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# Design of Symmetrical and Unsymmetrical Aerofoil Using CFD Analysis

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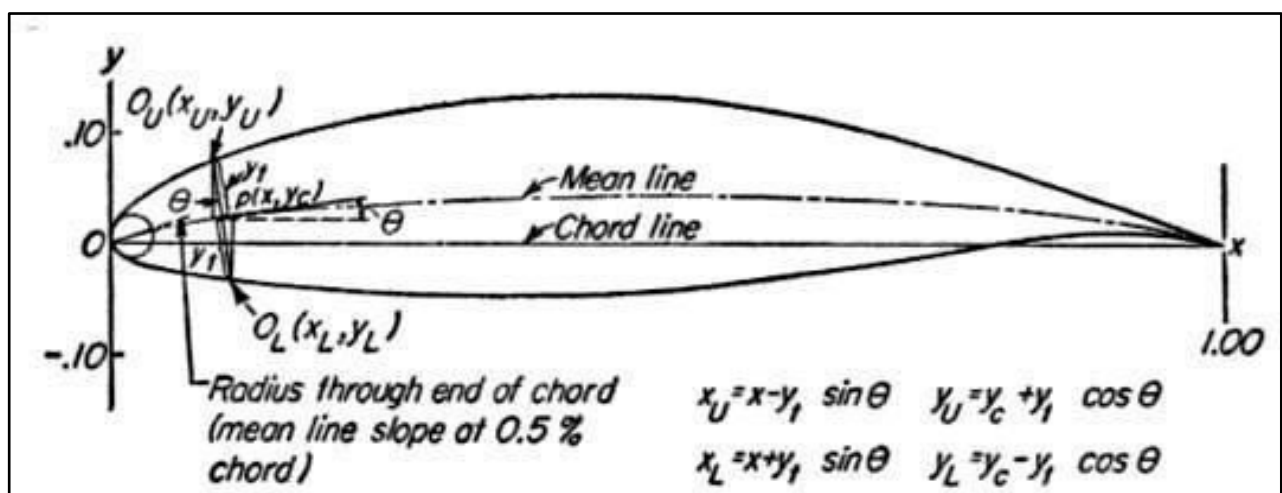
**ABSTRACT:** This project explores aerofoil design and analysis using CATIA for design and ANSYS for Computational Fluid Dynamics (CFD). Aerofoils are crucial in aerodynamics, impacting lift, drag, and overall performance in aerospace, automotive, and wind energy. Differentiating between symmetrical and asymmetrical aerofoils, the study compares NACA 0012 and NACA 4421, concluding that the asymmetrical NACA 4421 performs better. This analysis aids in understanding aerodynamic forces and optimizing design for various applications.

**KEYWORDS:** Aerofoil, CATIA V5, ANSYS, CFD.

## I. INTRODUCTION

Aerodynamics studies the movement of air around objects like aerofoils. It's crucial for understanding flight, with origins dating back to the 18th century. Engineers use a standard atmosphere for simplification, representing average air conditions. Flight is governed by four forces: lift, weight, thrust, and drag. Flow is classified based on velocity, from subsonic to hypersonic. Incompressible aerodynamics assumes constant density, while compressible aerodynamics considers density changes.

The boundary layer is a thin layer of air over surfaces like aircraft wings, transitioning from slow to fast-moving air. It can be smooth (laminar) or chaotic (turbulent), affecting aerodynamics. An aerofoil is a streamlined shape generating lift when air flows over it, crucial for aircraft wings. Its asymmetric shape creates lift by altering air pressure. The NACA aerofoil series transformed design with systematic equations defining camber, thickness, and position. The four-digit series, like NACA 2412, denotes key parameters, aiding aircraft wing design since the mid-20th century



NACA Aerofoil Geometrical Construction



**II. RELATED WORK**

Kumar Sahu & Mr. Shadab Imam (2015) conducted a simulation analysis on transonic flow over an aerofoil to address issues related to shock wave generation and drag reduction. Their findings revealed that shock wave strength and drag increase with Mach speed, impacting cruise speed due to wave drag and boundary layer thickening. They suggested using swept wings to mitigate drag and Mach-induced control effectiveness changes. Additionally, they noted that increasing angle of attack boosts lift coefficient until reaching a stall at 16°. They optimized a supercritical aerofoil design by adding a cusp-like structure to the trailing edge. Their study highlights the importance of aerodynamic characteristics and experimental validation in aerofoil design, emphasizing the impact of shock waves on flow properties like pressure, temperature, and density.

**III. METHODOLOGY**

open catia v5 and create a new part on the xy plane. insert points at coordinates (0,0,0) and (1,0.0022). use the spline tool to join points 1 to 67 and 67 to 128. connect the two splines created in steps 3 and 4. save the file in \*step format. same procedure is repeated for design naca 4421 aerofoil.

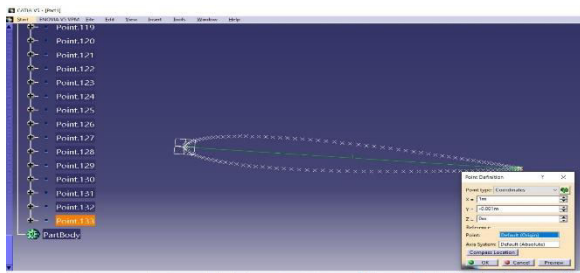
X(mm)	Y(mm)
100	0.2
95	2.11
90	3.85
80	6.91
70	9.5
60	11.6
100	0.2

NACA 4421 coordinates

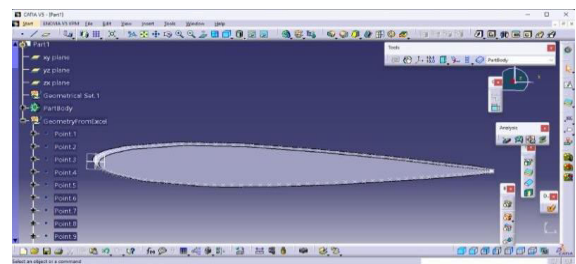
X(mm)	Y(mm)
100	0.126
99.94161	0.13419
99.76658	0.1587
99.47532	0.19938
99.0685	0.25595
98.54709	0.32804
97.91229	0.41519

NACA 0012 coordinates

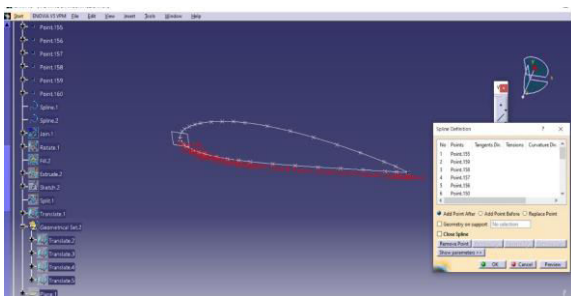
**IV. CAD MODELLING**



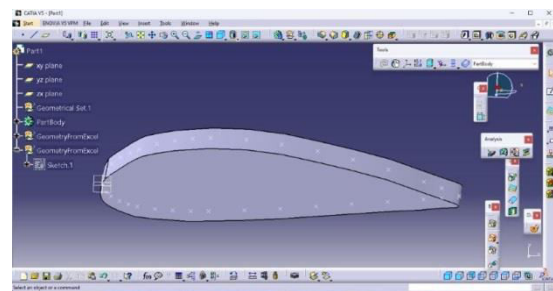
NACA 0012 coordinates conversion into points



3D model of symmetrical Aerofoil



NACA 4421 SPLINE CONVERSION FROM POINTS



3D MODEL OF UNSYMMETRICAL AEROFOIL





### V. ANALYSIS

The history of ANSYS Workbench begins with the establishment of ANSYS, Inc. in 1970 by Dr. John Swanson. Initially focused on finite element analysis (FEA), ANSYS expanded to include thermal analysis and computational fluid dynamics (CFD) in the 1980s. ANSYS Workbench emerged in the early 2000s as a unified simulation environment, integrating various ANSYS tools. It has since evolved to streamline simulation processes and remains a leading platform for engineering analysis and optimization.

CFD uses numerical methods to analyse fluid flow, vital in engineering. Equations representing conservation laws form the basis. CFD employs finite difference, finite volume, and finite element methods for discretization. CFD workflows involve pre-processing (geometry, grid generation), solving (using CFD solvers like FLUENT), and post-processing (interpreting and visualizing results). FLUENT is widely used for simulating flows, offering various physical models and extensive post-processing capabilities. The below procedure is taken into consideration while analysing an aerofoil.

Generation of Domain: Import and edit geometry and draw shapes for aerofoil Then generate profiles.

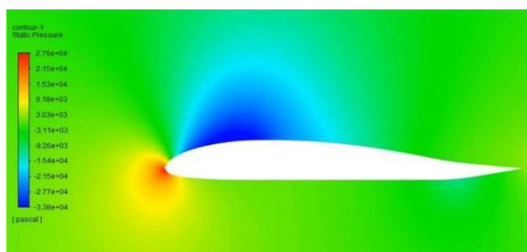
Meshing: Adjust mesh settings and define sizing and inflation and create connections.

Setup: Enable double precision and parallel processing set up solution parameters and define boundary conditions Then run solution and visualize results.

### VI. EXPERIMENTAL RESULTS

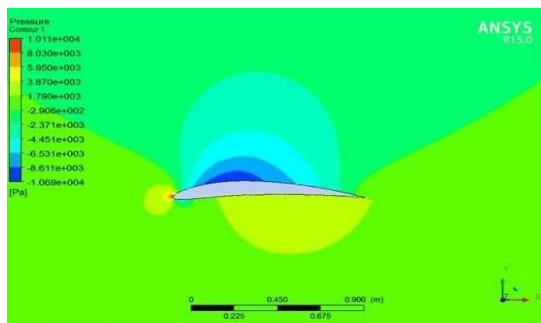
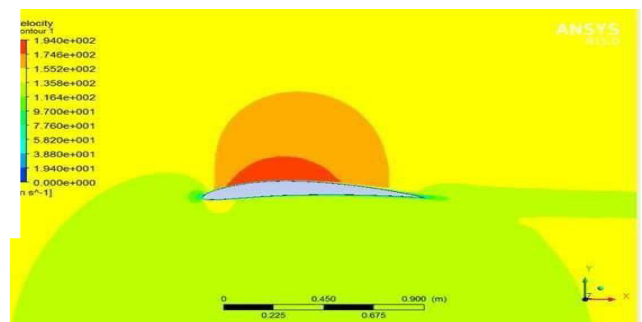
NACA 0012 At Mach number 0.9 At angle of Attack (AOA) 0°

Pressure Distribution

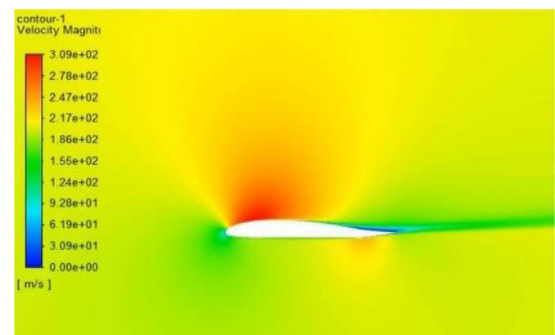


At Mach number 0.9 At AOA 0°

Velocity Distribution



NACA Pressure Distribution



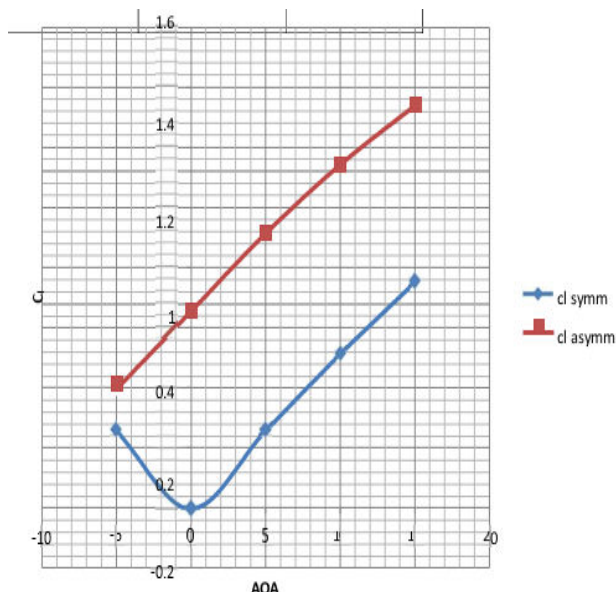
Velocity Distribution



NACA 4421 At Mach number 0.9 At angle of attack 15°

AOA	Cd symm	Cd asymm
-5	2.27E-02	-5.27E-03
0	1.05E-02	1.34E-02
5	2.27E-02	5.36E-02
10	5.53E-02	1.14E-01
15	1.04E-01	1.89E-01

Cl vs AOA at Mach number 0.9

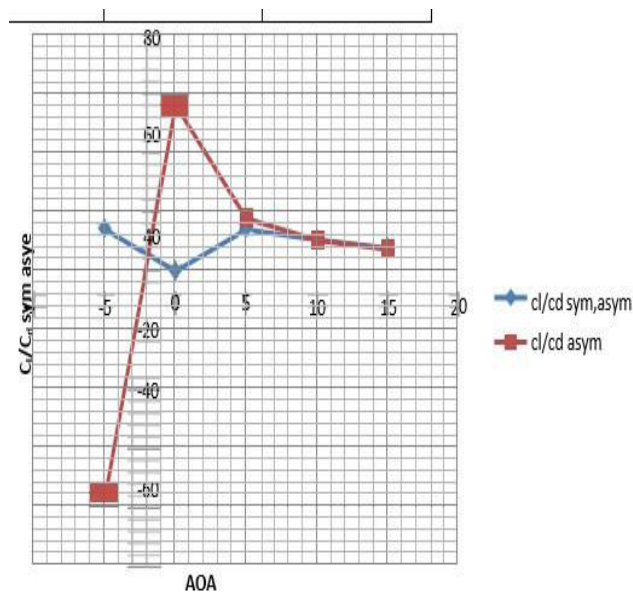


resulted graph of Cl vs AOA

At Mach number 0.9 At Angle of attack 15°

AOA	Cl / Cd symm	Cl / Cd asymm
-5	1.42E+01	-76.654
0	-6.80E-02	56.45
5	1.42E+01	17.928
10	1.06E+01	10.544
15	7.81E+00	7.43

Cl /Cd vs AOA at mach number 0.9



resulted graph of Cl /Cd vs AOA i.e Efficiency vs AOA

The above figure represents  $Cl / Cd$  vs. AOA at Mach number 0.9 which shows comparison between symmetric and asymmetric aerofoil where lift to drag ratio is taken on y axis and angle of attack is taken on x axis. Lift to drag ratio represents performance of aerofoil, hence above graph shows performance of asymmetric aerofoil is better than performance of symmetric aerofoil at zero AOA, vice versa at negative AOA and almost similar at positive AOA.

### VII. CONCLUSION

The CFD Analysis Of NACA 0012 And NACA 4421 Aerofoils Revealed: Pressure, Velocity, And Turbulence Contours Matched Mach Inputs And Angles Of Attack. Lift And Drag Coefficients Increased With Angle Of Attack. Stall Occurred At 15°, Causing Decreased Lift And Increased Drag Coefficients For Both Aerofoils. Optimum Lift Coefficients Were 1.5 At 16° For NACA 4421 And 15° For NACA 0012. The Lift-To-Drag Ratio Favoured The NACA 4421 Aerofoil, Indicating Better Performance Than NACA 0012.

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