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# Study the effect of material type on aircraft structures

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## Abstract

This study examines the critical influence of material selection on the performance and safety of aircraft structures, emphasizing the role of advanced simulation techniques like ANSYS in mechanical analysis. It highlights the diverse materials used in aerospace manufacturing, including aluminum alloys, carbon fiber-reinforced polymers, and titanium alloys, each offering unique mechanical properties that affect weight, strength, and durability. By employing ANSYS Static Structure simulations, the research analyzes how these materials respond to various operational stresses, allowing for the identification of potential failure points and optimization of designs. The findings underscore the importance of integrating material science with mechanical analysis to enhance aircraft efficiency and reliability in a rapidly evolving aerospace industry.

**Keywords:** Aircraft structure; Finite element modeling; Aircraft material; Stress analysis

## 1. Introduction

The effect of materials on aircraft structures is a critical consideration in aerospace engineering, as the choice of materials directly influences performance, weight, and safety. Different materials exhibit unique mechanical properties, such as tensile strength, fatigue resistance, and thermal stability, which can significantly affect how an aircraft withstands various operational stresses. To analyze these stresses, engineers often utilize advanced simulation software like ANSYS, which provides a robust platform for finite element analysis (FEA). By modeling the aircraft structure and applying relevant loads and boundary conditions, ANSYS enables engineers to predict how materials will behave under different scenarios, identify potential failure points, and optimize designs for enhanced durability and efficiency. This interplay between material selection and mechanical analysis is essential for the development of reliable and high-performance aircraft.

## 2. Materials Used in Aircraft Structure Manufacturing

The materials used in the manufacture of aircraft structures play a pivotal role in determining the overall performance, safety, and efficiency of the aircraft. Traditionally, aluminum alloys have been favored for their excellent strength-to-weight ratio, corrosion resistance, and ease of fabrication, making them ideal for fuselage and wing structures [1]. However, advancements in materials science have led to the increased use of composite materials, such as carbon fiber-reinforced polymers, which offer superior strength, reduced weight, and greater design flexibility. Titanium and its alloys are also employed for critical components due to their high strength, low density, and exceptional resistance to extreme temperatures and corrosion. Additionally, newer materials, like advanced high-strength steels and hybrid composites, are being explored to meet the evolving demands of aerospace design, focusing on enhancing performance

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while minimizing weight. The careful selection of these materials is essential for optimizing aircraft efficiency, safety, and longevity.[2]

### 2.1. AIRFOIL terminology and definitions

AIRFOIL In the airfoil profile as shown on figure 1 , the forward point is called the leading edge and the rearward point is called the trailing edge. The straight line connecting the leading and trailing edges is called the chord line of the airfoil. The distance from the leading edge to the trailing edge measured along the chord line is designated as a chord (c). The mean camber line is the locus of points midway between the lower surface andupper surface when measured normal to the mean camber line itself. The camber is the maximum distance between the mean camber line and the chordline, measured normal to the chord line. The thickness is the distance between the upper and lower surfaces also measured normal to the chord line. The shape ofthe airfoil atthe leading edge is usually circular, with a leading-edge radius of 0.02c, where c is the chord length. The upper and lower surfaces are also known as suction and pressure surface respectively.[3-5]

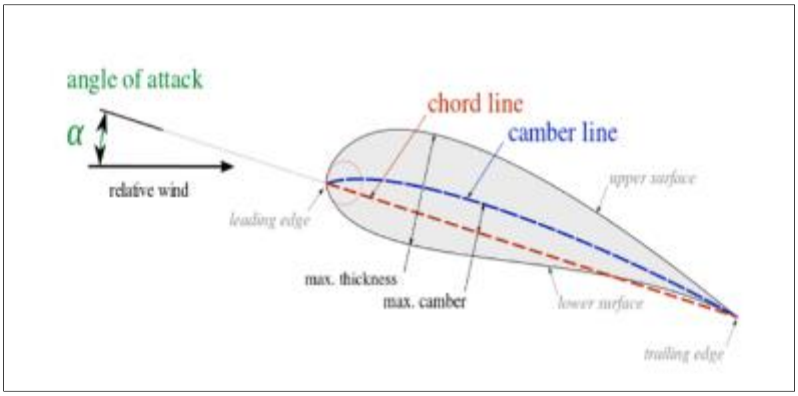


**Figure 1** the airfoil profile

resources available for computation allowthe designers to design and optimize the airfoils specifically tailored to a particular application.

## 3. Material selection

The metals used in the aircraft manufacturing industry include steel, aluminium, titanium and their alloys [6]. Table 1 lists the materials used in this study.

### 3.1. Wing design

**Table 1** materials used in this study

| Material | Common Aircraft Types | Applications |
|---|---|---|
| Aluminum Alloys | Commercial Jets, General Aviation | Fuselage, Wings, Tail Structures |
| Carbon Fiber Reinforced Polymer (CFRP) | Modern Jets (e.g., Boeing 787, Airbus A350) | Wings, Fuselage, Control Surfaces |
| Titanium Alloys | Military Aircraft (e.g., F-22, F-35) | Engine Components, Structural Supports |
| Steel Alloys | Cargo Aircraft, Military Transport | Landing Gear, Engine Mounts |
| Glass Fiber Reinforced Polymer (GFRP) | Light Aircraft, UAVs | Fairings, Interior Components |
| Magnesium Alloys | General Aviation, Some Military Aircraft | Structural Components, Castings |
| Aluminum-Lithium Alloys | Advanced Commercial Jets | Fuselage, Wing Structures |
| Hybrid Composites | Next-Generation Aircraft | Various Structural Applications |

PROCEDURE The amount of lift produced by an airfoil depends upon many factors. They are angle of attack, the lift devices used (like flaps), the density of air, the area of wing, the shape of wing, the speed at which the wing is travelling. Some Factors affecting wing size they are cruise drag, stall speed, take-off and landing distance. The first step is to get the airfoil shape in the CATIA workbench [8]. As we are considering that wing is designed with only one airfoil throughout, **it** has to be scaled down accordingly to gather required shape of a wing profile [8].

### 3.2. Static Structural Simulation by Ansys

This section focuses on the static analysis of the aircraft fuselage stringer under the influence of a static load. Figure 2 illustrates the geometric configuration of the aircraft fuselage.

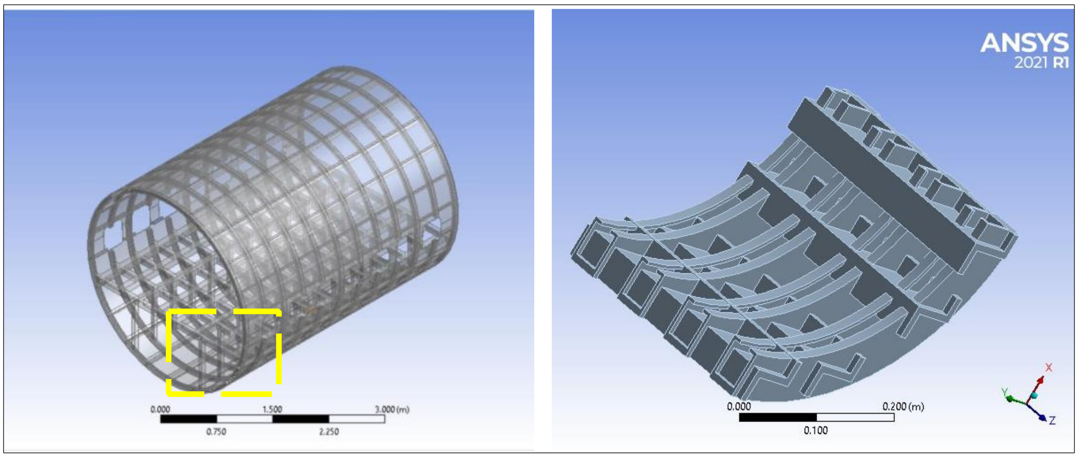


**Figure 2** Geometry ion Structure

## 4. Discussion

The discussion is divided into two parts according to the type of material used in manufacturing. The first part is aluminium and the second part is titanium.

### 4.1. aluminium

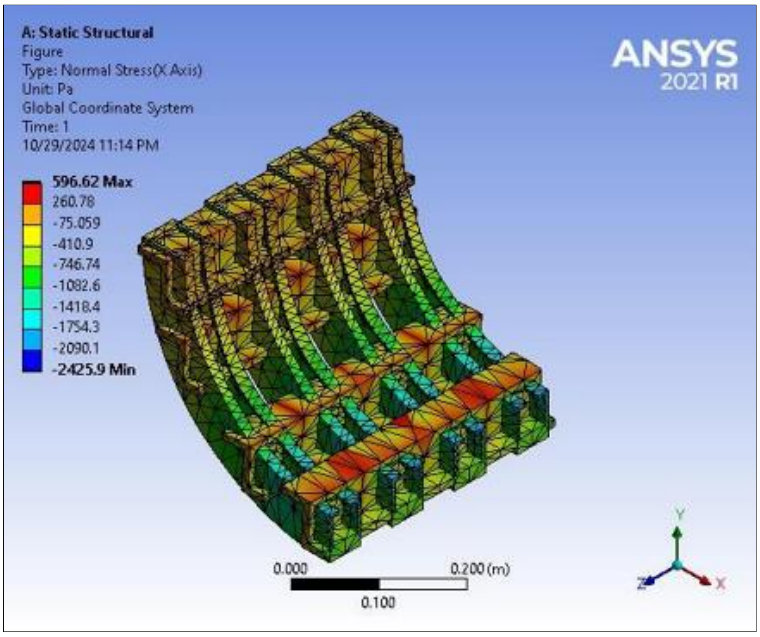


**Figure 3** Normal Stress

Figures 3 to 6 sequentially present the results of the analysis, including the distribution of normal stress, equivalent stress (von Mises stress), directional deformation, and shear stress. In additional to table 2 list the final values for static behaviour parameters. These results provide a comprehensive understanding of the structural behaviour and stress distribution in the fuselage stringer, offering valuable insights for enhancing its mechanical performance under static loading conditions.

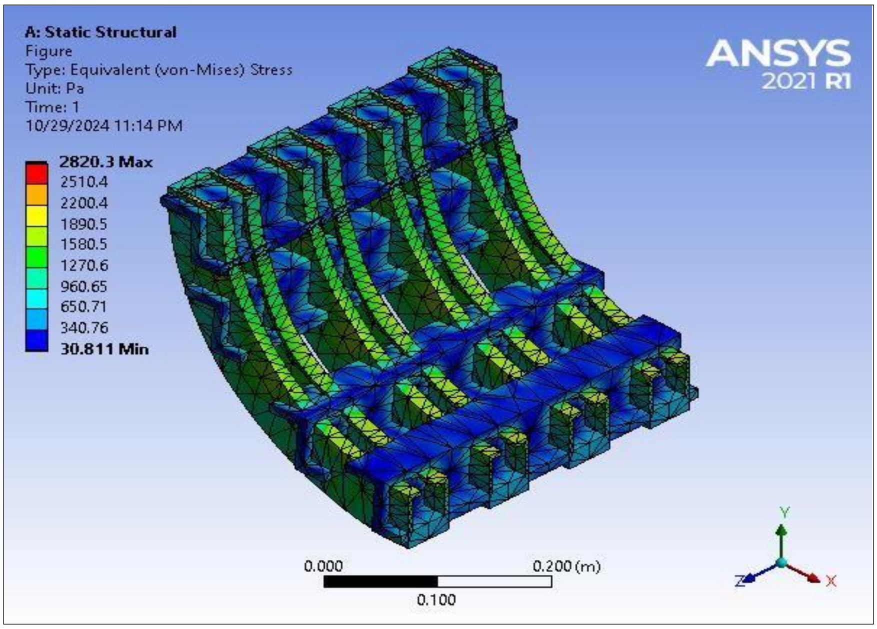


**Figure** 4 Equivalent Stress

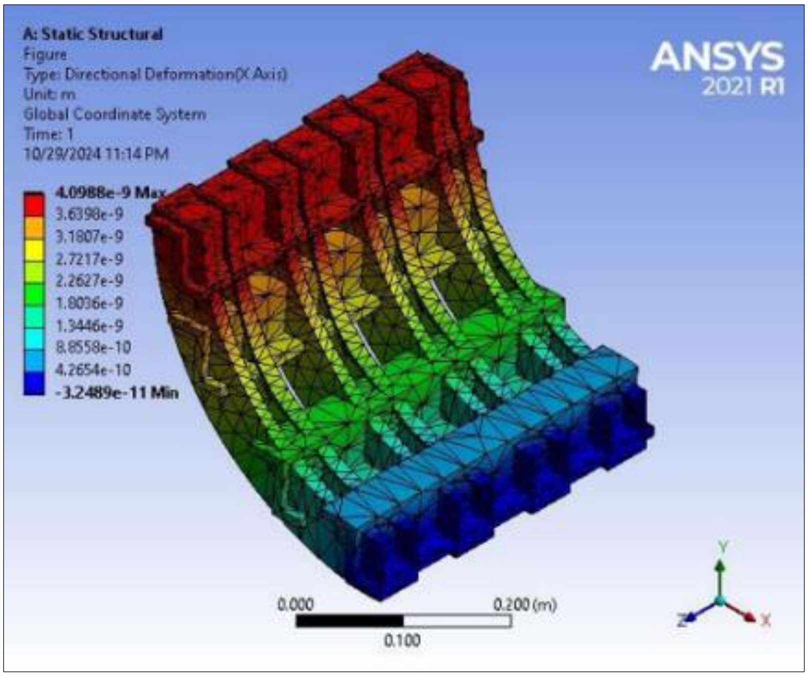


**Figure** 5 Directional Deformation

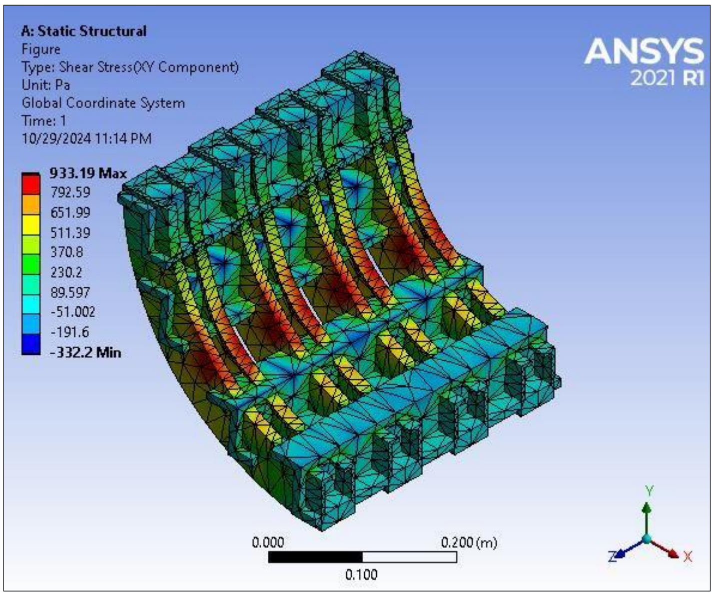


**Figure 6** shear stress

**Table 2** Aluminum results

| Stress | Max Value |
|---|---|
| normal strees | 596.62 pa |
| Equivalent Stress | 2820.3 pa |
| Directional Deformation | 4.0998e-9 |
| Shear stress | 933.19pa |
| Material | Aluminum alloy, |

### 4.2. Titanium Alloys

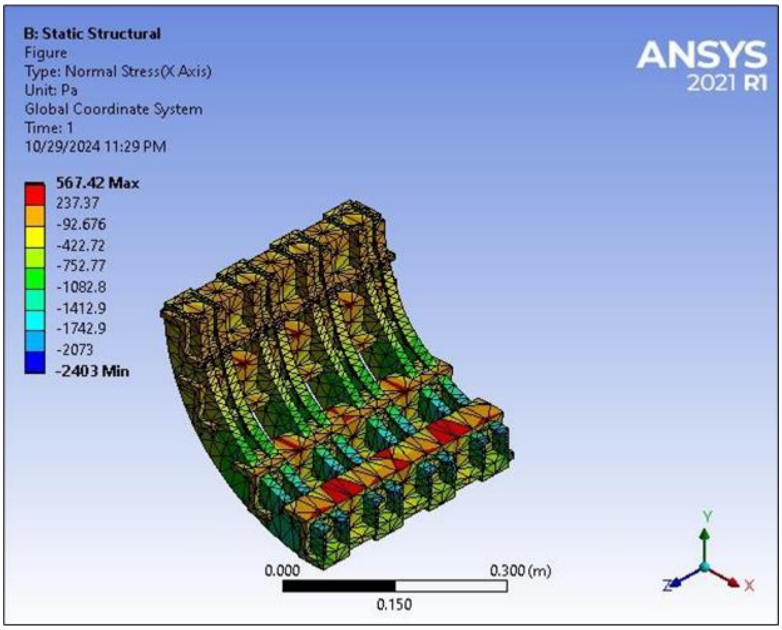


**Figure 7** Normal Stress

Figures 7 to 10 sequentially present the results of the analysis, including the distribution of normal stress, equivalent stress (von Mises stress), directional deformation, and shear stress. In additional to table 3 list the final values for static behaviour parameters. These results provide a comprehensive understanding of the structural behaviour and stress distribution in the fuselage stringer, offering valuable insights for enhancing its mechanical performance under static loading conditions.

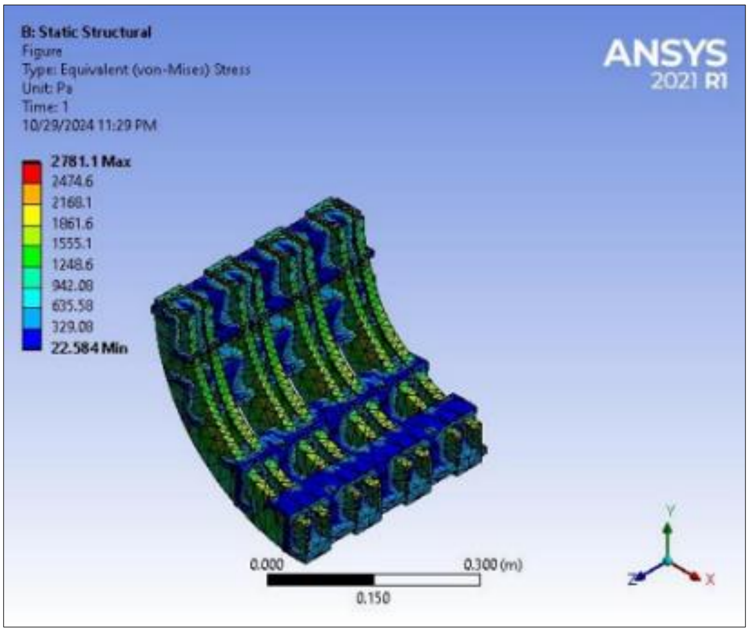


**Figure 8** Equivalent Stress

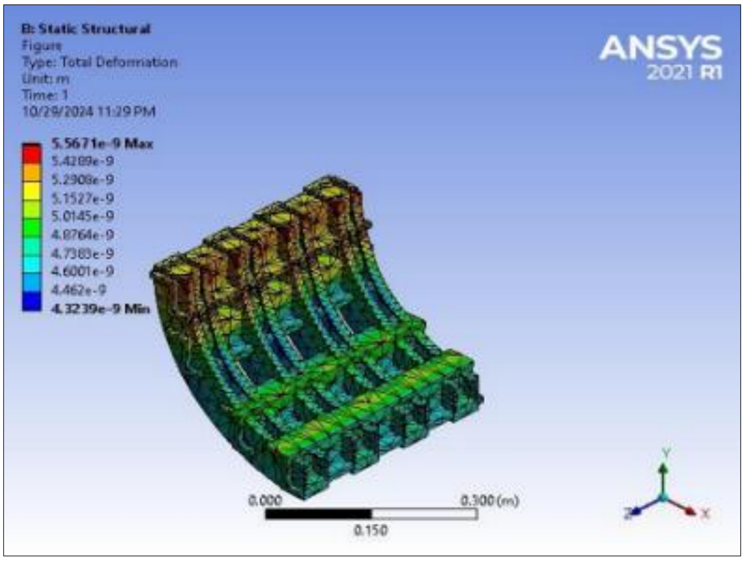


**Figure 9** Directional Deformation

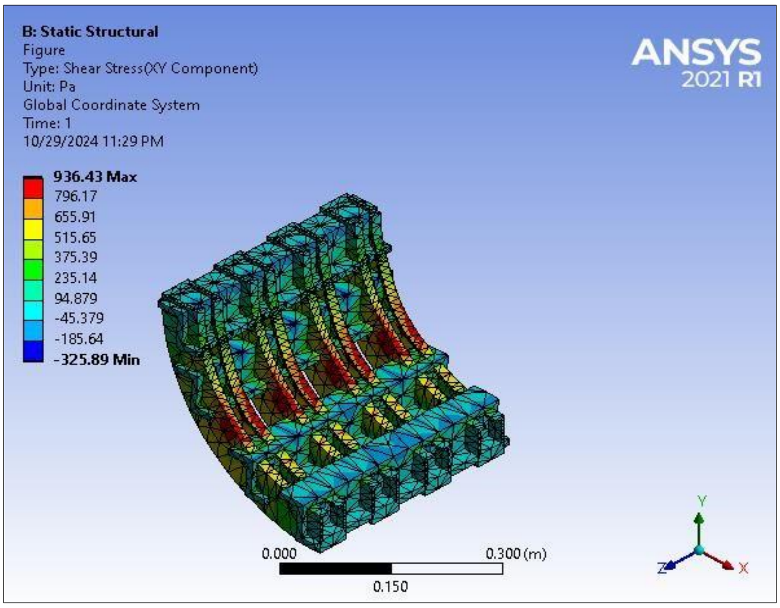


**Figure 10** shear stress

**Table 3** Titanium results

| stress | Max Value |
|---|---|
| normal strees | 567.42 |
| Equivalent Stress | 2781.1 pa |
| Directional Deformation | 5.567e-9 |
| Shear stress | 936.43pa |
| Material | Titanium Alloys |

### 4.3. Compassion study

Finally, Table No. 4 shows the comparison between the static analysis parameters for each of the two types of materials used.

**Table 4** compassion study

| stress Max Value | | stress Max Value | |
|---|---|---|---|
| normal stress | 567.42 | normal stress | 596.62 pa |
| Equivalent Stress | 2781.1 pa | Equivalent Stress | 2820.3 pa |
| Directional Deformation | 5.567e-9 | Directional Deformation | 4.0998e-9 |
| Shear stress | 936.43pa | Shear stress | 933.19pa |
| Material | Titanium Alloys | Material | Aluminum alloy, |

## 5. Conclusion

The stress simulation results for titanium alloys and aluminum alloys highlight distinct mechanical characteristics that can influence material selection in engineering applications. Titanium alloys exhibit a normal stress of 567.42 pa and an equivalent stress of 2781.1 pa, demonstrating excellent resistance to deformation under load, with a minimal directional deformation of 5.567e-9. Their shear stress is measured at 936.43 pa, indicating strong shear resistance. In contrast, aluminum alloys show a higher normal stress of 596.62 pa and an equivalent stress of 2820.3 pa, alongside a slightly lower directional deformation of 4.0998e-9. Although both materials perform well under stress, titanium alloys tend to offer superior mechanical properties, particularly in high-performance applications. However, aluminum alloys are often more cost-effective and lightweight, making them advantageous for projects where budget and weight are critical factors. Ultimately, the choice between the two materials should consider the specific application requirements, balancing performance with cost-effectiveness.

## Compliance with ethical standards

### *Disclosure of conflict of interest*

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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