

NANYANG TECHNOLOGICAL UNIVERSITY
School of Mechanical and Aerospace Engineering

MA 4702
CA 1
AIRCRAFT STRUCTURES II

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Grade: _____

1 INITIAL MODEL

The structure of the UAP exhibits two lines of symmetry—both horizontal and vertical—across its centre with geometrical and loading symmetry. This allows for simplification of the model to a quarter-model with symmetry boundary conditions. This approach allows for lower computation effort. Furthermore, due to the symmetry conditions along the axes, the stresses and displacements derived in the quarter model will accurately reflect to the entire model.

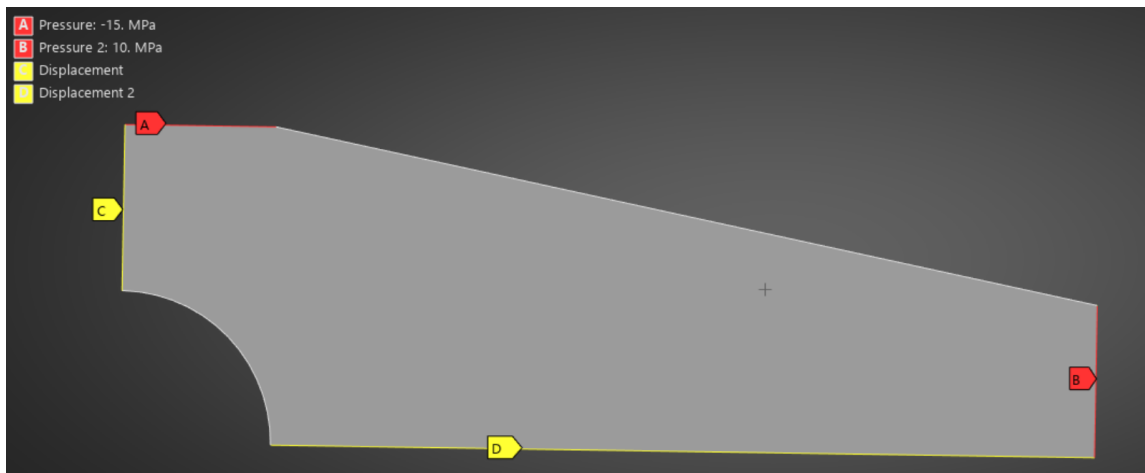


Figure 1: 2D - Quarter-model of the UAP Structure

To further optimize the model, a mesh convergence study was performed to determine the ideal level of mesh refinement. The goal was to ensure the stresses obtained from the mesh are stable and do not change significantly with further mesh refinement, while preventing over-refining to reduce computational effort.

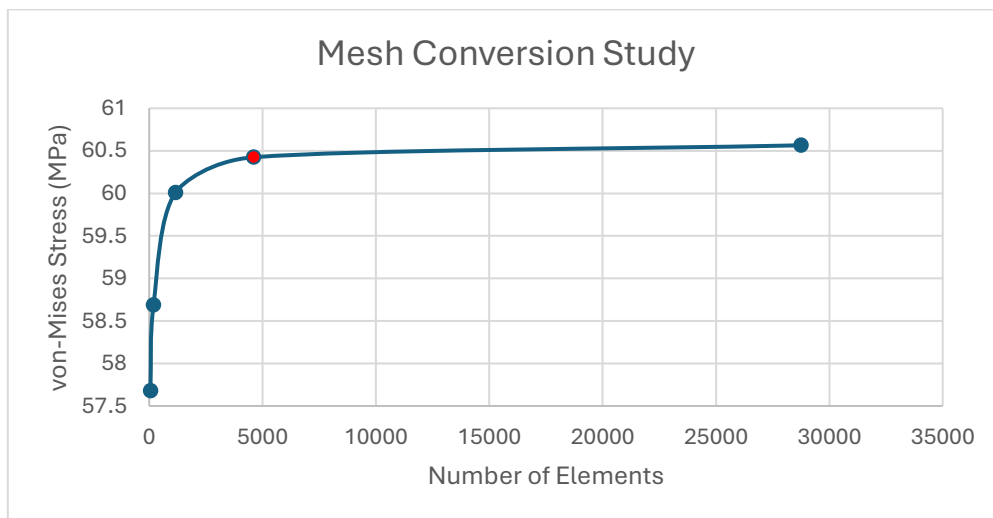


Figure 2: Mesh Convergence Study

Based on the study, a mesh size of 0.5 mm was used, corresponding to the fourth iteration (in red) in Figure 3 which shows the stress converging.

1.2 Results

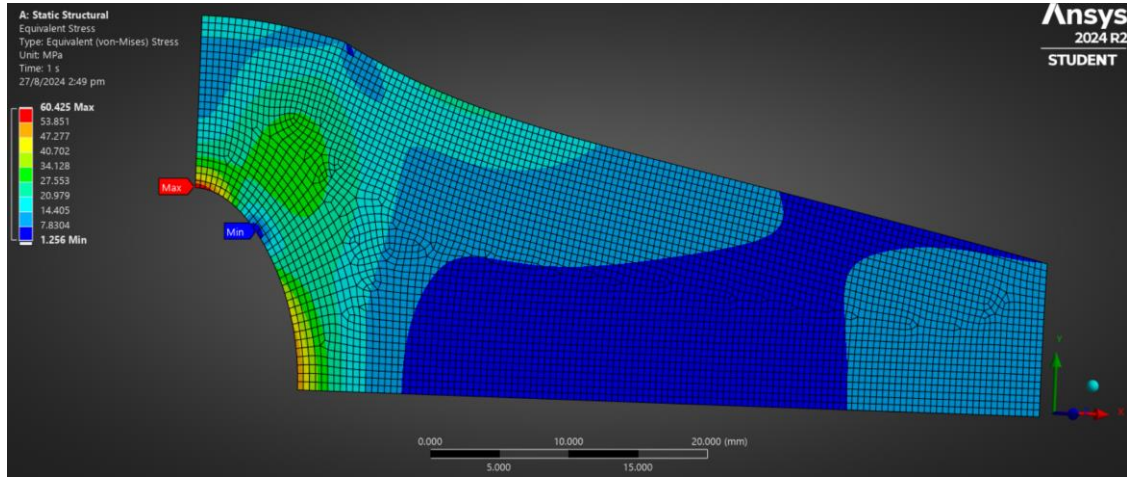


Figure 3: Contour Plot of von-Mises Stress

Based on the analysis, the maximum von-Mises Stress in the model was 60.425 MPa, with a maximum deformation of 0.45734 mm in the x direction and 0.53106 mm in the y- direction.

2 STRESS RELIEVING HOLES

The objective of this analysis is to investigate the effects of introducing stress-relieving holes in the UAP structure to mitigate localized stress concentrations and improve the structure's fatigue life

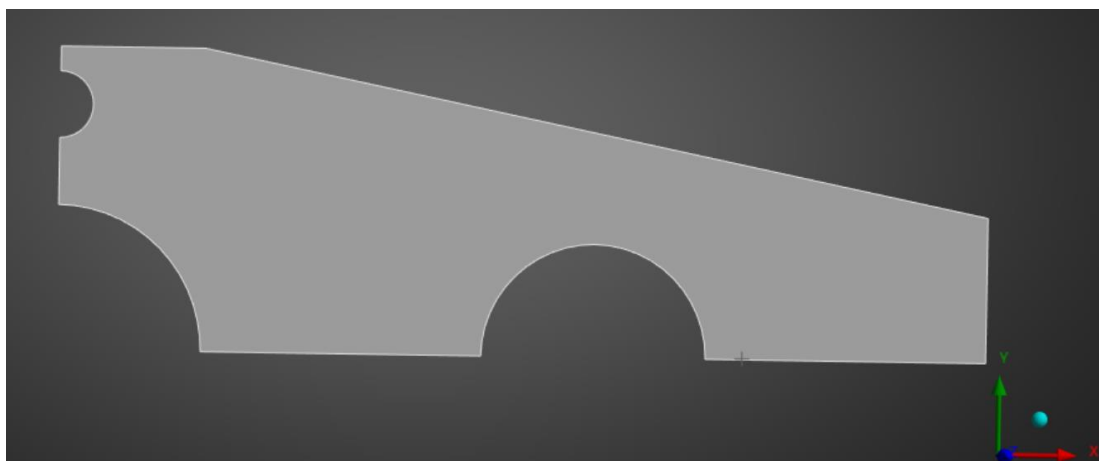


Figure 3: 2D - Quarter-model of the UAP Structure with Stress Relieving Holes

A quarter-model of the UAP structure, like the initial setup, was utilized to analyse the stress-relieving effects of holes introduced in high-stress regions. Figure 3 illustrates the modified

quarter-model with strategically positioned holes. The introduction of stress-relieving holes reduced the von-Mises stress concentration by 6.27%, lowering the maximum stress to 56.634 MPa. However, it must be noted that the hole on the left of the structure contributes the greatest to the stress relief as compared to other holes, and that the effect of stress relief is greatly diminished at other parts of the structure.

3 WEIGHT OPTIMISATION

Weight reduction is a critical factor in aerospace design, as it directly impacts fuel efficiency, range, and maneuverability of an aircraft. This chapter aims to reduce the weight of the UAP structure using ANSYS. Through topology optimisation in ANSYS, areas in the quarter-model were removed through the reduction of weight. Circular holes were strategically introduced in areas where stress and deformation limits remained within 112% and 180% of the maximum values observed in the original model.

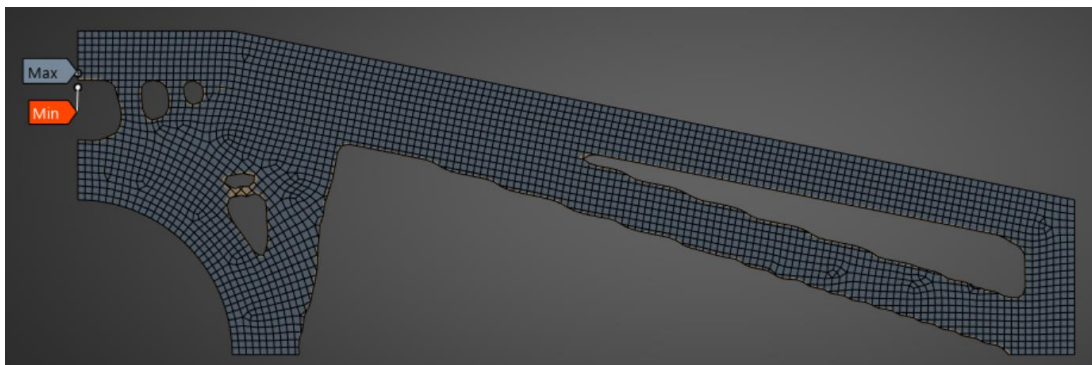


Figure 4: Results from Topology Optimisation

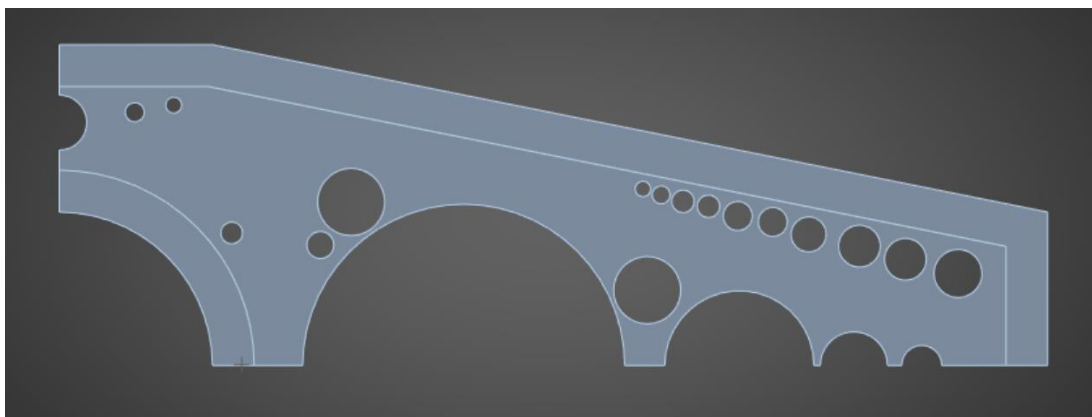


Figure 5: Model obtained from Reducing Weight of Structure

Based on the above model, the maximum stress obtained was 67.382 MPa, deformation in the x and y direction are 0.60385 mm and 0.60408 mm. The mass of the quarter-model was reduced from 5.65×10^{-3} kg to 3.93×10^{-3} kg, which is a 30.4% decrease in mass.

4 DISCUSSION AND CONCLUSION

The structure of the UAP with stress-relieving holes can reduce the peak stress experienced by the model by 6.27%. By reducing the peak von-Mises stress, the overall fatigue life and integrity of the structure is enhanced, minimising the risk of fatigue failure and other stress-related issues due to cyclic loading, especially in aerial purposes such as flight. This enhances the lifespan of the aircraft, minimise structural failures and extend the aircraft's service life.

On the other hand, focusing on weight optimisation, while reducing the weight by 30%, increases the maximum stress experienced. This trade-off between weight reduction and increased stress should be carefully managed as reducing the weight of the aircraft is crucial as it allows for lower consumption of fuel, improves overall performance and makes an aircraft more efficient, more manoeuvrable and increase its range.

However, manufacturing the weight-optimised structure will be time-consuming and requires careful precision in machining the holes, leading to higher production costs. Additionally, due to the number of holes on the structure, maintenance will be more complex, time consuming and costly due to the intricacies of the design. Compared to the stress-reduced structure, it has fewer circular holes and therefore comparatively less time-consuming and complex.