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INTERNATIONAL CONFERENCE ON COMPUTATIONAL METHODS IN ENGINEERING & HEALTH SCIENCES 2023



A new Master Course in Applied
Computational Fluid Dynamics

team aardhan

presents

AEROFOIL OPTIMISATION

Kanak Agarwal

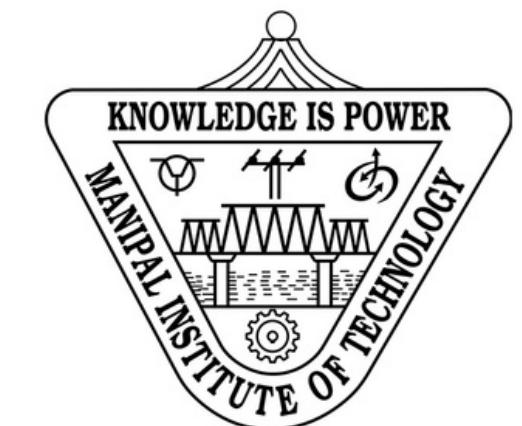
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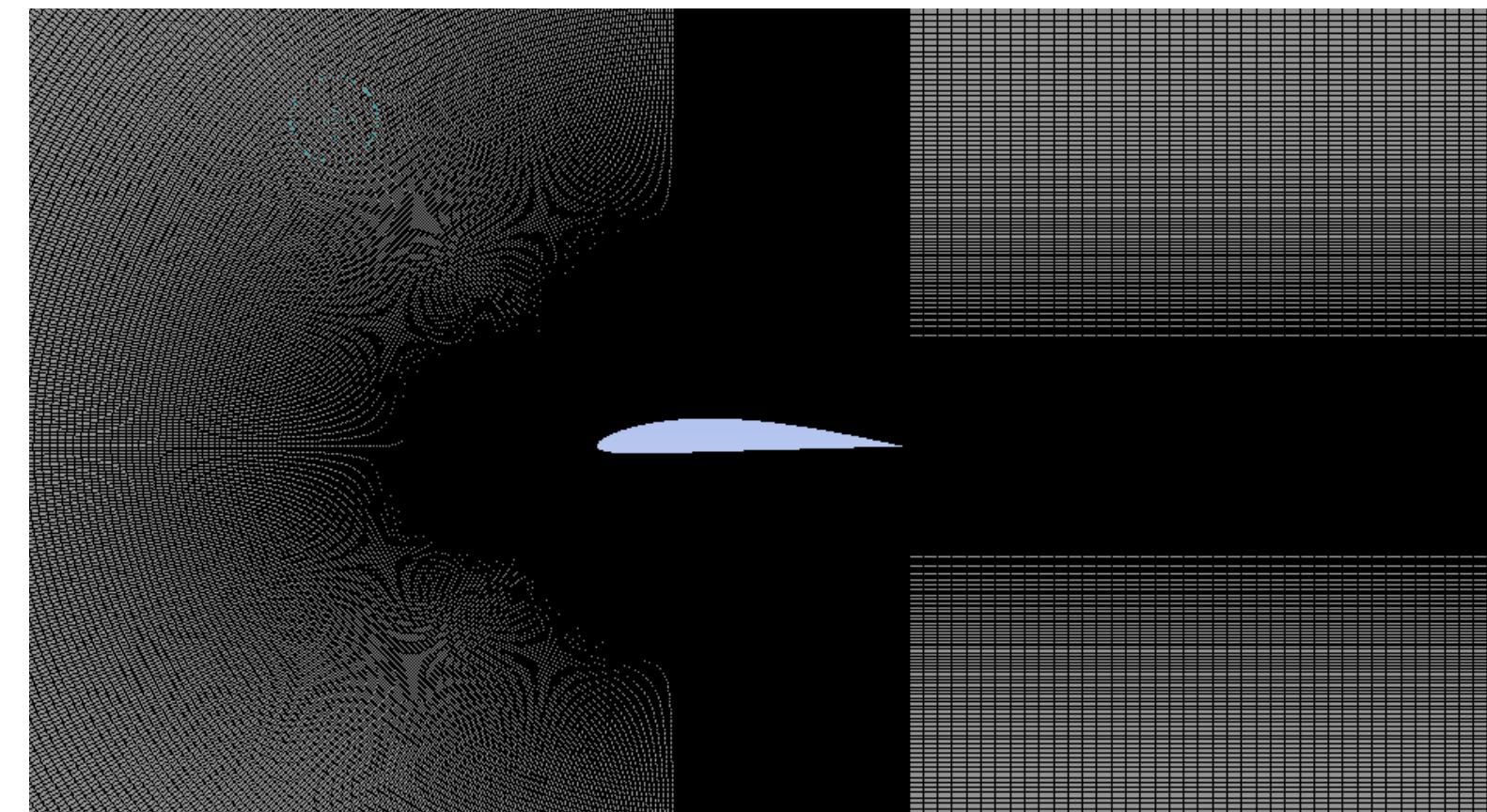


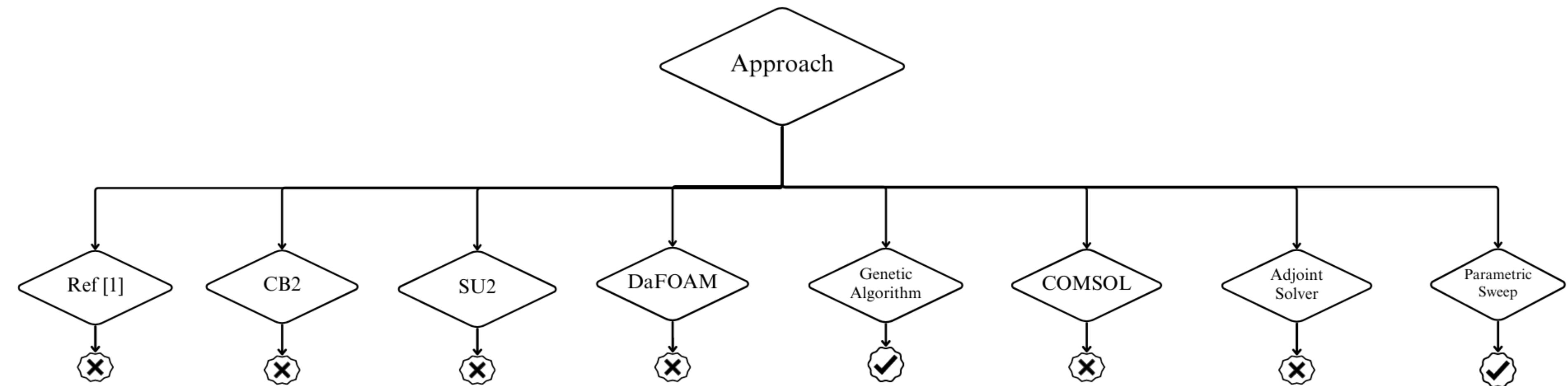
MANIPAL INSTITUTE OF TECHNOLOGY



Parametric Sweep

- A Parametric Simulation was conducted in Ansys Fluent to gain an insight into the given problem, this was done for Mach numbers 0.3 to 0.79 with a step of 0.1 and angle of attacks 2, 3.5, and 5 degrees.
- Multiple meshes were made, finally, the mesh with the following parameters was chosen:
 - Number of Elements - 409700
 - Max skewness - 0.5219
 - Min Orthogonality - 0.4677
 - Average Aspect Ratio - 8.5846





Ref[1] Airfoil Optimization Using XFOIL and PARSEC Geometric Parameterization (MATLAB File Exchange)

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MATLAB File Exchange

This approach was abandoned due to the unavailability of the PARSEC coefficients during the initial stages of the study, and it felt inappropriate to use an existing code for a competition.

This approach was abandoned due to the unavailability of the L/D based optimisation.

CB2

SU2

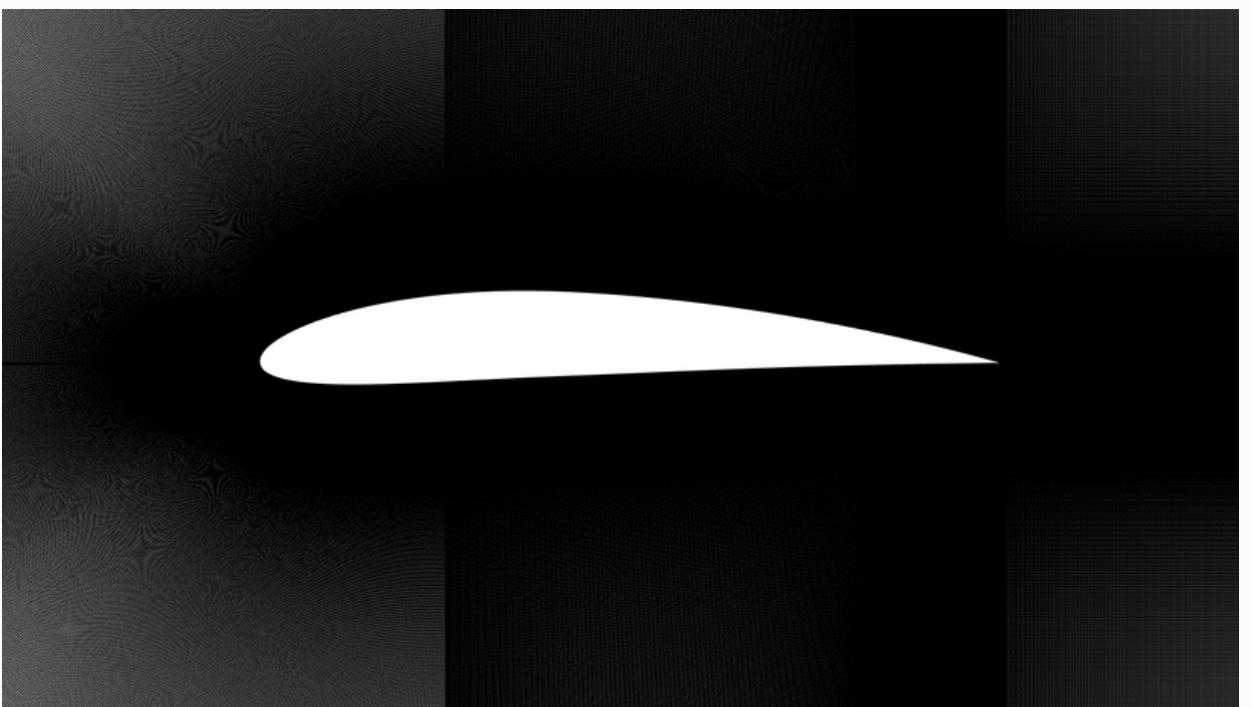
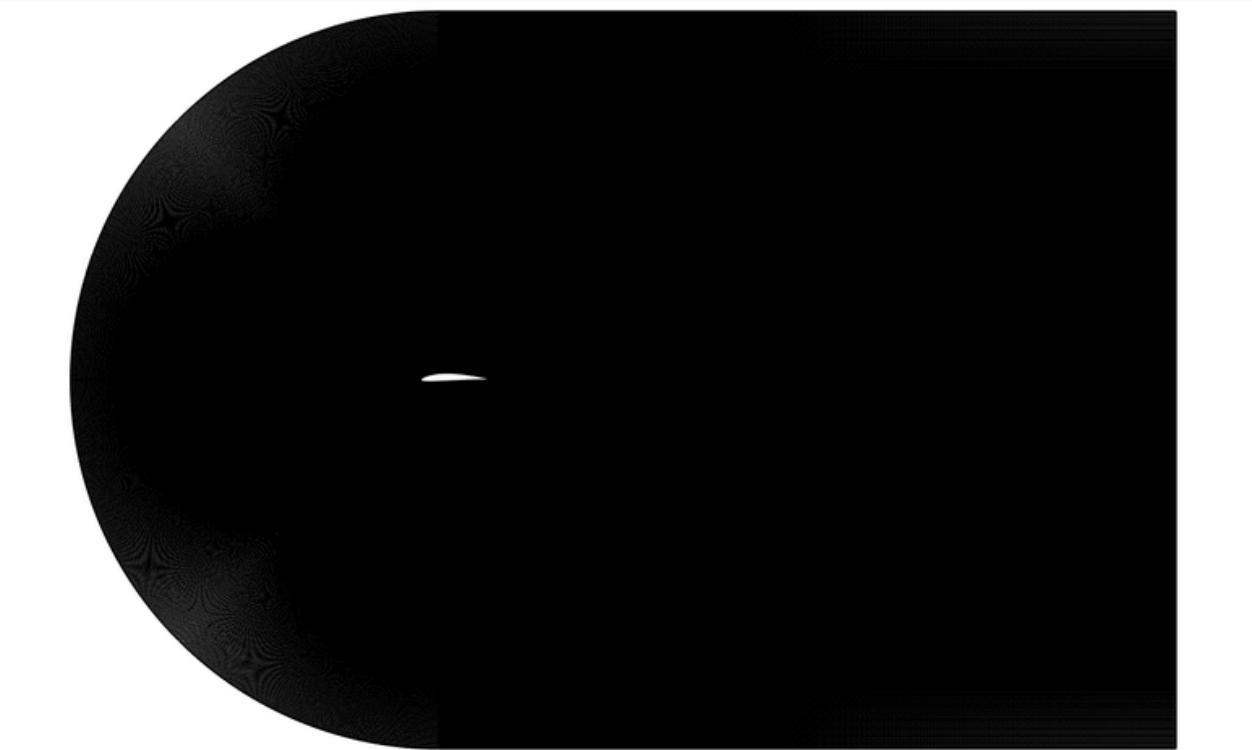
This approach was abandoned due to technical difficulties faced during software installation.

This approach was abandoned due to the inability to introduce a shape constraint in the current architecture; this was confirmed by Dr. Ping He, the author of the solver.

DaFOAM

COMSOL

As the deadline approached, we tried using COMSOL. We were able to make the mesh but couldn't set up and get the simulation running due to the novelty of the software.



Statistics

Mesh

Build All

Geometric Entity Selection

Geometric entity level: Entire geometry



Element Quality

Quality measure: Skewness

Statistics

Mesh with unmeshed edges

Mesh vertices: 3970967

Element type: All elements

Quads: 3967000

Edge elements: 14934

Vertex elements: 1972

Domain element statistics

Number of elements: 3967000

Minimum element quality: 0.479

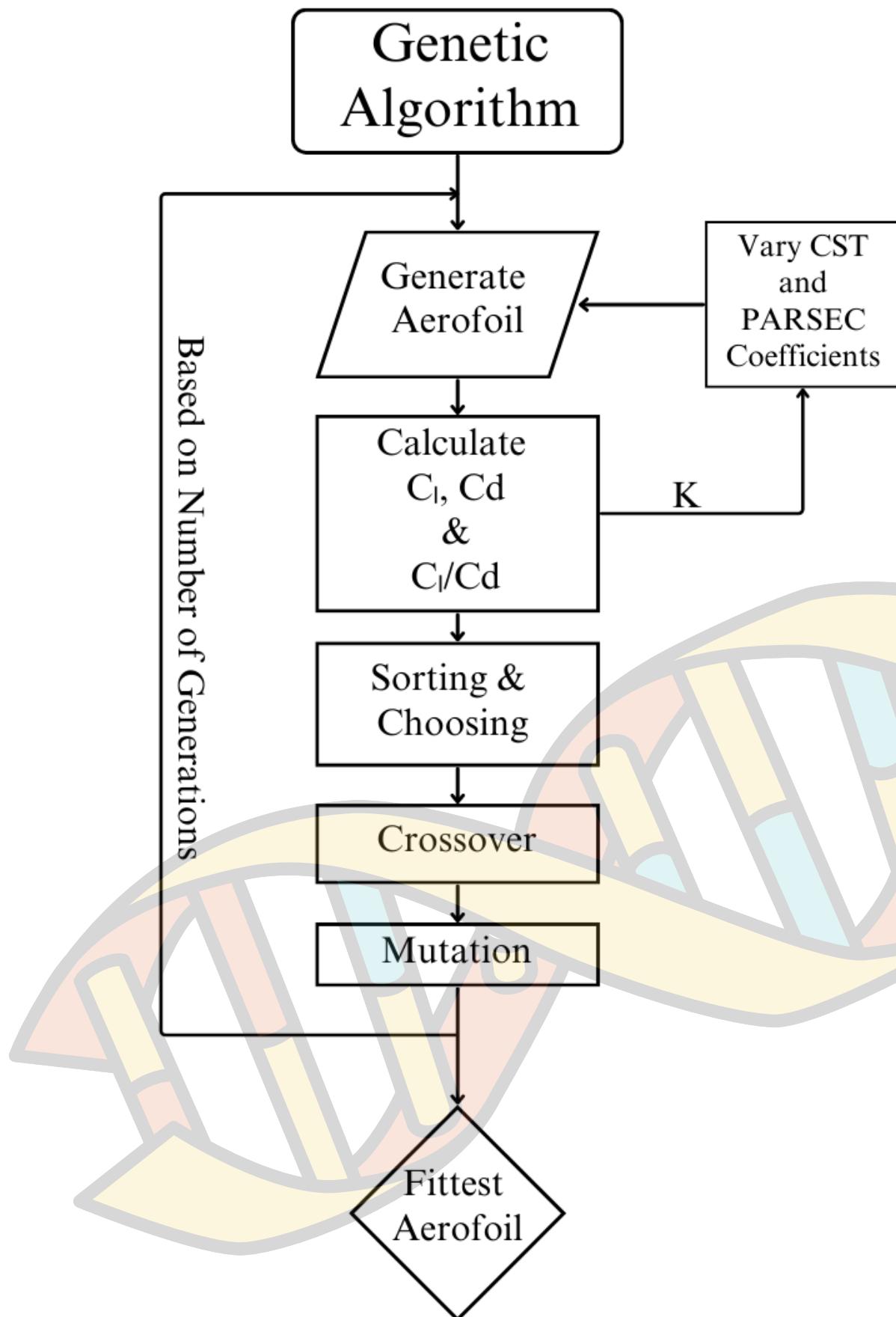
Average element quality: 0.9748

Element area ratio: 7.912E-5

Mesh area: 139.2 m²

Element Quality Histogram

Genetic Algorithm



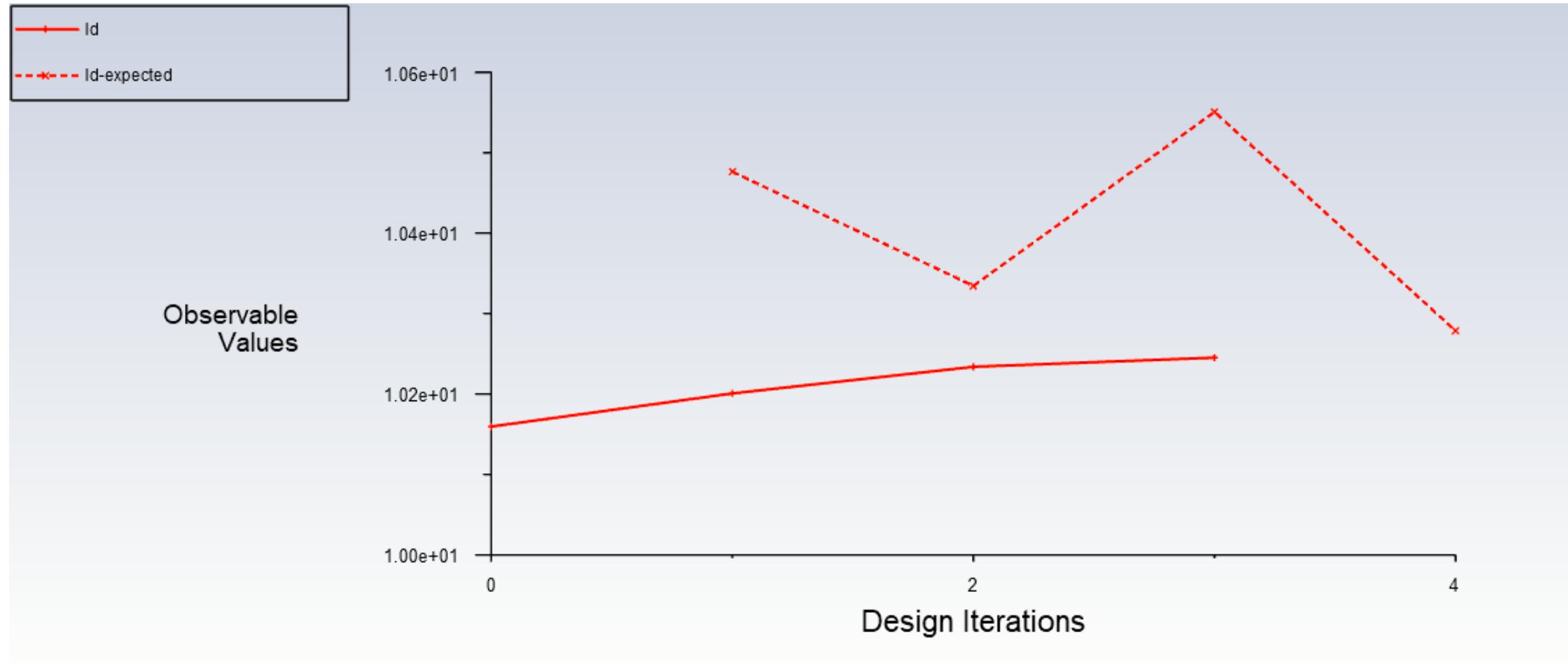
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- The Initial Aerofoil was generated using the standard equations.
- The CST and PARSEC coefficients were varied based on the predefined limits.
- The algorithm was built to optimize one of the following parameters:
 - Coefficient of Lift (C_l)
 - Coefficient of Drag (C_d)
 - L/D ratio

Genetic Algorithm Specifications

- Number of Generations: 40
- Number of aerofoils generated: 30

Ansys Adjoint Solver

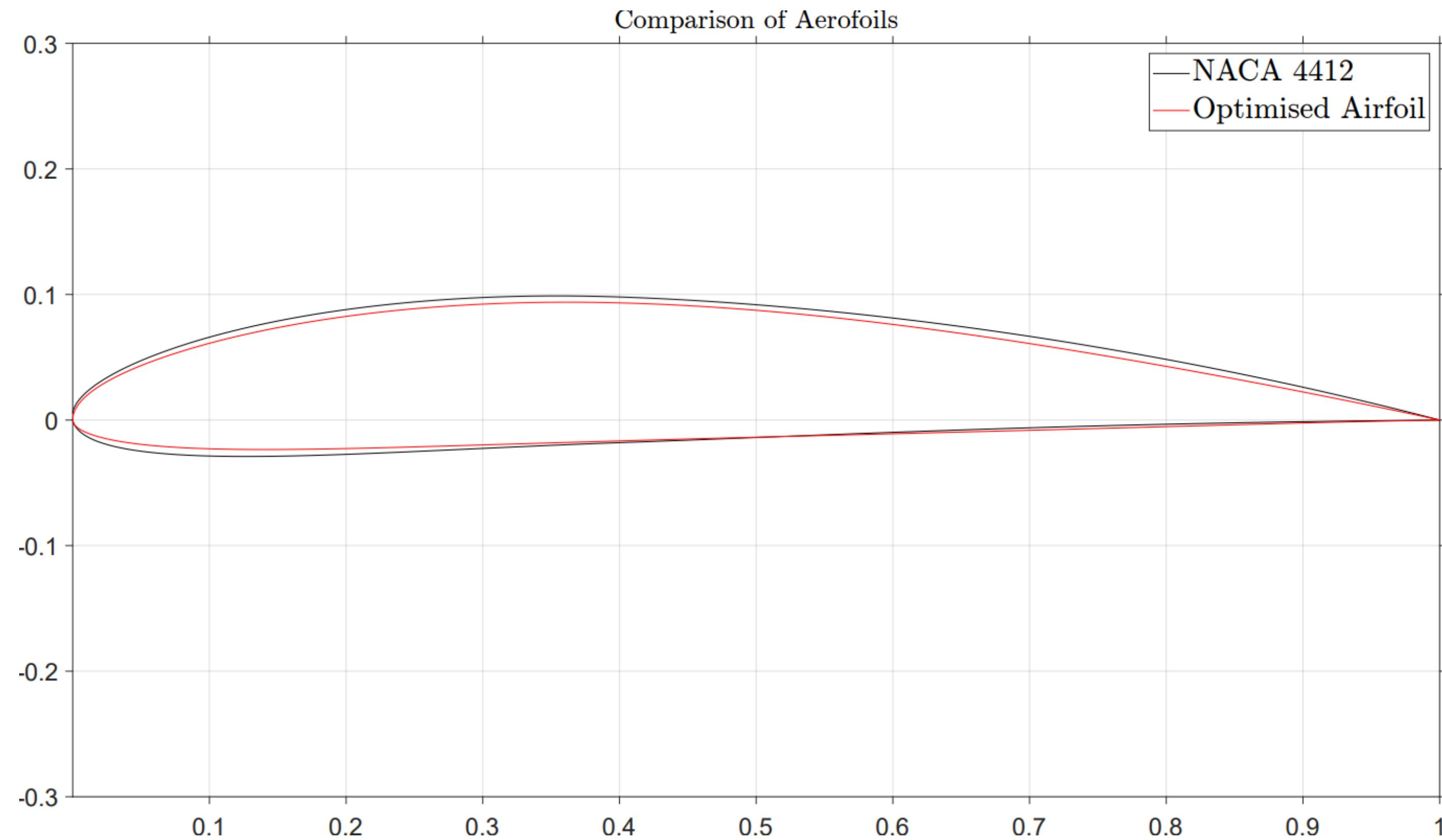


During the concluding phases of the competition, we implemented this approach. However, we encountered the following challenges:

- Either the minimum element quality criteria were not satisfied.
- The L/D ratio remained unchanged beyond a specific number of design point iterations.

Final Approach

As the deadline was approaching we chose genetic algorithm as our final approach and carried out a parametric sweep on the aerofoil thus obtained to validate the results of our optimisation.

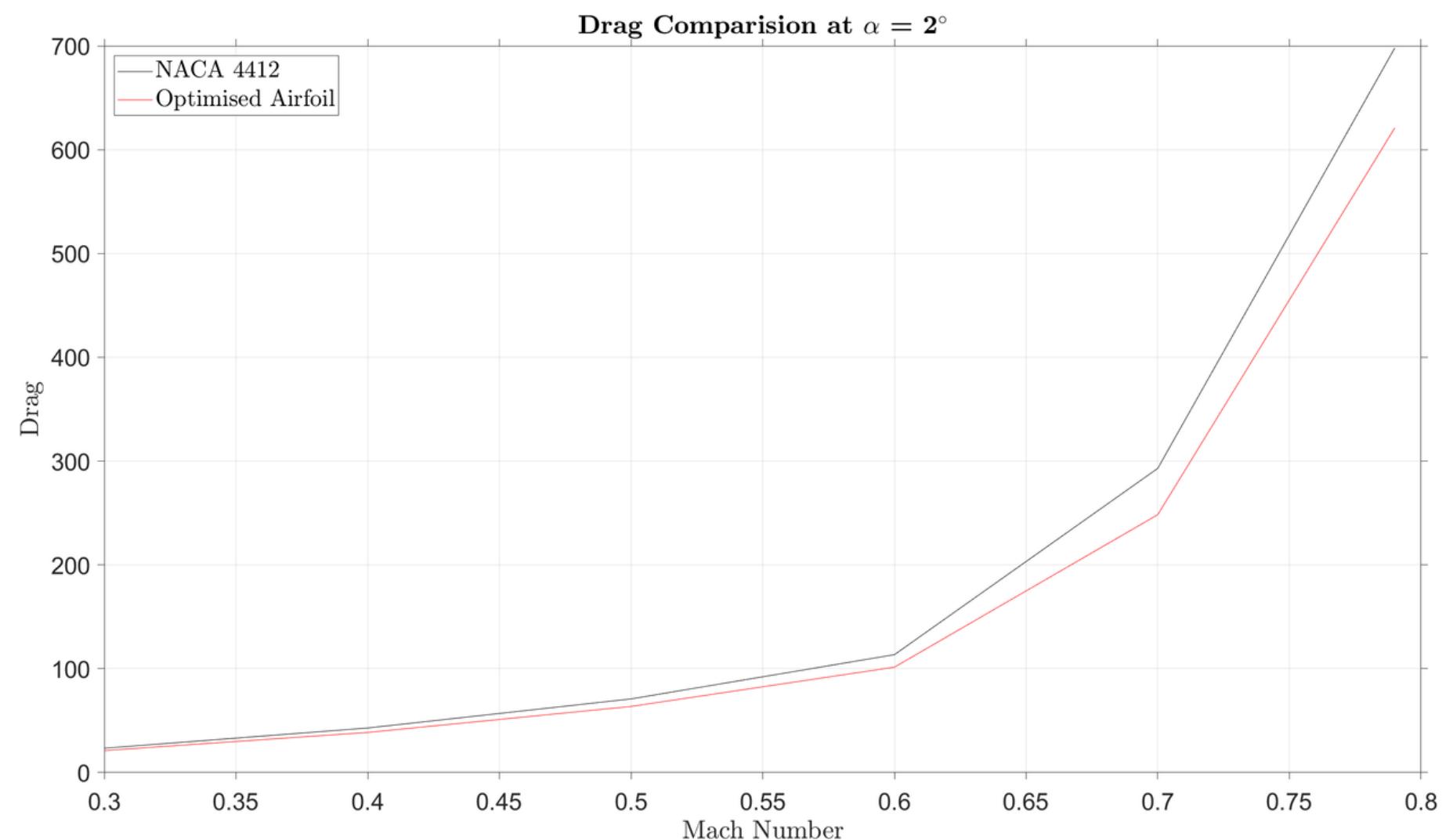
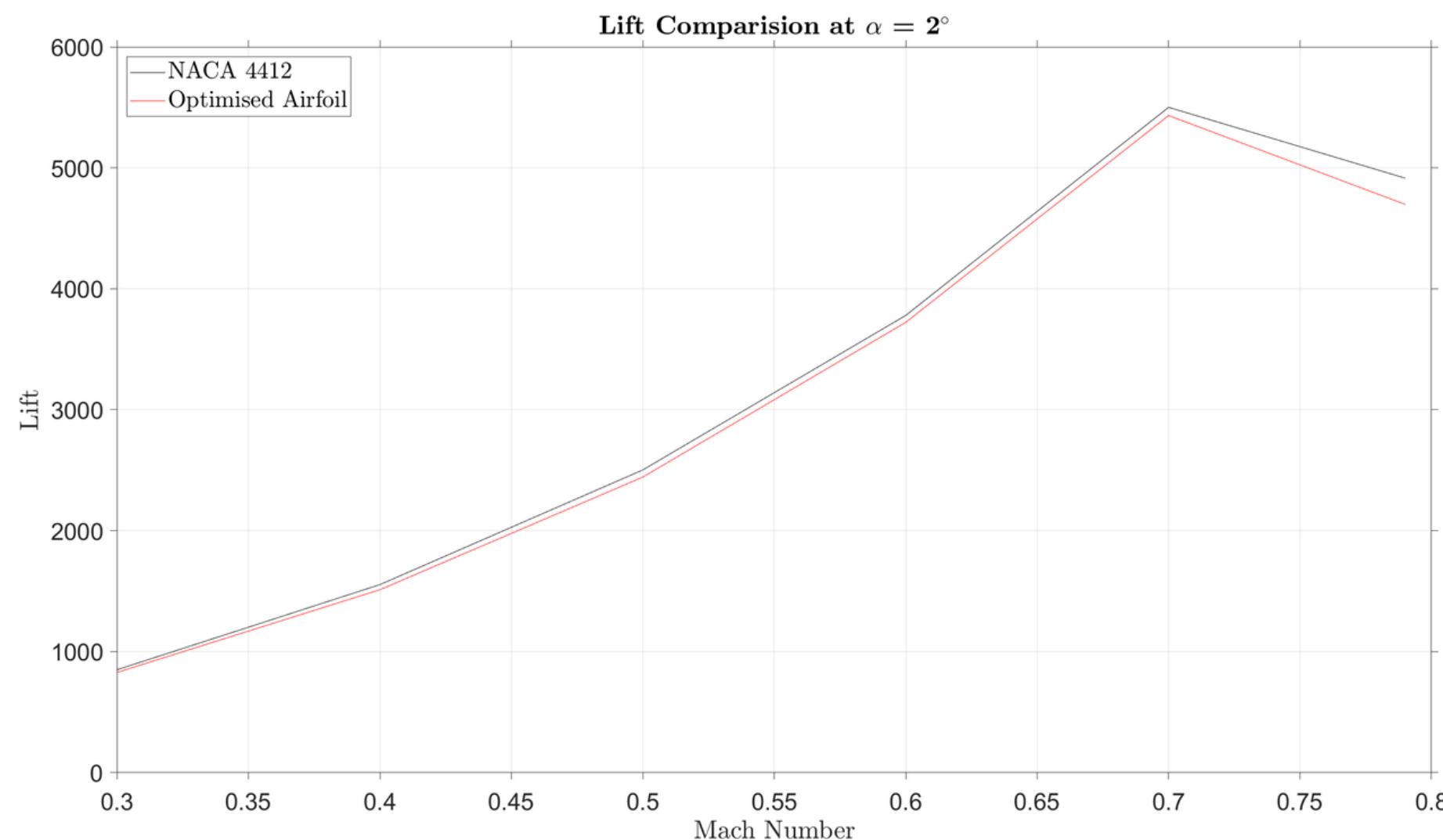


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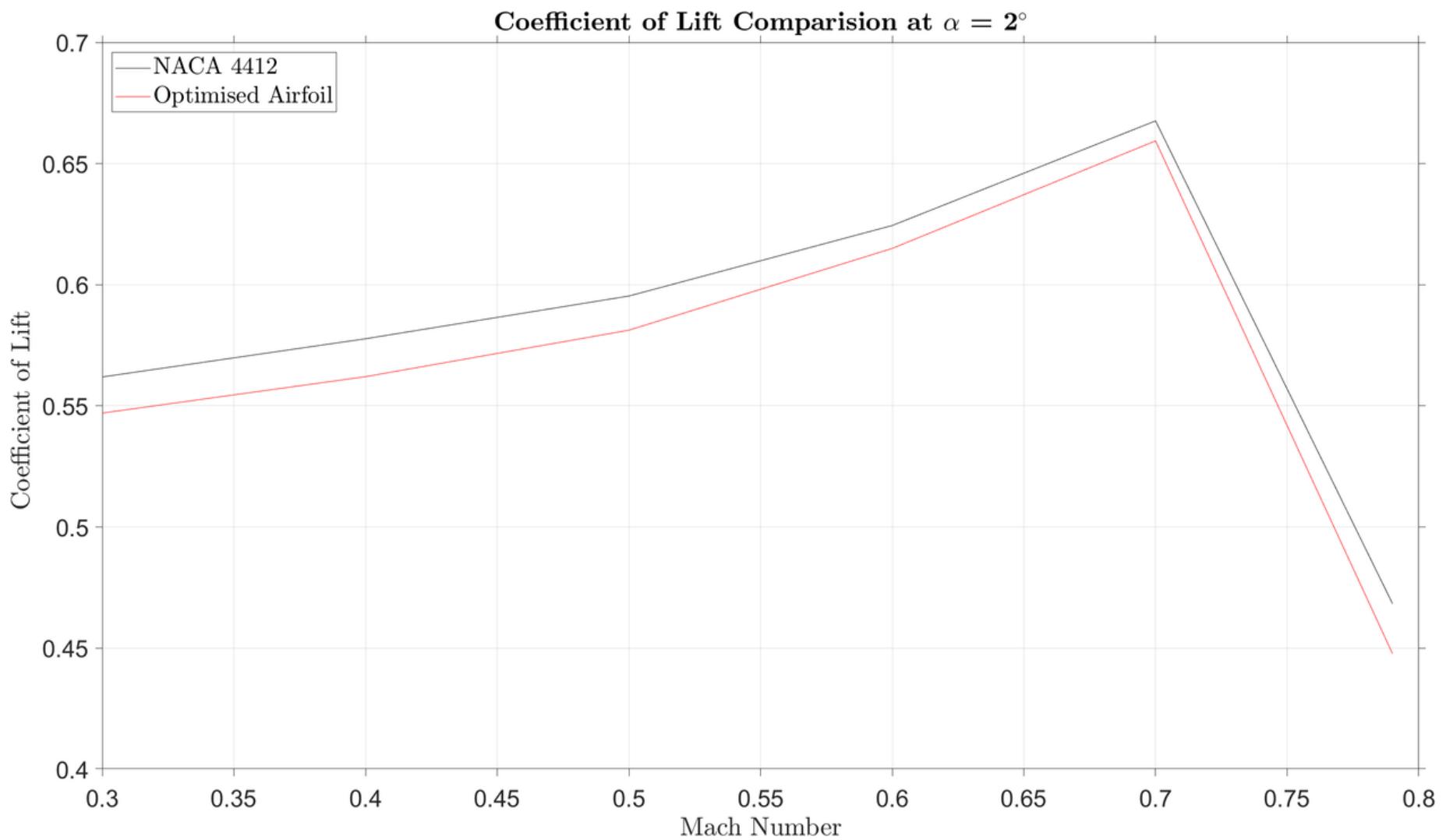
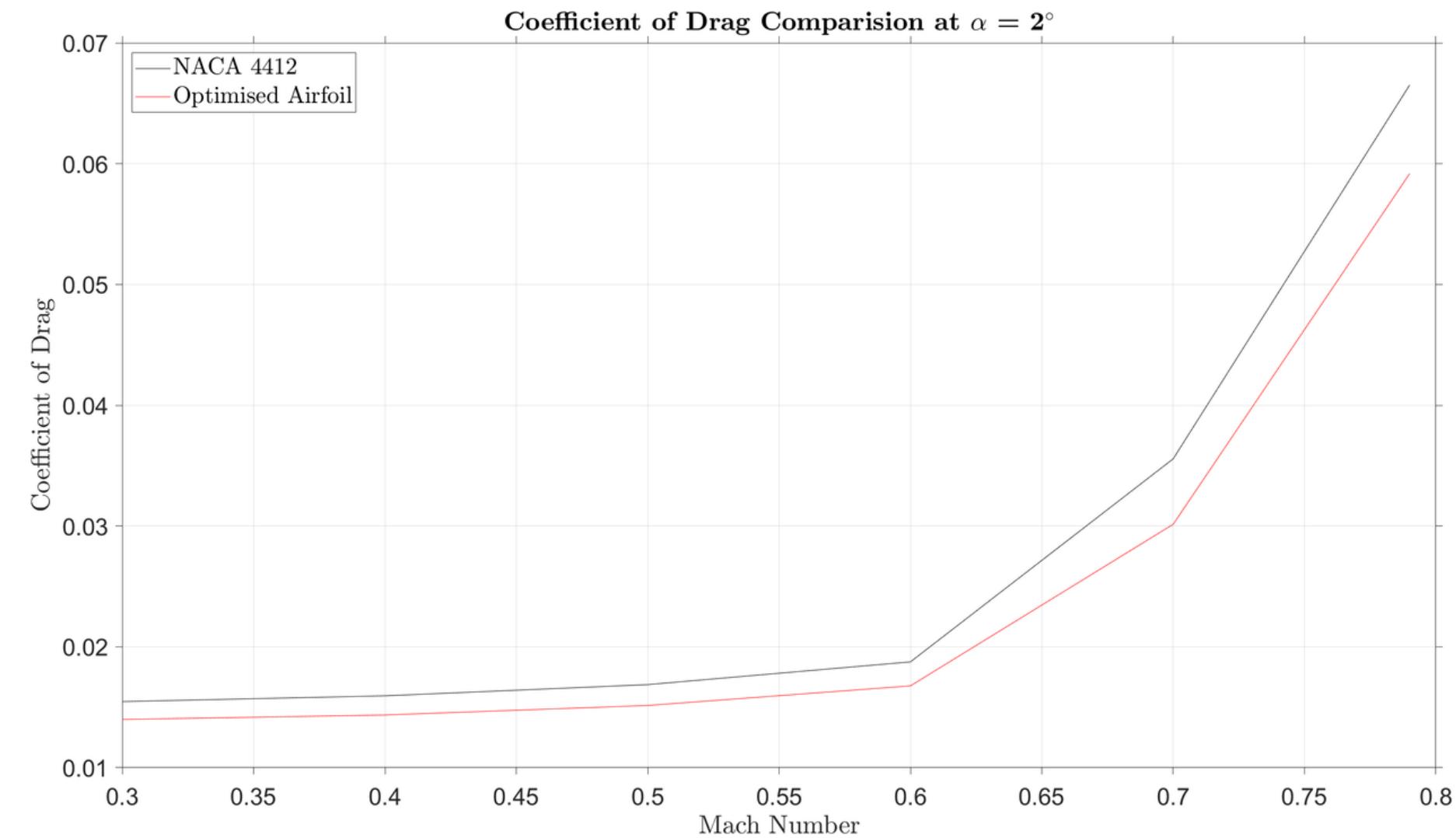
PARAMETRIC
SWEEP
ANALYSIS

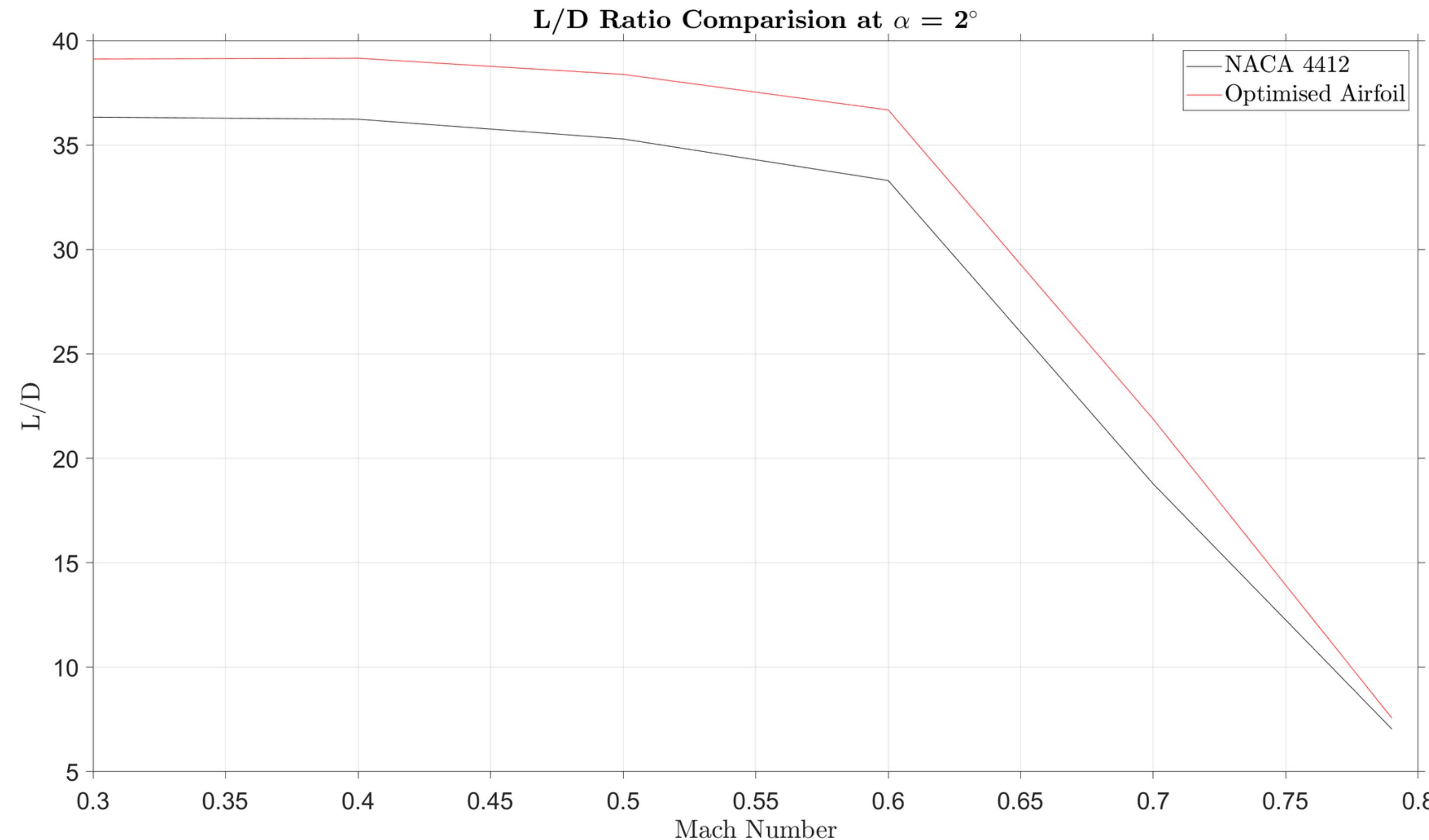


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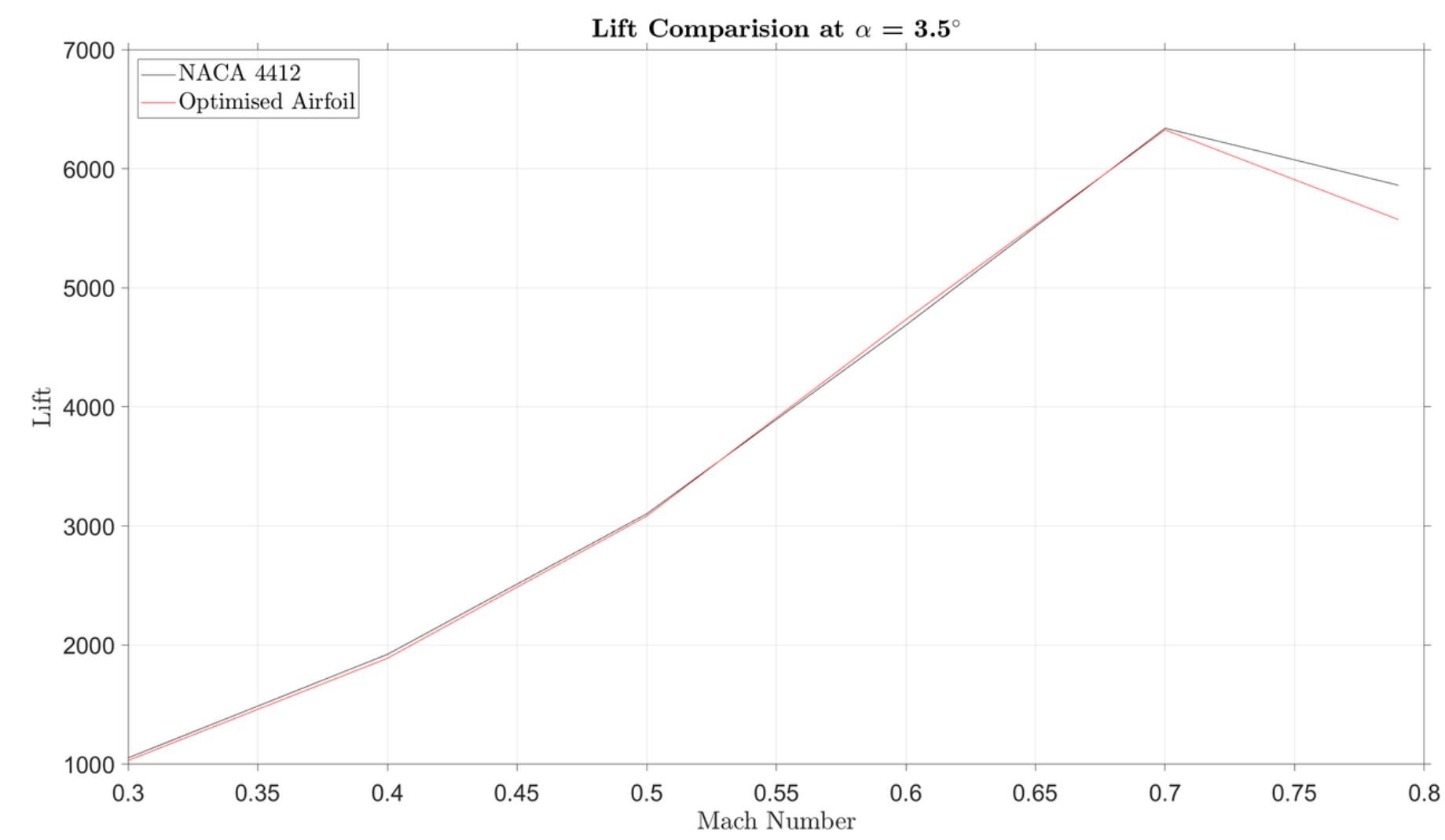
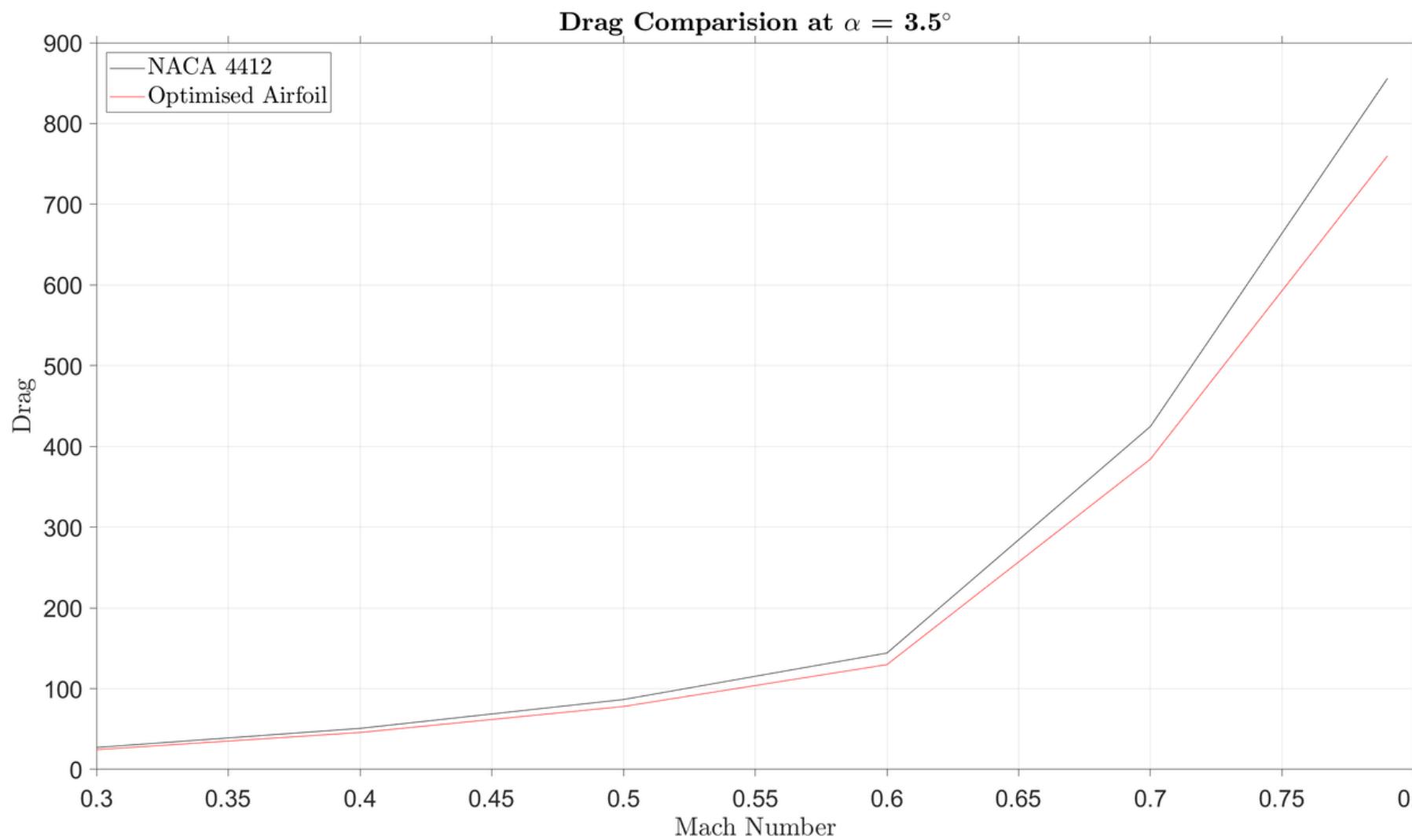


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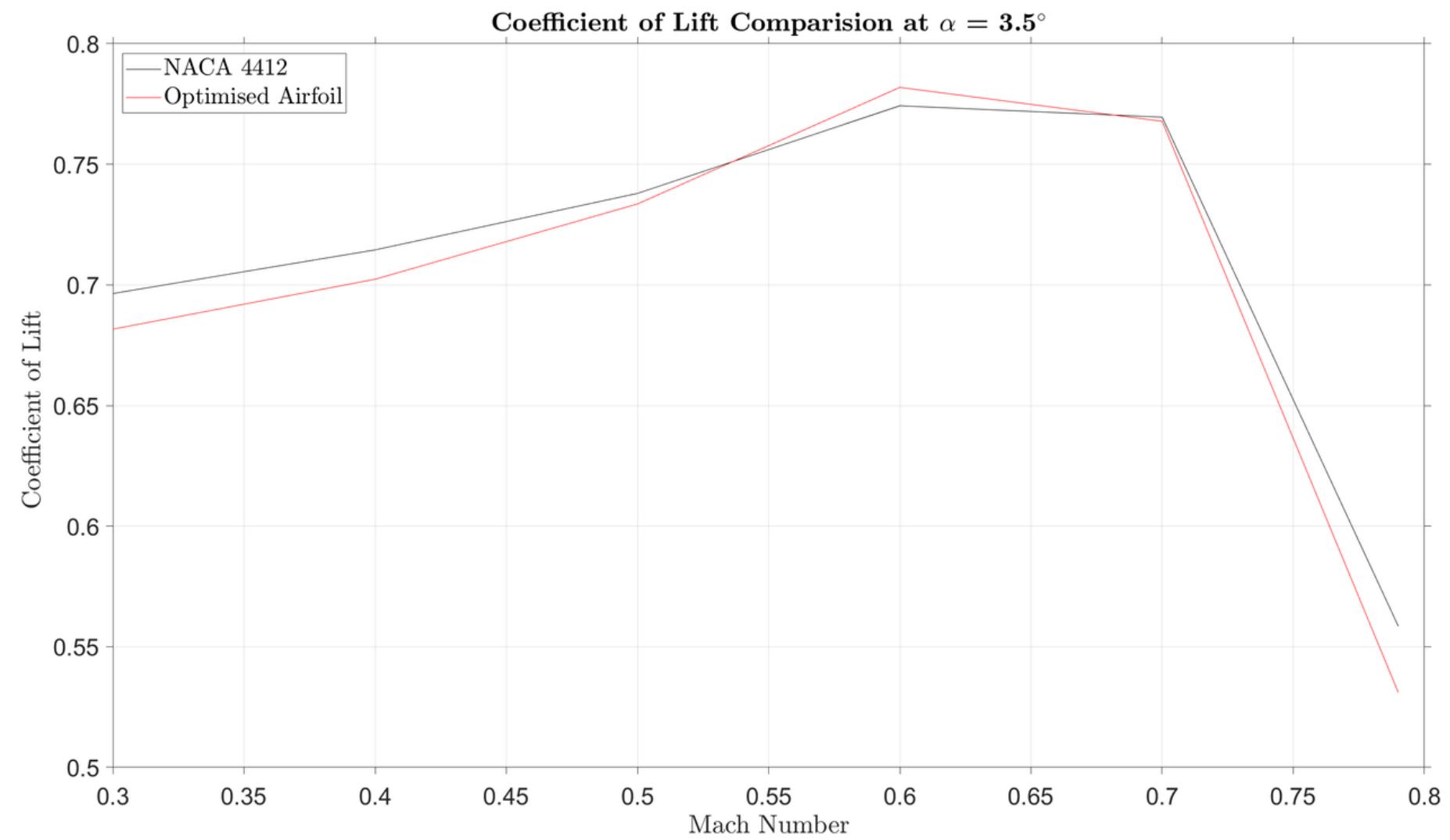
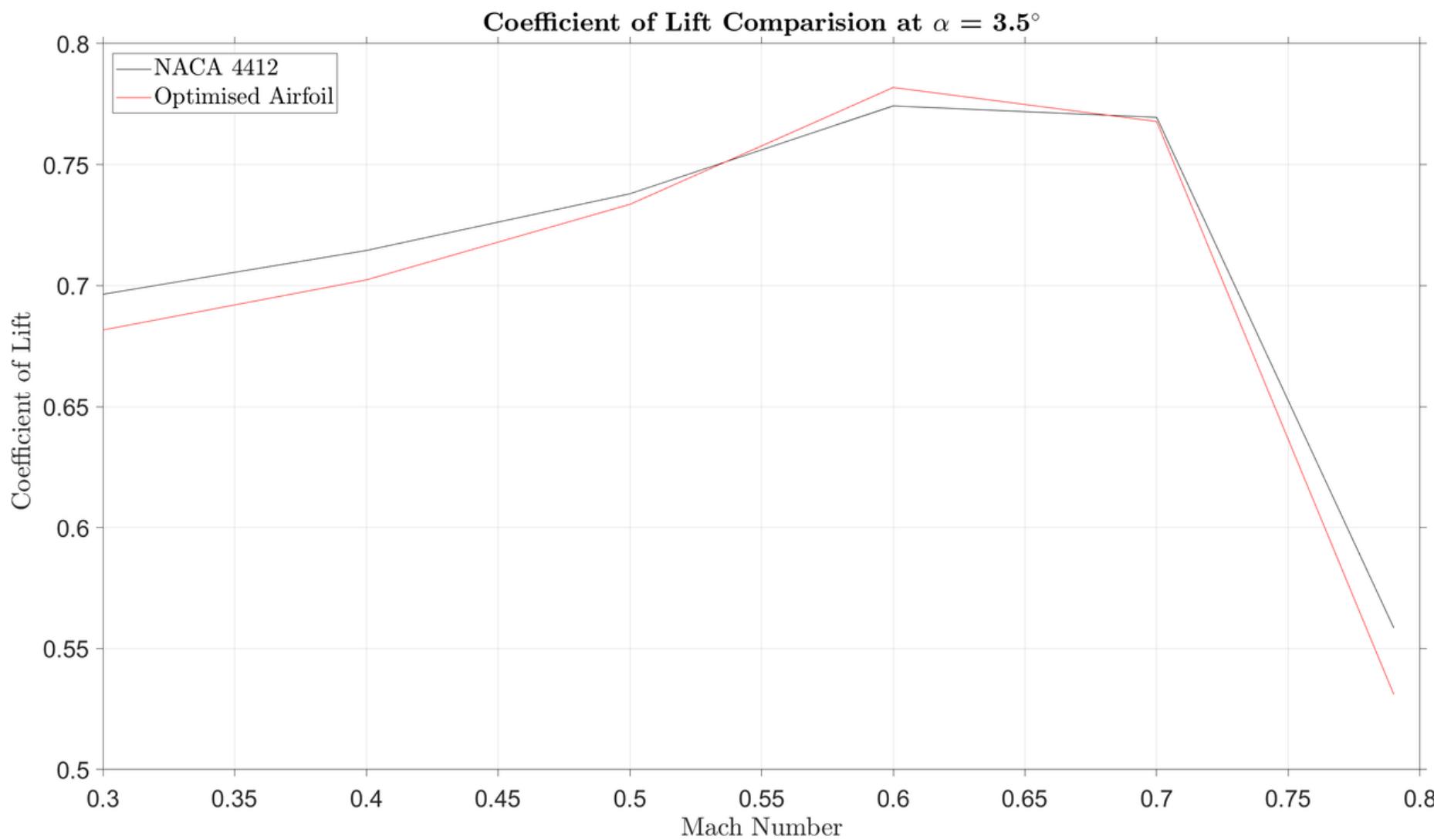


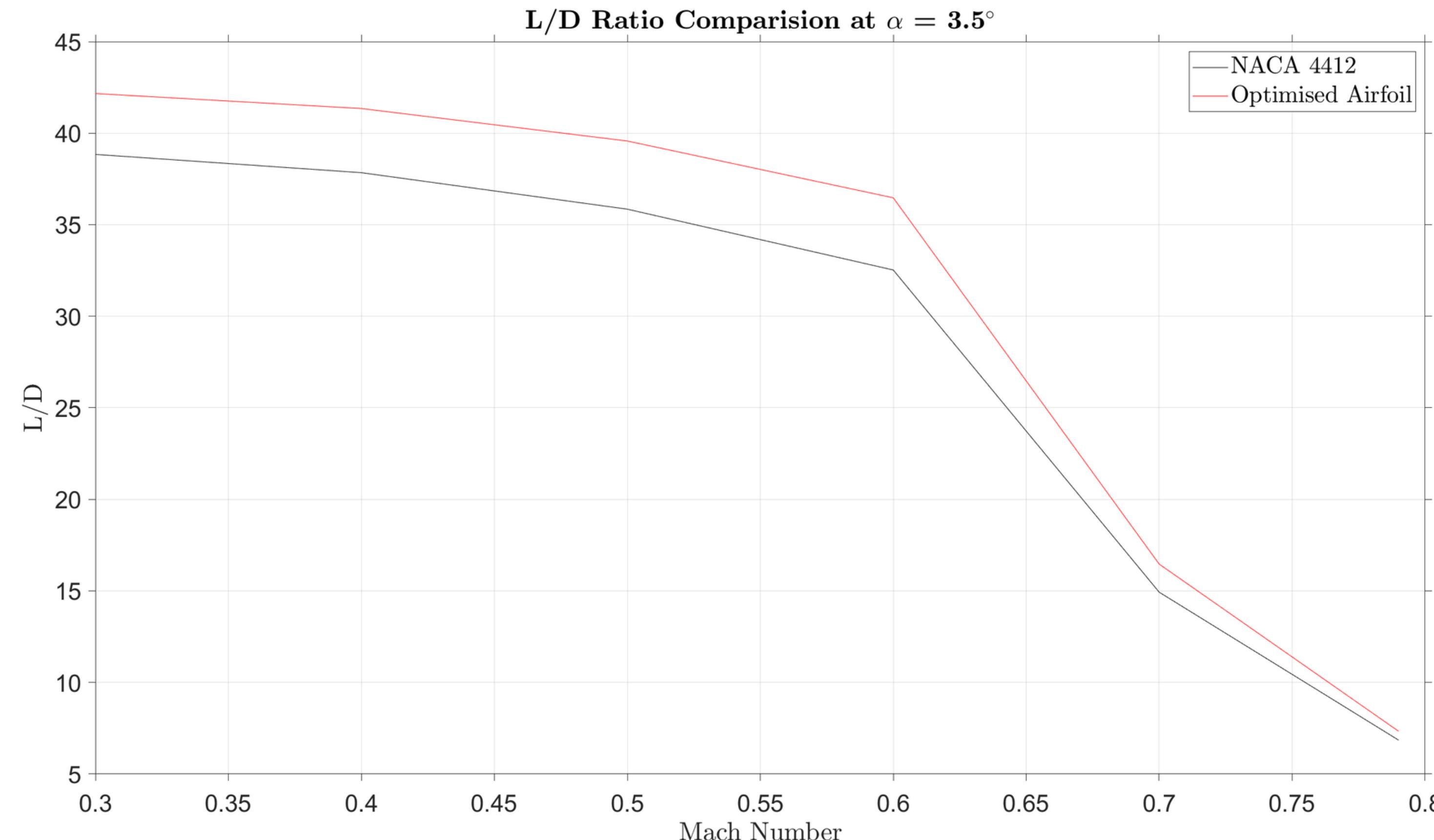


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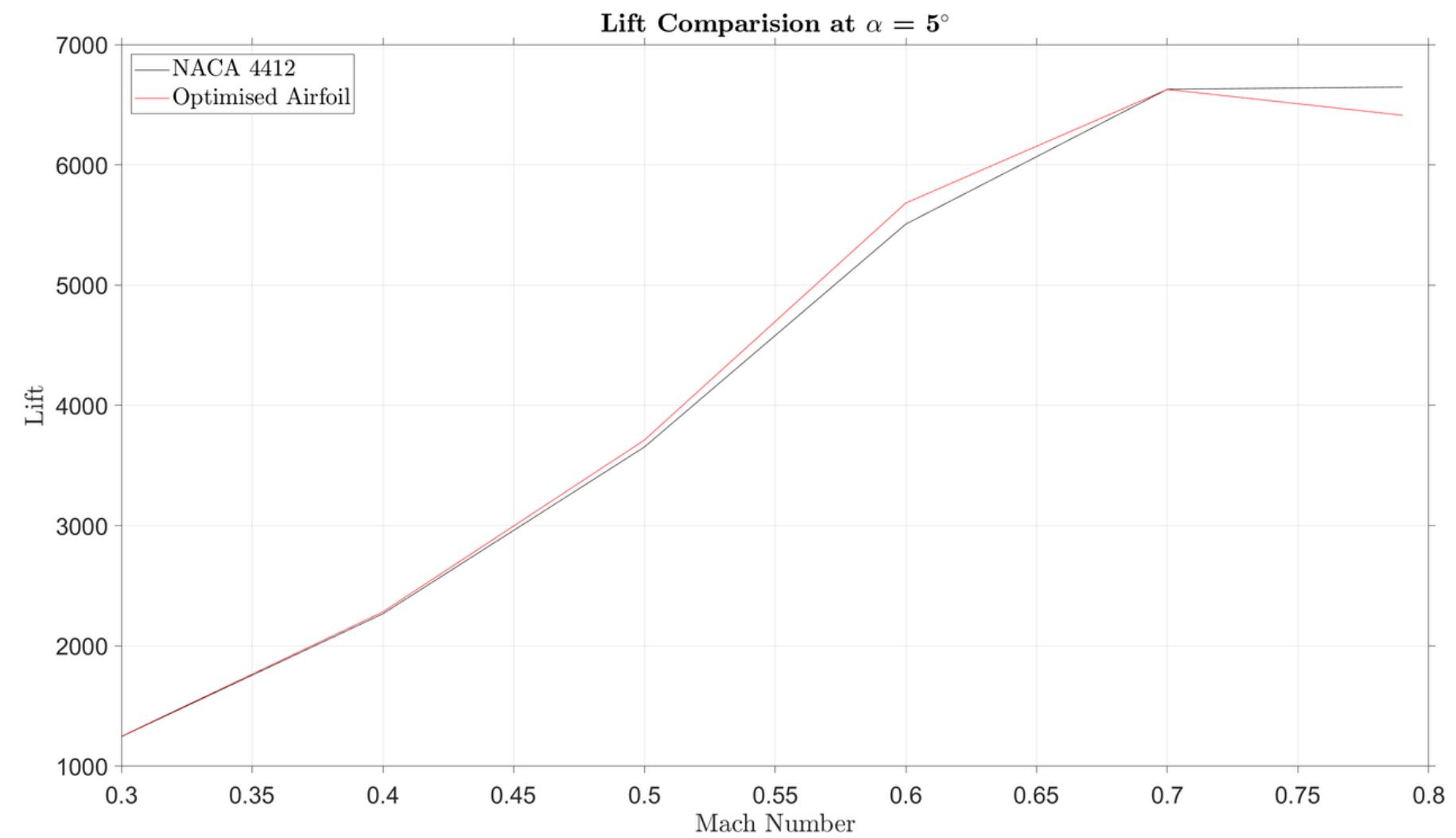
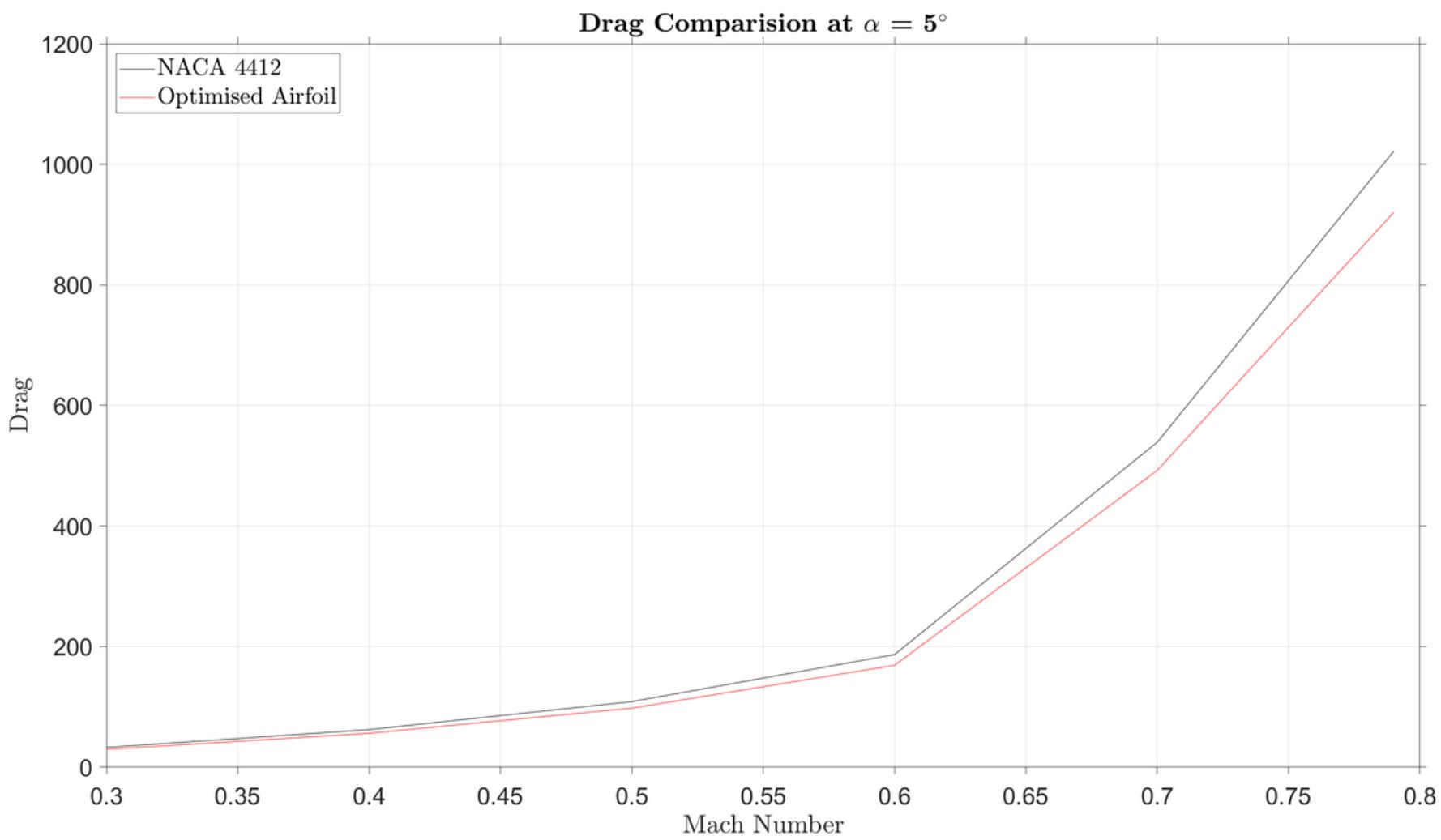


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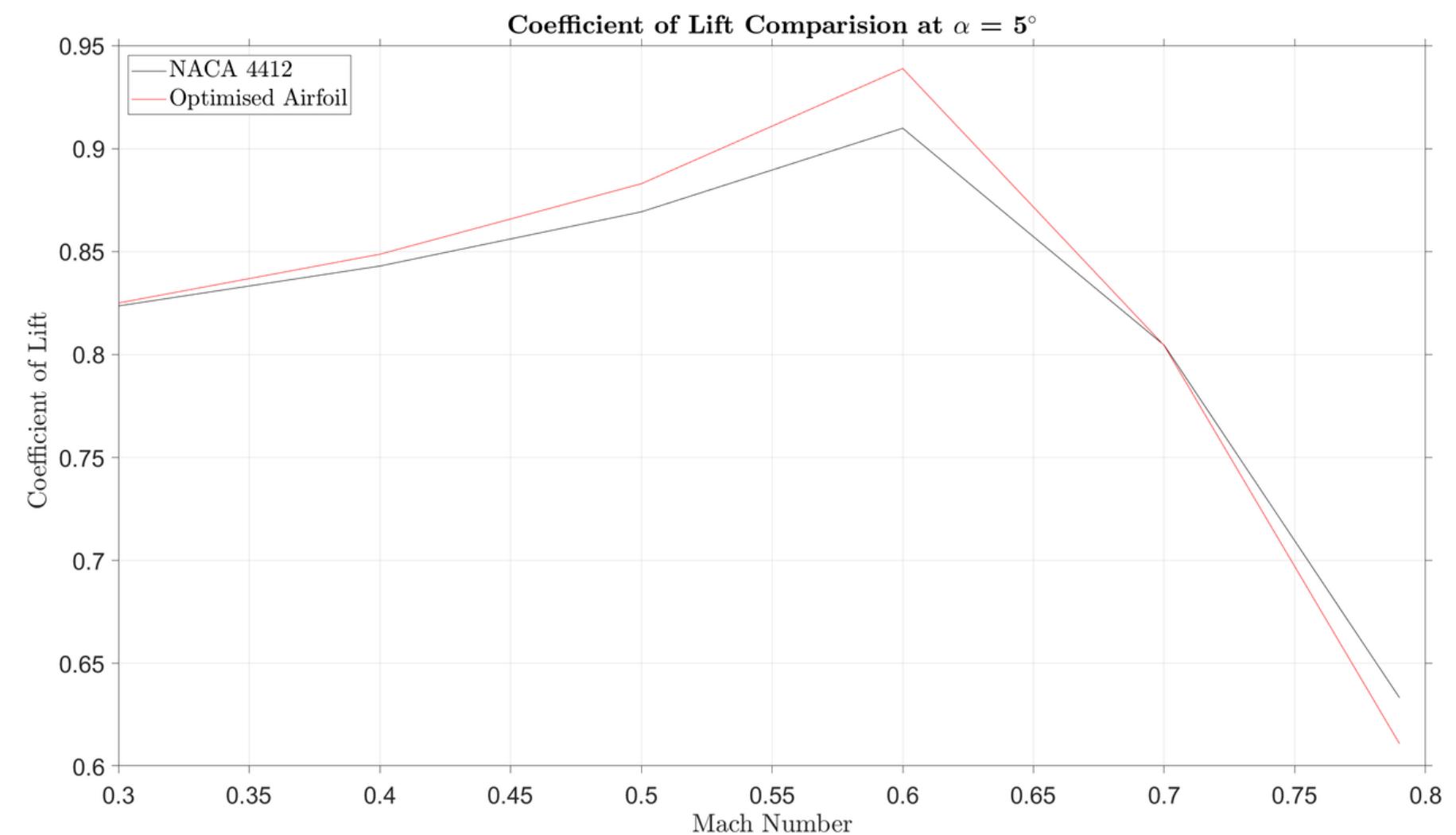
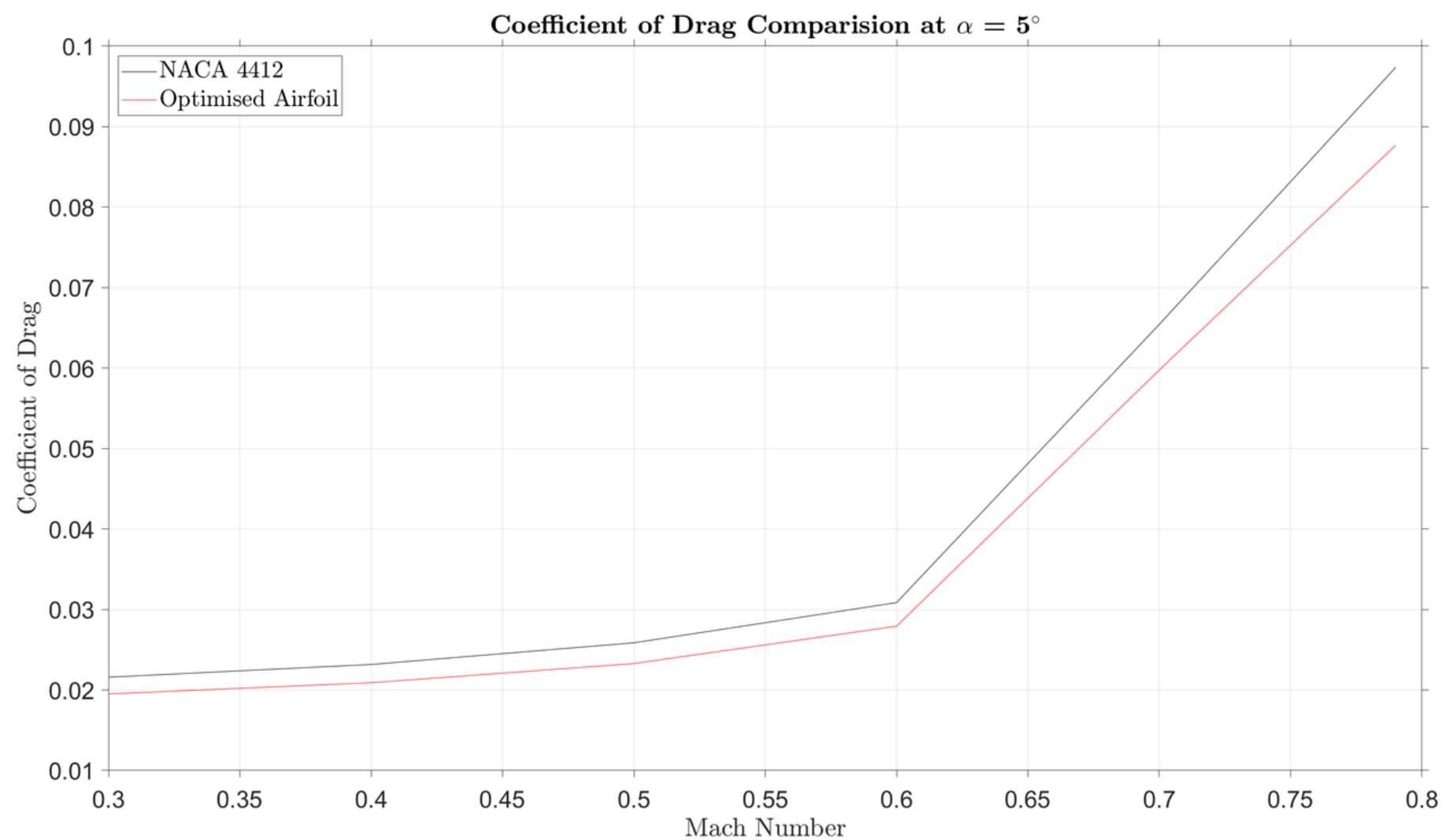




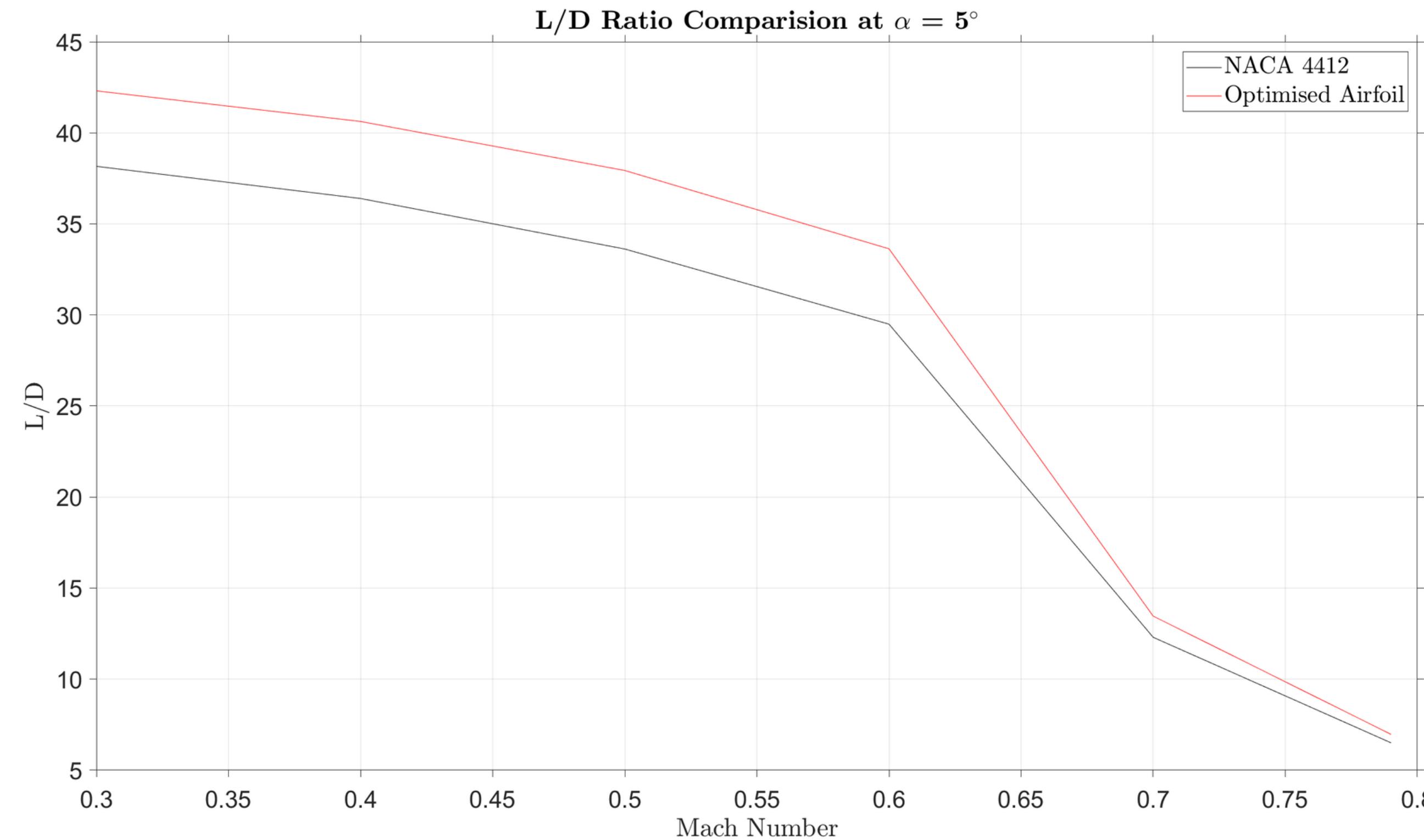
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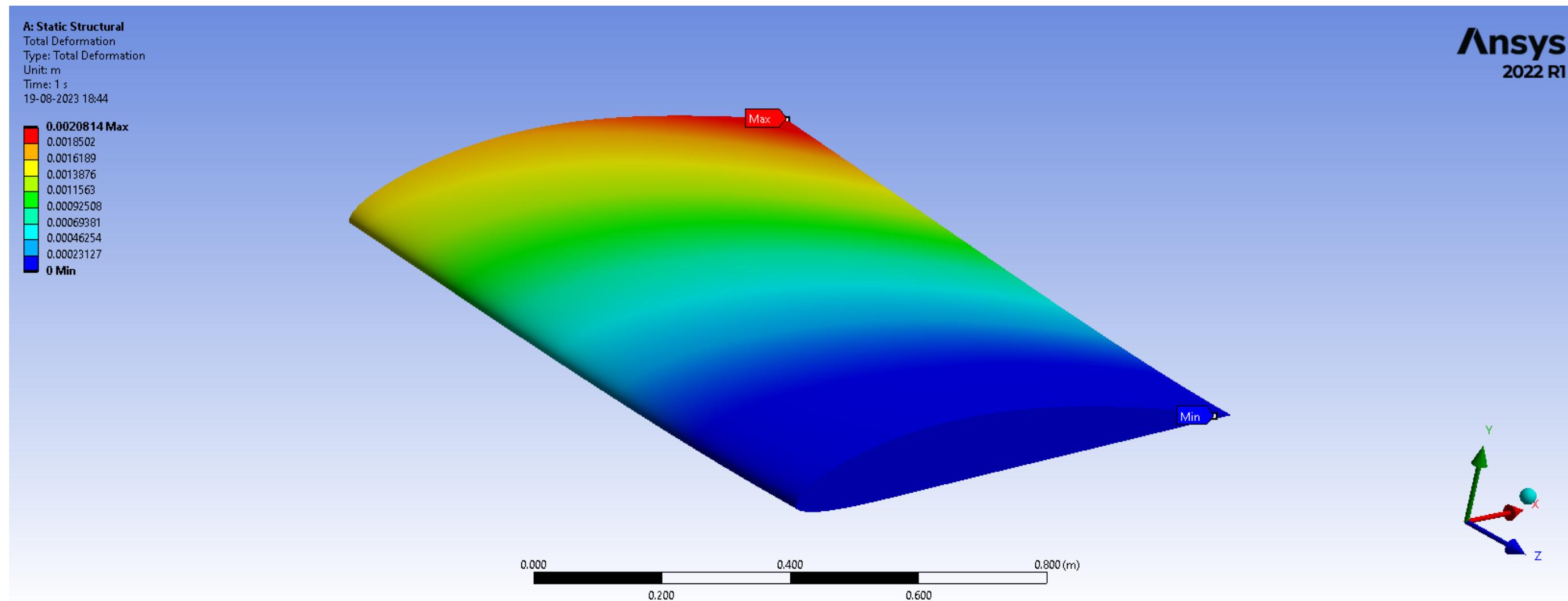
STATIC STRUCTURAL ANALYSIS

A Static Structural Analysis was carried out in Ansys Mechanical to choose the material.

The simulation was carried out by considering a wingspan of 1m, a fixed support at one end of the wing and the calculated pressure was assigned to the upper and lower surfaces of the wing with a factor of 1.5.

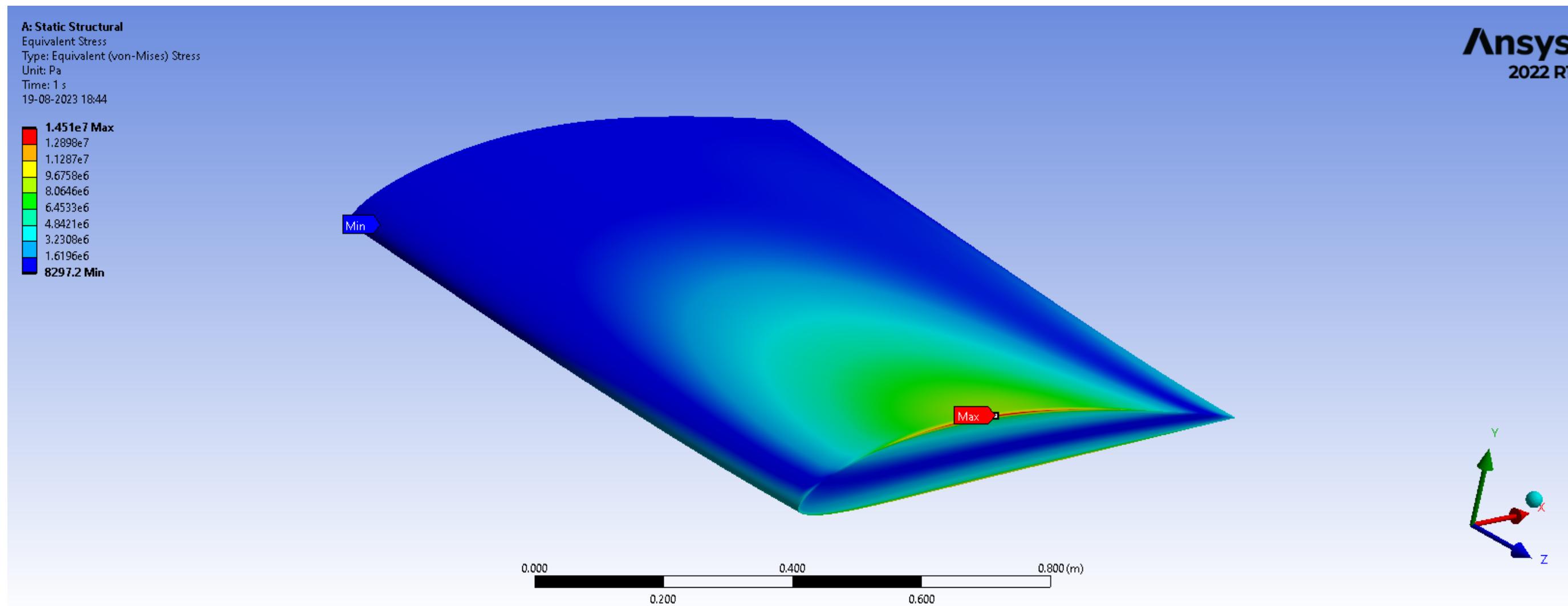
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Material - CFRP



Max Deformation - 0.0020814 m

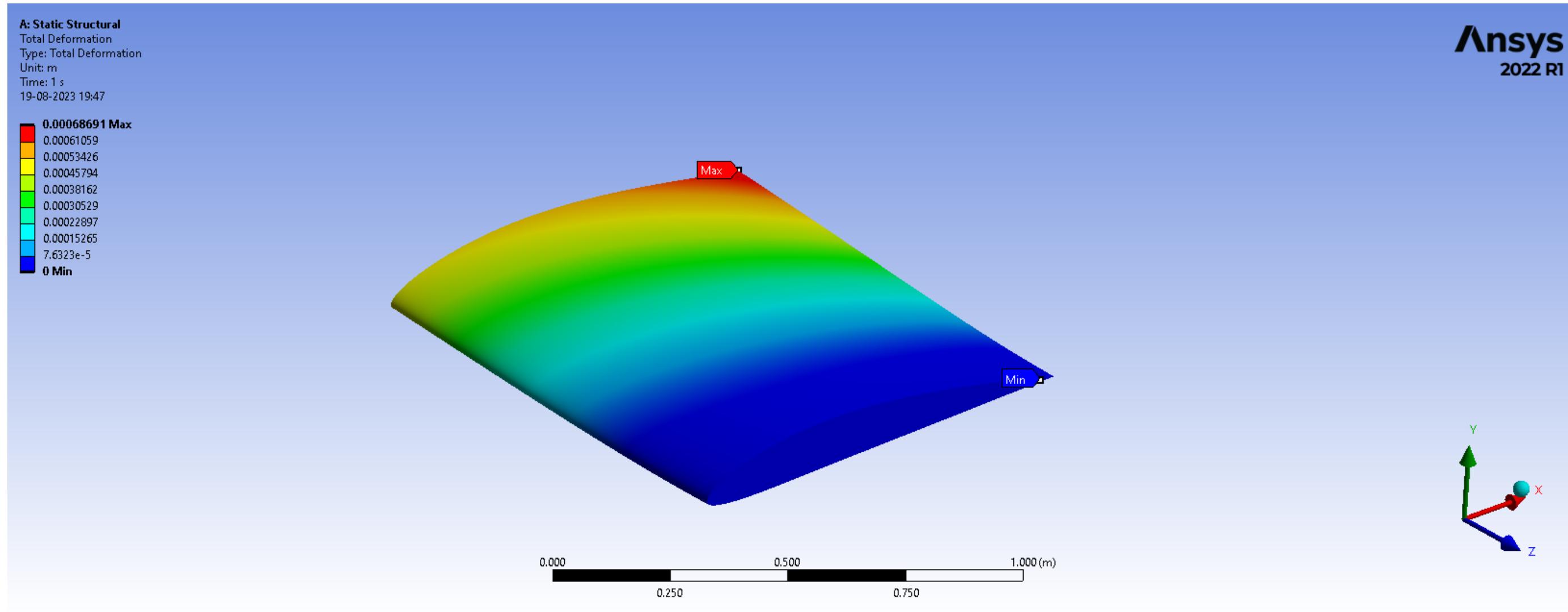
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Equivalent Stress

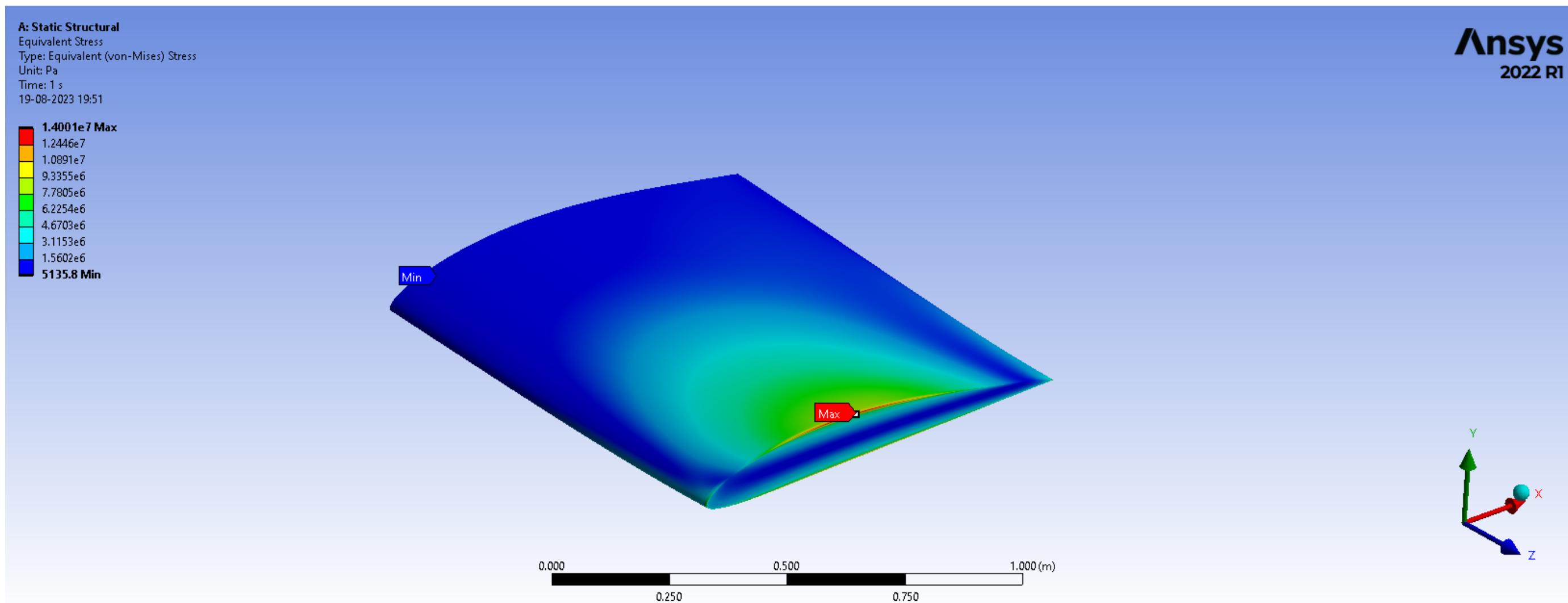
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Material - Aluminium 6061 T4



Max Deformation - 0.00068691 m

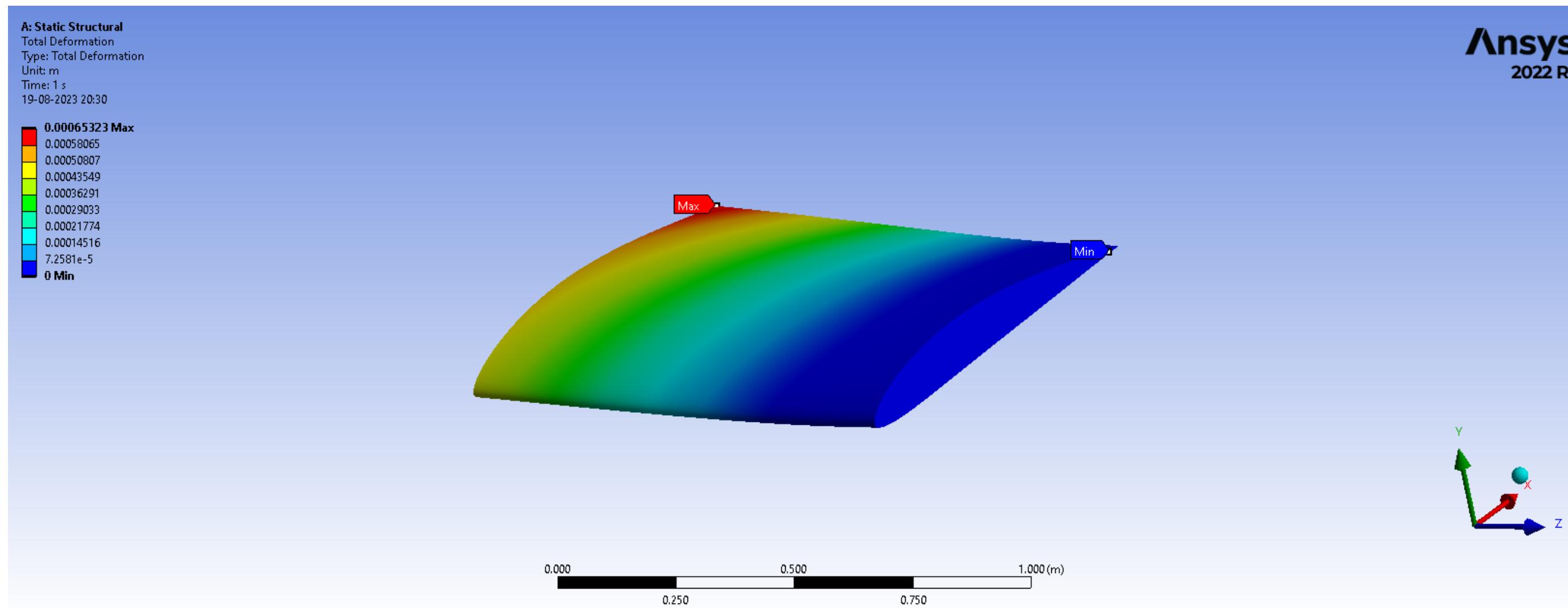
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Equivalent Stress

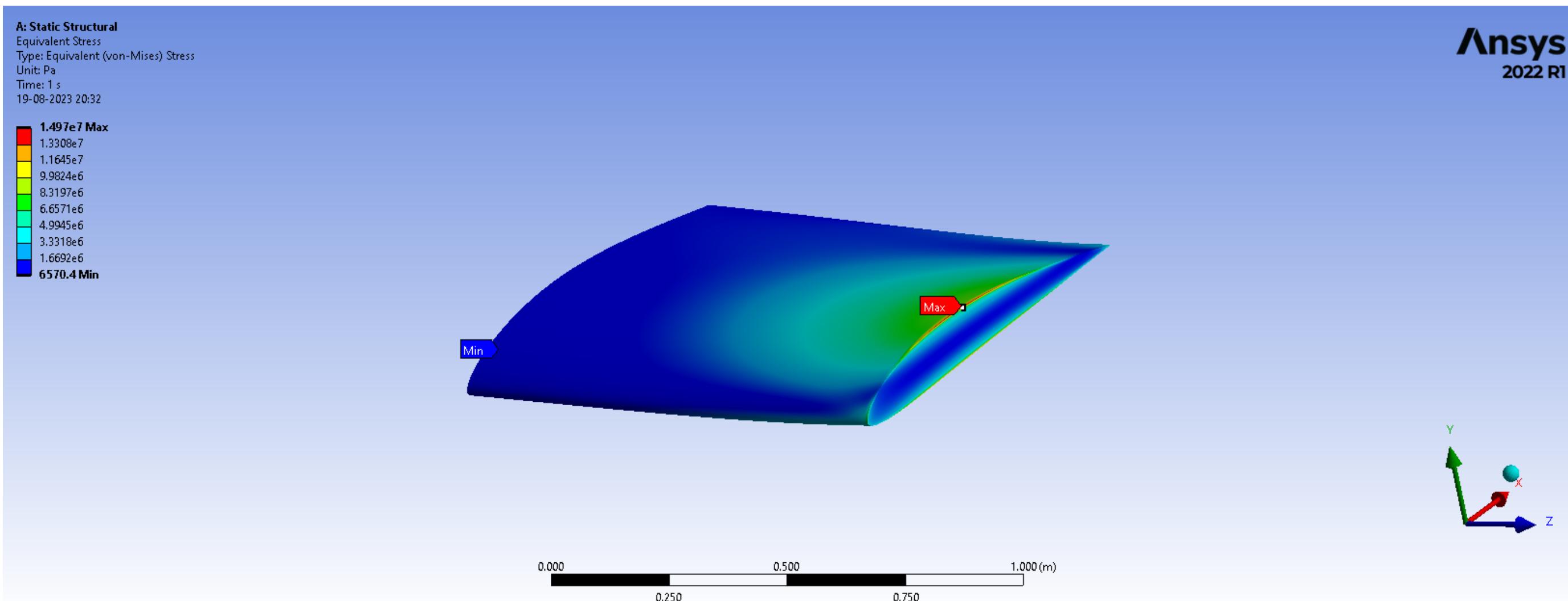
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Material - Aluminium 2024



Max Deformation - 0.00065323 m

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Equivalent Stress

RESULTS OF MATERIAL SELECTION

Chemical Composition of Al 2024 (values in wt%)

Elem.	Nominal value	Experimental value
Si	0.50	0.48
Fe	0.50	0.49
Cu	3.8-4.9	4.1
Mn	0.3-0.9	0.6
Mg	1.2-1.8	1.4
Cr	0.1	0.9
Zn	0.25	0.23
Ti	0.15	0.12
Al	Rem	Rem

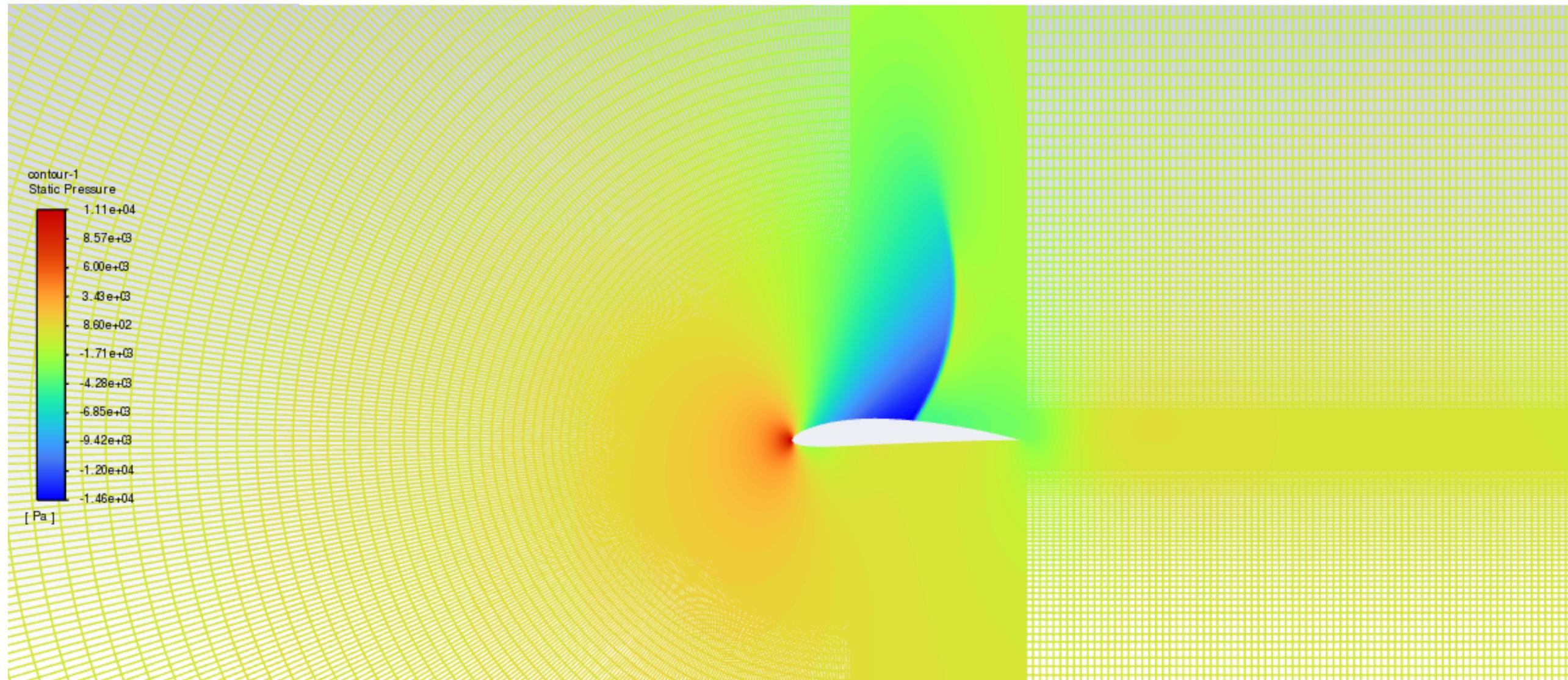
Courtesy - ResearchGate



Based on the analyses carried out, the material chosen was Aluminium 2024, as it had a maximum deformation of just 0.00065323 m

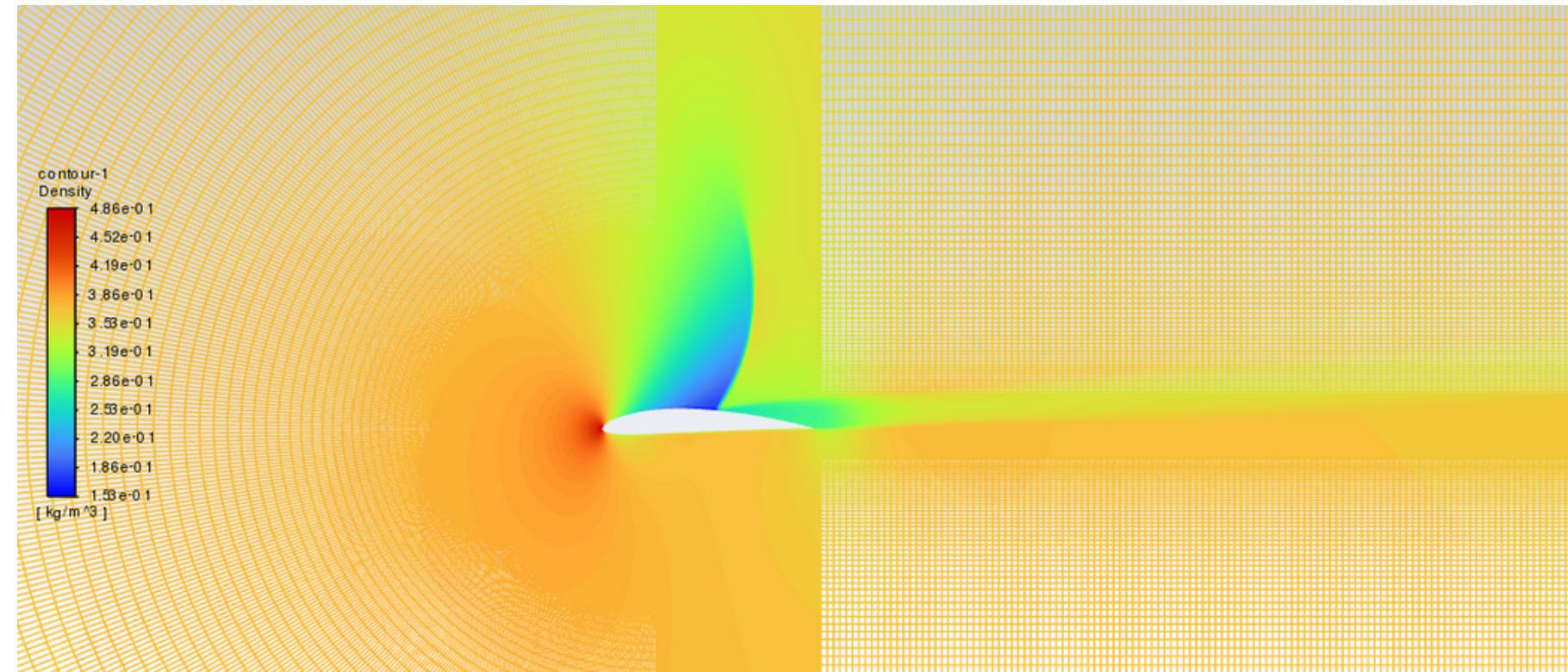
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Mach 0.79 and Angle of Attack 5 degree

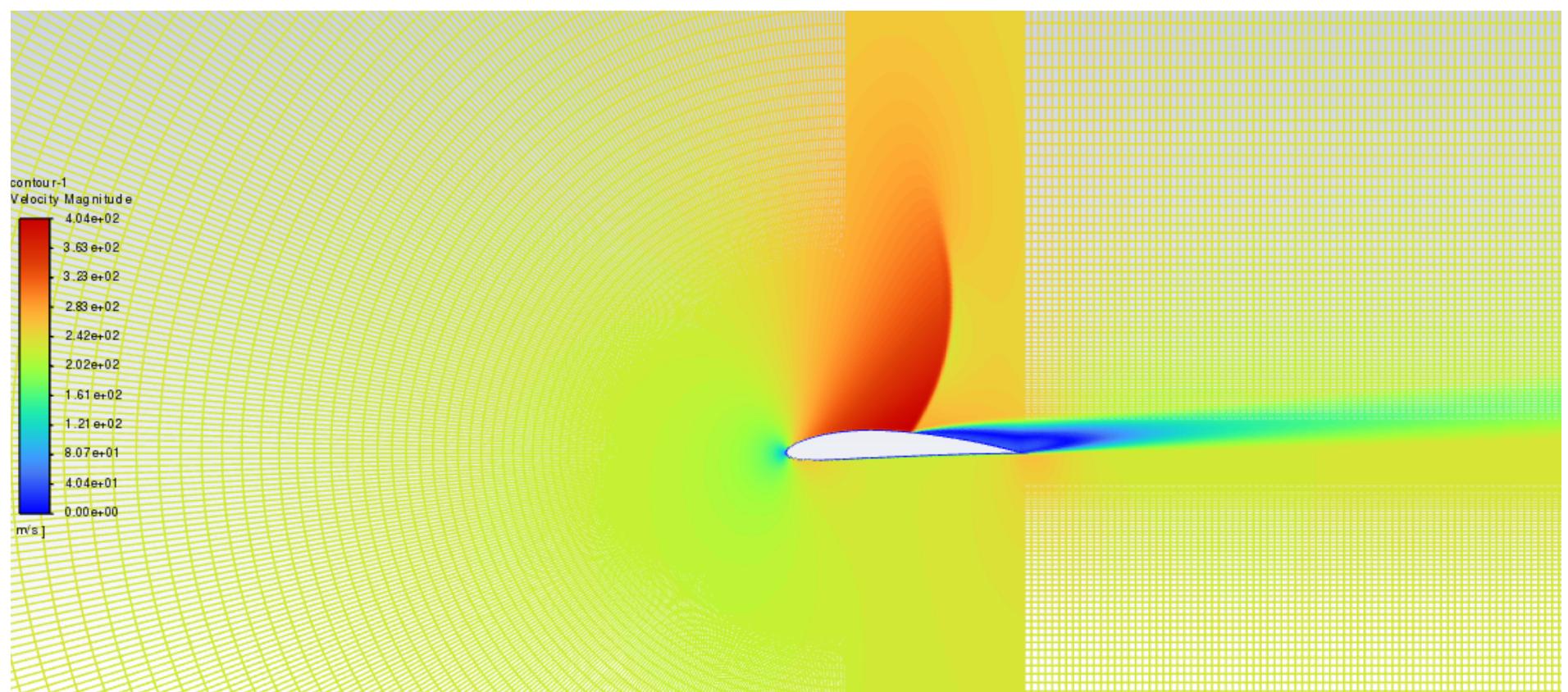


Pressure Contour

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Velocity Contour



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Thank You