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# INVESTIGATING AND ANALYSING DAMAGE ASSESSMENT OF BIRDSTRIKE IMPACT ON NACA 9417

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## ABSTRACT

A critical safety concern in aviation industry is bird strike hence holds the research study in this paper. Using the method of SPH- smooth particle hydrodynamics for finite element analysis, the study analyses the effects of bird strikes on the leading edge of the wing from various angles. Influenced by the angles of bird strike the result shows Results reveal important deformation of the wing. Also, kinetic energy and von Mises stress at impact site is examined. The research holds immediate effects, damage assessment, modelling of material, and repair techniques. For enhance resilience by bird strike informed by bird strike is inflicted to understand the extent. Structural response to impacts, guiding the selection of material to enhance the safety is aided in predicting in material modelling. Study of repairing techniques is essential for knowing strategies to reduce damage and maintain aircraft integrity. All things considered, the study provides insightful information on the dynamics of bird strikes, guiding actions to improve aircraft dependability and safety.

Keywords: LS-Dyna software, bird impact resistance, von Mises stress, smooth particle hydrodynamics (SPH), damage assessment, material modelling, advanced structures, swept wings, FEA modelling, structural deformation, and repair methods.

## 1.1 Introduction

Preventing bird strikes on aircraft, particularly on swept leading edge components, is an ongoing concern for the aviation industry. These crashes usually happen during low altitude flight, take off, or landing, and happen when the leading edge of the wing increases the risk. Advanced methods like experimental testing and finite element analysis (FEA) are needed to investigate the impacts of bird strikes. In depth analysis of structural responses under various impact scenarios is made possible by FEA simulations, and experimental testing yields actual data on the results of controlled bird strikes. Analysis of FEA and data obtain from the experimental gives us design parameters that impacts resistance, such as material properties of the wing structure, leading edge thickness, geometry, and presence of protective layers. Understanding this is essential to efficient the aircraft design and also improving overall resistance to bird strikes. Bird strikes can cause dents, tears, or holes in the wing skin, altering structural integrity and potentially increasing more damage. Overall understanding of the bird strike is essential to safeguard flight after a bird strike encounter. To minimize the damage the study also has damage assessment done over some materials and optimize the structural integrity.

## 1.2 Leading Edge of Wing

The leading edge of the wing is essential component of aircraft wing. It serves as the leading edge that engages with air during flight. It plays a crucial role in generating aerodynamic lift and also lets the airflow pass through. The wing is typically streamlined and as the leading edge is in front it optimizes wing efficiency as in minimizing drag and optimizing wing performance. Modern aircraft often have swept leading edge structures known for their aerodynamic efficiency. The edge is created with special designs and material to withstand various aerodynamic forces and external influences, including the potential risk of strikes. While designing we also consider the parameters such as thickness, shape, and incorporation of protective layers have been carefully considered to ensure optimal performance and structural integrity over the aircraft's lifespan.

## 1.3 Bird Strike Analysis

Bird strike analysis is a very important analysis done for aviation safety and involves a detailed assessment of the effects of bird strikes on aircraft's structural integrity. This research uses advanced techniques such as given finite element analysis (FEA) and experimental testing to simulate and study the effects of bird strikes. The FEA model gives us a detailed study of the structural response to different impact scenarios, considering factors such as bird size, speed, and impact angle. In the real time, experimental tests expose real aircraft structures to controlled bird strikes, providing real-world data on resulting damage and structural integrity. Keeping structural concerns as the main, this analysis also considers changes in aerodynamic changes caused by bird strikes.

### 1.4 Leading Edge Bird Strike

Leading edge bird strike test is a very crucial in aspect of flight safety and focuses on the sensitivity of the wing's leading edge to bird strike impact. This study uses advanced techniques such as finite element analysis and experimental testing to evaluate the structural and aerodynamic effects of bird strikes on the leading edge. The study considers factors such as bird size, impact speed, and angle to simulate real-world scenarios.

### 1.5 Smoothed Particle Hydrodynamics (SPH)

Smoothed Particle Hydrodynamics (SPH) is a numerical method that is a very important and useful tool for simulating bird strikes. Not similar to traditional finite element methods, SPH uses a meshless approach and represents the bird as a collection of particles or liquid elements. This meshless approach has several advantages for bird strike analysis: Geometric flexibility: SPH can create complex process geometries, allowing you to Irregular shapes can also be included.

• Large deformations in FEA: SPH give efficient simulate the large deformations and material fragments in the structure gives us the characteristic of bird strike events.

• Material Behaviour of SPH: SPH unifies various material models, including bird's body and aircraft structures, to accurately give us the aircraft structure impact behaviour.

### 1.6 NACA 9417

The NACA 9417 airfoil is a classic wing design known for its versatility. Simple to manufacture and offering good low-speed lift, it remains a popular choice despite the existence of more modern airfoils.

### 1.7 Damage Assessment

Damage assessment has two approaches: evaluating the physical impact and the potential for structural weakness. Firstly, the technicians will carefully inspect the leading edge of the wing for dents, cracks, or punctures caused by the bird strike. This visual inspection may be aided by tools like X-rays to identify any hidden damage within the material. Secondly, the engineers will investigate forces which are the causes in the impact. Factors like the bird's size, speed, and angle of impact are considered to understand the stress placed on the wing structure. Specialized software and analyses can simulate the impact and predict areas where the wing has the sensitivity in structurally of wing. By combining a thorough visual inspection with an analysis of the impact forces, engineers can determine the intensity of the damage and assessed the wing structure remains safe for continued flight.

### 1.8 Material Modelling

In FEA, rather than using real materials, here it is used material modelling. It's like creating a digital recipe for the material, telling the computer how it will behave under stress and strain. This helps it predict how things will break or bend under the pressure, making sure bridges and airplanes are built safe and strong.

### 1.9 Repair Techniques

Repairing bird strike damage on aircraft wings involves a delicate dance between optimizing material use and ensuring the wing's structural integrity. For minor cracks or dents, patches or bonded overlays made from lightweight composite materials can restore the wing's profile and reinforce the weakened area. The choice of repair method hinges on the damage intensity and the need to advance both material usage and structural integrity.

## 2 LITERATURE REVIEW

One area of study focuses on aerodynamic effects. Hansen et al. in their paper "[1] Study tell us that All tubercle arrangements examined in the investigation..." investigated the impact of strategically placed bumps (tubercles) on airfoils. While these tubercles can improve lift after a stall (loss of lift due to airflow separation), they can also decrease lift before reaching the stall point. Leading-edge vortices (LEVs), swirling airflows crucial for lift generation, have been observed in small birds by Hubel et al. [2] ("Tatjana Y. Hubel* and Cameron Tropea [2] paper signifies...") and Vidler et al. [3] ("J. J. Vidler, E. J. Stadhuis, G. D. E. Povel [3] The findings demonstrate..."). Their research suggests that LEVs could potentially benefit the flight performance of larger birds as well. Material selection is another critical aspect. Research by McCarthy et al. in "[4] Modelling of Bird Strike on an Aircraft Wing Leading Edge Made from Fibre Metal Laminates – Part 1: Material Modelling" and "[5] Part II" highlights the exceptional impact resistance of Fiber Metal Laminates (FMLs) for leading edges vulnerable to bird strikes. Regulations, as outlined in Federal Aviation Regulations, Part 25 [7], ensure that aircraft can withstand bird strikes at designated speeds. Studies by Tatlie [9] ("A Numerical Investigation of a Bird Strike on the Structure of an Aircraft Wing Leading Edge [9]") and Guo et al. [12] ("Composite Leading Edge Impact Resistance Yijing GUO et al [12]") delve into the bird strike resistance of various materials like carbon fiber and explore methods for further improvement. Simulations are a valuable tool for predicting the impact of bird strikes. Belega [6] ("Impact Simulation with an Aircraft Wing Using SPH Bird Model by Bogdan Alexandru BELEGA [6]") and McCarthy et al. [10] ("Modelling Bird Strikes on FML Leading Edges (Part 2) [10]") use bird models in simulations to determine safe impact velocities and refine simulations for FML wings. Goyal et al. [11] ("Bird Strike Modelling with Lagrangian Formulation - Vijay K. Goyal et al [11]") and Goraj et al. [13] ("Refining Bird Strike Simulations - Zdobyslaw Goraj & Kamila Kustron [13]") focus on meshing techniques in Lagrangian simulations to enhance the accuracy of these simulations. Optimizing bird strike resistance is an ongoing pursuit. Nizampatnam [14] ("Accurate Bird Strike Load Predictions-Lakshmi S. Nizampatnam [14]") emphasizes the importance of detailed data acquisition from bird strike events to improve future simulations and mitigation strategies. Di Caprio et al. [15] ("Optimizing Leading Edge Design (Francesco Di Caprio et al [15]") explore design optimization using algorithms to improve resistance while minimizing weight, a crucial factor in aircraft design. Guimard et al. [16] ("Refining Bird Strike Simulations for Composite Structures - J.-M. Guimard & S. Heimbs [16]") investigate using Abaqus software to simulate bird strikes on composite structures, incorporating more intricate bird models for improved accuracy. Safety remains paramount in aircraft design, as highlighted by Siddiqui [18] ("Prioritizing Safety in Aircraft Design - Tariq Siddiqui (2014) [18]"). Collaborative efforts among manufacturers, operators, and regulators ensure stringent safety standards throughout the aircraft lifecycle [18]. Looking ahead, research is focused on advancements in non-destructive testing for damage assessment after bird strikes [19] and overcoming challenges associated with using composite materials in pressurized fuselages [20]. Di Caprio et al. [21] ("Bird Strike Optimization Through Design - Francesco Di Caprio et al (2020) [21]") emphasize the importance of further optimizing aircraft components to mitigate bird strike risks. This ongoing research plays a vital role in ensuring the safety of aircraft and passengers.

## 3 VALIDATION

### 3.3 Paper Study-

"A Numerical Investigation of a Bird Strike on the Structure of an Aircraft Wing Leading Edge" (Mehmet Seha Tatlier* Mechanical Engineering, Osmaniye Korkut Ata University, 80000 Osmaniye, Turkey)

The study investigates the impact of bird approaching angles on the deformation of a simplified wing leading edge of a commercial aircraft using finite element analyses. The smooth particle method is employed for bird-wing interaction, with Al6061-T4 aluminium alloy chosen for the wing leading edge material. Plastic deformation is addressed using the Johnson-Cook material model. The bird material is simulated as water due to its composition, and an impact velocity of 180 m/s is used. Despite variations in bird approaching angles (0°, 15°, 30°, 45°, 60°, and 90°), minimal differences in deformation are observed post-impact. The study highlights the lack of significant differences in wing leading edge deformation across various bird approaching angles, suggesting further experimental investigation is needed to confirm these findings.

## 3.2 Bird Model Creation and Geometry Preparation

At high speeds birds or any other soft objects undergo high distortion and acts like fluidic materials. Hence the smooth particle hydrodynamics (SPH) method which handles distortion problems is employed for the bird model. SPH model is Lagrangian meshless method. The parameters of models are given below:

**I.** Bird shape is assumed be hemispherical ended cylinder. Barber et. al. [13] investigated numerous bird species to come up with a bird density to be utilized in numerical studies and demonstrated a density of 950 kg/m3.

**II.** At high speed the bird body acts as a fluidic body crashing into the structures. Although there are many approaches to solve the bird strike problems, SPH stands out as a capable modelling approach for high-speed cases.

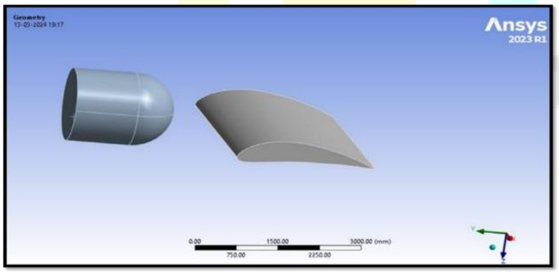



**Fig. 3.1 Geometry Preparation**

## 3.3 Mesh Generation

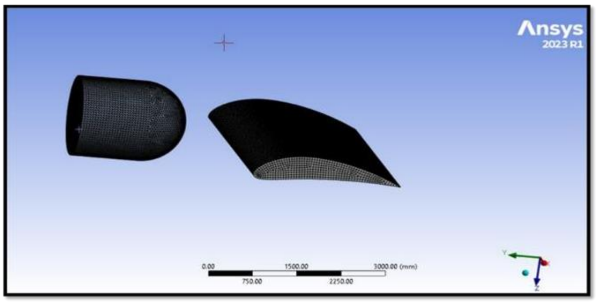



**Fig. 3.2 Mesh Generation of Bird Strike on NACA 9417**

| **Model** | **Mesh** |
|---|---|
| Rigid Face Mesh Type | Quad/ Tri |
| Physical Preference | Explicit |
| Element Order | Linear |
| Element Size | 45.0 mm |

## 3.4 Material Assignment and Boundary Conditions-

Material Assignment- Structural Steel

| **Structural Steel** | **Constants** |
|---|---|
| Density | 7.85e-006 kg mm^- 3 |
| Coefficient of Thermal Expansion | 1.2e+005 C^-1 |

| | |
|---|---|
| Specific Heat | 4.34+005 mJ kg^-1 C^-1 |
| Thermal Conductivity | 6.05e-002 W mm^-1 C^-1 |
| Resistivity | 1.7e-004-ohm mm |
| Compressive Yield Strength | 250 |
| Tensile Ultimate Strength | 460 |

Boundary Conditions-

| **Properties** | | |
|---|---|---|
| Volume | 3.8435e+009 mm3 | 2.9912e+003 mm3 |
| Mass | 30172 kg | 23481 kg |

### 3.4 Validation Results

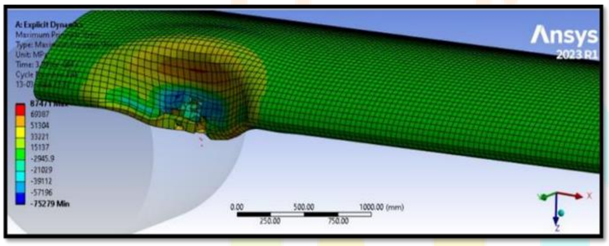



**Fig. 3.3 Total Velocity**

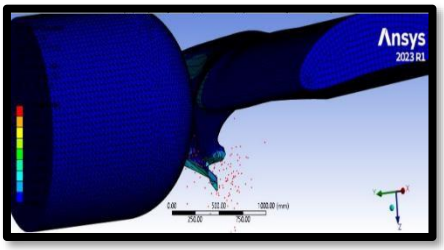



**Fig. 3.4 Total Deformation**

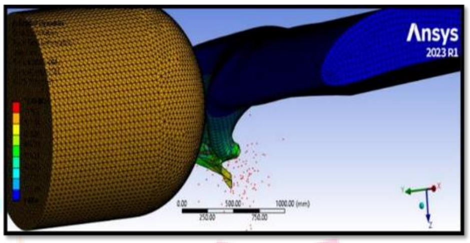



**Fig. 3.5 Maximum Shear Elastic Strain**

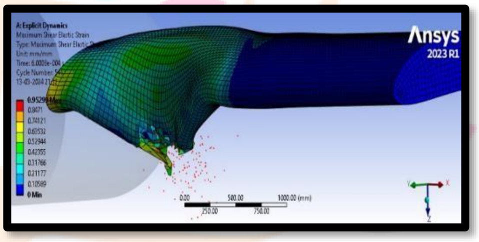



**Fig. 3.6 Maximum Principal Stress**

Deformation graph- *Comparison- At 60 degrees*

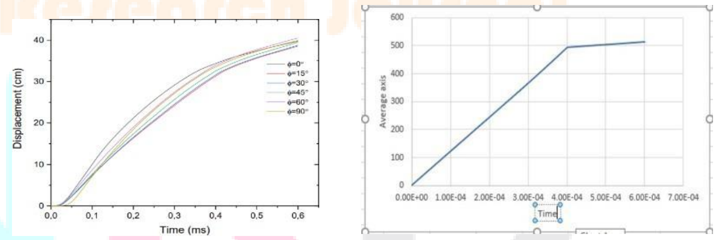



**Fig.3.7 Displacement Avg. Vs Time of Bird Strike**

## 4 Damage Assessment

Structural Analysis-

Structural analysis involves the study and prediction of how structures behave under various loading conditions to ensure their safety and functionality. Below are the 05 materials used for studying the material properties of leading the amount of damage caused on aircraft wing due to bird strike. (Sequences in the figures hold as-

1. Structural Analysis- Total Deformation, Equivalent stress, Equivalent strain
2. Fatigue Test- Damage, Safety factor, Life)

**A. Titanium Ti-6Al-4V**

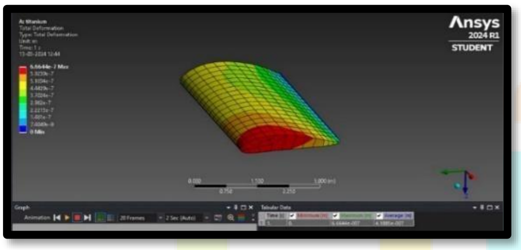
Properties: Youngs modulus= 110 GPa

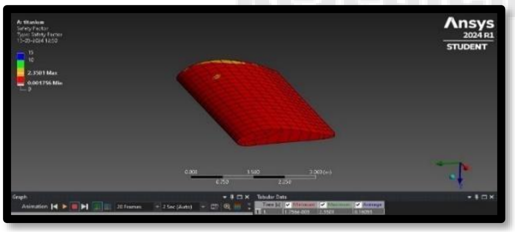
Poisson's ratio = 0.33

SN Curve:

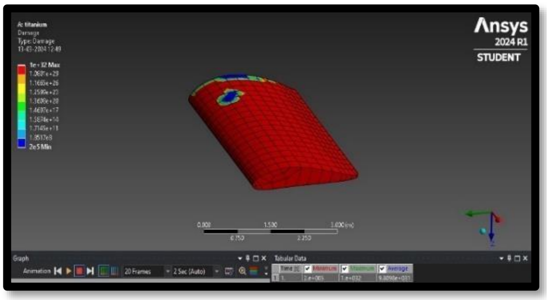
| Cycles(N) | Alternating Stresses (MPa) |
|---|---|
| 1000 | 350 |
| 10000 | 300 |
| 100000 | 250 |
| 1000000 | 200 |

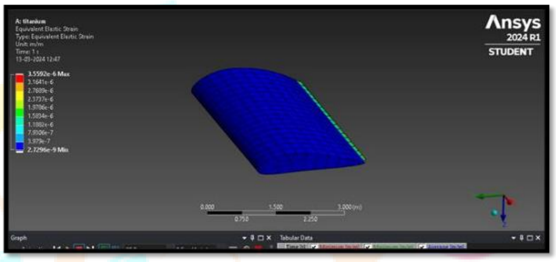
Static structural Test:




Fatigue Test:



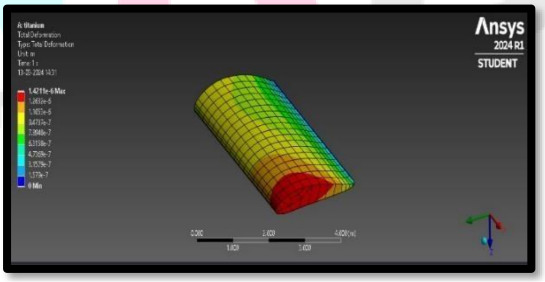

**B. Aluminium Alloy 2024 T4**

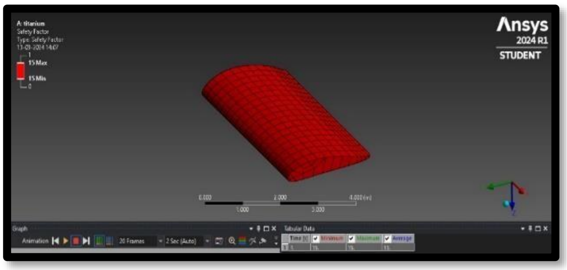
Properties: Youngs modulus= 73Gpa
Poisson's ratio= 0.33

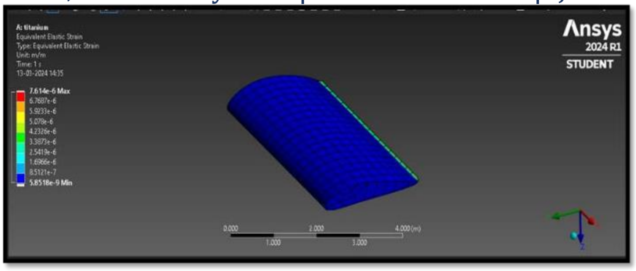
| Cycles(N) | Alternating Stresses (MPa) |
|---|---|
| 1000 | 150 |
| 10000 | 130 |
| 100000 | 110 |
| 1000000 | 90 |

S-N Curve:

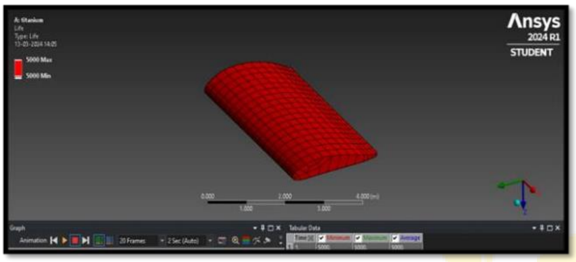
Static Structural Test:



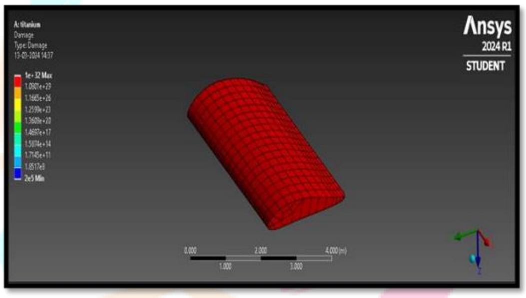


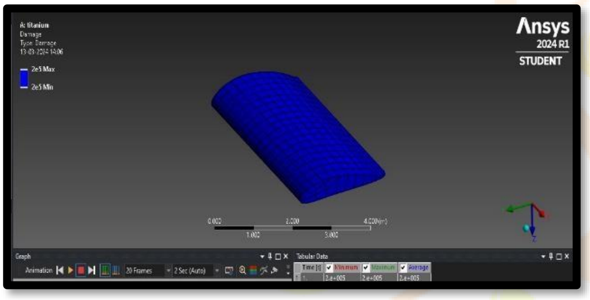



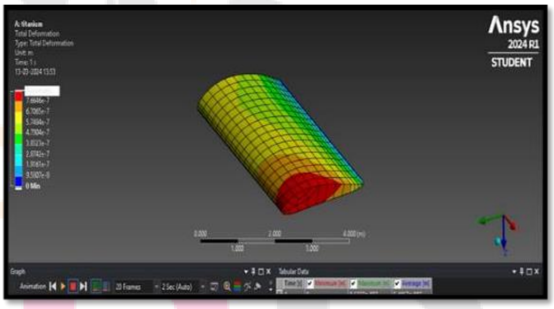

Fatigue Test:




Fatigue Test:




**C. MAG AZ 31B**

Properties:

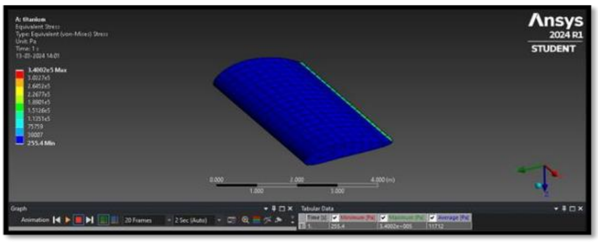
Youngs modulus= 45 GPa

Poisson's ratio= 0.35

SN Curve:

| Cycles(N) | Alternating Stresses (MPa) |
|---|---|
| 1000 | - |
| 10000 | 150 |
| 100000 | 142 |
| 1000000 | 115 |

Static Structural Test:



**D. (Super Nickel Alloy) Inconel 718**

Properties:

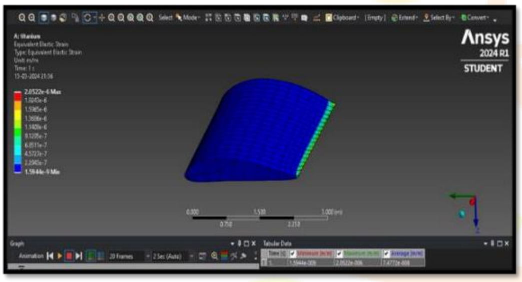
Youngs modulus= 200Gpa

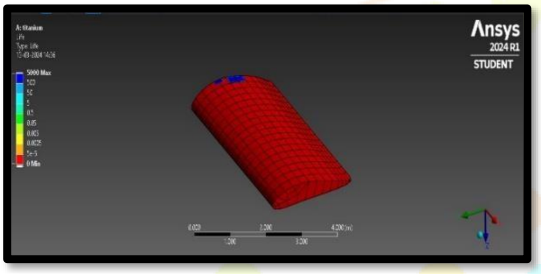
Poisson's ratio= 0.33

S-N Curve:

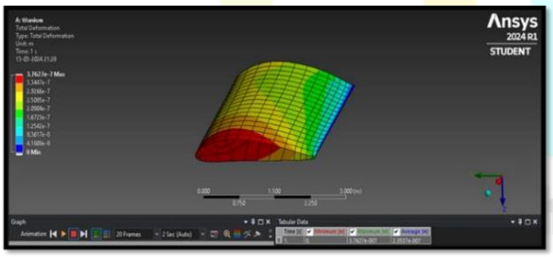
| Cycles(N) | Alternating Stresses (MPa) |
|---|---|
| 100000 | 550 |
| 1000000 | 500 |
| 10000000 | 400 |
| 100000000 | 350 |

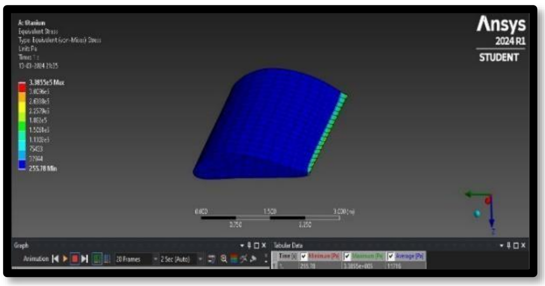
Static structural Test:




Fatigue Test:



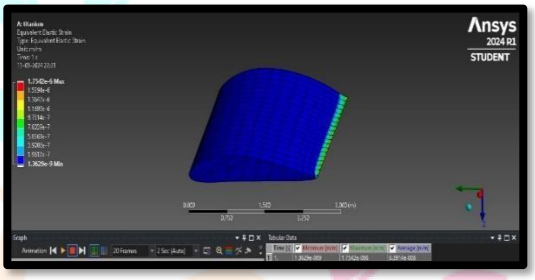



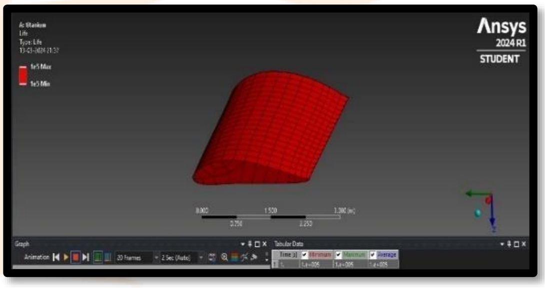

**E. Stainless Steel 304**

Properties:
Youngs modulus= 200Gpa Poisson's ratio= 0.33
S-N Curve:

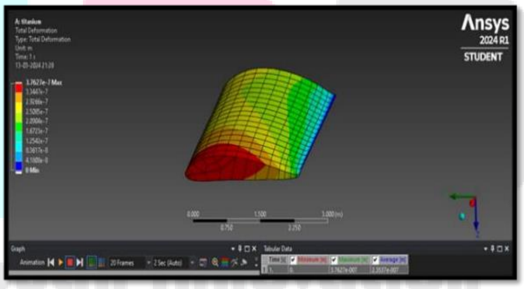
| Cycles(N) | Alternating Stresses (MPa) |
|---|---|
| 100000 | 550 |
| 1000000 | 500 |
| 10000000 | 400 |
| 100000000 | 350 |

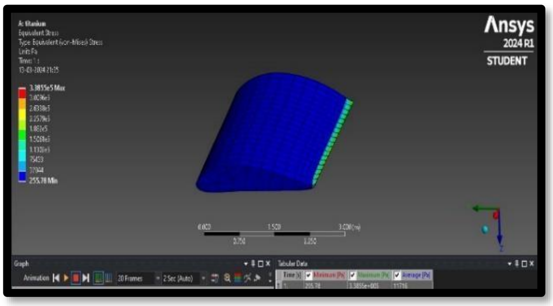
Static Structural Test:




Fatigue Test:



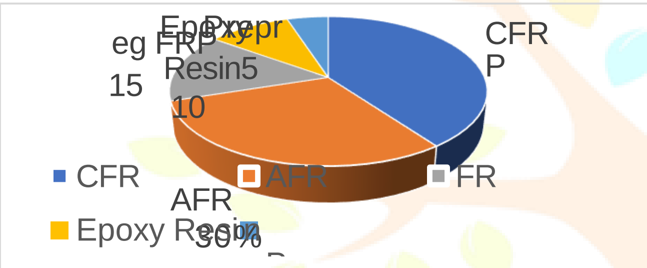



## 4 Repair Techniques

A Composite Patching

Aircraft components made of composite materials can be repaired using composite patches. These patches are designed to match the material properties and provide strength and durability. Following are some common composite patching materials-

- Carbon Fiber Reinforced Polymer (CFRP)
- Fiberglass Reinforced Polymer (FRP)
- Aramid Fiber Reinforced Polymer (AFRP)
- Glass Fiber Reinforced Polymer (GFRP)




**Pie chart: Amount of composite patching materials used in air foil**

B Surface Fillers and Sealants-

Surface fillers and sealants are materials used in aircraft manufacturing and maintenance to fill gaps, seams, and imperfections. They provide protection against environmental factors, maintain structural integrity, and ensure aerodynamic surfaces. Crucial role in reducing damage from bird strikes by reinforcing structural components and sealing potential entry points.

- Epoxy Fillers
- Polyester Fillers
- Micro-balloon Fillers
- Body Filler Aircraft Sealants
- Corrosion Inhibiting Sealants
- Fireproof Sealants
- Fuel Tank Sealants
- Surface Primers
- Adhesive Sealants

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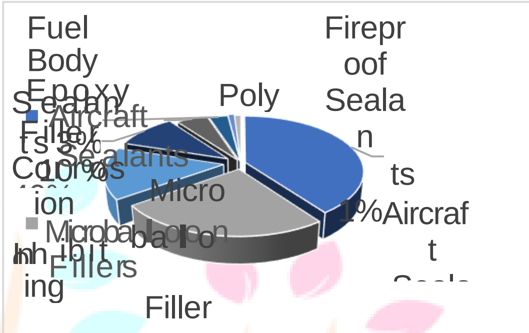


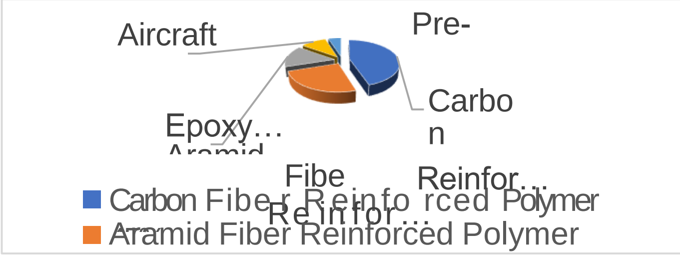

**Pie Chart: Amount of Surface Fillers and Sealants materials used in air foil**

C Corrosion Protection

Corrosion protection involves methods to prevent metal degradation caused by chemical reactions with the environment. It includes using coatings, inhibitors, and corrosion-resistant materials to minimize or eliminate corrosion. Effective corrosion protection preserves the structural integrity of components, reduces safety risks, and avoids costly repairs.

- Carbon Fiber Reinforced Polymer
- Aramid Fiber Reinforced Polymer (AFRP)
- Epoxy Resin (as a corrosion protection coating)
- Aircraft Sealants (with corrosion inhibiting properties)

- Pre-Impregnated (Prepreg) Materials (with corrosion-resistant fibres)




## 5 Selection of New Material

From above material study we have chosen 4 materials as follows with their properties-

**A. Carbon Fiber Reinforced Polymer (CFRP) (Composite Patching- 40%, Corrosion Protection- 45%)**

High Strength

Low Weight

Stiffness

Corrosion Resistance

Fatigue Resistance

Dimensional Stability

Electrical Conductivity

Anisotropic Properties

| | |
|---|---|
| Density | 1600 (kg/m³) |
| Coefficient of thermal expansion | 1.0 to 2.5 x 10^-6 |
| Melting Temperature | 150 to 300°C |
| Young's Modulus | 100GPa |
| Poisson's Ratio (V) | 0.33 |
| Yield Strength | 300- 800 Mpa |
| Ultimate Tensil Strength | 1000- 3000 Mpa |
| Thermal Conductivity | 1- 10 W/(m·K) |
| Specific Heat | 0.8- 1.5 J/(g·K) |

**B. Aramid Fiber Reinforced Polymer (Corrosion Protection- 25%)**

High Strength

Low Weight

Impact Resistance

Fatigue Resistance

Chemical Resistance

Dimensional Stability

Low Thermal Conductivity

Non-Conductive

| | |
|---|---|
| Density | 1400 kg/m³ |
| Coefficient of thermal expansion | 2 to 5 x 10^-6 |
| Melting Temperature | 500°C |
| Young's Modulus | 70GPa |
| Poisson's Ratio (V) | 0.3 |
| Yield Strength | 600 to 1500 Mpa |
| Ultimate Tensil Strength | 700- 1600 Mpa |
| Thermal Conductivity | 0.1- 0.3 W/(m·K) |
| Specific Heat | 1.2- 1.5 J/(g·K) |

**C. Micro-balloon fillers (Surface Fillers and Sealants 25%)**

Density Reduction

Strength-to-Weight Ratio

Thermal and Electrical Insulation

Dimensional Stability

Enhanced Surface Finish

Acoustic Damping

Customizable Properties

| | |
|---|---|
| Density | 200- 700 kg/m³ |
| Coefficient of thermal expansion | 10^-6 10^-3 |
| Melting Temperature | Depends on the matrix material |
| Young's Modulus | 50 - 150 GPa |
| Poisson's Ratio (V) | 0.25 - 0.35 |
| Yield Strength | 50 - 300 MPa |
| Ultimate Tensil Strength | 100 - 500 MPa |
| Thermal Conductivity | 0.1 - 50 W/(m·K) |
| Specific Heat | 800 - 2000 J/(kg·K) |

D. **Corrosion Inhibiting Sealants (Surface Fillers and Sealants 15%)** I.

Corrosion Resistance

Sealing Capabilities

Damage Mitigation

Flexibility and Durability

Long-Term Protection

| | |
|---|---|
| Density | 1300 kg/m³ |
| Coefficient of thermal expansion | 50 - 100 × 10^(-6) /°C |
| Melting Temperature | 343 m/s in air at 20°C |
| Young's Modulus | 50 - 500 MPa |
| Poisson's Ratio (V) | 0.3 - 0.5 |
| Yield Strength | 2 - 10 MPa |
| Ultimate Tensil Strength | 5 - 20 MPa |
| Thermal Conductivity | 0.1 - 0.5 W/(m·K) |
| Specific Heat | 1 - 2 J/(g·°C) |

## 6 Composite Bird Strike Resistant Material (CBSRM)

- By combining-
  - APRH (Corrosion Protection- 25%)
  - CFRP (Composite Patching- 40%, Corrosion Protection- 45%)
  - Micro-balloon fillers (Surface Fillers and Sealants 25%)
  - Corrosion Inhibiting Sealants (Surface Fillers and Sealants 15%)

We can create a powerful new material known as ***<u>'Composite Bird Strike Resistant Material (CBSRM).'</u>***

- Composition-
  - **<u>Carbon Fiber Reinforced Polymer (CFRP):</u>** Utilize carbon fibers from

    CFRP for their high strength-to-weight ratio and stiffness properties.
  - **<u>Aramid Fiber Reinforced Polymer (AFRP):</u>** Incorporate aramid fibers

    alongside carbon fibers to provide additional impact resistance and energy absorption capabilities.
  - **<u>Microballoon Fillers:</u>** To enhance impact absorption and reduce material density lightweight microballoon fillers are integrated into the composite matrix.
  - **<u>Corrosion Inhibiting Sealants:</u>** Protection against environmental degradation includes corrosion inhibiting sealants with the composite structure.
- Properties-
  - **<u>High Impact Resistance:</u>** The combination of carbon and aramid fibers, reinforced with micro balloon fillers, creates a material with exceptional impact resistance, capable of absorbing energy from bird strikes.

- **Lightweight:** For composite to remain lightweight without compromising strength micro balloon helps to reduce material density.
- **Corrosion Protection:** Corrosion inhibiting sealants incorporated into the composite matrix provide long- term protection against environmental degradation, enhancing durability and lifespan.
- **Medium Eco-Friendliness:** While not entirely biodegradable, the use of aramid fibres and corrosion inhibiting sealants ensures medium Eco friendliness by minimizing environmental impact compared to

  conventional materials.
- **Cost-Effectiveness:**

By leveraging carbon and aramid fibres alongside micro balloon fillers and corrosion inhibiting sealants, the material can be produced at a competitive cost while maintaining high performance.

## 7 Results:

In the solutions phase we have gone for total deformation, maximum principal stress and maximum principal elastic strain. We have found out the stress and strain bearing properties of MAT_21 is better than aluminium alloys and other composites that we have referred to in this project. We have total deformation at an average of 3.4409e-003 mm, maximum principal elastic strain to be 5.2151e-007 mm/mm, and maximum principal stress -3.4086e-002 MPa.

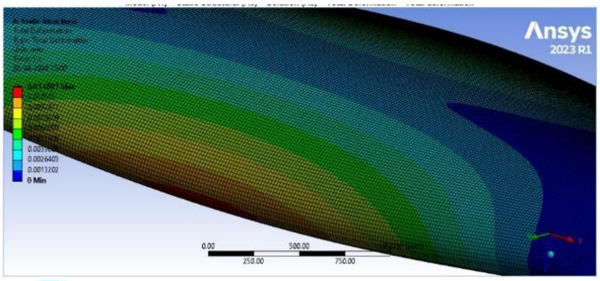



**Fig. 7.1 Total deformation**

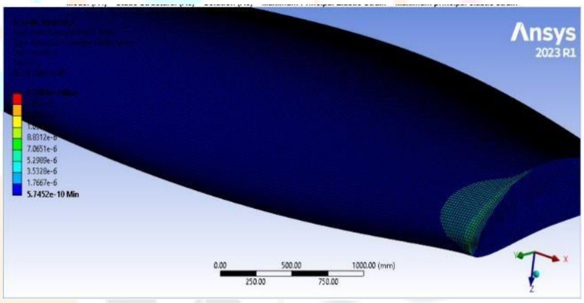



**Fig. 7.2 Maximum principal elastic strain**

When the data of all the materials is considered and compared MAT_21 has better stress and strain handling qualities. Material properties that we have gotten are as follows:

| MAT_21 | Constants |
|---|---|
| Density | 1.15e5 kg/m^3 |
| Young's Modulus | 60125 MPa |
| Poisson's Ratio | 0.33 |
| Bulk Modulus | 58946 MPa |
| Shear Modulus | 22603 MPa |
| Tensile Yield Strength | 602.5 MPa |
| Tensile Ultimate Strength | 1757.3 MPa |

As can be seen from the table above the material is pretty light compared to other materials used currently in aerospace industry. Therefore, it can be seen in a positive light as an alternative in the sector. More over the properties are much better than the current materials with a yield strength of 602.5 MPa and ultimate strength at 1757.3 MPa. The S-N curve of the material MAT_21 is also very favourable to the use conditions of aerospace sector.

| Alternating Stress MPa | Cycles |
|---|---|
| 4000 | 10 |
| 2800 | 20 |
| 2500 | 50 |
| 2400 | 100 |
| 2200 | 1000 |
| 2000 | 10000 |
| 1757.3 | 1000000 |
| 1500 | 10000000 |
| 1200 | 100000000 |
| 1000 | 1000000000 |

The best way to understand the durability and application of any material is the factor of safety (FOS) of the material. Here we have a material with the FOS of 15 which is considered very high as compared to other materials (FOS of 7 -10). When the materials are used in the manufacturing the FOS falls to about 1.25 to 2.5. However, MAT_21 will give a better FOS for the same thickness (about 2.5-4).

## 8 Conclusion:

In, conclusion the material that is stimulate has better qualities. The material has better stress and strain carrying properties and the FOS of the material gives it a more flexible use case. The amount of application that we can see is wide ranged that is in structures such as the wings and fuselage. Additionally, we may be able to use it for manufacturing jet engines once thermodynamic analysis is completed. We are hoping to see a wider application of the material MAT_21 then what we are thinking right now.

## 9 Future Work:

Future work is to increase the bird strike analysis to similar wing cases. Additionally, the structural deformation including strain and stress graph will also be studied. In this summary, quantitative analysis has efficiently shown using maximum stress and maximum strain. Comprehensive qualitative evaluation further exploring the physics will be taken subsequently. More required research could focus on developing more accurate and detailed bird strike models to predict effects of bird strike on aircraft structures.

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