FLOW BEHAIVIOUR OVER SUPERCRITICAL AEROFOIL RESPECTIVE TO NACA AEROFOIL

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Abstract - *In aviation dynamic developments are being done to enhance the performance of aircraft wing design and hence lift and drag characteristics. Fundamental objective of this research is to compare the aerodynamics characteristics and demonstrating the superiority of supercritical aerofoil SC20410 over NACA0010 aerofoil and its advantages over NACA. For this purpose distribution of pressure over the top surface of supercritical aerofoil SC20410 and NACA0010 airfoil at different mach number has been analyzed with the help of ANSYS design modular. The meshing is done by using ANSYS ICEM CFD, which is software pack used for CAD analysis and generation of mesh. The meshed model is imported in ANSYS CFX. We will see in this research how coefficient of drag decrease and coefficient of lift increase as we increase the mach number for two different aerofoil NACA0010 and SC20410.*

Key Words: *Supercritical Aerofoil, NACA series, ANSYS ICEM CFD, Drag Divergence*

1. INTRODUCTION

Historical background says that various development of airfoil development took place till now. Earlier wing design testing was done with the help of wind tunnel testing methods but now days with advancement of computer technology the task has become very easier than earlier one. Design of wing and its optimization is done in different CAD software package and their analysis in some analytical software like ANSYS. The aerodynamics characteristics are obtained very accurately with the help of these CAD and CFD analysis. In current era of technology we have the most advanced aerodynamics in the field of aeronautics. Current days manufacturing companies are developing very high aerodynamics characteristics of aircraft like B787 Dream liner wing tips design has highest possible efficiency in aerodynamics of aircraft. In the steps of development a number of wing design has been obtained in NACA series system. Supercritical aerofoil design and development is one of the currently used in aeronautical field. There are number of advantage of supercritical aerofoil over the conventional aerofoil. This research theory has shown the benefits of supercritical aerofoil with respect to conventional aerofoil.

NACA 4 digit aerofoil generator:

NACA ABXX, where

A – Maximum camber when divided by 100

B – Position of maximum camber divided by 10

XX – thickness divided by 100

Ex. NACA 1412,

A = 1, i.e. camber is 0.01 or 1% of chord

B = 4, i.e. position of camber is at 0.4 or 4% of chord

XX = 12, i.e. thickness of aerofoil is 0.12 of 12% of chord

The plot of above aerofoil data by the aerofoil tools is given below.

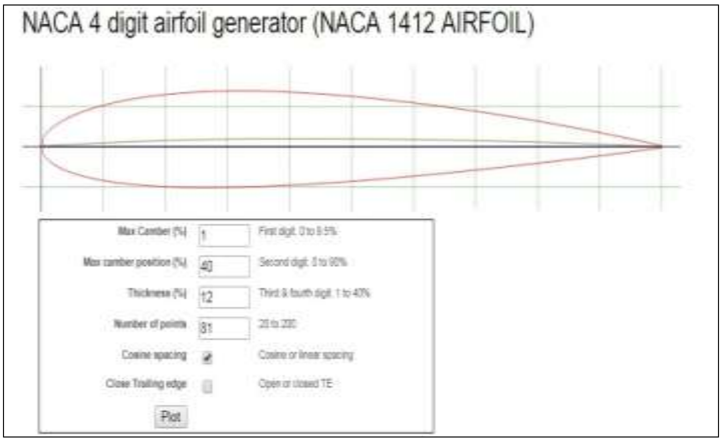


Fig 1. Aerofoil Generator of NACA 4 Digit System

Supercritical Aerofoil:

A conventional aerofoil have some supersonic region over the surface as subsonic free stream mach number increase and approach to transonic region. A plot of such type of aerofoil is shown below.

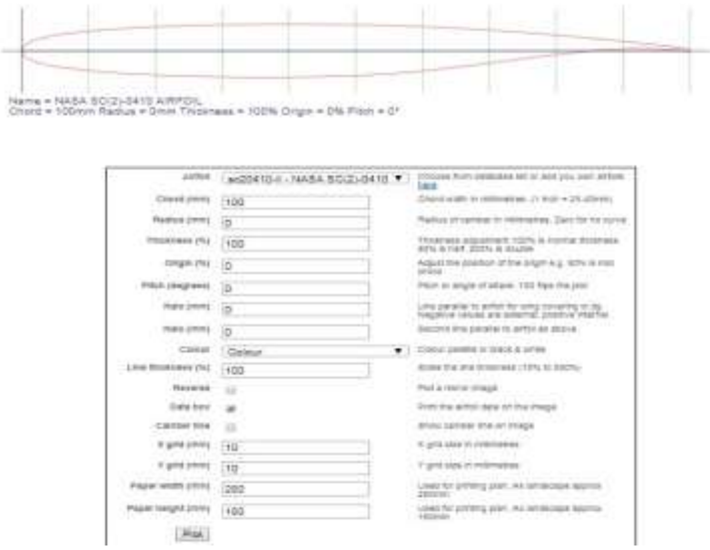


Fig 2.Aerofoil Generator of SC20410

LITERATURE SURVEY

A. A.B.M. Toufique Hasan, Md. Mahbub Alam(2013): This research article show the buffeting phenomena of supercritical aerofoil when there is interaction between induced oscillatory shock wave and airflow boundary layer. The result used the help of RANS to verify the buffering in transonic region. Research computed the data at free stream mach number of 0.77 and varying the AOA from 2^0 to 7^0.

B. Ravikumar T, Dr. S B Prakash (2014) this study mainly focus on the flow separation over the supercritical airfoil with the variation of angle of attack. It uses the CFD simulation method for gaining the results at AOA varying from 0^0 to 22.5^0at discrete values. It further estimate the maximum velocity, maximum pressure etc. with respect to change of AOA

C. Sonia Chalia (2016): This research work shows basically the comparison between a conventional airfoil and supercritical aerofoil. Also show a number of benefits of evaluation of supercritical aerofoil respective to a common airfoil in NACA series. It studies the flow separation, drag divergence about the airfoil shape and stalling criteria of wing.

D. Mohamed A. Fouad Kandil, Abdelrady Okasha Elnady (2017) this is another experiment on the behaviors of air flow and its resulted characteristics over the airfoil. Which uses the ANSYS design modular for object orientation and CFD for the analysis and to obtain all the aerodynamic coefficients

E. Haci Sogukpinar (2018) In this research work the performance of NACA0012 was done with different modification on the airfoil to obtain a better perfoemance and found effective lift coefficient stall characteristics. The result was experimented numerically by varying thickness of pressure type.

F. K.Soundarya (2018) The main objective of this project is to carry out design and analysis of various supercritical airfoils with same cruising local velocity along with the study of aerodynamic characteristics such as drag co-efficient and critical Mach number. The objective is to improve the Mach number of a subsonic aircraft at transonic Mach speeds. The design profile chosen is based upon existing airfoils used in Airbus A380-800.

G. Amol kumar singh, Vipin Kumar, Er Rahul Malik, Sanjay BhandarI (2018) analyzed the modal and theoretical analysis of Aircraft Wing. Aero elastic phenomena arise when structural deformations induce changes on aerodynamic forces. The additional aerodynamic forces from some sort of perturbation cause increase in the structural deformations, which lead to greater aerodynamic forces. Aero elasticity is the science which studies the interaction among aerodynamics, inertia and elastic forces

DETAILED PROCEDURE

Here simulation setup design of airfoil is performed using ANSYS design modular by using the coordinates provided and Meshing is done by using ANSYS ICEM CFD, which is very famous software pack that is utilized in CAD model analysis and generation of meshes.

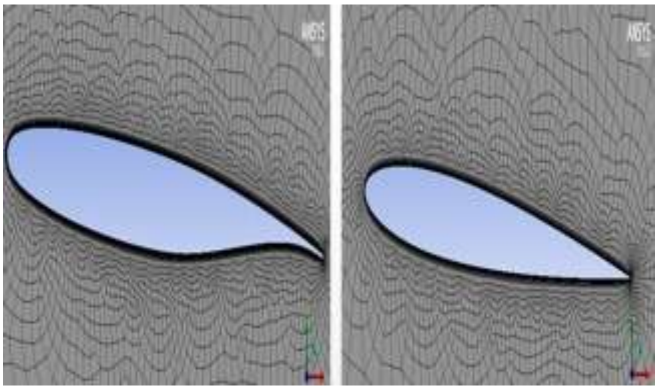


Fig 3. Zoom View of Meshed Model of SC20410 and NACA0010 Airfoil

The boundary condition is given as per the following table.

General	
Solver Type	Density Based
Time	Transient
Velocity Formulation	Absolute
2D Space	Planar
Models	
Multiphase	Off
Energy	On
Viscous	Standard K-e, Standard Wall Function
Materials	
Fluid	Air Ideal Gas
Fluid Definition	Material Library

Numerical Calculation for NACA Aerofoil and Supercritical Aerofoil

Speed of Sound: a = $\sqrt{\gamma RT}$

γ = 1.4

R= 287 J/Kg-K

T= 300K

Mach Number M= Assumed near Transonic Region

Flow Speed V (m/s) = M * a

Gauge Pressure (Pa) = ½ * ρ*V^2

Drag Force (N) = Calculated from the simulation

Lift Force (N) = Calculated from the simulation

Coefficient of Drag (C_d) = $\frac{Drag\ Force(N)}{½ * \rho * V2}$

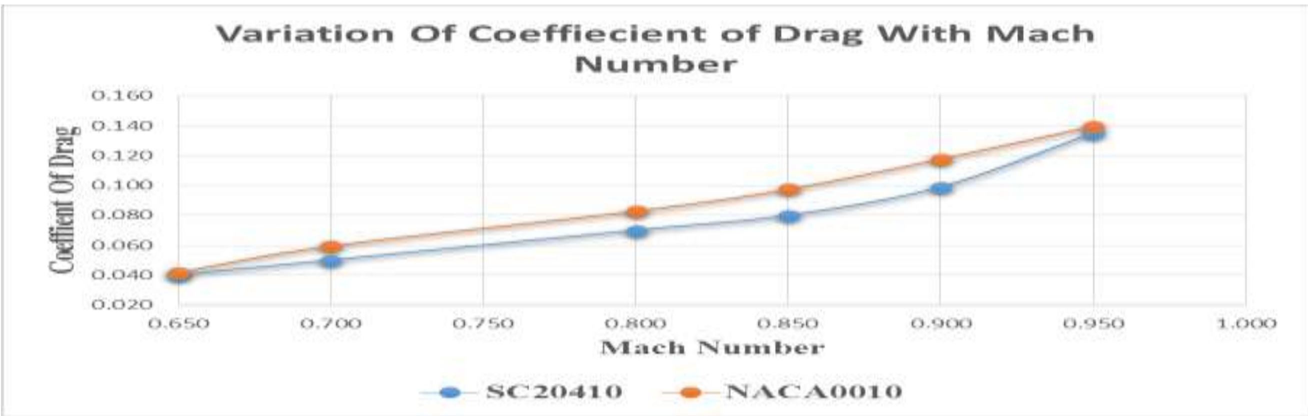
Coefficient of Lift (C_l) = $\frac{Lift\ Force(N)}{½ * \rho * V2}$

Tables obtained for NACA0010 and SC20410 are written two below respectively.

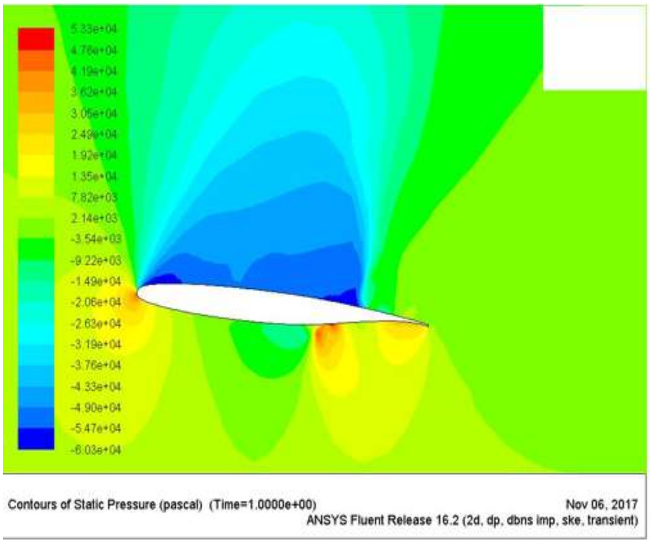
Obtained Value of Forces for NACA0010 airfoil							
Speed Of Sound (300K)	Mach No.	Flow Speed (m/s)	Gauge Pressure (Pa)	Drag Force (N)	Lift Force (N)	Coefficient Of Drag	Coefficient Of Lift
347.20	0.65	225.68	31210.80	1309.00	23755.00	0.04	0.76
347.20	0.70	243.04	36197.14	2156.00	21252.00	0.06	0.59
347.20	0.80	277.76	47277.90	3403.00	31553.00	0.08	0.67
347.20	0.85	295.12	53372.32	4444.29	33428.00	0.10	0.63
347.20	0.90	312.48	59836.09	5922.00	30467.00	0.12	0.51
347.20	0.95	329.84	66669.22	7694.00	37685.00	0.14	0.57

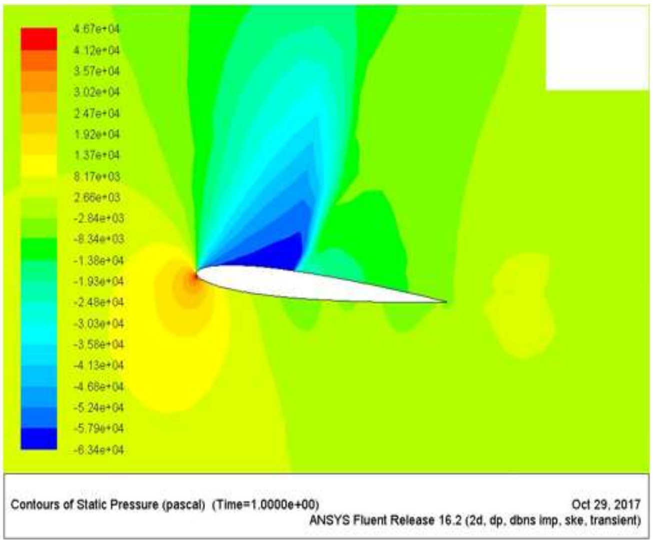
Obtained Value of Forces for SC20410 airfoil							
Speed Of Sound (300K)	Mach No.	Flow Speed (m/s)	Gauge Pressure (Pa)	Drag Force (N)	Lift Force (N)	Coefficient Of Drag	Coefficient Of Lift
347.20	0.65	225.68	31210.80	1248.35	32746.34	0.04	1.05
347.20	0.70	243.04	36197.14	1809.74	37978.00	0.05	1.05
347.20	0.80	277.76	47277.90	3309.24	51314.00	0.07	1.09
347.20	0.85	295.12	53372.32	4269.51	51968.00	0.08	0.97
347.20	0.90	312.48	59836.09	5923.39	52502.00	0.10	0.88
347.20	0.95	329.84	66669.22	8999.76	51549.00	0.13	0.77

Graphical representation of comparison between NACA0010 and SC20410 for coefficient of drag and with respect to mach number is shown in following graph.

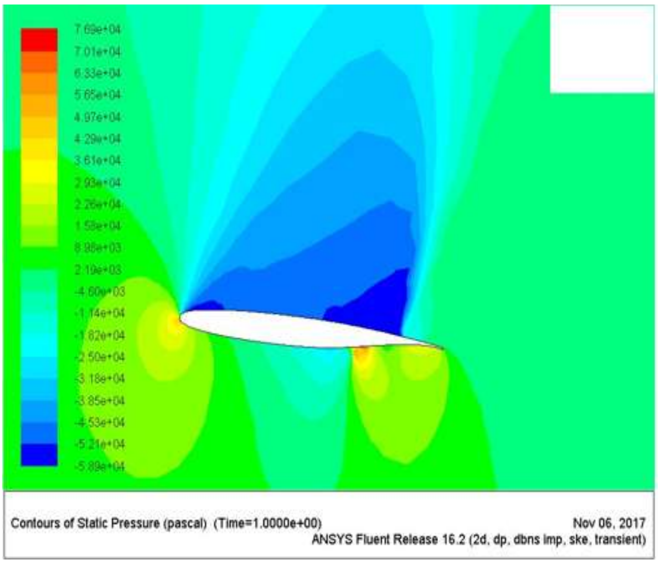


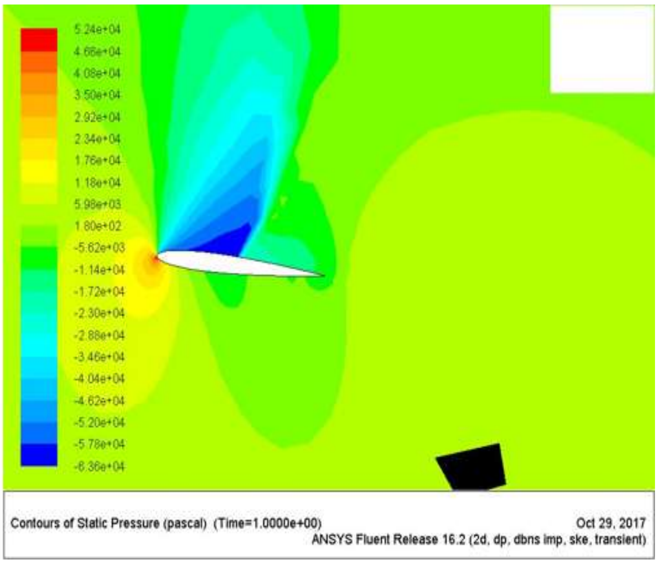
Comparison between airfoils using static pressure contour plot - Analytic View of Static Pressure Variation @ M=0.8 for SC20410 and NACA0010 Airfoil is shown in following picture



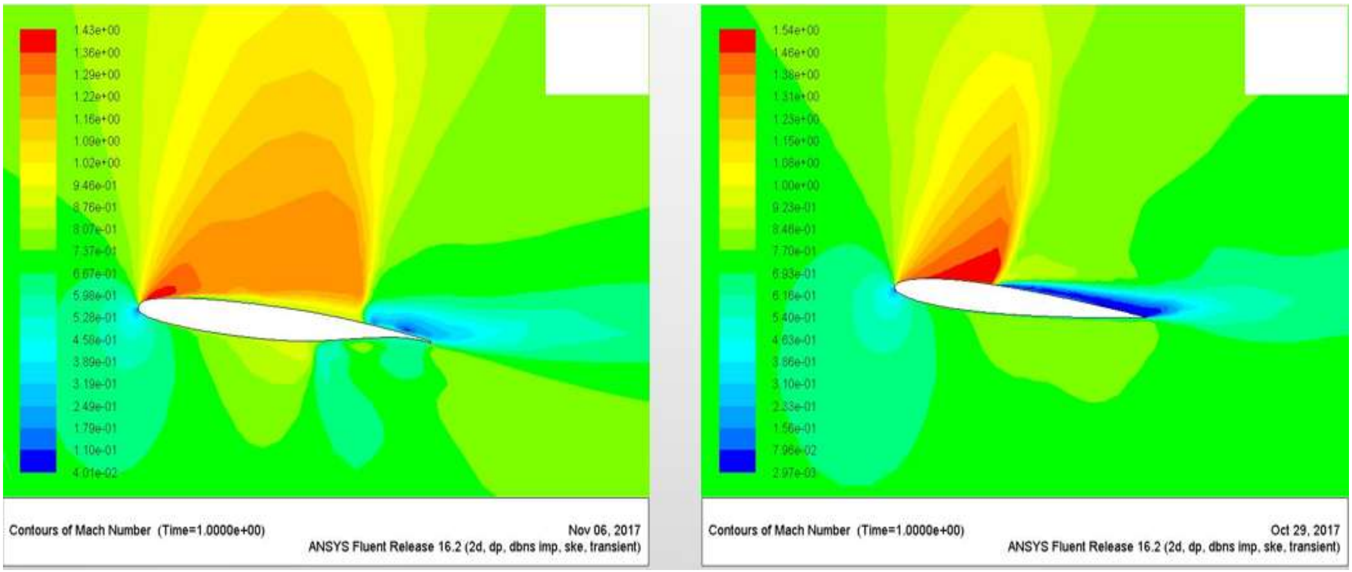


Comparison between airfoils using static pressure contour plot - Analytic View of Static Pressure Variation @ M=0.85 for SC20410 and NACA0010 Airfoil is shown in following picture

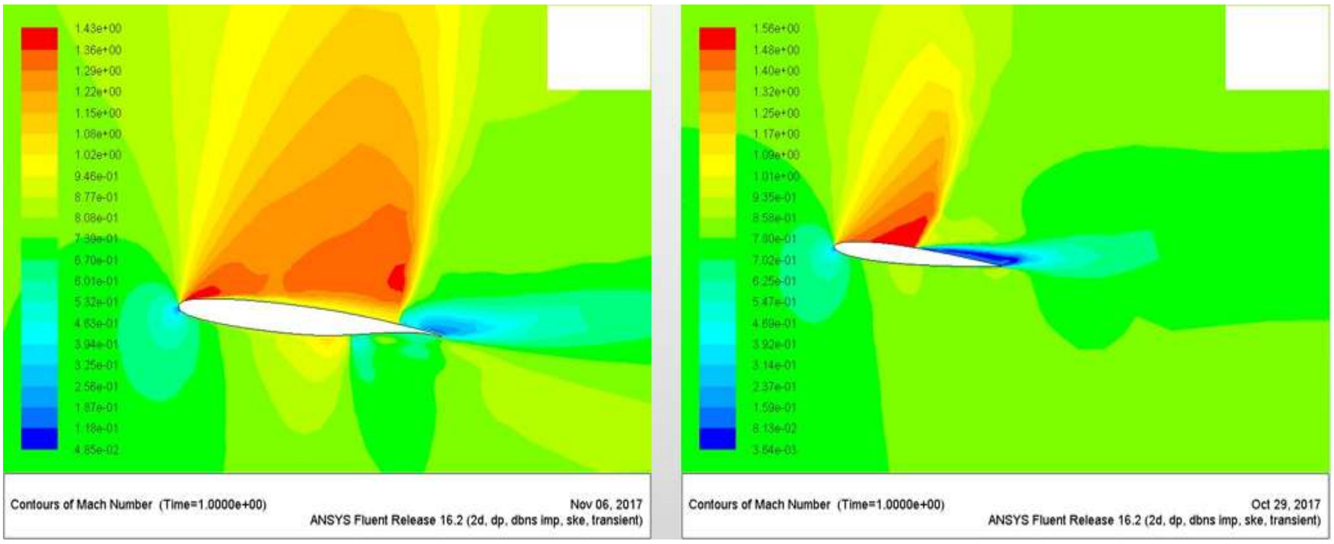




Comparison between airfoils using mach number contour plot - Variation of mach number @ M=0.8 for SC20410 and NACA0010 Airfoil is shown in following picture.



Comparison between airfoils using mach number contour plot - Variation of mach number @ M=0.85 for SC20410 and NACA0010 Airfoil is shown in following picture.



DISCUSSION & CONCLUSION

RESULT 1. STATIC PRESSURE

Local loss of static pressure on the top surface of supercritical aerofoil gradually varies with the mach number and covers whole of surface even at low transonic range comparatively to NACA aerofoil that is one factor of good lifting characteristics although at higher transonic region this result is almost same for both the airfoil. Simultaneously the local static pressure at bottom surface becomes stronger with variation of mach number in transonic region for supercritical airfoil comparatively NACA airfoil.

RESULT 2. MACH NUMBER

Mach number on the top surface of supercritical airfoil varies and covers the whole of surface as we tend to higher transonic range. In the result we can say that flow separation is delayed and normal shock also delayed at aft side of supercritical airfoil while for the NACA airfoil flow separation is very early and normal shock occurs at ahead of mid position. Because of whit comb design of supercritical airfoil local mach number at aft bottom is less than conventional airfoil.

RESULT 3. Drag Divergence Mach number

From the graph obtained between coefficient of drag and mach number shows that for supercritical airfoil coefficient of drag is less than conventional drag. There is a effective gap between curve of supercritical airfoil and conventional airfoil in the transonic range from mach 0.7 to 0.9. At higher mach means

WAVE DRAG

Wave drag becomes predominant for the conventional airfoil when the flow approaches the transonic region. This dominant wave drag is delayed by using the supercritical airfoil, which reduces the considerable amount of drag at speed near the transonic zone. Hence from the upper results we can conclude that in all respect supercritical airfoil has greater aerodynamics efficiency than conventional airfoil.

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