Comparison of Aerodynamic Performance of NACA 4412 and 2412 using Computational Approach

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Abstract
Comparison of the Aerodynamic Performance characteristics of two popular airfoils NACA 2412 and NACA 4412 were observed under the same flow conditions at 2 million Reynolds Number. ANSYS was used for the creation of geometry and meshing and FLUENT was used as a solver. Various Aerodynamic parameters were compared for a range of Angle of Attack and the performance of each airfoil were compared and the selection of optimal airfoil for specific aerodynamic characteristics were concluded.

Keywords - *Angle of Attack, Stall, Turbulence Model.*

I. INTRODUCTION

An airfoil is 2D cross section of a wing. The airfoil cross section experiences force when it travels through a fluid medium. There is pressure distribution on the upper surface and the lower surface of the airfoil due to its motion. The pressure differential on the surfaces causes the aerodynamic forces such as Lift and Drag to be generated. These forces vary with angle of attack which is defined as the angle between the chord and free stream velocity. The lift coefficient increases with increase in angle of attack till a particular point, after which the airfoil stalls.
NACA are the common airfoils which are designed and widely used today. There are four series, five series and six series airfoils where each number gives information about specific airfoil design parameters.

II. AIRFOIL NOMENCLATURE AND TERMINOLOGIES [1]

1. Camber: It is the maximum distance between the mean camber line and the chord when measured perpendicularly.
2. Mean Camber Line: It is the locus of the points halfway between the upper and lower surface of the airfoil.
3. Chord line: It is the straight line joining the leading edge and trailing edge.
4. Thickness: It is the distance between the upper and lower surface of the airfoil.

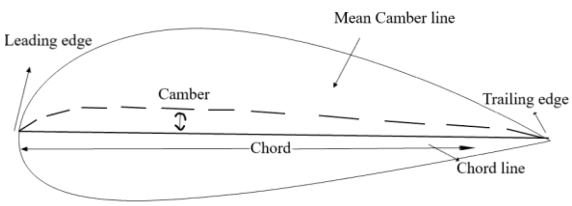

Figure 1 Airfoil Nomenclature

Some of the other terminologies associated with the airfoil are as follows:

1. Lift: It is the component of the resultant aerodynamic force which is perpendicular to the flow direction.
2. Drag: It is the component of the resultant aerodynamic force which is parallel to the flow direction.
3. Angle of Attack: It is the angle between the free stream velocity and the chord of the airfoil.
4. Reynolds number: It is a dimensionless number which gives information about the nature of the flow and is defined as the ratio of inertial flow to the viscous flow.

III. CONSTRUCTION OF GEOMETRY AND MESHING

The airfoil coordinates were obtained from the airfoil database [2] and imported onto design modeller of ANSYS. The domain was created and split into different domains for meshing. The model is as shown in the figure. Both the airfoils had the same domain dimensions.

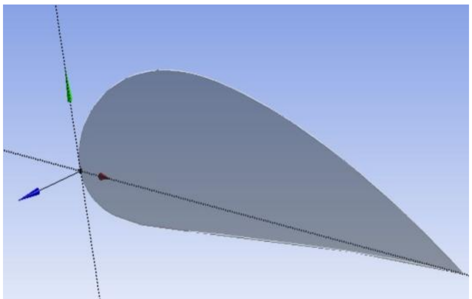

Fig 2 Geometry of NACA 4412 created in Design modeller

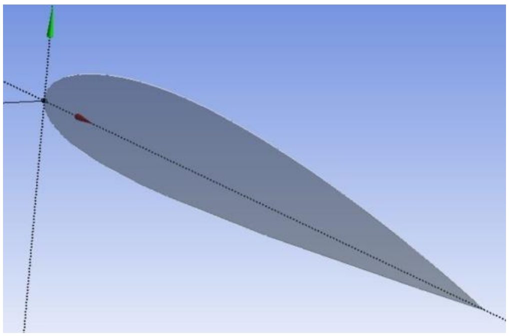

Fig 3 Geometry of NACA 2412 created in Design modeller

The meshes were generated using Meshing component of ANSYS. A C grid structured mesh was generated and the figure is as shown below:

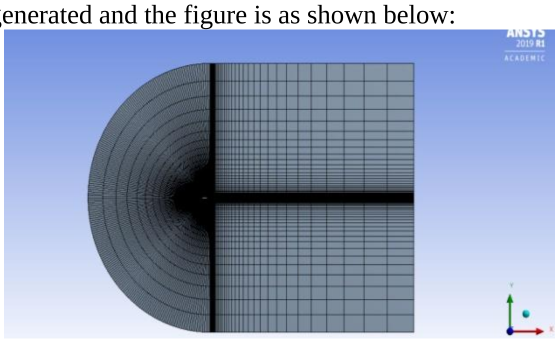

Fig 4 Mesh of 2412

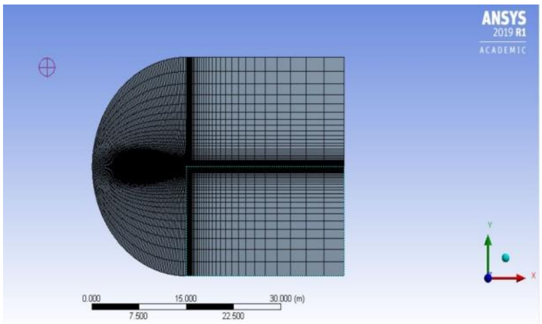

Fig 5 Mesh of 4412

The mesh quality was found to be optimal.
The meshes were imported into the fluent solver where the boundary conditions, turbulence model etc were selected.

IV. PROCESSING ON FLUENT AND SELECTION OF TURBULENCE MODEL

Turbulence model is the construction with the help of mathematical models to predict the effects of turbulence on the airfoil.
K-ω model is a two equation turbulence model which is used for RANS equations. It uses two variables, k which is the kinetic energy and ω which is the specific rate of dissipation [3]. This model is combined with SST model which is Shear Stress Transport which is also widely used. [4]
The input parameters along with specific conditions as indicated in the table below were given on FLUENT.

Solver	Pressure based steady
Viscous Model	K- ω SST model
Density(kg/m^3)	1.225
Viscosity(kg/m-s)	1.7894e-05
Turbulence intensity ratio	0.1
Turbulence length scale	0.3
Inlet Velocity	29.12
Reynolds Number	2 million
Chord length	1 m
Momentum	Second Order upwind
Pressure velocity coupling	Coupled

Table 1: FLUENT Details

V. RESULTS AND DISCUSSION

A. Cp Contours

The contours of coefficient of pressure for 2412 and 4412 are shown below and this is at a specific angle of attack of 8 degrees.

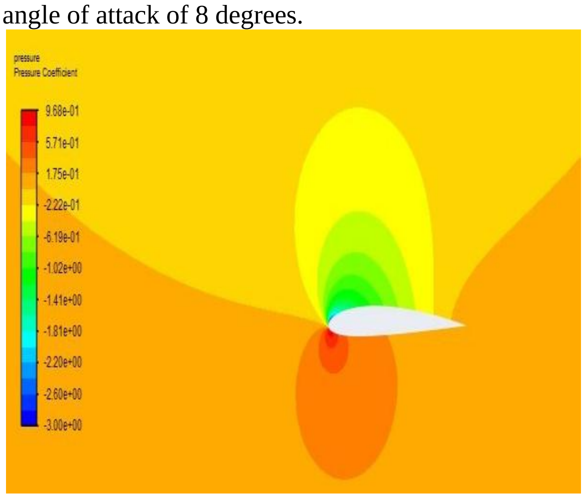

Fig 6 Cp plot for NACA 2412

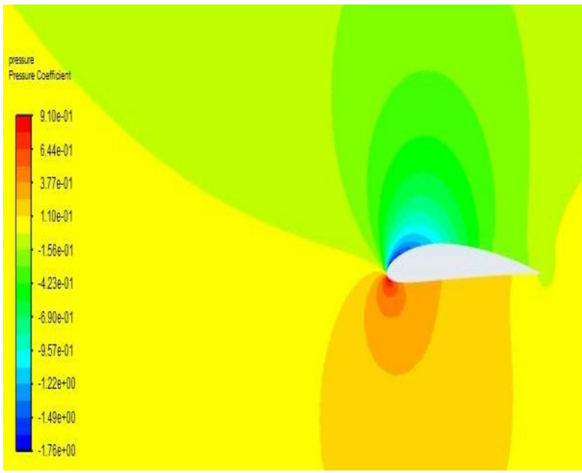

Fig 7 Cp plot for NACA 4412

B. Velocity Contours

The velocity contours of velocity in the Y direction is as shown in the figure below for 2412 and 4412 respectively.

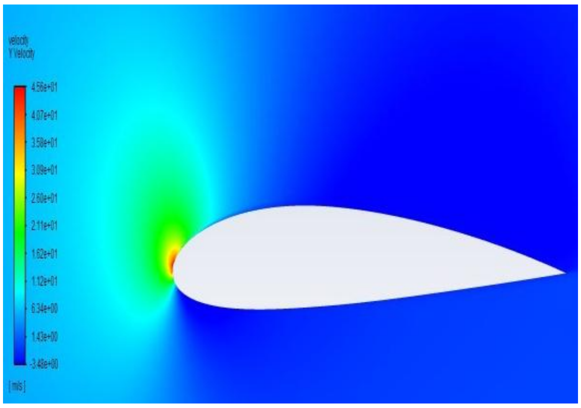

Fig 8 Y Velocity Contour for NACA 2412

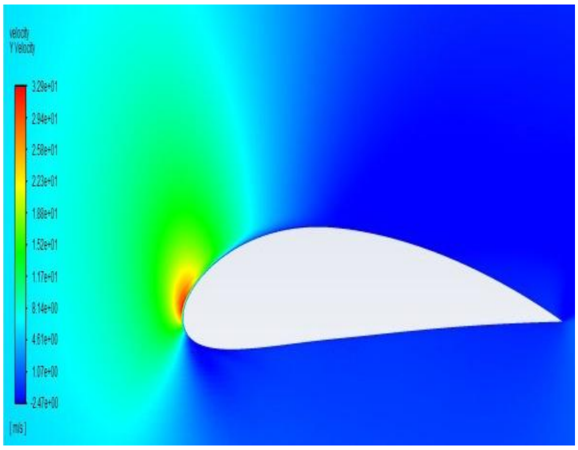

Fig 9 Y Velocity Contour of NACA 4412

C. ***Aerodynamic Comparison Plots***

The plots are C_l vs. Angle of Attack and C_d vs. Angle of Attack for both the airfoils. The variation of coefficient of lift and drag with respect to Angle of Attack are seen. Stall characteristics are also observed and the variation in stall under the same condition for the two airfoils is compared. We also get information about Cl_{max} and Cd_0 which are important aerodynamic parameters.

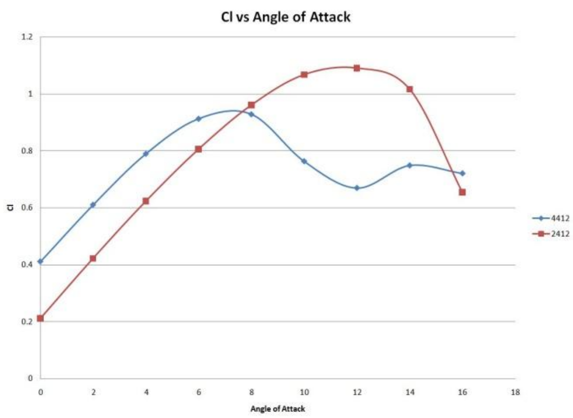

Fig 10 Coefficient of Lift vs. Angle of Attack

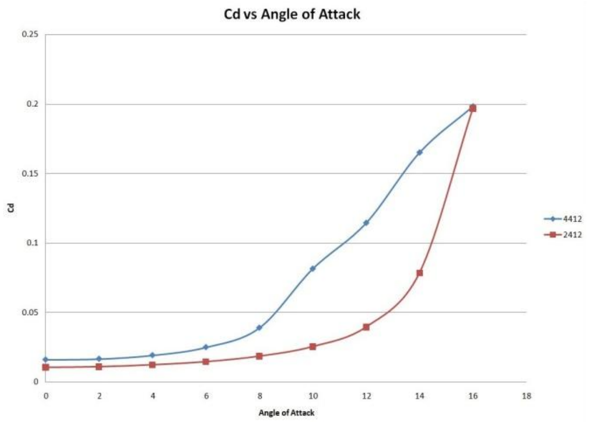

Fig 11 Coefficient of Drag vs. Angle of Attack

VI. CONCLUSION

1. From the figure (6) and (7) we can see that there is higher pressure generated on the lower surface for the NACA 2412 than for NACA 4412 at the same angle of attack, thus the lift generated is more as there is greater pressure difference on the upper and lower surface.
2. From figure (8) and (9) we can see that the maximum Y velocity reaches 45m/s for NACA 2412 and 32m/s for NACA 4412.
3. We can conclude from figure (10) that the coefficient of lift increases with the increase in angle of attack, but at stall angle, the lift drops and this is known as the critical condition.
4. The stall angle for 4412 is 8^0 and that of 2412 is 12^0 thus from this we can conclude that at the same flow conditions the 2412 stalls at a higher angle of attack.
5. From figure (10) we can see that till 8^0, the lift generated by the 4412 airfoil is greater than 2412 but the drag almost remains the same which can be seen in figure 11, thus we can conclude that when the aircraft is has a mission profile where its angle of attack does not exceed 8^0, the NACA 4412 can be used.
6. However for an aircraft with a mission profile where the angle of attack has a greater range, the NACA 2412 is optimal because it has a higher $(Cl)_{max}$ value than the 4412.
7. From figure (11) we can see that the drag values of the 2412 are generally lesser than the 4412.
8. We can conclude that the NACA 2412 has a considerable aerodynamic advantage over the NACA 4412 at 2 million Reynolds number

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