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Topology Optimization for Aircraft Mounting Bracket

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Presentation outline

- Introduction
- Aim and objectives
- Methodology to use
- Scope and constraints
- Draft of timetable or research plan
- Conclusion
- Future work
- References

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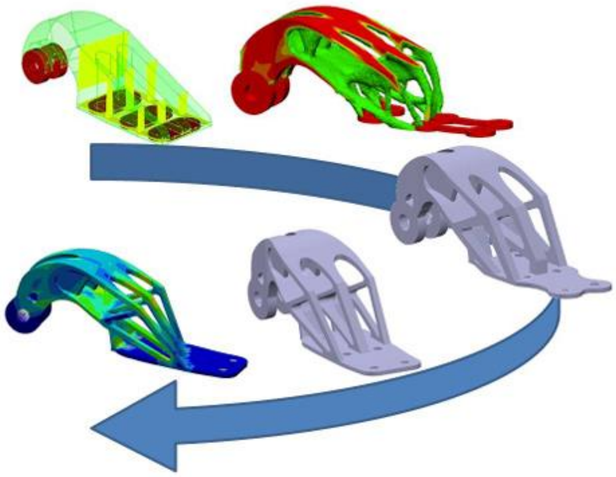
Introduction

- Topology Optimization (TO) is a sophisticated computer-aided technique.
- It is used to determine the optimal material distribution within a design space.
- Unlike traditional methods that focus on predefined geometries and materials, TO seeks the most effective material layout.
- The goal is to optimize components such as brackets, wings, or frames.



Application in Aerospace Engineering

Mounting brackets are critical components in aircraft, serving as attachment points for various systems and structural elements.

- It's used to attach parts of the engine casing or internal tubes to the main structure. The bracket holds:
- Piping
- Sensors
- Small mechanical subsystems

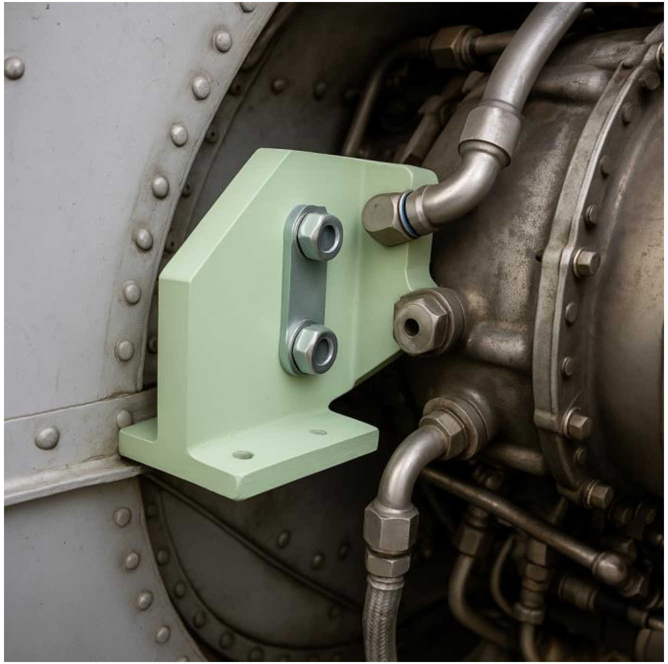


Figure 1. Mounting bracket

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Topology optimization: Classification based on Design Approach

- **Topology Optimization**
  - **Density-based method**
    - density variable (0 to 1)
    - Most widely used method (SIMP)
  - **Level-set based method**
    - Implicitly defined using level set functions.
    - Good for capturing smooth boundaries

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Problem statement
Traditional methods

Over-engineered

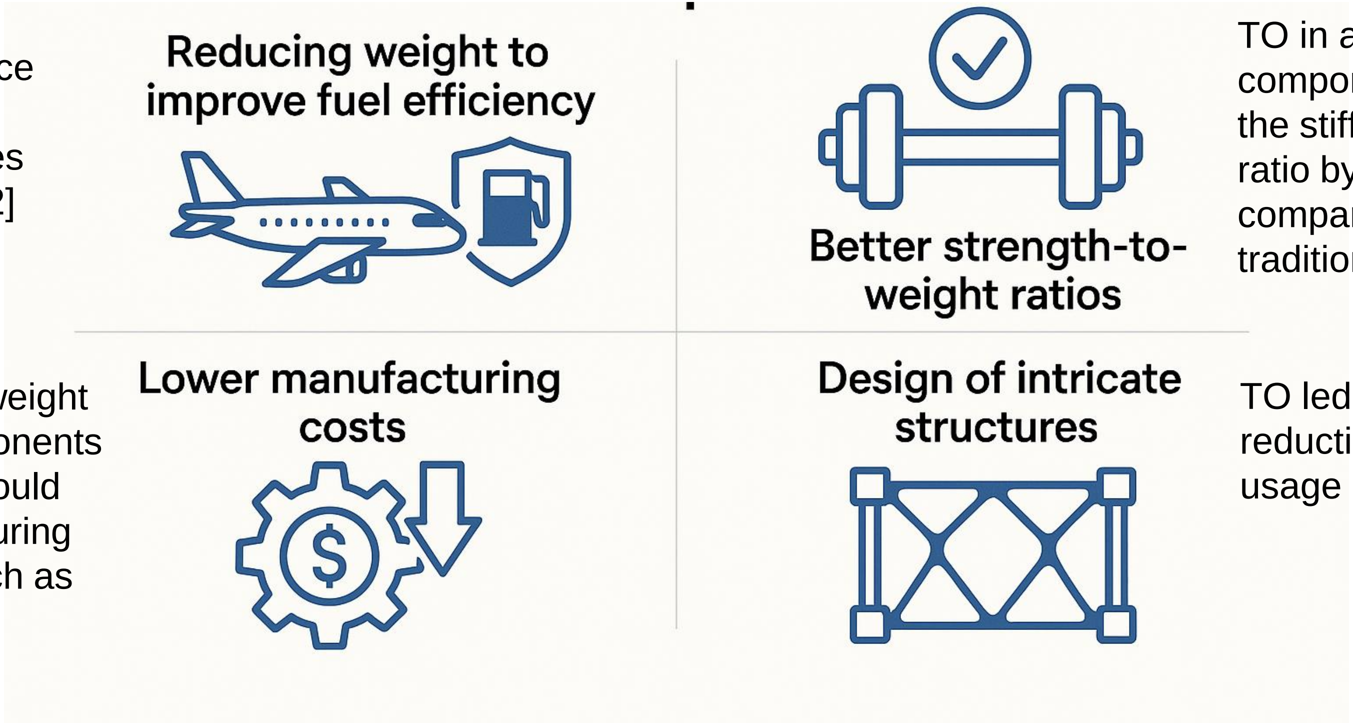
Excess material usage

Increased weight.

Motivation of the project: Why implementing TO?

TO helped reduce the weight of aircraft structures by up to 15%. [2]

TO in aerospace components improved the stiffness-to-weight ratio by **20-40%** compared to traditional designs. [4]



Designing lightweight structural components for spacecraft could lower manufacturing costs by as much as **20-30%**. [3]

TO led to a 50% reduction in material usage [5]

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Aim and objectives

Aim:

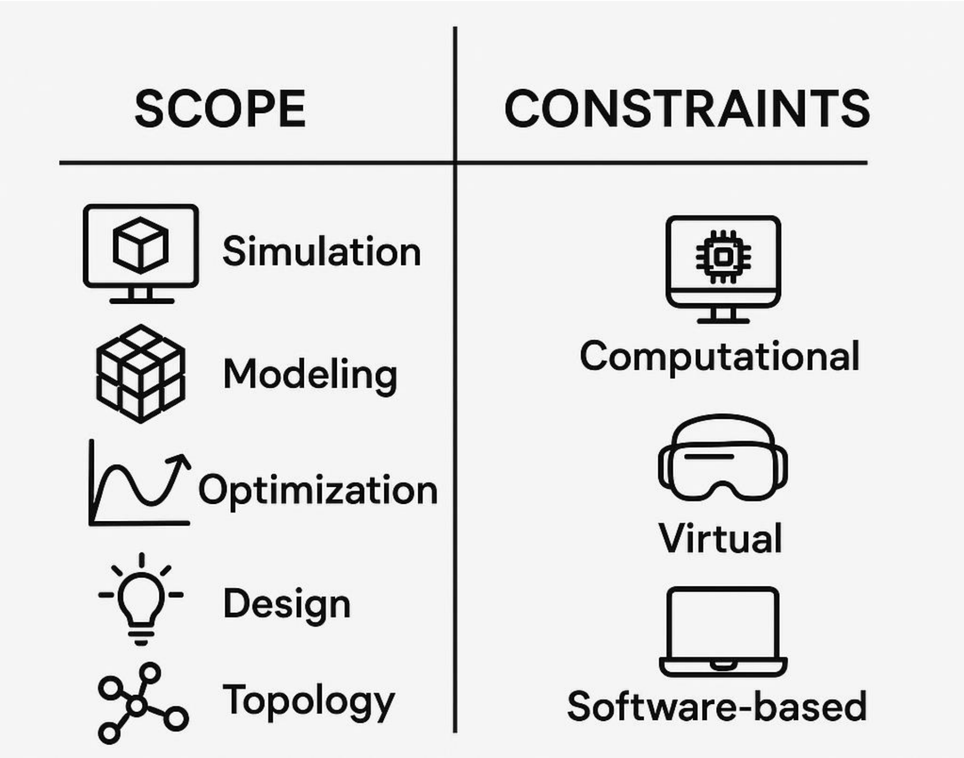
- To optimize the design of mounting brackets in aircraft by employing topology optimization techniques (Density based and Level Set Based methods) to reduce weight, while maintaining stiffness.

Objectives:

- Analyze Deformation and Stress Effects
- Determine load conditions
- Material distribution strategies
- Simulation and Validation

Scope and constraints

Modeling: The use of software tools to analyze the behavior of a structure under different conditions without creating a physical form. Optimization: Improving design parameters such as weight, stiffness or material usage using algorithms; Modeling: Ability to create CAD models. Design: Investigation of the shape of a structure based on performance criteria.



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Literature Review

Component	Application of Topology Optimization	Weight Reduction	Performance Enhancement	Key Benefits	Author,year
Aircraft Wings	Optimized material distribution within the spars and ribs ensures lightweight construction	25-30% weight reduction	Increased aerodynamic effect and structural strength	Increased fuel efficiency.	Minghao, 2022
Fuselage Design	Optimizing the use of material for handling dynamic load	40% weight reduction	Provides structural integrity from a safety standpoint while at the same time reducing weight.	Reduced weight, high fuel efficiency, minimized operating costs	Phuong, 2019
Engine Mounting Brackets	Optimizing the use of material for handling dynamic load	20-25% weight reduction	Ensures durability performance	Enhanced performance minimized material costs	Rozvany, 2001
Landing Gear Supports	Redesigning internal structure	20-30% weight reduction	Maintains necessary strength and	Improved safety, reduced weight	Suzuki, 1999
Other Components (e.g., Avionics Brackets, Winglets)	Reducing weight in auxiliary systems	Variable (up to 20% weight reduction)	Enhanced structural performance	Overall weight reduction	Zhang, 2000

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Methodology

CAD model preparation → **Optimization Techniques** → **Comparative Analysis** → **Overall Results**

1ST

Importing exist CAD model or creating new using CAD software

2nd

Define the design space, material properties, boundary conditions, and load cases

3rd

Weight reduction, component stress, minimum factor of safety

4th

Results

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Material: Structural Steel

Parameters	Value
Young Modulus	200 GPa
Poisson ratio	0.3
Endurance limit	170 MPa
Yield stress	250 MPa
Ultimate tensile stress	460MPa

Table 1. Material Properties

Figure 2. Structural steel

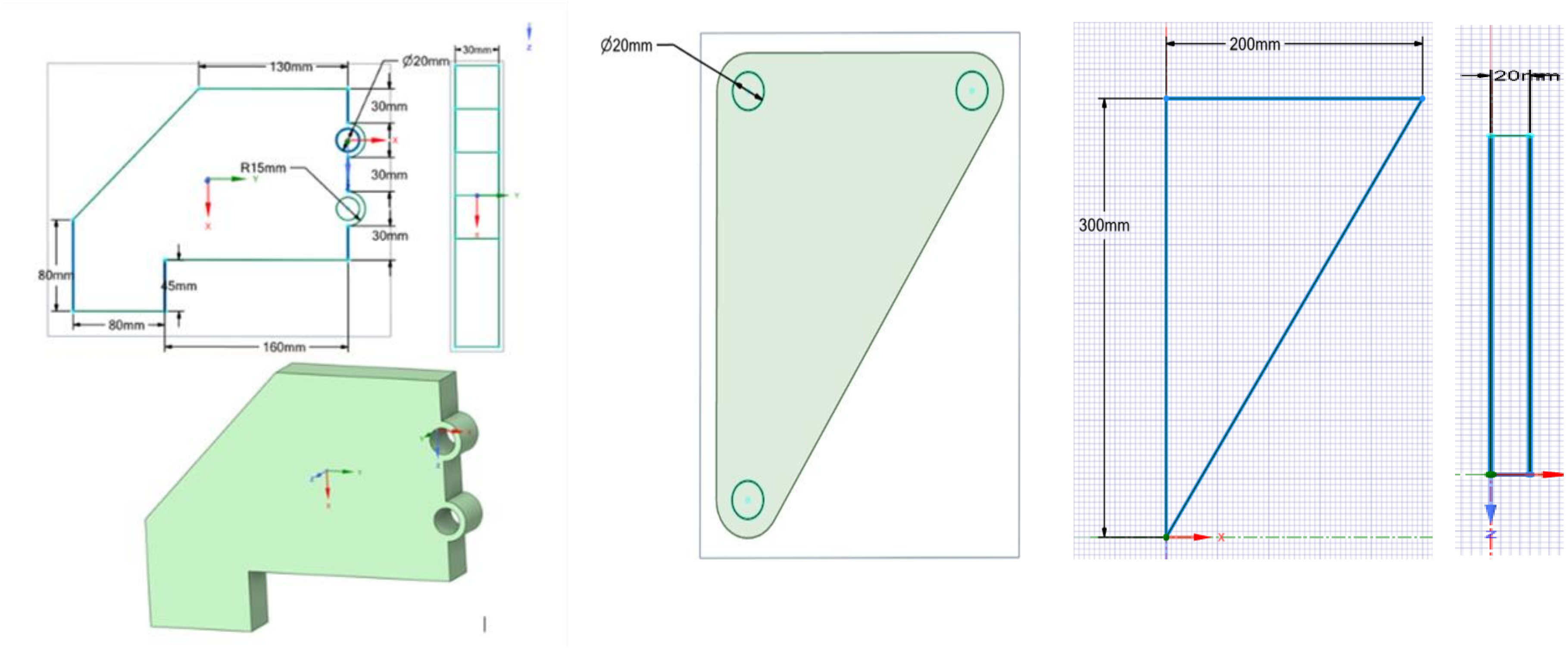

Figure 3. Sketches of the models

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Ansys modules connection

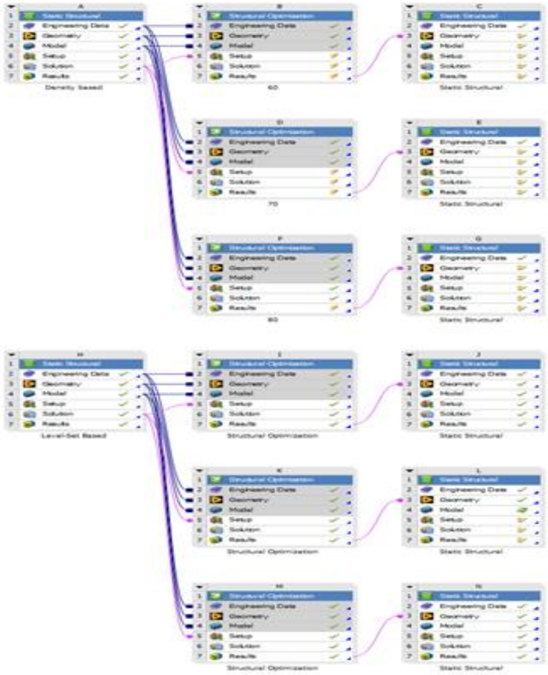

Figure 4. The Ansys modules connection

Connections in ANSYS define how different parts of a model interact with each other, simulating real-world joints and interfaces.

Mesh

Table 2. Mesh convergence

	Equivalent stress (MPa)	Change, % RMS error	Nodes	Elements
1	103.93		12509519	3053248
2	110.83	6.64	19614608	4802823
3	115,15	3,9	25103681	6156920

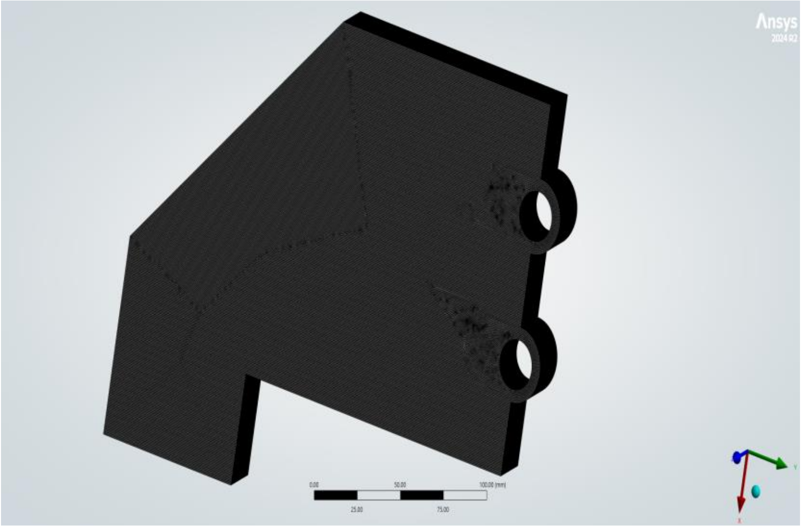

Figure 5. Mesh with the element size 0,6 mm

Mesh

Table 3. Mesh convergence

	Equivalent stress (MPa)	Change, % RMS error	Nodes	Elements
1	8,53		2506074	597765
2	8,89	4,22	4810128	1158092
3	9,03	1,57	6970593	1687842

Figure 6. Mesh with the element size 0,7

Boundary conditions and loads

A)The bluish surfaces are fixed

B) The pressure (red vector 4 MPa) is along the vertical direction

C) Material: Structural Steel

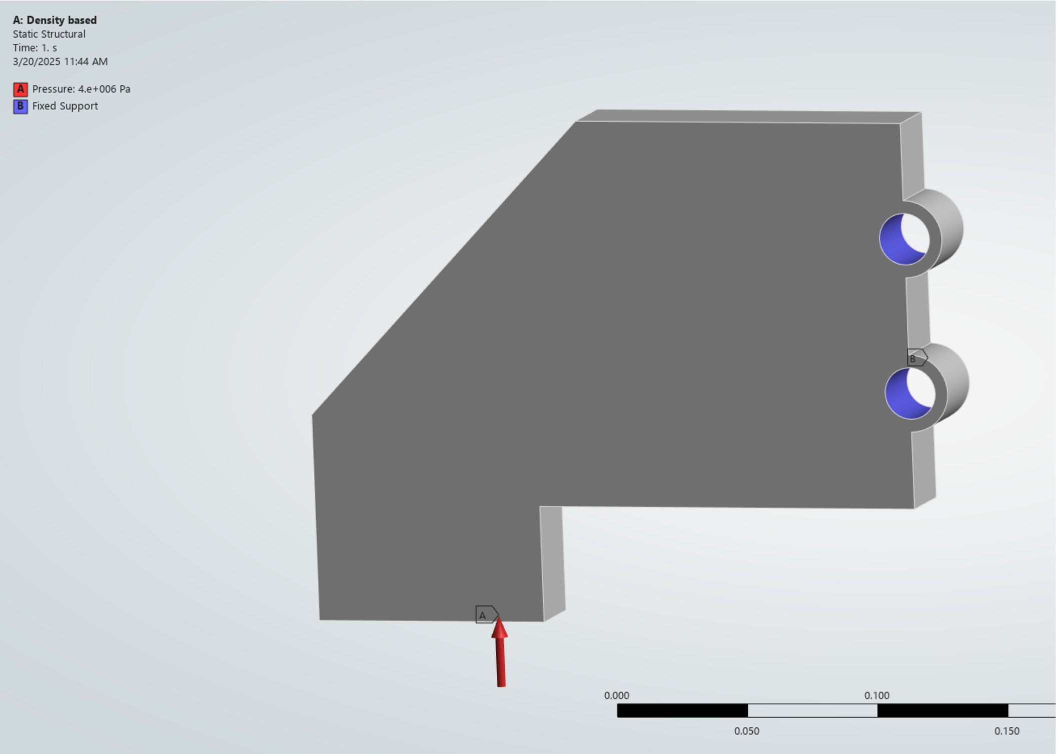

Figure 7. model in Ansys

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Boundary conditions and loads

Component: Cylindrical support with two holes

Load Applied: 1000 N in the X-direction and 500 N in the Y-direction on one hole

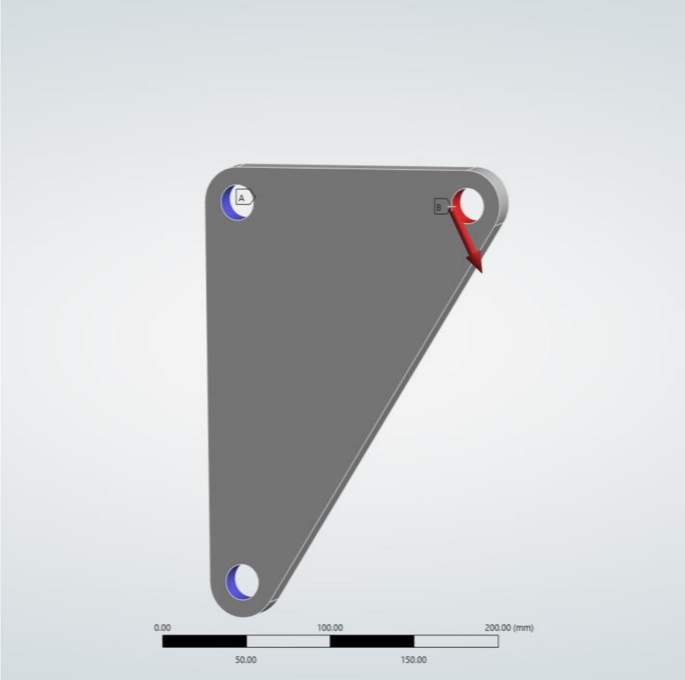

Figure 8. model in Ansys

Results

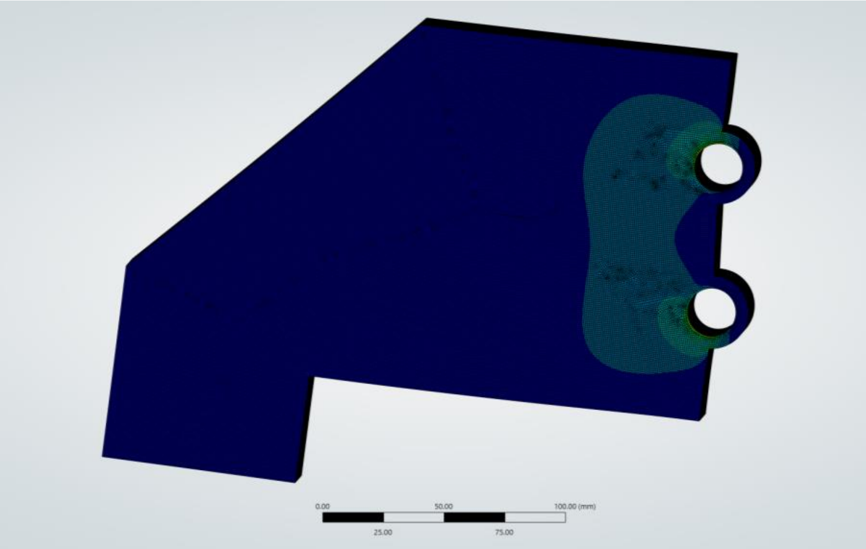

Figure 9. Equivalent stress

Figure 10. Equivalent stress

Equivalent stress, often referred to as **von Mises stress**, is a scalar value derived from the complex state of stress at a point.

The color gradient indicates the magnitude of stress:

- **Red/Hot colors** signify areas of **high stress**.
- **Blue/Cool colors** indicate areas of **low stress**

Results

Figure 12. Optimized bracket's shapes

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Results

Density Based	Original Bracket Equivalent stress	Original bracket Total deformation	70%	70%	80%	80%	90%	90%
			Equivalent stress	Total deformation	Equivalent stress	Total deformation	Equivalent stress	Total deformation
Min	36300 Pa	0. m	8.6798e+005 Pa	0 m	1.5369e+006 Pa	0 m	1.2275e+006 Pa	0. m
Max	9.2155e+007 Pa	3.9365e-005 m	8.5603e+007 Pa	4.6172e-005 m	9.3495e+007 Pa	4.3969e-005 m	8.7304e+007 Pa	4.2201e-005 m
Mean	1.1515e+007 Pa	1.4659e-005 m	1.3666e+007 Pa	1.4636e-005 m	1.5176e+007 Pa	1.1175e-005 m	1.2411e+007 Pa	1.3881e-005 m

Table 4. Results of density- based method

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Results

Level-Set Based	Original Bracket Equivalent stress	Original bracket Total deformation	70% Equivalent stress	70% Total deformation	80% Equivalent stress	80% Total deformation	90% Equivalent stress	90% Total deformation
Min	36300 Pa	0. m	2.3216e+005 Pa	0 m	7.4513e+005 Pa	0 m	2.8318e+005 Pa	0. m
Max	9.2155e+007 Pa	3.9365e-005 m	1.0357e+008	5.4098e-005 m	9.4396e+007 Pa	5.86e-005 m	1.4878e+008 Pa	1.5814e-004 m
Mean	1.1515e+007 Pa	1.4659e-005 m	1.6861e+007 Pa	1.7111e-005 m	1.6844e+007 Pa	1.9047e-005 m	1.9956e+007 Pa	7.978e-005 m

Table 5. Results of level-set based method

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Results

Density Based	Original Bracket	Original bracket	70%	70%	80%	80%	90%	90%
	Equivalent stress	Total deformation	Equivalent stress	Total deformation	Equivalent stress	Total deformation	Equivalent stress	Total deformation
Min	12069 Pa	1.5972e-008 m	6963. Pa	0. m	13263 Pa	1.5286e-008 m	20922 Pa	1.9453e-008 m
Max	8.6053e+006 Pa	3.6357e-006 m	8.7785e+006 Pa	3.991e-006 m	9.1398e+006 Pa	3.804e-006 m	9.0892e+006 Pa	3.8367e-006 m
Mean	9.4292e+005 Pa	8.2283e-007 m	1.3689e+006 Pa	9.6586e-007 m	1.0989e+006 Pa	9.0357e-007 m	1.0307e+006 Pa	8.8035e-007 m

Table 6. Results of density- based method

Results

Level-Set Based	Original Bracket Equivalent stress	Original bracket Total deformation	70% Equivalent stress	70% Total deformation	80% Equivalent stress	80% Total deformation	90% Equivalent stress	90% Total deformation
Min	36300 Pa	1.5972e-008 m	13263 Pa	1.5286e-008 m	20922 Pa	1.9453e-008 m	29274 Pa	1.9761e-008 m
Max	9.2155e+007 Pa	3.6357e-006 m	9.1398e+006 Pa	3.804e-006 m	9.0892e+006 Pa	3.8367e-006 m	8.6783e+006 Pa	3.6211e-006 m
Mean	1.1515e+007 Pa	8.2283e-007 m	1.0989e+006 Pa	9.0357e-007 m	1.0307e+006 Pa	8.8035e-007 m	9.6331e+005 Pa	8.1329e-007 m

Table 7. Results of level-set based method

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Draft of timetable and research plan

Phase	Task	Duration	Timeline
Phase 1	Literature Review and Material Preparation	3 months	June - August 2024
	- Review the literature on AIRCARFT Bracket Shape and Lattice Optimization.	1 month	June 2024
	- Identify, study, and prepare raw materials.	1 month	July 2024
	- CAD model preparation	1 month	August 2024
Phase 2	Experimental Trials and Testing	5 months	September 2024 - January 2025
	-Setup Optimization in ANSYS	1 month	September 2024
	- Optimization Runs	1 month	October-November 2024
	- Prototype Fabrication	2 months	January 2025
	- Physical Testing	1 month	February 2025
Phase 3	Data Analysis and Comparison	3 months	March - April 2025
	-Review and Revisions	0.5 months	Mid-March - Early April 2025
	- Record conclusions, offer suggestions, and draft the thesis.	1.5 months	March - April 2025

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Conclusion

- Weight Optimization Achieved: Successfully reduced mass to 70%, 80%, and 90% while retaining structural integrity.
- ▯ Dual Optimization Approaches:

Density-based method: Enabled complex geometry generation and flexible design exploration.

Level-set method: Offered smoother and more manufacturable shapes.

- ▯ FEA and Parametric Modeling: Efficient use of Ansys SpaceClaim enabled iterative design and accurate simulation of different loading and boundary conditions.
- ⚖▯ Balance of Stiffness and Strength: Optimized designs maintained structural performance under varying loads.
- ⚠▯ Study Limitations:

No experimental validation due to time constraints.

Idealized loading scenarios; real-world fatigue and thermal stresses were not fully captured.

Future work

Based on the results of this study, future work will focus on improving the realism and practical use of the optimized design. A key area of interest is the use of improved material models to better understand the behavior of modern engineering materials under complex loading conditions.

However, in the future, I would like to address these limitations:

- Conducting experimental tests on physical prototypes
- 3D printing optimized designs to assess their structural performance
- Comparing experimental data with numerical results

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