Study of NACA 4412 and Selig 1223 Airfoils Through Computational Fluid Dynamics

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Abstract

NACA (national advisory committee for aeronautics) airfoils have been generated according to the NACA standards. The effects of fluid flow have been studied over the two airfoils 4412 and S1223 through computational fluid dynamics. The comparison was done on the basis coefficient of lift and coefficient of drag. The angle of attack was varied and their effect was seen on velocity, pressure, coefficient of lift and coefficient of drag. In the present research the angle of attack will be varied from 0 degree to 15 degree with the increment of 5 degree.

Keywords: *Angle of Attack, CFD Analysis, NACA 4412, S1223 airfoils*

I. INTRODUCTION

Computational fluid dynamics (CFD) is a branch of fluid mechanics that uses numerical methods and algorithms to solve and analyze the problems involving fluid flow. Computers are used to perform the calculations required to simulate the interaction of liquid and gases with surfaces defined by boundary condition. It is fast, accurate and reliable method of analyzing the variation of the flow over and within a body. CFD in early 1970's the use of supercomputers to solve aerodynamics problems began to pay off. One early success was the experimental NASA aircraft Himat (high maneuverable aircraft technology) designed to test concepts of high maneuverability of next generation of fighter planes. Wind tunnel tests of a preliminary design for Himat showed that it would have unacceptable drag at speed near the speed of sound if built that way the plane would be unable to provide any useful data. The cost of redesigning it for further wind tunnel tests would have been around $150,000 and would unacceptably delayed the project, instead the wing was redesigned by computer at cost of $6000 [1]. Thus the CFD has reduced the cost of a product by a huge factor. The various industries like automobile Industry, marine industries and aeronautics industries have been all up in this field. The function of CFD is not only to save cost and time but also it can simulate extreme Flight conditions for example in early 21st century the engineers and scientist wanted to build a plane that could fly at very high speed at very high altitude this was a concept of transatmospheric vehicle Which has been the subject of study in many countries during 1980s and 1990s [1]. Anyone stepped in the aeronautics has a major thrust to fly higher and faster to push the limits. There are no wind tunnels that can simultaneously simulate the higher mach numbers and high flow field temperatures to be encountered by transatmospheric vehicle, and the prospects of such wind tunnel in 21st century is not encouraging. Hence, the major player in the design is computational fluid dynamics. Present study focuses on the comparison of NACA4412 and S1223airfoil and their applications. The NACA 4412 has been used in sports plane. The example includes AAI-AA2 mamba aircraft, aeronca series aircraft like aeronca 65-tac defender, aeronca 11ac chief etc while the S1223 is an airfoil used in heavy lift cargo planes [2].

II. OBJECTIVE

The purpose of this study was to conduct computational fluid dynamics analysis of NACA 4412 and S1223 airfoils with below mentioned objectives.

- To model a NACA 4412airfoil and S1223 airfoils.
- Perform computational fluid dynamics flow analysis using fluent software.
- Compare the coefficient of lift and drag between them.
- To provide reasoning for their respective application.

III. AIRFOIL NOMENCLATURE

The airfoils used in present study for CFD were modeled according to the NACA standard. The terminologies associated with airfoil are leading edge, trailing edge, chord length, angle of attack, camber and thickness (Figure 1). The NACA 4412airfoil has a certain geometry defined by its number itself, shown in table 1.

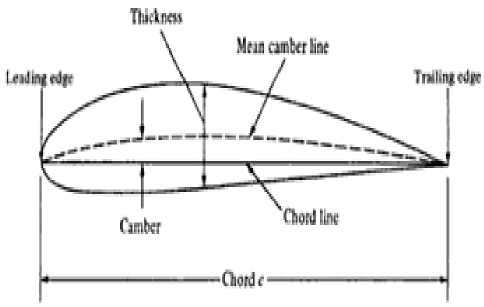

Figure 1: Shows the Terminologies Associated with Airfoil

Table 1: Shows the Geometry Parameters of NACA 4412airfoil [3]

NACA 4412 airfoil		
S. No	**Digit Number**	**Characteristics**
1.	4	4% is maximum camber in percentage of chord
2.	4	40% is the location of maximum camber in percentage of chord
3.	12	12% is the maximum thickness in percentage of chord

Table 2: Shows Geometry Parameters of S1223airfoil [3]

S1223 airfoil		
S.No	**Terminology**	**Characteristics**
1.	Maximum camber	8.1% of chord length
2.	Position of maximum camber	49% of chord length
3.	Maximum thickness	12.1% of chord
4.	Position of maximum thickness	19.8% of chord

IV. METHODOLOGY

A. Model Development

The airfoil models have been generated in airfoil generator [3]. The generator output excel file was given in terms of x and y coordinates. It was converted to notepad by adding z coordinate as zero. A fine mesh is created around the airfoil for accurate results in Gambit software.

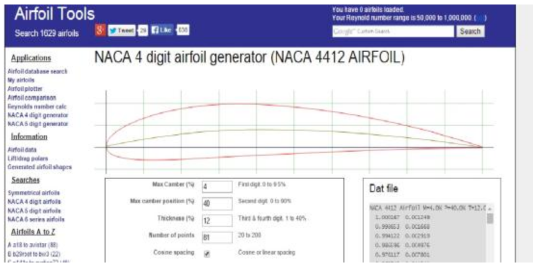

Figure 2: Shows the Profile of NACA 4412 Airfoil [3]

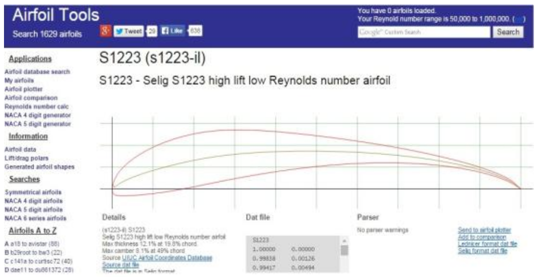

Figure 3: Shows The Profile of S1223Airfoil [3]

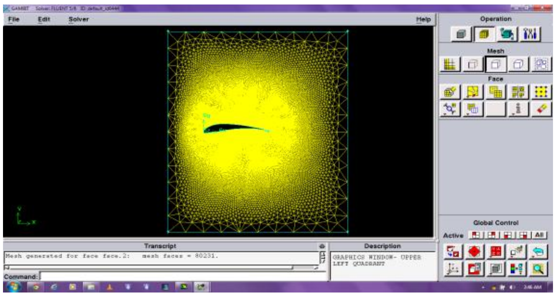

Figure 4: Shows the Meshed Model in Gambit Software

B. Computational Fluid Dynamics Analysis

The mesh file from gambit is imported in the fluent software for further analysis. The input parameters given were velocity, type of model, amount of residual and number of iterations. The fluent solver yields the result of coefficient of lift and drag, pressure and velocity variations.

Table 3: Shows the Input Parameters for CFD Analysis of Airfoils

Input Parameters	
Inlet velocity(air)	2.5 m/s
Density (air)	1.225 kg/m^3
Viscosity (air)	1.7894e-05 Ns/m^2
Model	laminar
Residual	1e-03
Number of iterations	1000
Reynolds number	30000

The result of CFD analysis was shown as pressure and velocity contours. The pressure and velocity contours for various angle of attacks from 0 to 15 degree of NACA 4412 and S1223 airfoils were shown in Figure 5-20.

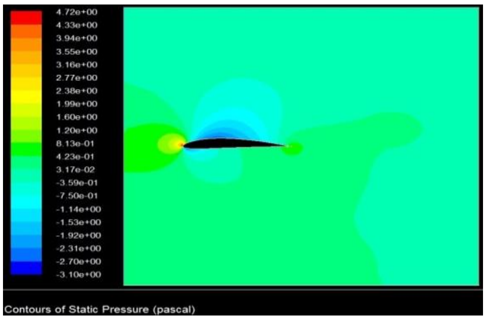

Figure 5: Shows The Pressure Contours Of 4412 Airfoil At 0 Degree Angle Of Attack

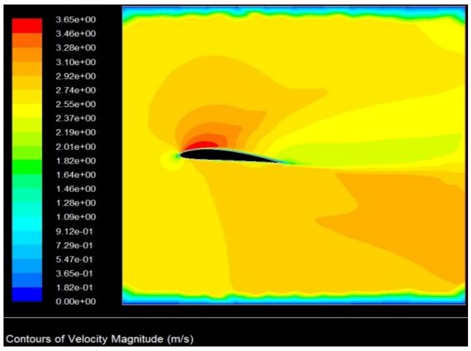

Figure 11: Shows The Velocity Contour Of 4412 Airfoil At 5 Degree Angle Of Attack

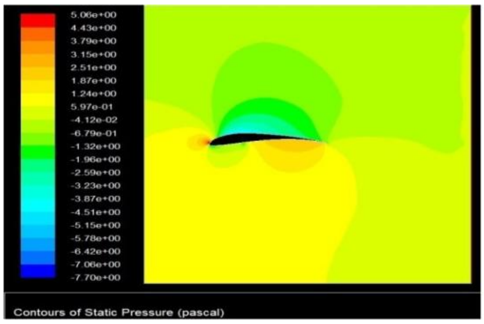

Figure 6: Shows The Pressure Contours Of S1223 Airfoil At 0 Degree Angle Of Attack

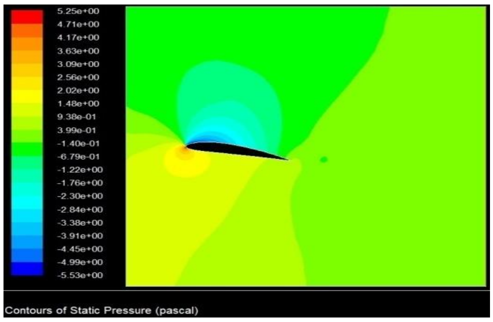

Figure 13: Shows The Pressure Contours Of 4412 Airfoil At 10 Degree Angle Of Attack

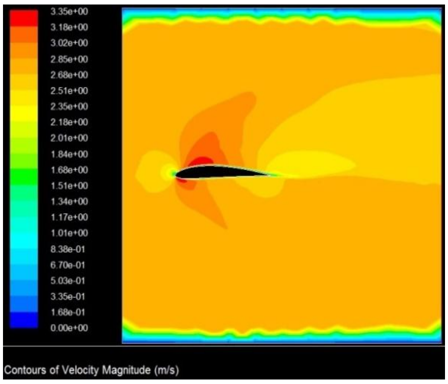

Figure 7: Shows The Velocity Contours Of 4412 Airfoil At 0 Degree Angle Of Attack

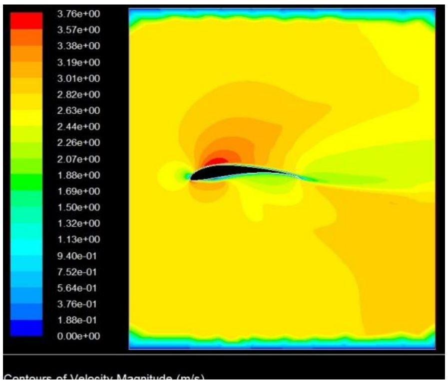

Figure 8: Shows The Velocity Contour Of S1223 Airfoil At 0 Degree Of Angle Of Attack

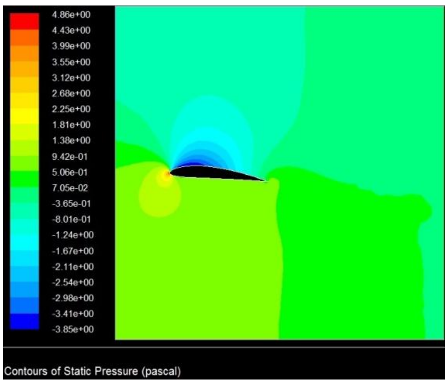

Figure 9: Shows The Pressure Contour Of 4412 Airfoil At 5 Degree Angle Of Attack

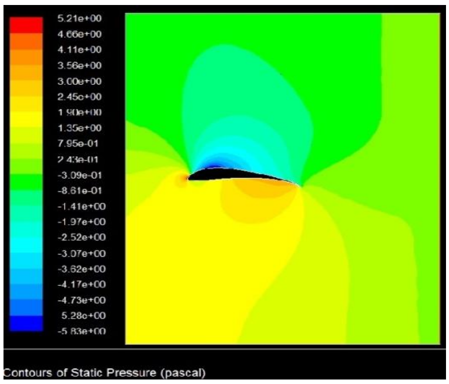

Figure 10: Shows The Pressure Contour Of S1223 Airfoil At 5 Degree Angle Of Attack

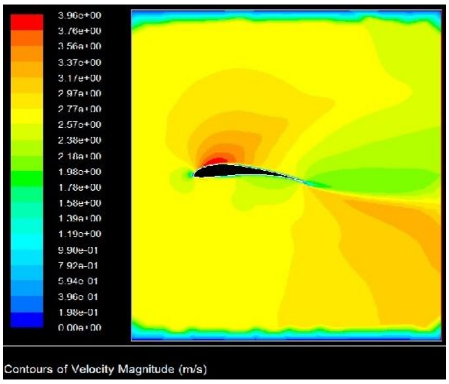

Figure 12: Shows The Velocity Contour Of S1223 Airfoil At 5 Degree Angle Of Attack

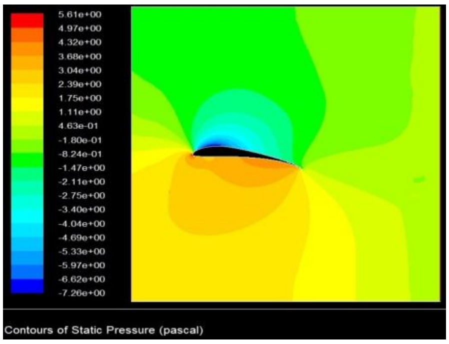

Figure 14: Shows The Pressure Contour Of S1223 Airfoil At 10 Degree Angle Of Attack

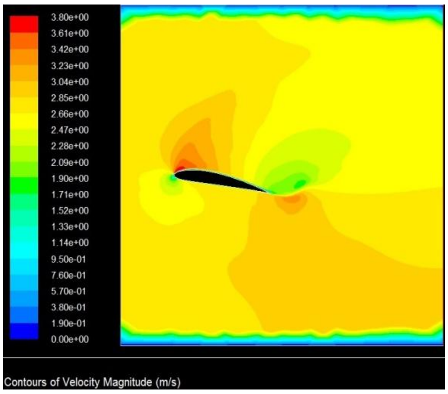

Figure 15: Shows Velocity Contour Of 4412 Airfoil At 10 Degree Angle Of Attack

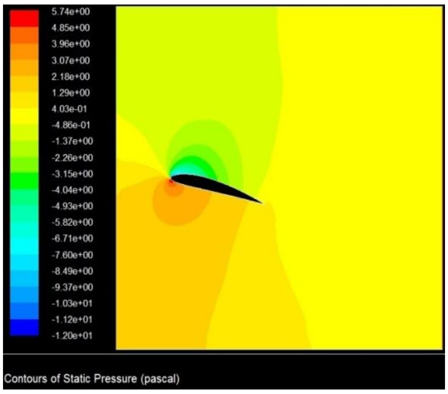

Figure 17: Shows The Pressure Contour Of 4412 Airfoil At 15 Degree Angle Of Attack

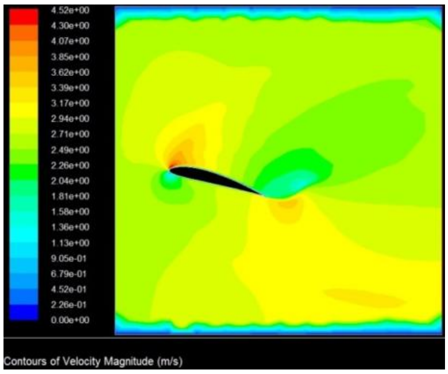

Figure 19: Shows The Velocity Contour Of 4412 Airfoil At 15 Degree Angle Of Attack

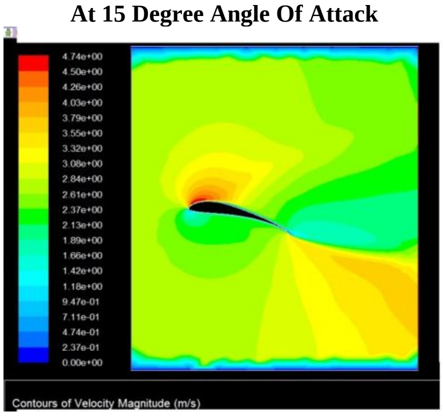

Figure 20: Shows The Velocity Contours Of S1223 Airfoil At 15 Degree Of Attack

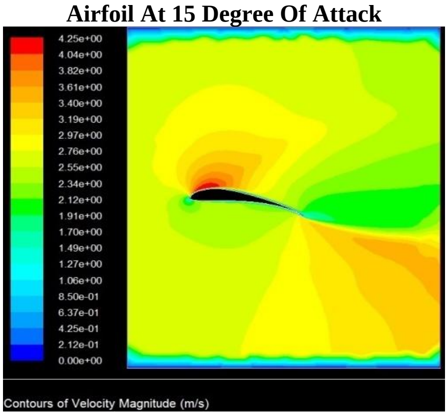

Figure 16: Shows The Velocity Contours Of S1223 Airfoil At 10 Degree Angle Of Attack

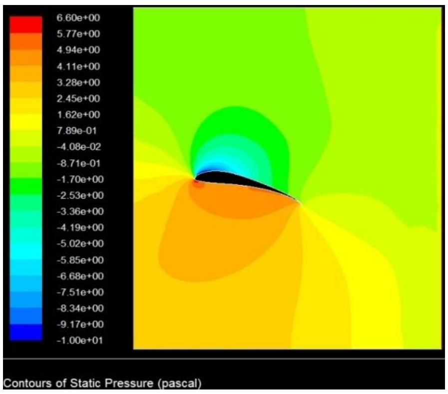

Figure 18: Shows The Pressure Contours Of S1223 Airfoil At 15 Degree Angle Of Attack

V. RESULTS

The coefficient of lift and drag were calculated and compared for both the airfoils 4412 and S1223 at different angle of attacks. The results are shown in Table 4**.** The pressure and velocity contours show the reason for increasing lift at different angle of attacks. With the increase in the angle of attack, pressure at the bottom of airfoil surface increases. It also increases at the top but not as significant as compared to bottom surface. Due to this, there was an increase in the pressure difference between the surfaces. This resulted in increased net force, whose vertical component is lift and horizontal is drag. Thus there was an increase in coefficient of drag and lift (Figure 5-20). The area of airfoil, velocity and density of air were kept constant over various angles of attack.

Table 4: Shows the Comparison of NACA4412 and S1223 Airfoil

NACA 4412 airfoil				S1223 airfoil		
Angle of Attack (Degree)	**cl (coefficient of lift)**	**cd (coefficient of drag)**	**cl/cd**	**cl**	**cd**	**cl/cd**
0	0.22	0.05	4.4	0.82	0.09	8.28
5	0.67	0.07	9.57	1.26	0.15	8.07
10	0.88	0.13	6.47	1.70	0.25	6.84
15	1.25	0.22	5.58	2.13	0.38	5.61

VI. CONCLUSION

In case of NACA 4412 airfoil, drag and lift coefficient are low as shown Table 4. Thus suitable for use in sports planes. The sport plane has to cruise to high velocity as compared to the heavy lift cargo planes. Therefore the drag force should be less, achieved by low drag coefficient. Because of the high velocity the airfoil is able to maintain the lift force even in the case of low lift coefficient.

In the case of S1223 airfoil, drag and lift coefficient are high as shown in Table 4. Thus is suitable for heavy lift cargo planes. The lift force requirement is higher in cargo planes as it has to lift heavy loads. This is achieved by high lift coefficient. The velocity requirement in cargo planes is lesser as compared to sports plane. Due to lesser velocity the drag force is less even in case of high drag coefficient (Table 4). But since the evolution of aircraft came into existence the focus is always kept on getting high lift at low drag. Since both cannot be achieved simultaneously the balance has to be maintained according to the application.

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