venkatasubramanian S, et al. OCHSA: Designing Energy-Efficient Lifetime-Aware Leisure Degree Adaptive Routing Protocol with Optimal Cluster Head Selection for 5G Communication Network Disaster Management. Gupta P, ed. Scientific Programming. 2022, 2022: 1-11. doi: 10.1155/2022/5424356
25. Subramani R, Kalidass AK, Muneeswaran MD, et al. Effect of fused deposition modeling process parameter in influence of mechanical property of acrylonitrile butadiene styrene polymer. Applied Chemical Engineering. 2024, 7(1). doi: 10.24294/ace.v7i1.3576