

Selection of Aerofoil based on Lift and Drag Coefficients using ANSYS FLUENT Software

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Abstract

This paper deals with the selection of aerofoil based on Lift and Drag Characteristics. Two different type of aerofoils such as ordinary Aerofoil and Supercritical Aerofoil that are being used in currently are selected namely NACA0012 and NACA SCA0714 are being considered for analysis. The tests are conducted using ANSYS FLUENT simulation software. The two aerofoils are tested at various Angles of Attack (-10°, -5°, 0°, 5°, 10°) and at two different flow conditions. Finally, the aerofoil with its angle of attack is tabulated with its lift and drag coefficients. The test results of both aerofoils are compared and results are concluded.

Keywords: Aerofoils, characteristics, Supercritical Aerofoil, NACA0012, NACA SCA0714, ANSYS FLUENT, Angles of attack, Lift and Drag Coefficients

INTRODUCTION

Aerofoil

An aeroplane has become a common mode of transportation in this modern period than in the past. People around the globe have started using this mode of transportation as a normal means. So, this has led to the development in field of

aerodynamics. Development was to be made in the design of aeroplane. So, Mechanical field is found to be the starting for its development. Initially developed planes faced difficulties in setting up lifting surfaces or wings, a method of balancing and controlling the aircraft and means of propulsion. These

difficulties were overcome by the introduction of Aerofoil around 18th century.

Aerofoils are the cross sectional shape or profile that is obtained by the intersection of an aeroplane wing with a perpendicular plane. It's a body designed to produce a desired reaction force when in motion relative to surrounding air. When aerofoils oriented at a suitable angle, they deflect the oncoming air resulting a force on an aerofoil in the direction opposite to the deflection, this force is called aerodynamic force. This can be resolved into two as Lift and Drag.

The lift and drag are created by the turning effect of air in the vicinity of the aerofoil, that creates curved streamlines, resulting in the pressure difference with lower pressure on one side and higher pressure on other. This pressure difference is accompanied by a velocity difference via Bernoulli's principle. So, the resulting flow field above the aerofoil has a higher average velocity on the upper surface than on the lower surface.

Super Critical Aerofoil

A supercritical aerofoil is an aerofoil primarily designed, to delay the onset of wave drag in the transonic speed range.

Supercritical aerofoils are characterized by their flattened upper surface, highly cambered (curved) aft section, and larger leading edge radius compared with NACA 6-series laminar aerofoil shapes. Standard wing shapes are designed to create lower pressure over the top of the wing.

The camber of the wing determines how much the air accelerates around the wing. As the speed of the aircraft approaches the speed of sound the air accelerating around the wing will reach Mach 1 and shockwaves will begin to form. The formation of these shockwaves causes wave drag. Supercritical aerofoils are designed to minimize this effect by flattening the upper surface of the wing.

Supercritical aerofoils feature four main benefits:

- 1) They have a higher drag divergence Mach number.
- 2) They develop shock waves further aft than traditional aerofoils.
- 3) They greatly reduce shock-induced boundary layer separation.
- 4) Their geometry allows for more efficient wing design.

Lift

The component of the force perpendicular to the direction of motion is called lift. The lift on an aerofoil is primarily the result of its angle of attack and shape. The lift generated by the wing sustains the weight of the aircraft to make flight in the air. Lift is mainly due to unequal pressure on the aerofoil surface.

Drag

The component of the force defined to be parallel to the direction of the oncoming air flow. The drag force is due both to viscous friction forces at the surface of the aerofoil and to unequal pressure on the aerofoil surfaces facing toward and away from the oncoming flow.

Angle of Attack (AOA)

AOA is the angle between the oncoming air or relative wind and a reference line on the airplane or wing. Sometimes the reference line is a line connecting the leading edge and trailing edge at some

average point on a wing. As the nose of the wing turns up, AOA increases, and lift increases. Drag goes up also, but not as quickly as lift. The lift coefficient varies with angle of attack. Critical angle of attack is the angle at which maximum value of lift is obtained, which is also called as stall angle.

DESIGN OF AEROFOILS

NACA design:

The NACA aerofoils are standard aerofoil shapes for aircraft wings developed by the National Advisory Committee for Aeronautics (NACA). The shape of the NACA aerofoils 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 aerofoil and calculate its properties.

The formula for the shape of a NACA 00xx foil, with "xx" being replaced by the percentage of thickness to chord, is:

$$y_t = 5t \left[0.2969 \sqrt{\frac{x}{c}} - 0.1260 \left(\frac{x}{c} \right) - 0.3516 \left(\frac{x}{c} \right)^2 + 0.2843 \left(\frac{x}{c} \right)^3 - 0.1015 \left(\frac{x}{c} \right)^4 \right]$$

Where:

- c is the chord length,
- x is the position along the chord from 0 to c,
- y_t is the half thickness at a given value of x (centreline to surface), and

- t is the maximum thickness as a fraction of the chord (so t gives the last two digits in the NACA 4-digit denomination divided by 10).

This equation gives the thickness as percentage of the chord length, to get the thickness the above equation should be multiplied with c .

Inputs and Boundary condition:

The problem considers flow around the Aerospatiale aerofoil at different angles of attack. For that we take some initial inputs

and boundary condition for our problem which are shown in the table.

2D analysis of NACA aerofoils

The test results of 2D aerofoil are calculated using ANSYS FLUENT software.

The test is being conducted for both uniform and non-uniform flow conditions.

The results are shown only for the uniform flow conditions and similar procedure is followed for non-uniform flow conditions.

Table: 1

S.No	Input	Value
1	Velocity of flow	945km/hr(subsonic)
2	Operating temperature	300 K
3	Operating pressure	50Pa(assumption)
4	Model	Transition
5	Density of fluid	1.225 Kg/m ³
6	Kinematic viscosity	1.4607*10 ⁻⁵
7	Length	1 m
8	AOA	0°,5°,10°,-5°, -10°
9	Fluid	Air as an ideal

RESULTS

2D analysis OF NACA0012 under uniform flow condition

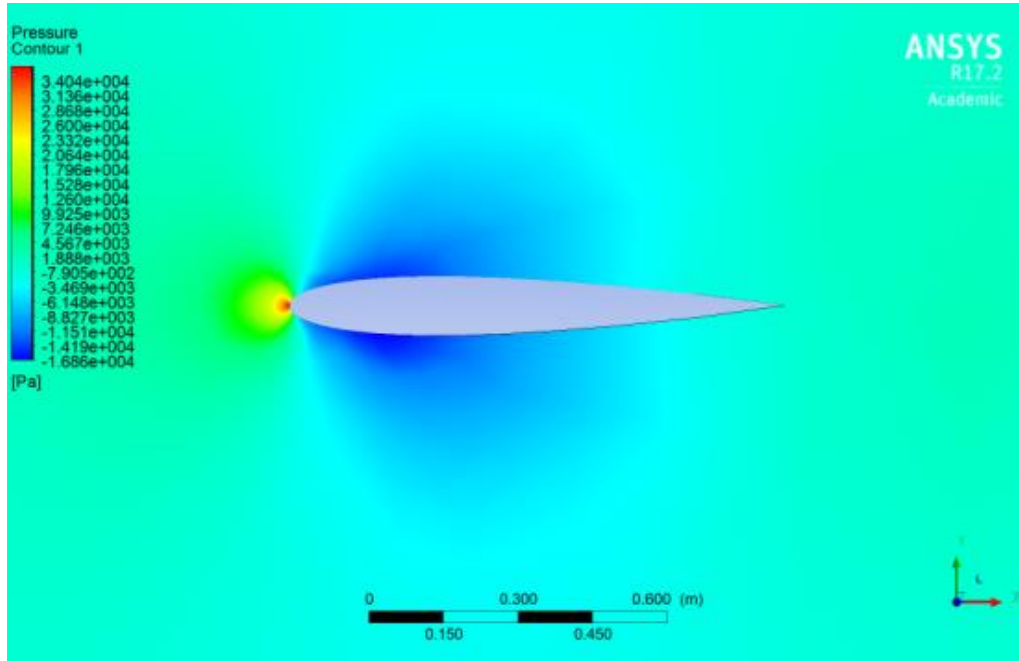


Fig: 1 NACA 0012 at Angle of Attack 0°

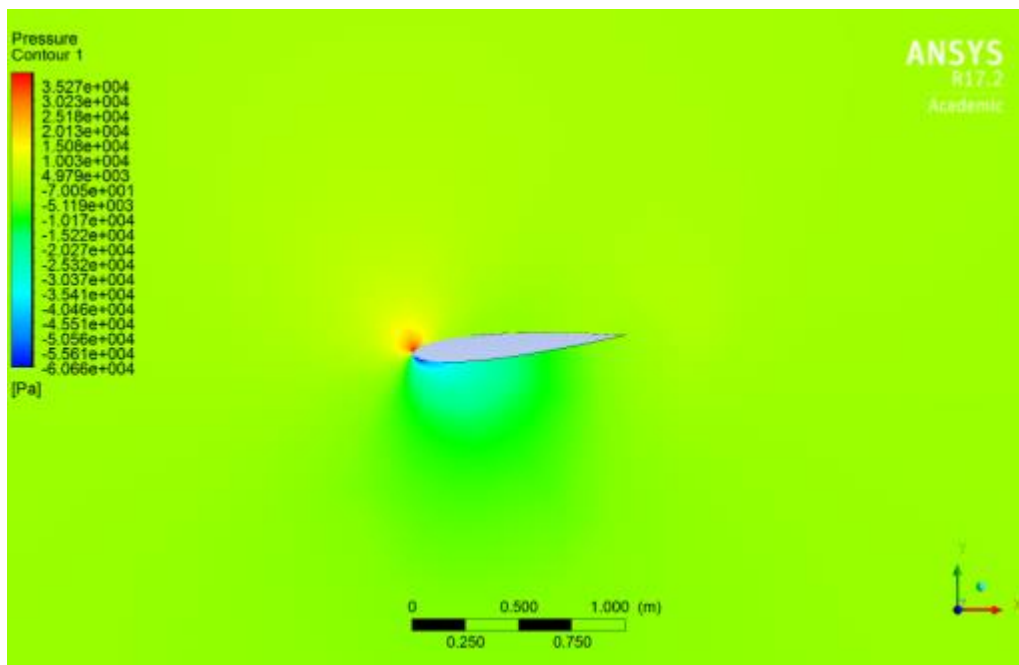


Fig: 2 NACA 0012 at Angle of Attack 5°

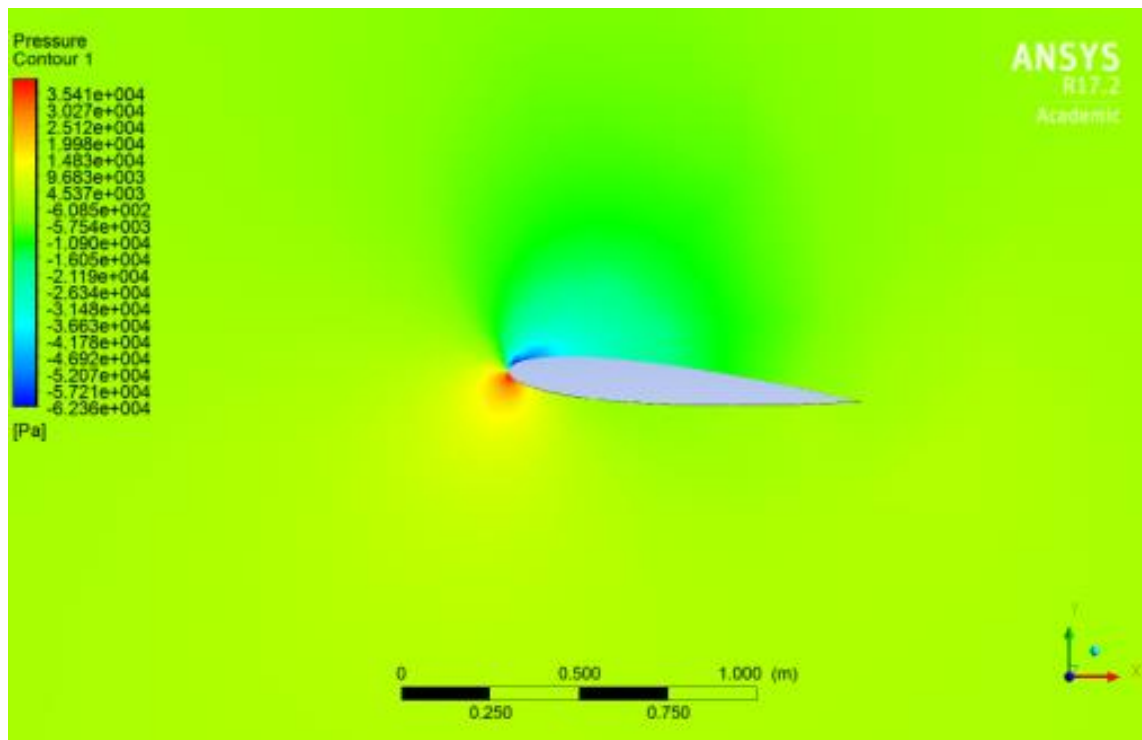


Fig: 3 NACA 0012 at Angle of Attack -5°

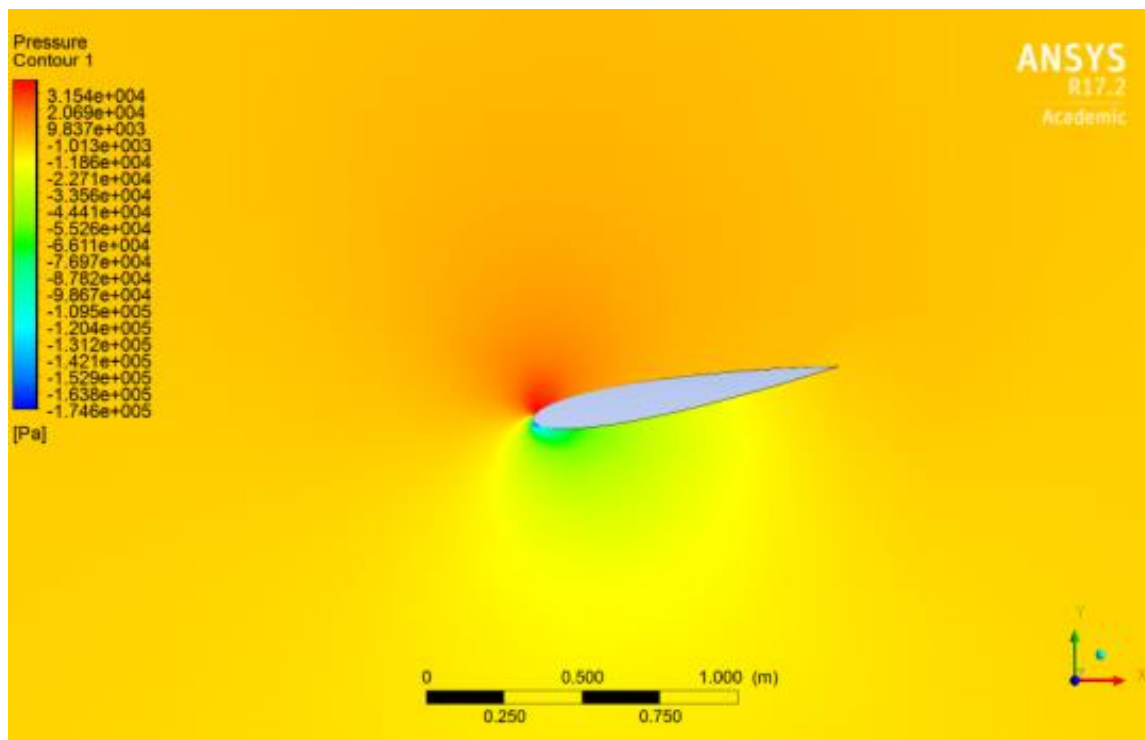


Fig: 4 NACA 0012 at Angle of Attack 10°

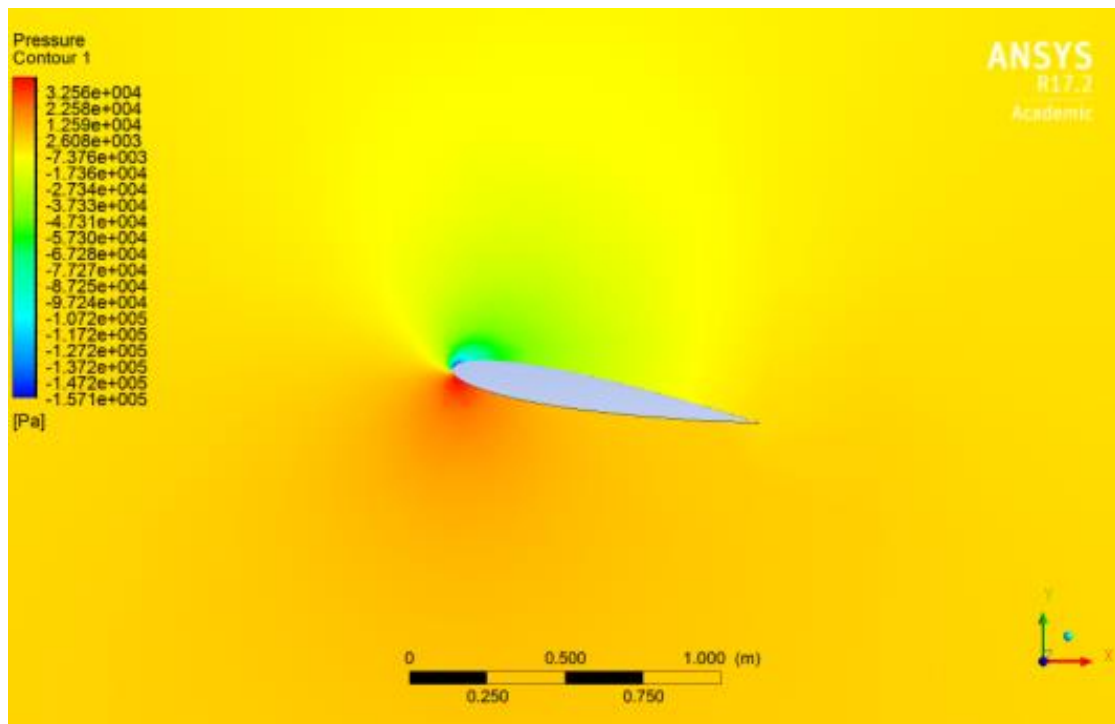


Fig: 5 NACA 0012 at Angle of Attack -10°

Table: 2

Angles of attack(θ)	Maximum pressure(N/mm ²)	Minimum pressure(N/mm ²)
-10°	3.256×10^{004}	-1.571×10^{005}
-5°	3.541×10^{004}	-6.236×10^{004}
0°	3.404×10^{004}	-1.686×10^{004}
5°	3.527×10^{004}	-6.066×10^{004}
10°	3.154×10^{004}	-1.746×10^{005}

2D Analysis for NACA SCA 0714 under uniform flow condition

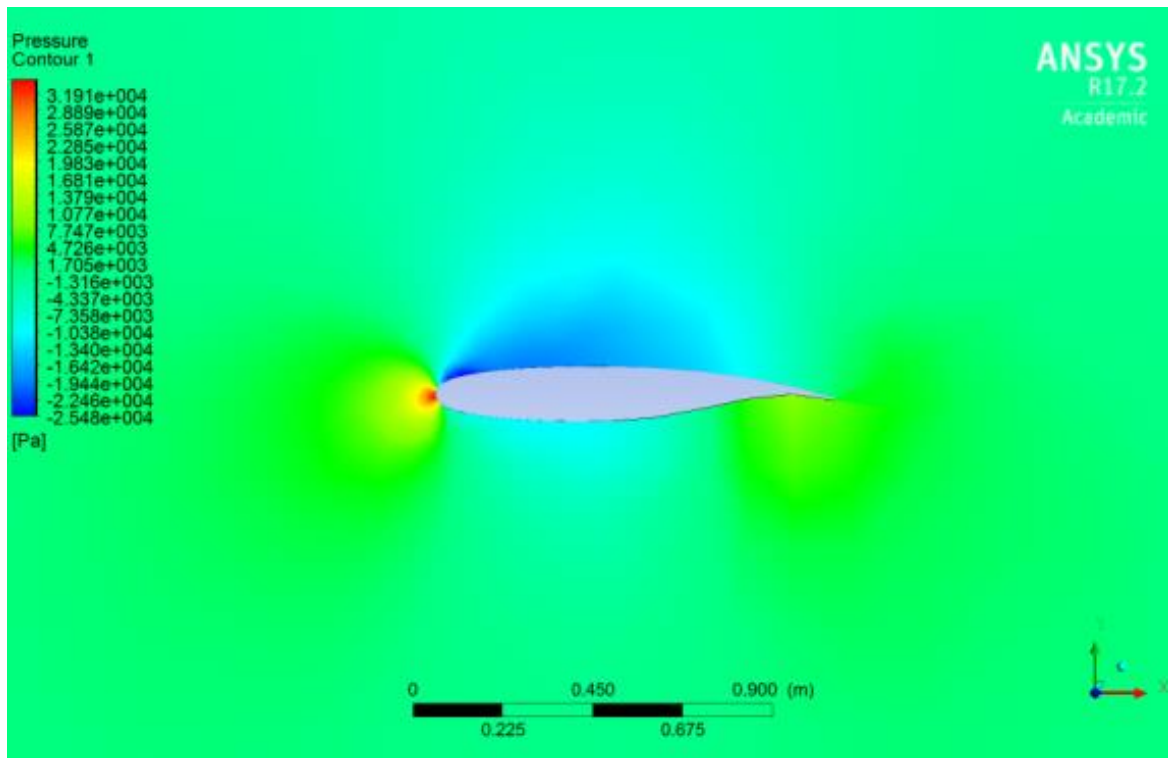


Fig: 6 NACA 0714 at Angle of Attack 0°

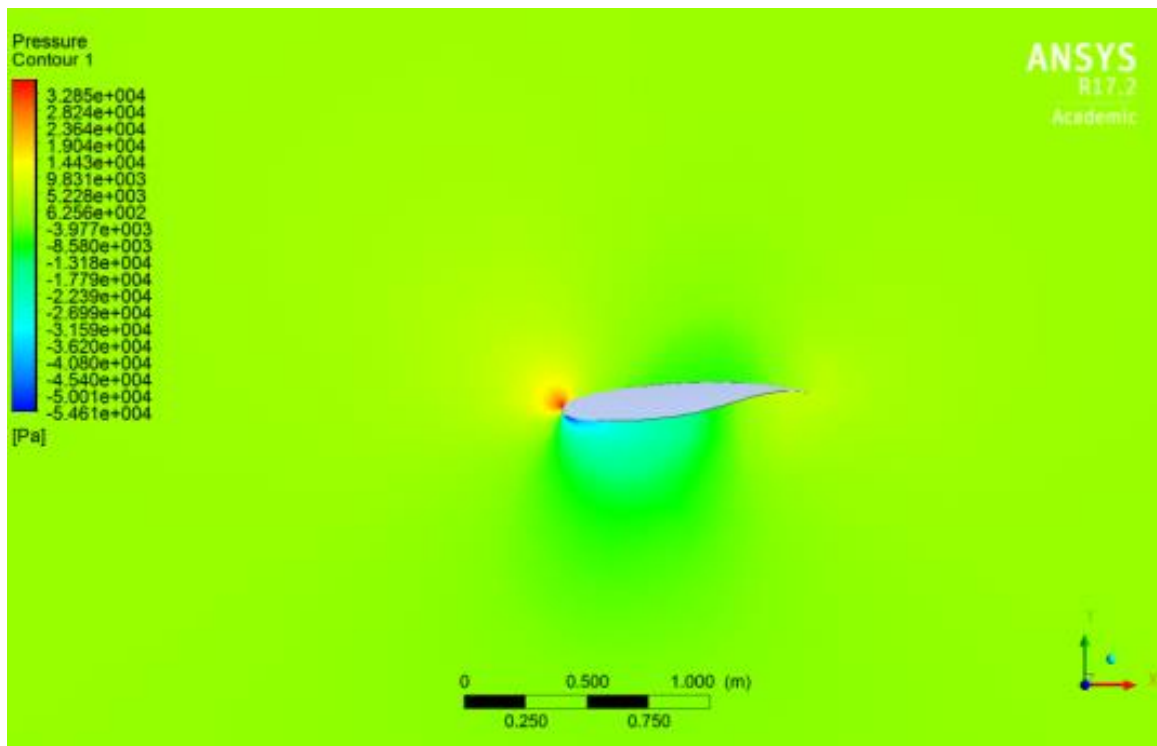


Fig: 7 NACA 0714 at Angle of Attack 5°

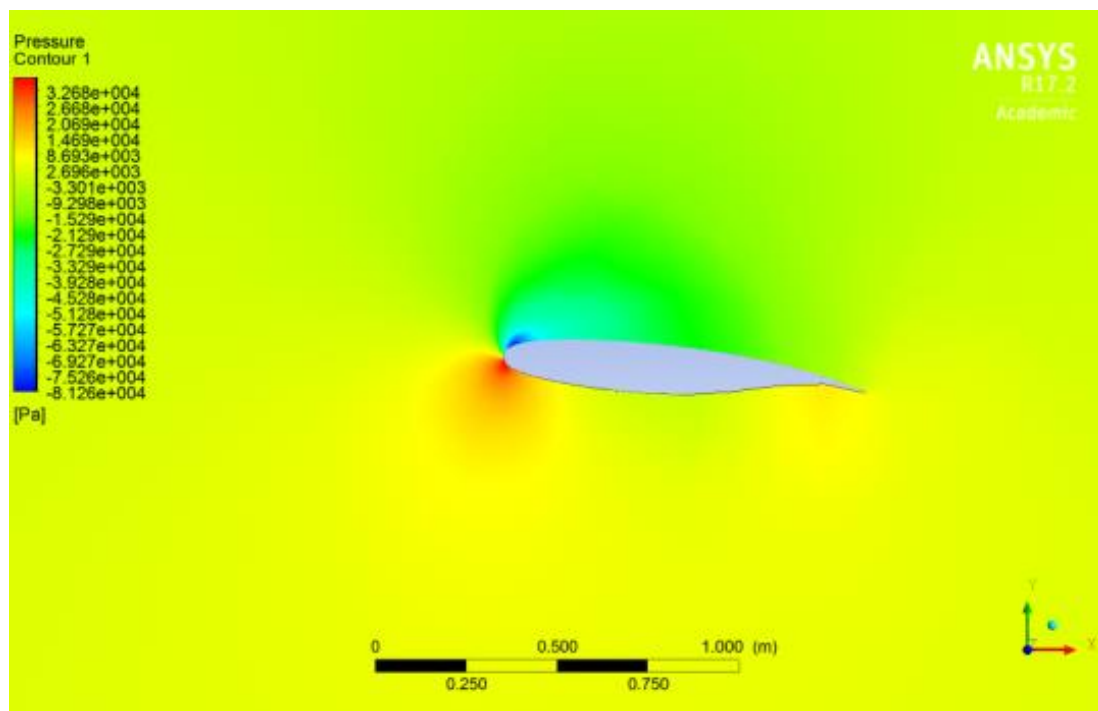


Fig: 8 NACA 0714 at Angle of Attack -5°

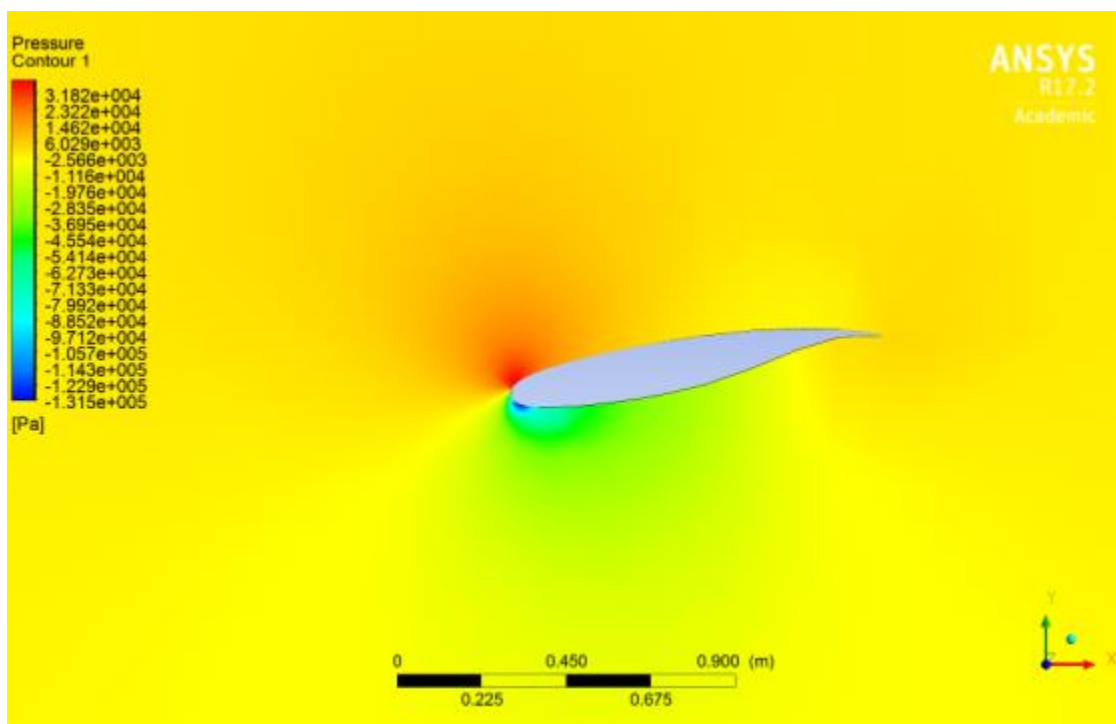


Fig: 9 NACA 0714 at Angle of Attack 10°

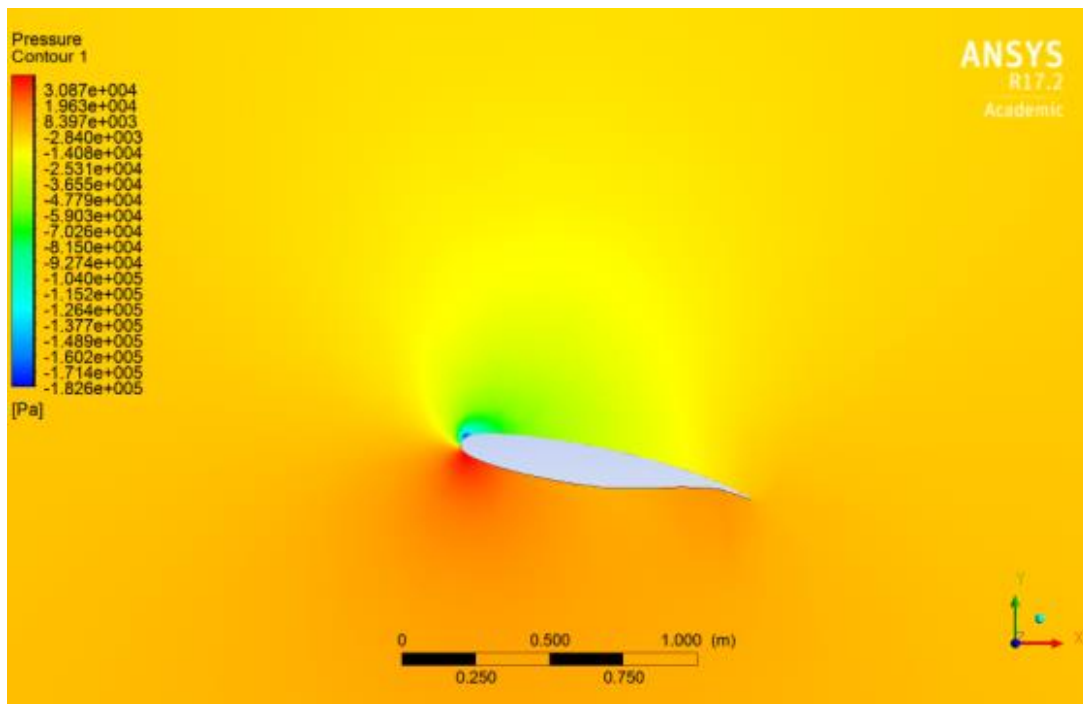


Fig: 10 NACA 0714 at Angle of Attack -10°

Table: 3

Angles of attack(θ)	Maximum pressure(N/mm ²)	Minimum pressure(N/mm ²)
-10°	3.087×10^{004}	-1.826×10^{005}
-5°	3.268×10^{004}	-8.126×10^{004}
0°	3.191×10^{004}	-2.548×10^{004}
5°	3.285×10^{004}	-5.461×10^{004}
10°	3.128×10^{004}	-1.315×10^{005}

Calculation of Lift And Drag Coefficients

The lift and drag co-efficients are calculated from the pressure values

$$C_d = (C_d)_{\text{pressure}} + (C_d)_{\text{skin friction}}$$

$$C_l = (C_l)_{\text{pressure}} + (C_l)_{\text{skin friction}}$$

$(C_d)_{\text{pressure}}$ -pressure force

$(C_l)_{\text{skin friction}}$ - viscous force

Table: 4 Lift and Drag coefficients for NACA0012 under Uniform flow

Angles of Attack(θ)	Coefficient of Drag	Coefficient of Lift
-10	0.065190891	0.21709556
-5	0.038122791	0.055860892
0	0.002790981	-0.1890393
5	-0.021654775	-0.45644728
10	0.028267166	-1.0010201

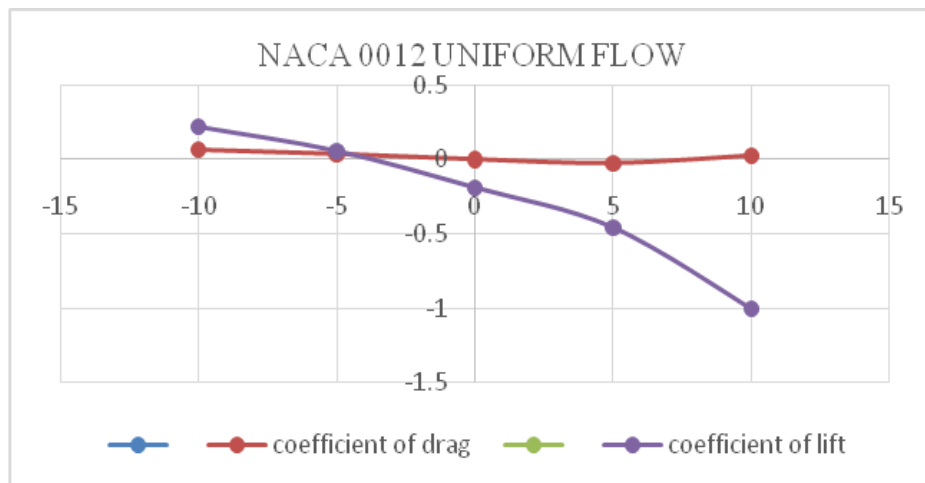


Fig: 11

Table: 5 Lift and Drag Coefficients for NACA SCA0714 under uniform flow

Angles of Attack(θ)	Coefficient of Drag	Coefficient of Lift
-10	-0.000633863	0.000125643
-5	0.00213518	0.6233081
0	0.024263832	0.276946
5	0.020146495	-0.29541183
10	0.039038737	-0.817958

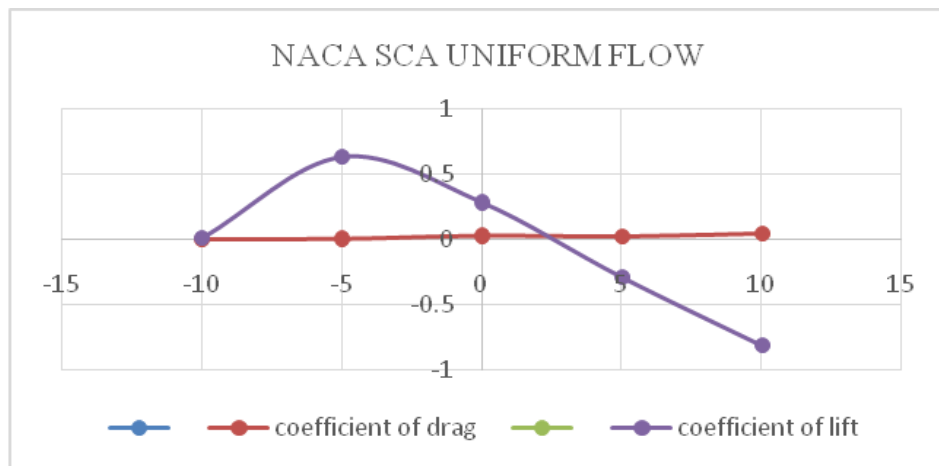


Fig: 12

Table: 6 Lift and Drag coefficients for NACA0012 under non uniform flow

Angles of Attack(θ)	Coefficient of Drag	Coefficient of Lift
-10	0.16830169	0.77894025
-5	0.099662474	0.7067752
0	0.003778813	0.05351348
5	-0.008292727	0.59078252
10	-0.085344535	0.77637661

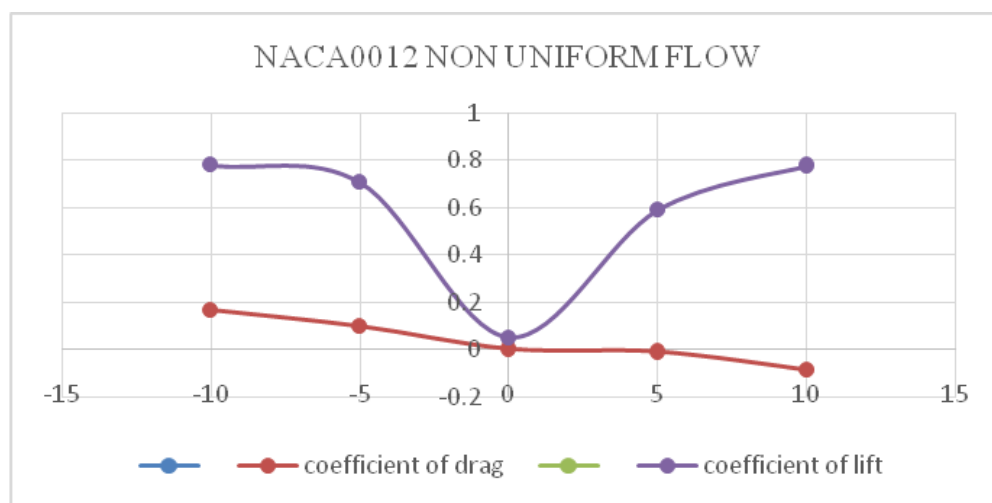


Fig: 13

Table: 7 Lift and Drag coefficients for NACA SCA0714 under non uniform flow

Angles of Attack(θ)	Coefficient of Drag	Coefficient of Lift
-10	0.00263801	-0.000519932
-5	0.051001565	0.3673918
0	0.03822941	0.89890605
5	-0.03534315	0.86005164
10	-0.091777666	0.85651666

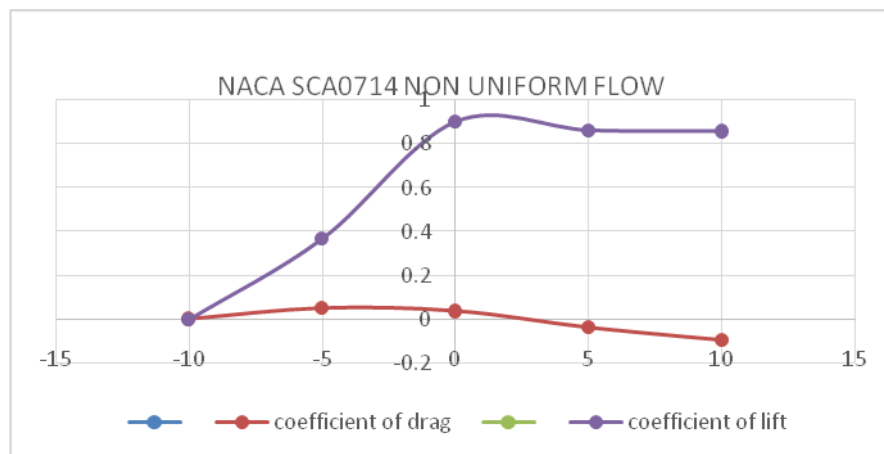


Fig: 14

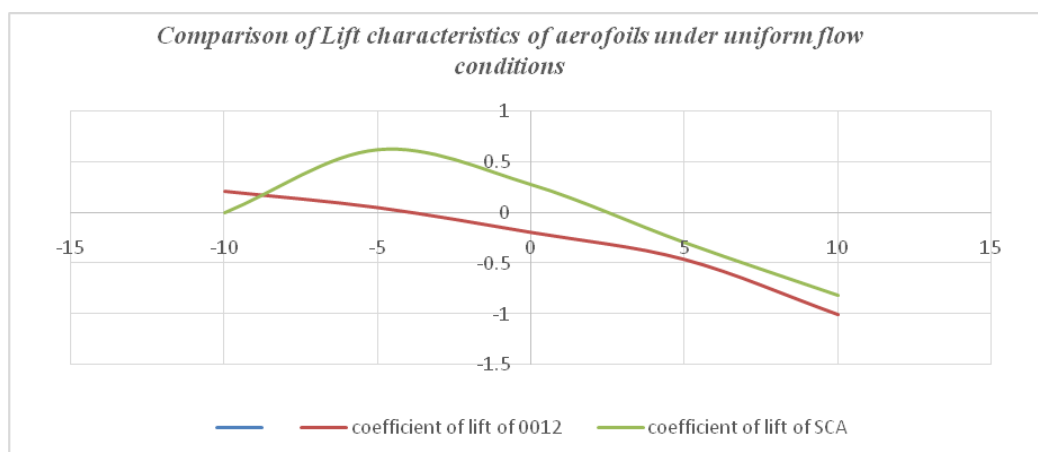


Fig: 15

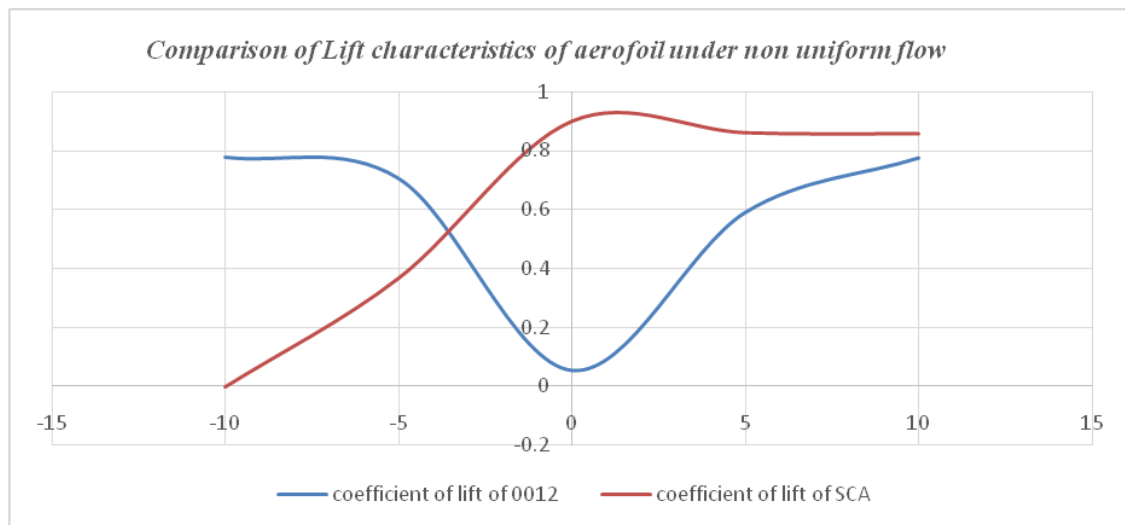


Fig: 16

CONCLUSION

When, the air at 945 km/hr is being passed to strike the aerofoil at various angles of attack following results has been observed:

- It can be seen that the lift coefficient and drag coefficient keeps varying at various angles of attack.
- The ordinary aerofoil NACA 0012 which is symmetrical in structure exhibits minimum value of lift value when compared to NACA 0714.
- The NACA 0012 show increase in drag value than the NACA 0714 aerofoil structure and also to be noted that the drag reduces as the angle of attack increases.
- If only lift and drag are to be considered while selecting the aerofoil, then the best option is to go with the Supercritical Aerofoils.
- This provides maximum value of lift at various angles of attack and considerably less drag coefficient.
- Hence, it can be concluded that the NACA SCA 0714 is the best suitable aerofoil which could replace the NACA0012 aerofoil and also its being recommended as it increases the performance of aeroplane in both terms of uniform and non-uniform flow.

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