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COMPARATIVE FLOW ANALYSIS OF NACA S6061 AND NACA 4415 AEROFOIL BY COMPUTATIONAL FLUID DYNAMICS

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ABSTRACT

In this study, a comparison has been drawn between the flow analysis of NACA S6061 and NACA 4415 aerofoil. The application of both airfoils is different. Here at zero angle of attack, the various parameters like pressure, velocity and turbulence are compared. The drag and lift coefficient of both has been analyzed. The results of this study were shown and simulated by using ANSYS 15. It has been found that NACA 4415 has lesser drag and lift at this angle of attack as compared to S6061 aerofoil which can be used for low Reynolds number application.

KEYWORDS: *NACA S606, NACA 4415, Aerofoil, ANSYS FLUENT, CFD, Drag, Lift*

Article History

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INTRODUCTION

Computational fluid dynamics (CFD) is a branch of fluid mechanics that uses numerical analysis and data structures to solve and analyze problems that involve fluid flows. Computers are used to perform the calculations required to simulate the interaction of liquids and gases with surfaces defined by boundary conditions. With high-speed supercomputers, better solutions can be achieved. Ongoing research yields software that improves the accuracy and speed of complex simulation scenarios such as transonic or turbulent flows. Initial experimental validation of such software is performed using a wind tunnel with the final validation coming in full-scale testing, e.g. flight tests. The analysis consists of several steps such as: problem statement, mathematical modeling, mesh generation, space discretization, time discretization, iterative solver, simulation run, post processing and verification.[1]

ANSYS Fluent software is the most-powerful computational fluid dynamics (CFD) tool available, empowering you to go further and faster as you optimize your product's performance. Fluent includes well-validated physical modeling capabilities to deliver fast, accurate results across the widest range of CFD and multiphysics applications.

The NACA airfoils are airfoil shapes of aircraft wings and were developed by the National Advisory Committee for Aeronautics (NACA). The shape of the NACA airfoils is described using a series of digits following the word "NACA". The parameters in the numerical code can be entered into equations to precisely generate the cross-section of the airfoil and calculate its properties.

S6061aerofoil are popular for gliders and sailplanes as they support low Reynolds number. NACA 4415 are cambered, unsymmetrical aerofoils. Thus, two aerofoils with different applications are compared and studied for the various parameters like pressure, velocity, turbulence, lift and drag.

DESCRIPTION OF AEROFOILS

The NACA four-digit wing sections define the profile as per the below Performa:[2]

- First digit describes the maximum camber as percentage of the chord.
- Second digit describes the distance of maximum camber from the airfoil leading edge in terms of percents of the chord.
- Last two digits describe the maximum thickness of the airfoils as percent of the chord.

For example, a '4415' airfoil is parsed to mean:

- The leading '4' indicates maximum camber is 4% of the chord length
- The '4' indicates maximum camber is at 40% of the chord length
- The '15' indicates maximum thickness is 15% of the chord length.[3]

LIFT AND DRAG:[2]

When a solid body is placed in a fluid flow and a non-symmetrical situation occurs, the direction of the forces on the body does not coincide with the direction of the flow. This principle makes flying possible. Discussion of lift and drag starts usually with the introduction of an airfoil. The resultant aerodynamic force F on an airfoil can be resolved into a lift force L perpendicular to the direction of undisturbed flight and a drag force D in the direction of flight. In steady level flight the drag is balanced by the thrust of the engine, and the lift equals the weight of the aircraft. These forces are expressed no dimensionally by defining the coefficients of lift and drag:

$$C_L = \frac{F_L}{\frac{1}{2}\rho A U^2}$$

$$C_D = \frac{F_D}{\frac{1}{2}\rho A U^2}$$

where

F_D and F_L = drag and lift force

C_L = lift coefficient

C_D = drag coefficient

ρ = density of the fluid

A = reference area

U = velocity of the undisturbed flow

GEOMETRY OF AEROFOILS

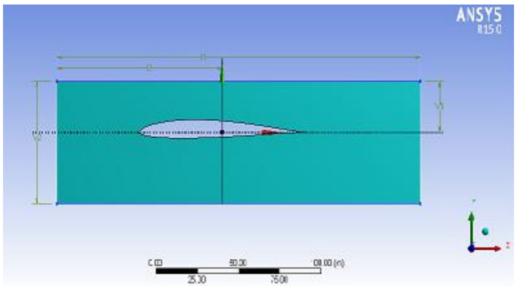

Figure 1: Geometry of S6061 Aerofoil

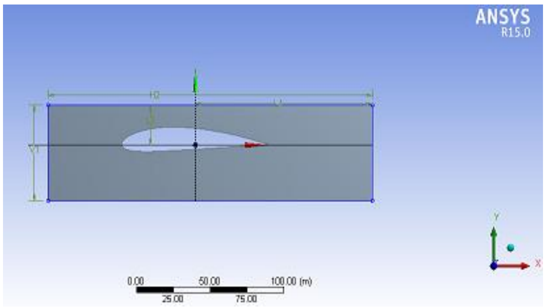

Figure 2: Geometry of NACA 4415 Aerofoil

MESHING OF AEROFOILS IN ANSYS 15

The aerofoils have triangular mesh with inflation of 15 layers added at the aerofoil section. The element size for edge sizing was taken as 0.5m.

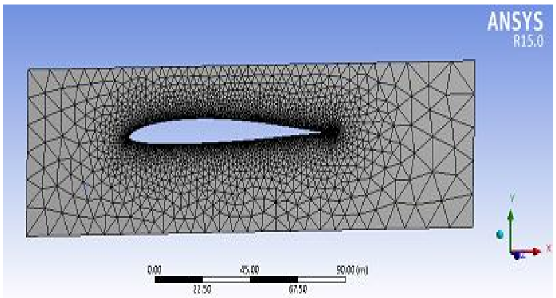

Figure 3: Meshing of S6061

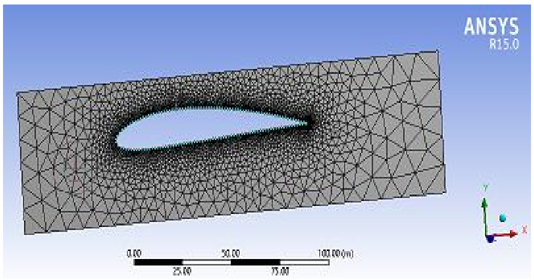

Figure 4: Meshing of NACA 4415

RESULTS AND DISCUSSIONS

Various parameters have been measured and presented in graphical form and the results are compared as follows:[1][2][3][4]

Static Pressure

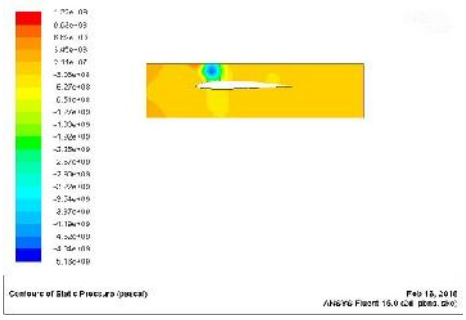

Figure 5: Contour of Static Pressure of S6061

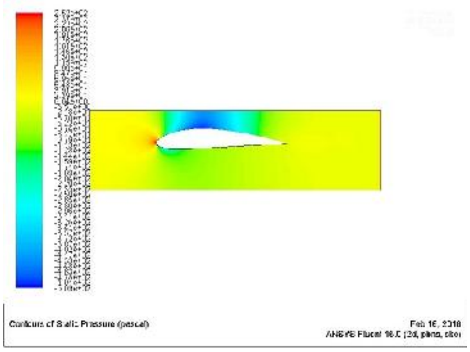

Figure 6: Contour of Static Pressure of NACA 4415

The static pressure affects the tip of NACA 4415 where it doesn't affect the S6061 aerofoil.

Dynamic Pressure

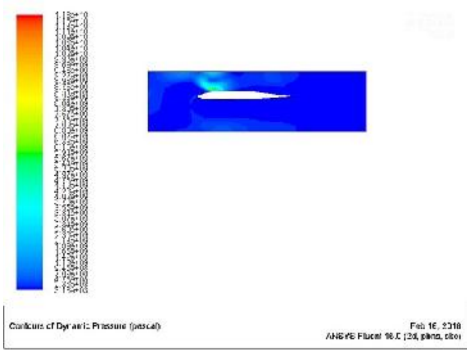

Figure 7: Contour of Dynamic Pressure of S6061

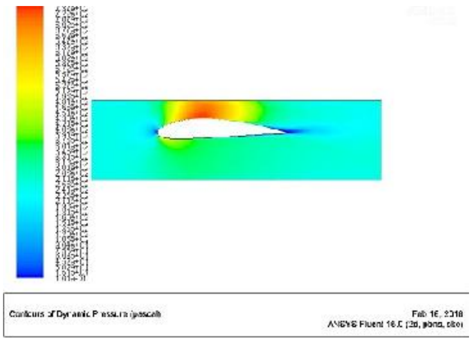

Figure 8: Contour of Dynamic Pressure of NACA 4415

The S6061 aerofoil is more safe in dynamic pressure than in NACA 4415 aerofoil.

Velocity Magnitude

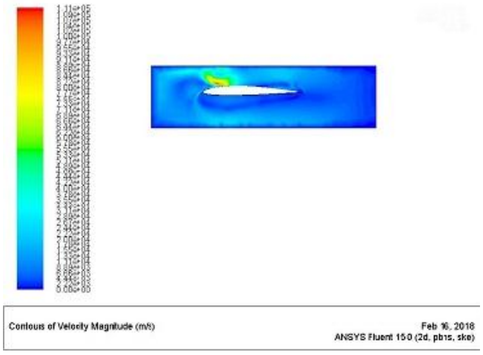

Figure 9: Contour of Velocity Magnitude of S6061

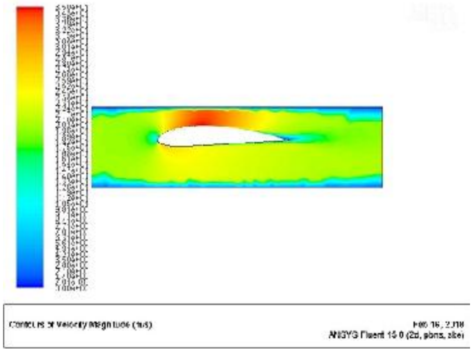

Figure 10: Contour of Velocity Magnitude of NACA 4415

The velocity magnitude shows the velocity of air flow over the aerofoil. The NACA 4415 aerofoil has more chances of boundary layer formation than S6061 aerofoil.

Turbulence Intensity

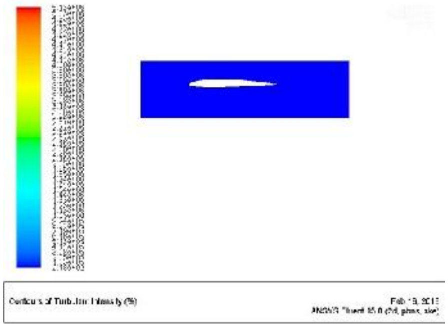

Figure 11: Contour of Turbulent Intensity of S6061

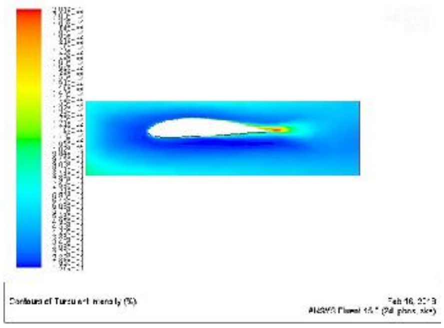

Figure 12: Contour of Turbulent Intensity of NACA 4415

The S6061 has no turbulence over the aerofoil whereas NACA 4415 is subjected to turbulence and vortex formation at the trailing edge.

Pathlines

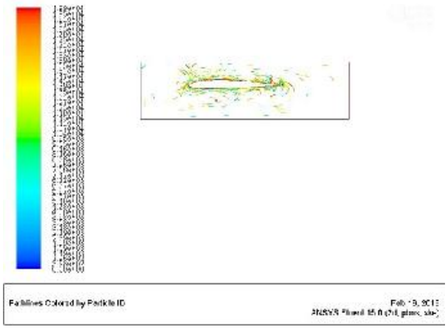

Figure 13: Pathlines of S6061

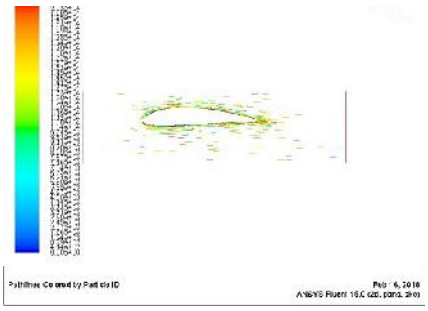

Figure 14: Pathlines of NACA 4415

The pathlines indicate the flow pattern of air over the aerofoil. The flow is more uniformly distributed over the NACA 4415 aerofoil as compared to S6061 aerofoil.

Assumptions

- The flow is 2D.
- Pure air is considered.
- Process is adiabatic and isothermal.
- Gravitational force is not considered.
- Pure dry air is considered for analysis
- Reynolds number is taken as Re = 5,00,000
- Inlet Velocity is 71.291m/s.

Defining Flow Parameters

From the geometry of the aerofoils and the above mentioned assumptions, the following reference value has been input to the system for the simulation and calculation of coefficient of drag and lift of the two aerofoils:

Table 1: Flow Parameters

Aerofoil	Initial Default Value	Values for Aerofoil S6061	Values for Aerofoil NACA 4415
Area (m^2)	1	908.087	908.087
Density (kg/m^3)	1.225	1.225	1.225
Depth (m)	1	1	1
Enthalpy (J/kg)	0	0	0
Length (m)	1	100.142	100.142
Pressure (Pa)	0	0	0
Temperature(K)	288.16	288.16	288.16
Velocity (m/s)	1	71.291	71.291
Viscosity (kg/m-s)	1.7894e-5	1.7894e-5	1.7894e-5
Ratio of Specific heats	1.4	1.4	1.4
No. of iterations	500	500	500

Coefficient of Drag (C_D)

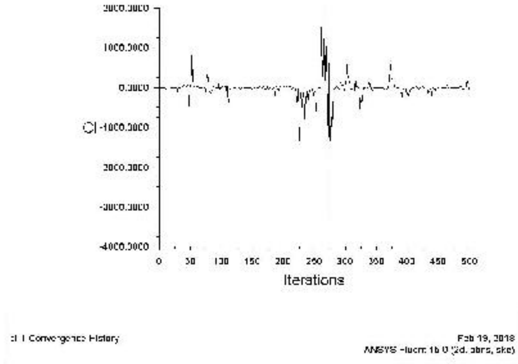

Figure 15: Convergence Plot of C_D of S6061

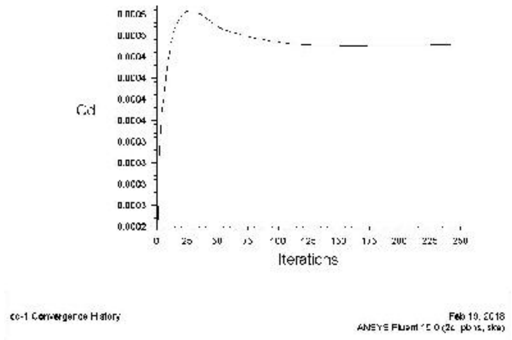

Figure 16: Convergence Plot of C_D of NACA 4415

The total final value of C_D for S6061 was found to be 0.001986 and that for NACA 4415 was found to be 0.0004389. Thus, at zero angle of attack the drag for NACA 4415 is less than S6061 aerofoil.

Coefficient of Lift (C_L)

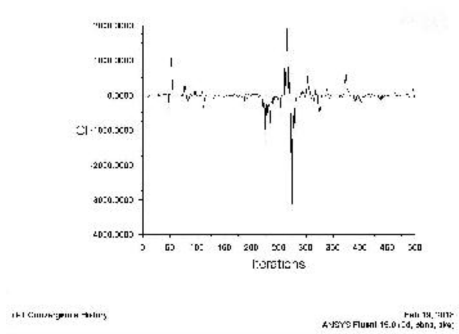

Figure 17: Convergence Plot of C_L of S6061

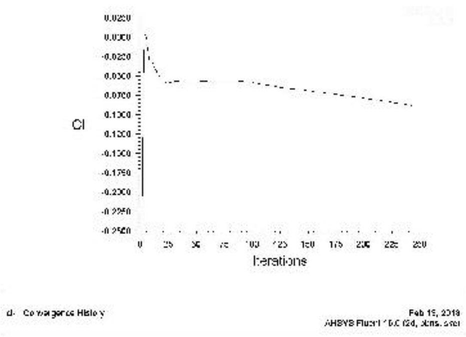

Figure 18: Convergence Plot of C_L of NACA 4415

The total final value of C_L for S6061 was found to be 0.9376 and that for NACA 4415 was found to be -0.087812. Thus at zero angle of attack the lift for NACA 4415 is less than S6061 aerofoil. The lift is negative at this angle of attack which means the aerofoil needs to be studied for other angle of attack to see the changes as the aerofoil gets lifted.

CONCLUSIONS AND SCOPE OF FURTURE STUDY

- From the study, it can be seen that the aerofoil S6061 can be used for low Reynolds number and NACA 4415 can be used for high Reynolds number.
- The static pressure is not affecting the S6061 aerofoil, while it is affecting the NACA 4415 aerofoil greatly.
- The turbulence is affecting the S6061 less than the NACA 4415 at this value of angle of attack.
- In comparison, it is found that at zero angle of attack the coefficient of drag of S6061 is much greater than that of NACA 4415.
- Further study can be done by changing the angle of attack of the aerofoils and comparing the various parameters like static and dynamic pressure, turbulence, coefficient of lift and drag for the same.

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