Analysis and modelling of stress concentration on riveted zones of thin structures

AEA 2024/2025 – Presentation 1

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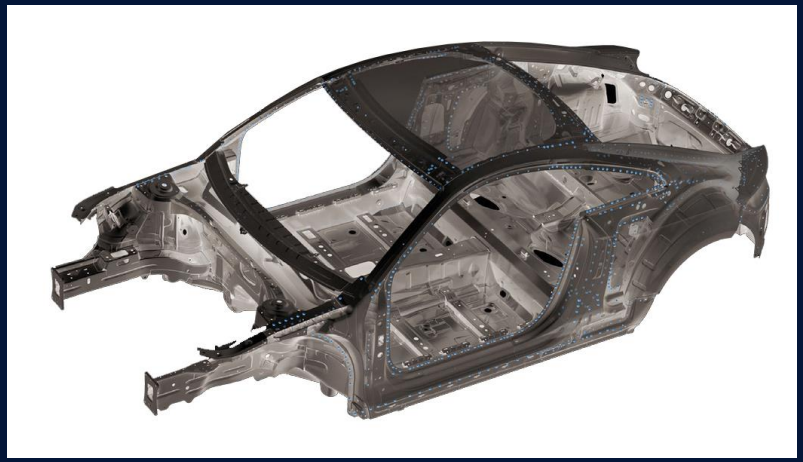
Aplications of rivet junctions

Furniture

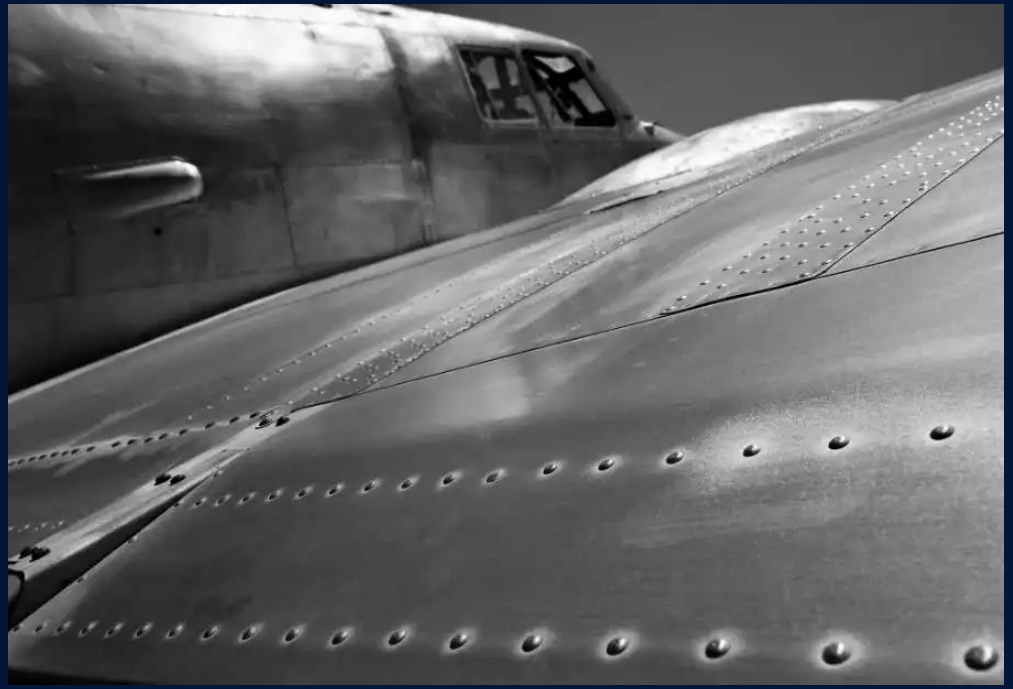


Automotive industry

Civil Construction

[1]

Applications of rivet junctions

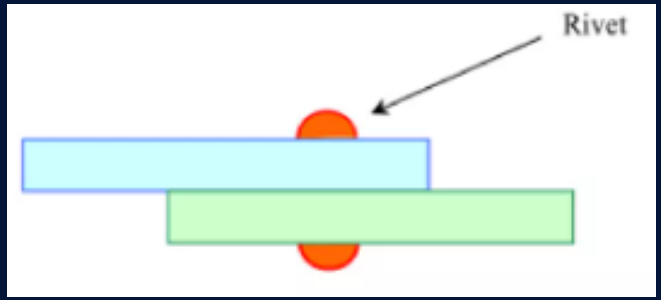


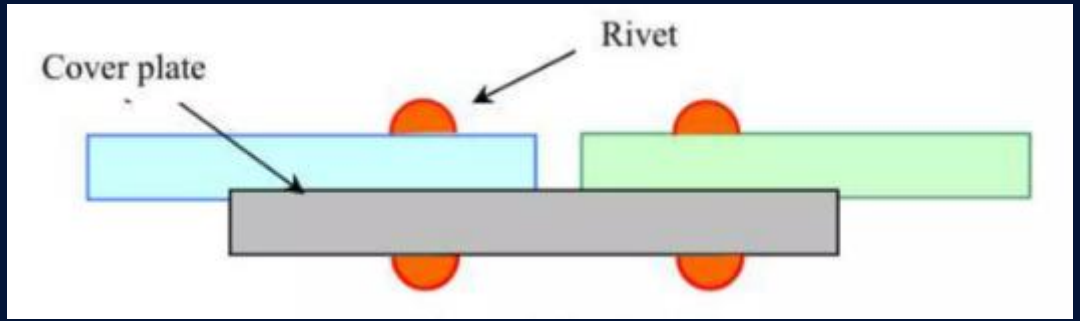
[2]

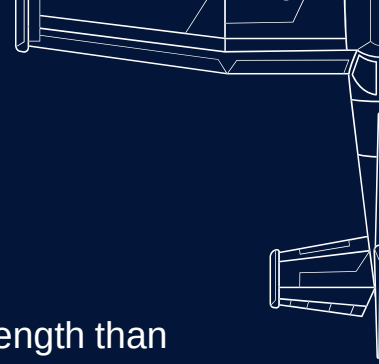
What?
Why?

RIVETS

Rivets are permanent fasteners used to join two or more plates or shell structures with different materials.







Advantages

- → Can connect boards from different materials;
- → Can have different types of finishes;
- → Can be used as clamps, spacers, shafts, electrical contacts, etc;
- → Can be assembled by high-speed automatic machines;
- → Simple and cheaper process;
- → High reliability.

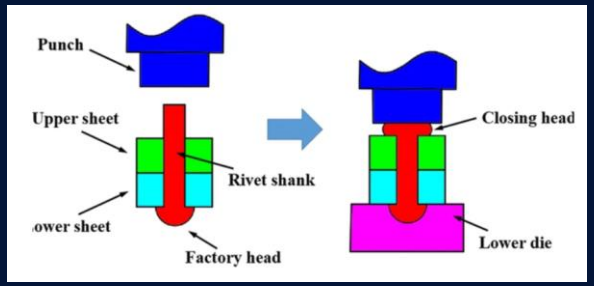
Disadvantages

- → Lower tensile and fatigue strength than screw and thread connections;
- → Typically, rivets need to be destroyed for maintenance or replacement;
- → When mass produced, it does not have the same precision as threaded connections.

Riveting technology

Normal riveting technology

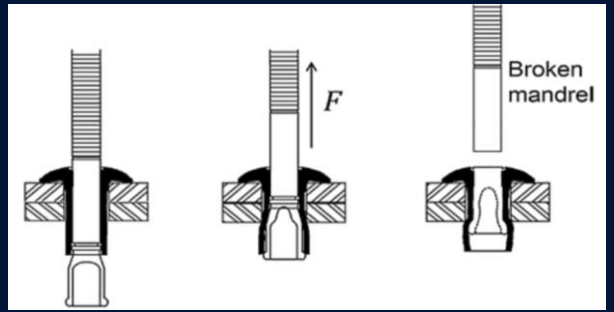
Conventional riveting



→ uses the plastic deformation of the rivet to join plates

[3]

Blind riveting



→ consists of two parts, which are the rivet body and the rivet stem

Novel riveting techniques

Reshaped riveting

→ high efficiency

→ low cost

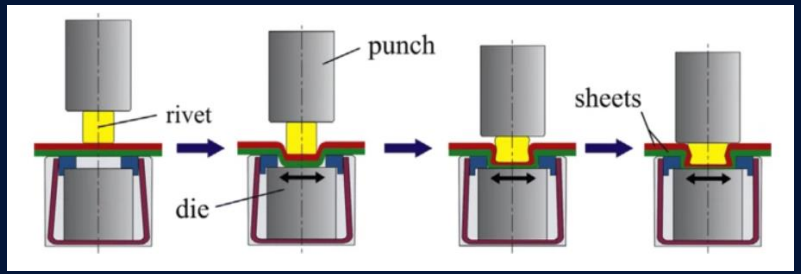
→ ability to join coated boards without damage

Restored riveting

→ allows you to renew the damaged closed joint

→ avoids material waste

Clinch technology



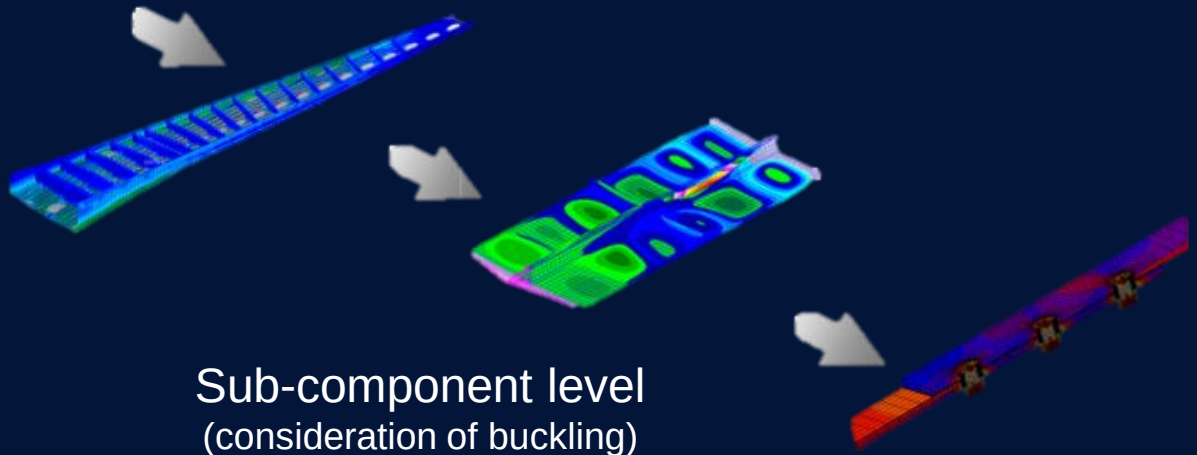
Self-piercing riveting

→ drilling and riveting can be achieved at the same time

→ coated board can be joined without destroying the coating

→ joint produced has high static and fatigue resistance

Aircraft level
(calculation of internal load)

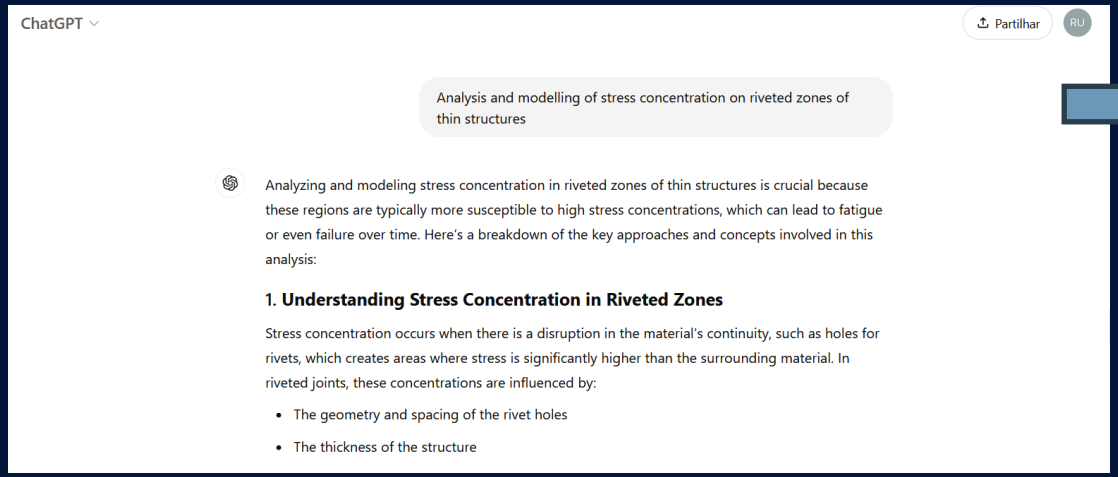


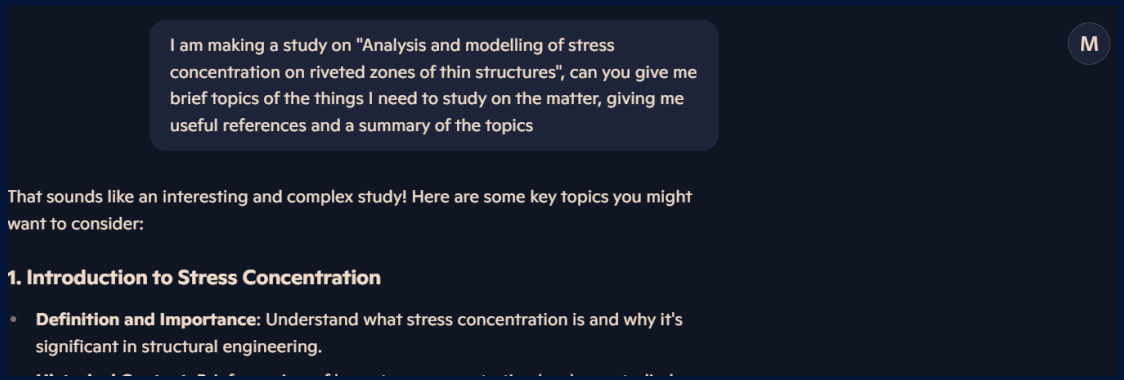
Sub-component level
(consideration of buckling)

Specimen level
(consideration of plasticity)

[4]

ChatGPT





Analytical Methods for Stress Concentration

Kirsch's Equations

Peterson's Stress Concentration Factors

Kirsch's Equations

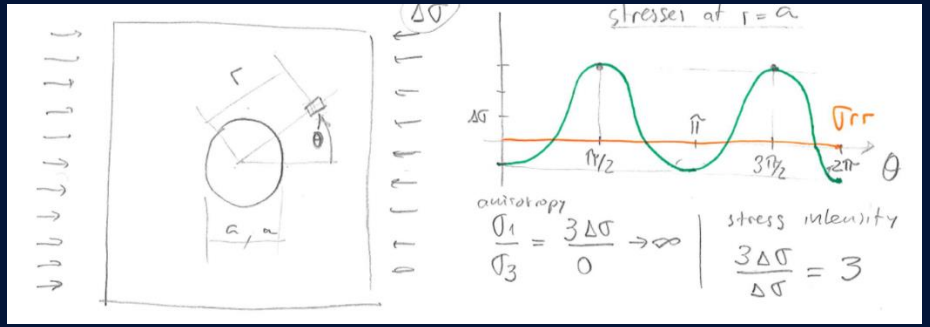
→ Used when there is only a single circular hole in an infinite plate;

→ Kirsch equations can approximate stress concentration factors;

$$\sigma_{rr} = \frac{\sigma}{2}.\left(1 - \frac{a^2}{r^2}\right) + \frac{\sigma}{2}.\left(1 - \frac{4a^2}{r^2} + \frac{3a^4}{r^4}\right).cos2\theta$$

$$\sigma_{\theta\theta} = \frac{\sigma}{2}.\left(1 + \frac{a^2}{r^2}\right) - \frac{\sigma}{2}.\left(1 + \frac{3a^4}{r^4}\right).cos2\theta$$

$$\tau_{\theta r} = -\sigma.\left(1 - \frac{3a^4}{r^4}\right).sin2\theta$$

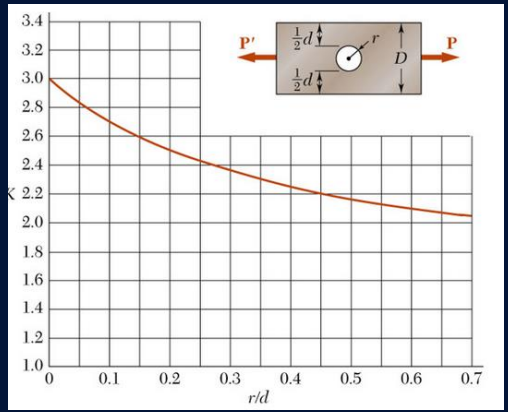


[5]

Peterson's Stress Concentration Factors

→ These factors provide empirical values for various geometries and load types

→ Allows engineers to estimate stress concentration factors (SCFs) around rivet holes in plates with known dimensions



[6]

Possible failure modes

Rivet shear

$$P = \frac{\pi d^2 \tau_1}{4b}$$

Bearing pressure

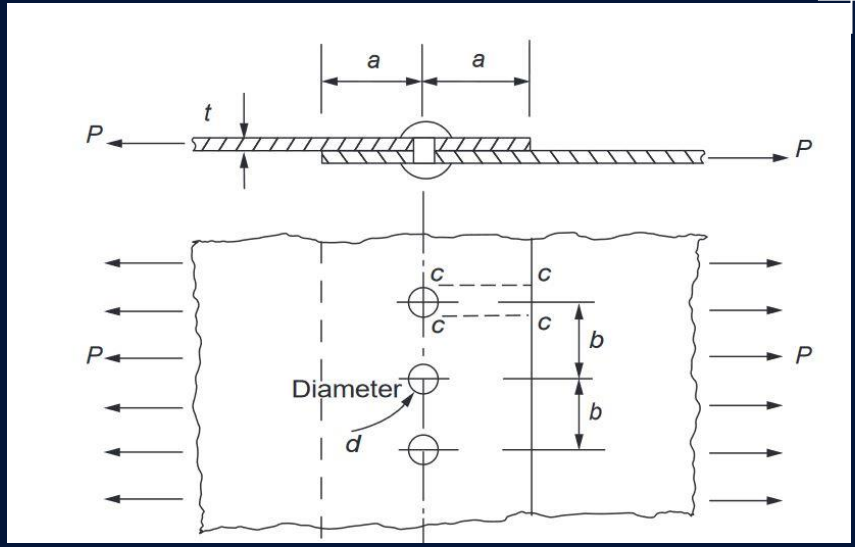
$$P = \frac{p_b t d}{b}$$

Shear failure in a plate

$$P = \frac{2at\tau_2}{b}$$

Plate failure in tension

$$P = \frac{\sigma_{ult} t(b-d)}{b}$$

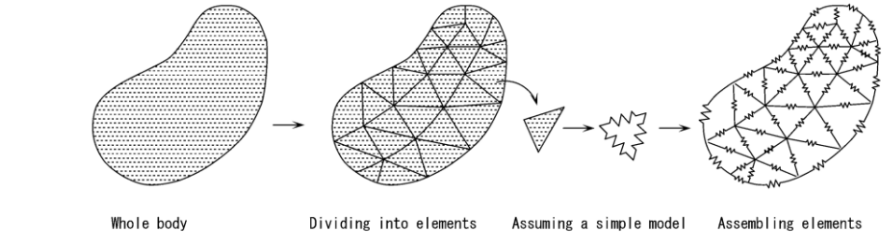


$$\eta = \frac{\sigma_{ult} t(b-d)}{b} \cdot \frac{1}{\sigma_{ult} t} = \frac{b-d}{b}$$

[7]

Computational analysis

FINITE ELEMENT METHOD (FEM)

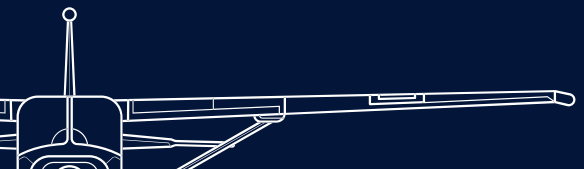


Trough a search on Springer
Keywords: “Finite Element Method”

[8]

Computational analysis (cont.)

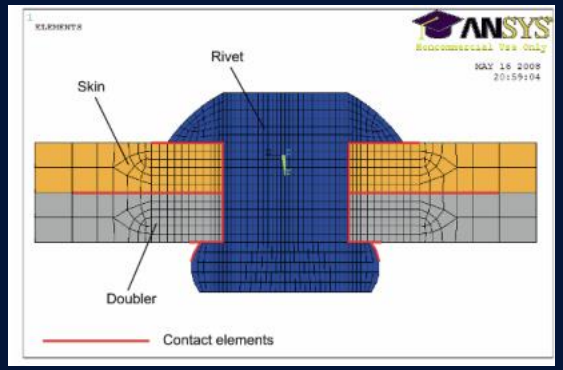
Modelling → Definition of the problem (load, boundary conditions, etc.) → Mesh construction and validation (skewness, orthogonal quality) → Solution and analysis/comparison

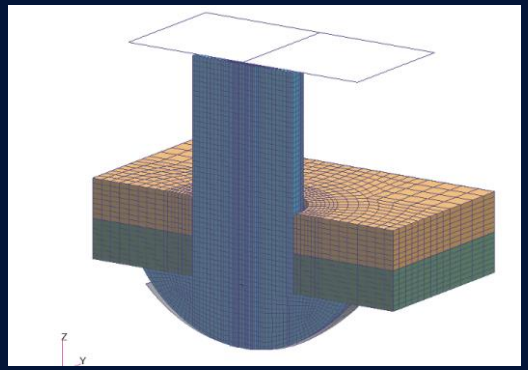


Computational analysis (cont.)

According to the chapter:
“Methods for Fem Analysis of Riveted Joints of Thin-Walled Aircraft Structures Within the Imperja Project” [9]

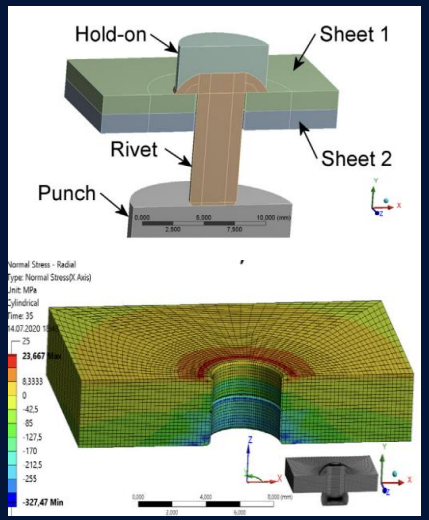
2 methods for local model:



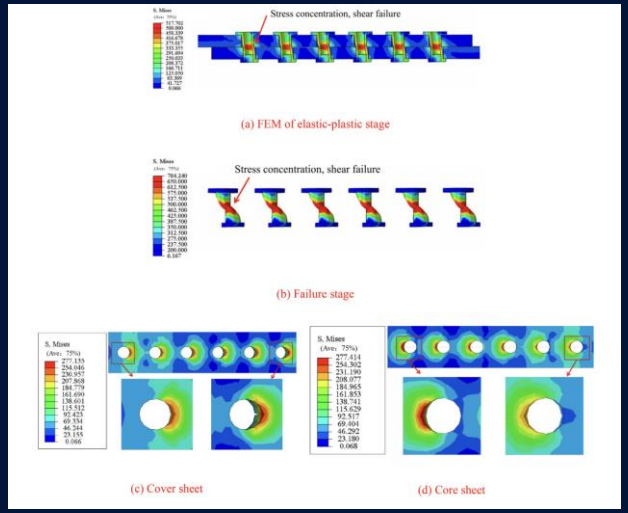


Example of keywords searched Google Academic, ResearchGate and Science Direct: ”rivet thin plate finite element”; “finite element method analysis of rivets on thin structures”; “computational analysis on rivets “

Computational analysis (cont.) & Ideas to explore



[10]



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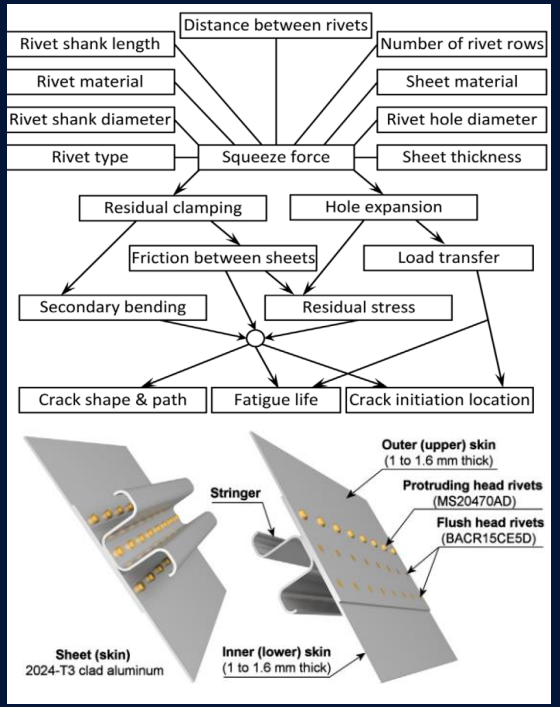


Next Phase

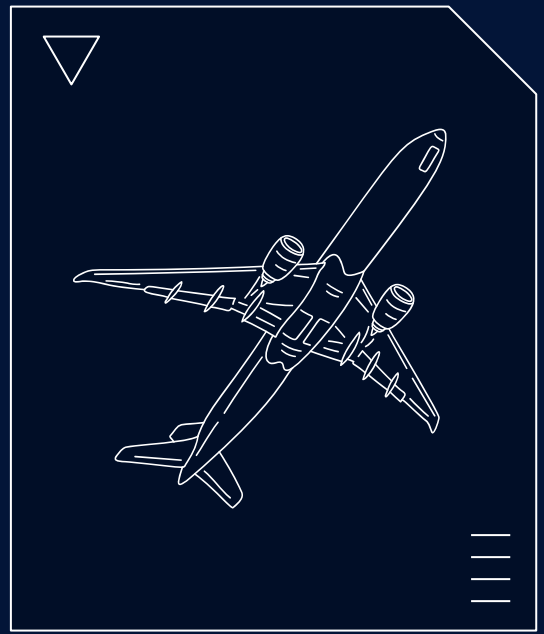
Riveted Junction in thin plates

Study a case, analytically and computationally, of the stresses in a system composed of two plates and two rivets in the previously mentioned cases.

Comparison between the analytical results, the computational ones and the experimental, from a case study already done.

Study the case where there is 3 plates in a rivet junction and compare it to the 2 plates case.

Analyze the different configurations of the riveted position in the connection between 2 plates.

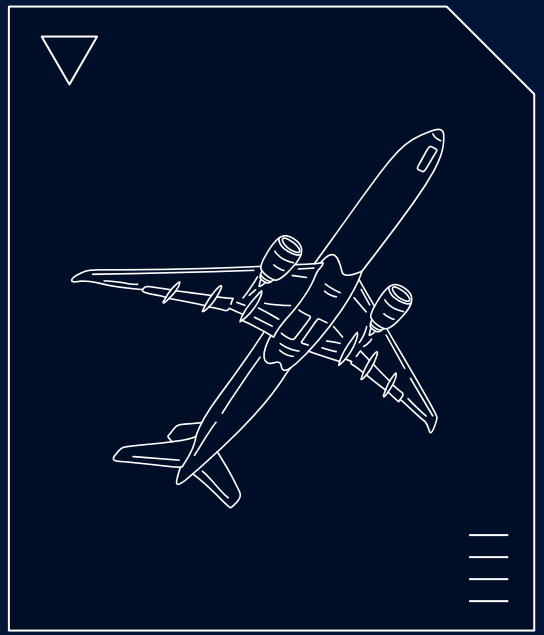


Next Phase

Shell structures

In case the previous study is successful and the is time left, the focus will be on the study of riveted shell structures

Analyze the differences between the curved and plates



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Thanks!

Does anyone have any questions?