PhD Aerospace Engineering Doctoral Meeting 2025

Parametric Modeling and Optimisation of Composite Airframes

PhD Candidate: Nikolaos Ziakos

Supervisor: Andrea Cini

ASD Lab

Objective and Methodology

- ***Objective:*** Develop an AI-enhanced design framework capable of performing both topology and composite sizing optimisation on parametric airframe geometries for civil and military aircraft.

- ***Methodology***:

1. Develop tools for the automated parametric creation of airframe FEA models.
2. Set up constraints and design variables for composite sizing optimisation.
3. Perform Design of Experiments (DoE) to evaluate the effect of structural topology parameters (rib, stringer, spar spacing) on the minimised weight achieved.
4. Use the data acquired to incorporate and train AI-based techniques.

Motivation and Impact

- ***Motivation:*** Pre-processing of structural models remains, for the most part, a manual and time-consuming process. At the same time, most early-stage tools lack flexibility and optimisation capabilities, with coupled topology and sizing optimization frameworks being rare in the literature.

- ***Impact:*** The framework proposed in this work aims to accelerate pre-processing of structural models and bring physics-based optimisation capabilities into the early-stage design phase, where both topology and sizing design variables are needed. Additionally, the introduction of AI-based techniques can reduce computational cost, with benefits for both academia and industry.

Parametric Wing Model

Key Features:

- **Geometry Definition** (e.g. span, taper ratio, surface area, sweep)
- **Internal Configuration** (e.g. rib and stringer spacing, spar location)
- **Automatic meshing and property definition**
- **Laminate ply-based modeling**
- **Boundary conditions and constraints definition**

Define parameters for geometry, structural layout and modeling.

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A Python script is used to calculate key coordinates for the geometry.

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A Hypermesh TCL script is generated by the Python script

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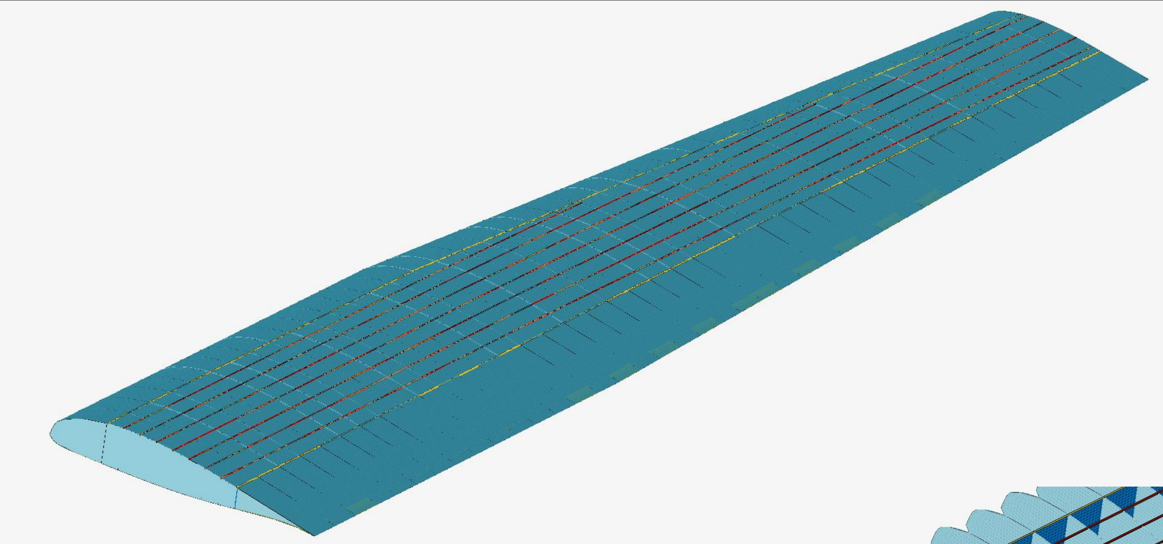
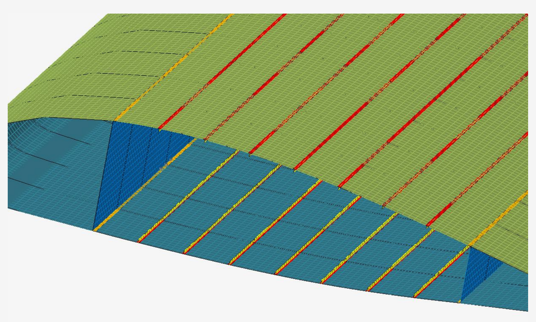
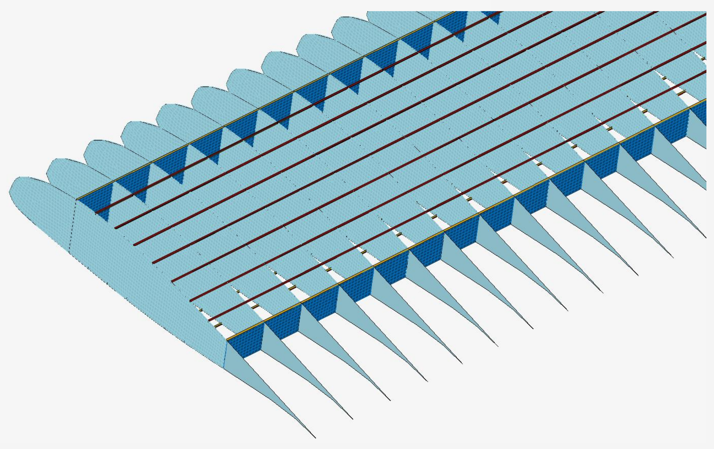
The entire model is created automatically using the TCL code as input on Hypermesh.





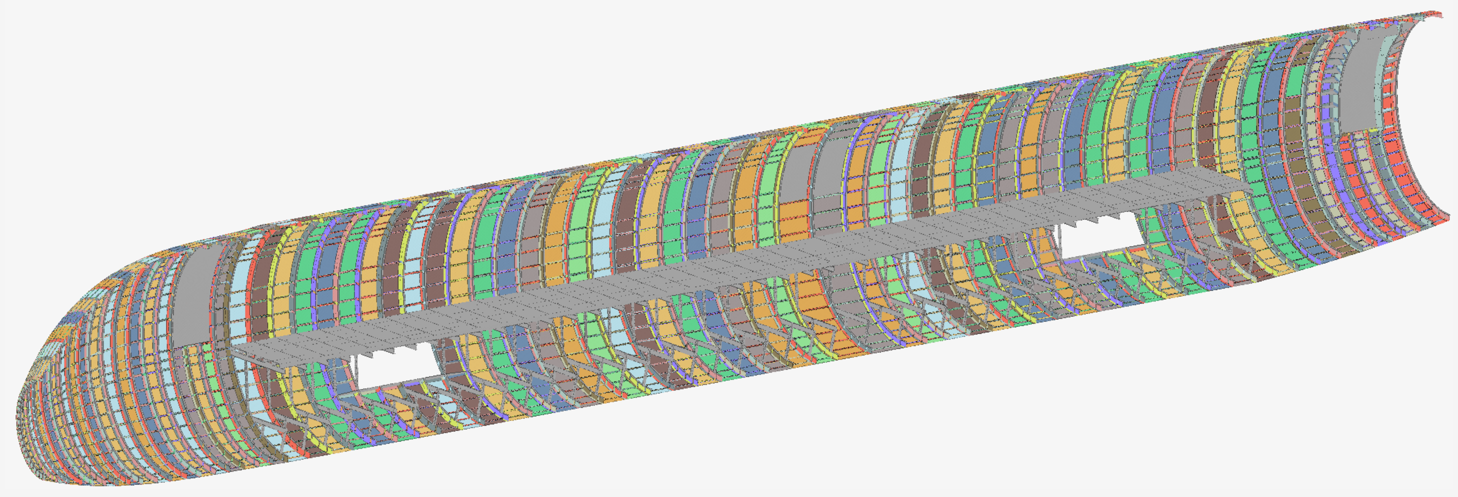


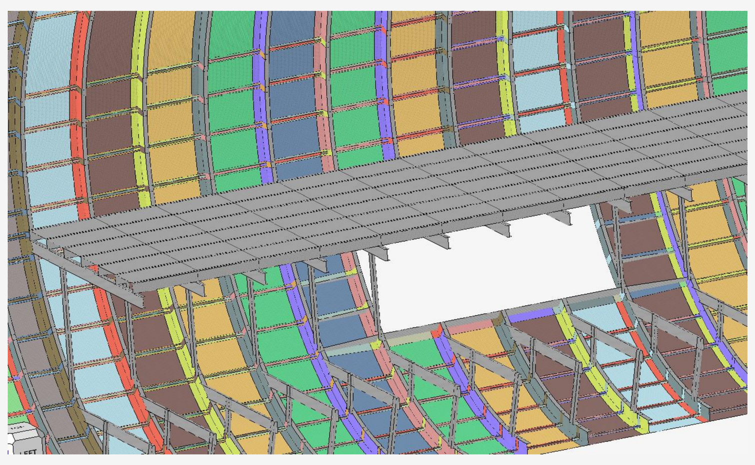
Figures 1-3. Wing Model created automatically using the parametric script

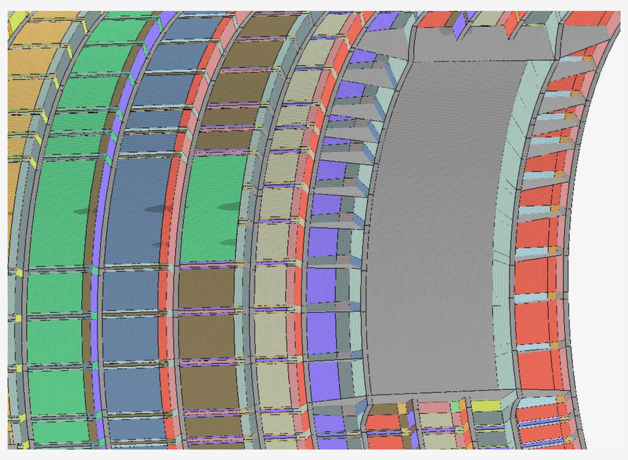
Fuselage Geometric Model

Key Features: (Under development)

- **Geometry Definition** (e.g. fuselage OML and dimensions, cutout and floor locations)
- **Internal Configuration** (e.g. frame and stringer spacing, cross sections)
- **Floor and Reinforced Cutouts modeling** (Passenger and cargo doors, windows)







Figures 5-7. Fuselage Geometry created via parametric script

Wing Composite Sizing Optimisation

- Accurate modeling of composite materials and constraints under limit load conditions.
- Stacking sequence optimisation could be included in the future.
- Optimisation based on **Optistruct's gradient-based algorithm**.

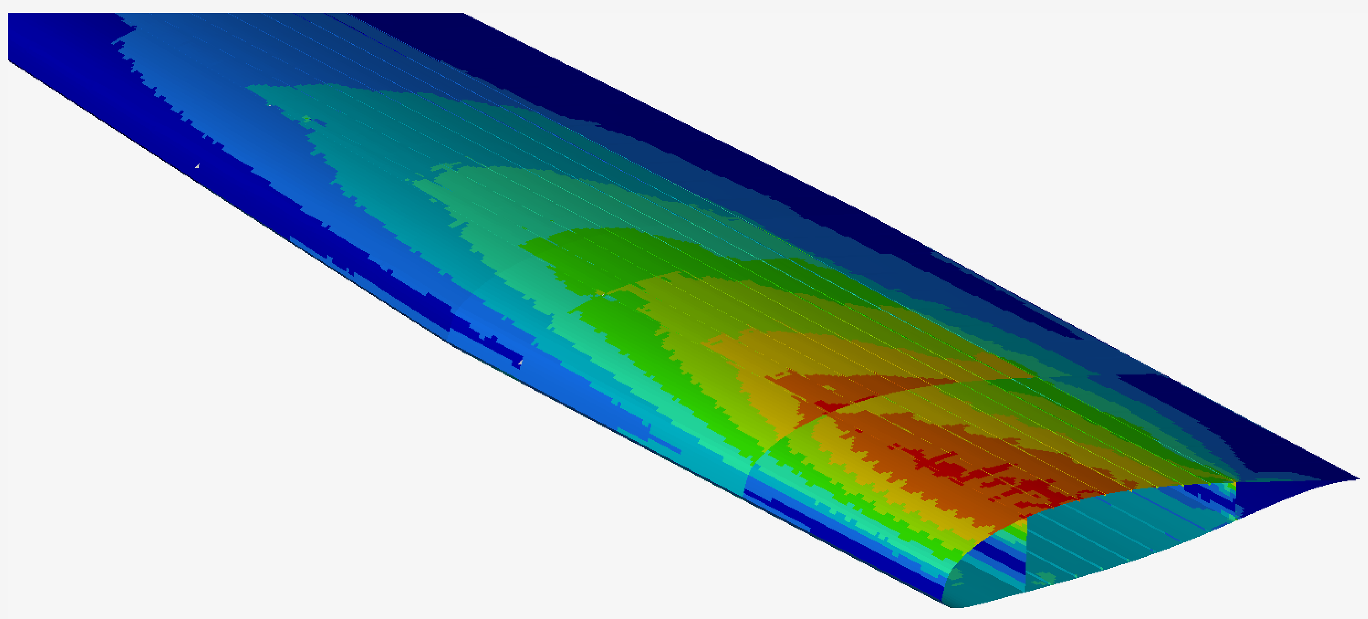


Figure 4. Composite strain distribution on optimised wing

Design of Experiments

- A sizing optimisation is performed in each iteration to determine the effect of the variation of the topology variable.
- Preliminary results show strong correlation with front spar location, and a smaller for the rear spar location.

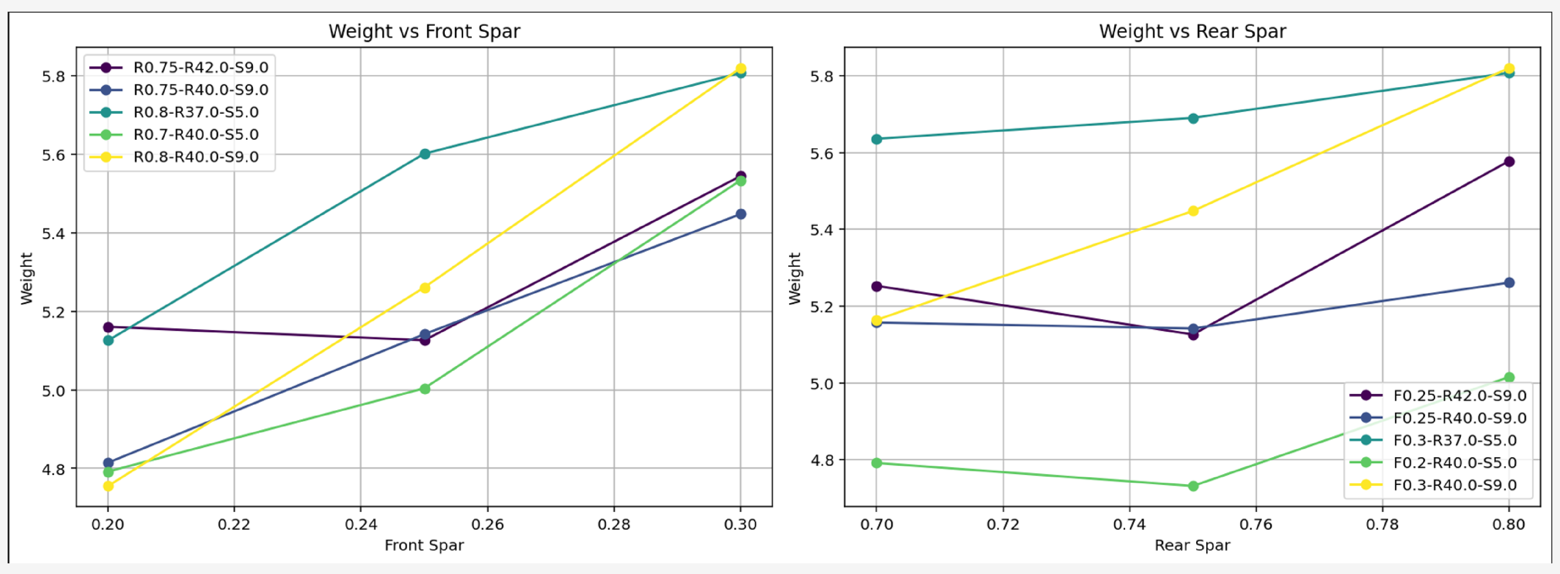


Figure 8. Design of Experiments results for the effect of spar location on wing weight

Future Work

- Complete the development of the fuselage model and integrate it with the wing.
- Enhance composite optimization with more detailed failure criteria and stacking rules.
- Conduct a comprehensive Design of Experiments to evaluate design sensitivities.
- Use DoE results to implement AI-based surrogate models and accelerate optimization.

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