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ANALYSIS OF TRANSONIC FLOW OVER SUPERCRITICAL AIRFOIL USING CFD FOR GAS TURBINE BLADES

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Abstract

Aerofoil plays a vital role in performance of the gas turbine as they are the key component of the gas turbine blade. The aerofoil is the characteristic design criterion which helps to generate the whole blade on its profile. The various design parameters such as chord length, chamber position, value of chamber, blade thickness; all helps to develop a unique blade profile which will perform better for the given operating condition. Since objective of a gas turbine is to generate the optimum rotation by utilizing the gas stream coming up to it thus the objective while selecting the aerofoil will be to select the aerofoil with maximum value of lift to drag ratio. Also in case of transonic flow the location of shock also plays important role as it will cause losses and various functional problems associated with flow process. As gas turbine operates in transonic zone condition thus selecting a suitable aerofoil for such condition is a important part. Thus in this work we have selected some suitable well defined supercritical aerofoil for national adversary of aeronautical community series. Which are being compared with REA2282 aerofoil so as to identify the optimum aerofoil for our purpose.

***Keywords**: NACA series, supercritical aerofoil, Gas turbine blade profile.*

1. Introduction

A critical device is an device designed, primarily, to delay the onset of wave sweep up the sonic speed vary. Critical airfoils are characterized by their planate side, extremely cambered (curved) aft section, and bigger vanguard radius compared with NACA 6-series laminal aerofoil shapes. commonplace wing shapes are designed to make lower pressure over the highest of the blade by fast the air exploitation the Bernoulli's principle. The camber of the wing determines what quantity the air accelerates round the wing. because the speed of the craft approaches the speed of sound the air fast round the wing can reach mach one and shockwaves can begin to make. The formation of those shockwaves causes wave drag. supercritical airfoils are designed to attenuate this result by flattening the side of the wing. Further NACA 8 series aerofoil has been widely used many researchers for generating the optimum aerofoil design for the gas turbine blade.

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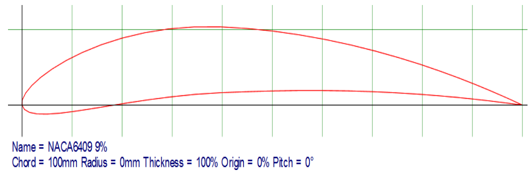

Fig 1 NACA 6 series aerofoil

The critical airfoils were recommended initial in European nation in 1940, when K.A. Kawalki at Deutsche Versuchsanstalt für Luftfahrt Berlin-Adlershof designed airfoils defined by elliptical leading edges, most thickness settled downstream up to fifty per cent chord and a flat side. Testing of those airfoils was according by B. Göthert and K.A. Kawalki in 1944. Kawalki's device shapes were just like Richard Whitcomb's. Hawker-Siddeley in Hatfield, European country designed in 1959-1965 improved device profiles called upper side rear-loaded airfoils, that were the premise of the airliner A300 critical wing, that initial flew in 1972.

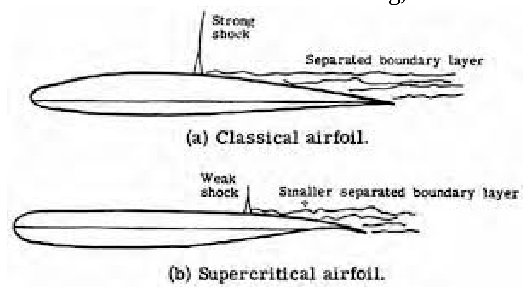

Fig 2 : boundary layer visualization in classical aerofoil and supercritical aerofoil

In the U.S., critical airfoils were studied within the Nineteen Sixties, by then National Aeronautics and Space Administration engineer Richard Whitcomb, and were initial tested on a changed North yankee T-2C Buckeye. when this initial check, the airfoils were tested at higher speeds on the TF-8A Crusader. whereas the planning was at first developed as a part of the supersonic transport (SST) project at National Aeronautics and Space Administration, it's since been chiefly applied to extend the fuel potency of the many high subsonic craft. The critical device form is incorporated into the planning of a critical wing and conjointly to the rotary engine blade profiles.

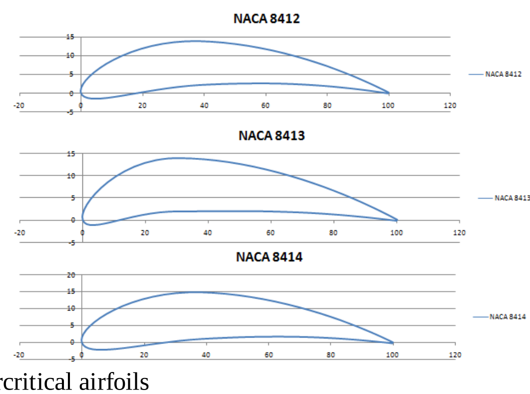

Fig 3 NACA 8 series supercritical airfoils

2. Methodology

To carry out the analysis we need to define a proper methodology thus shown below the methodology for carrying out the 2D simulation for the analysis of the aerofoils so as to identify the best available aerofoils for the purpose of the gas turbine blade profile.

Thus coming up to first step various aerofoils have been selected based on various study done. Basically aerofoils are divided in to two categories i.e critical and non critical aerofoils. In this work noncritical has been analysis with reference to REA2282 aerofoil. Thus comparative analysis has been carried out fot the following aerofoils REA 2282 (Base) ,NACA 8412, NACA 8413, NACA 8414.

I. Table 1 : analysis parameters

parameters	**Values**
Mach No.	0.729
AOA (base)	2.79°
Free stream pressure	1 Atm
Free stream temperature	300

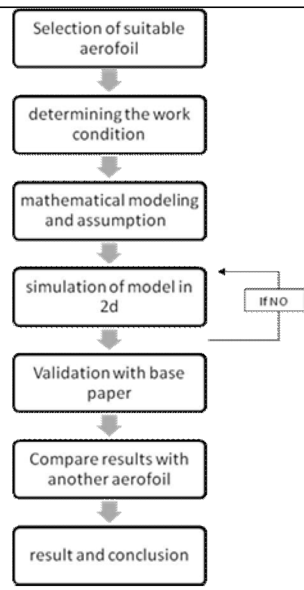

Fig 2: Flow chart of methodology for analysis

For the analysis a C mesh has been created around our airfoils of 1units each; as it is most reliable and widely used work envelop. The dimensions of the C mesh are as follows.

Table 2: C mesh boundary conditions

Top and bottom far field	12.5 of chord length
Upstream boundary	12.5 of chord length
Downstream boundary	20 of chord length

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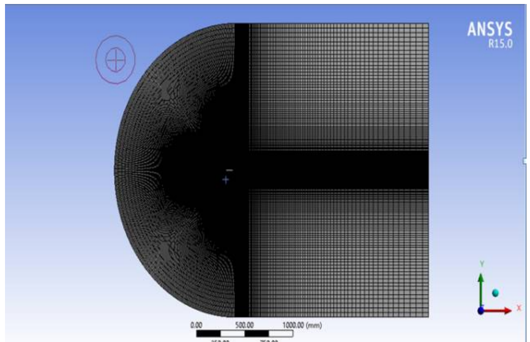

Fig 3 : C mesh domain

After completing the iteration with base aerofoil we get the aerodynamic parameters coefficient of drag and lift of the aerofoil which has been used to validate the results from the base work.

3. Aerodynamic Results

The aerodynamic parameters has been calculated using FVM solver ANSYS Fluent 15.0 for the airfoils NACA8412, NACA8413, NACA8414. The parameter calculated are coefficient of lift and drag also location of shock wave for varying angle of attack .

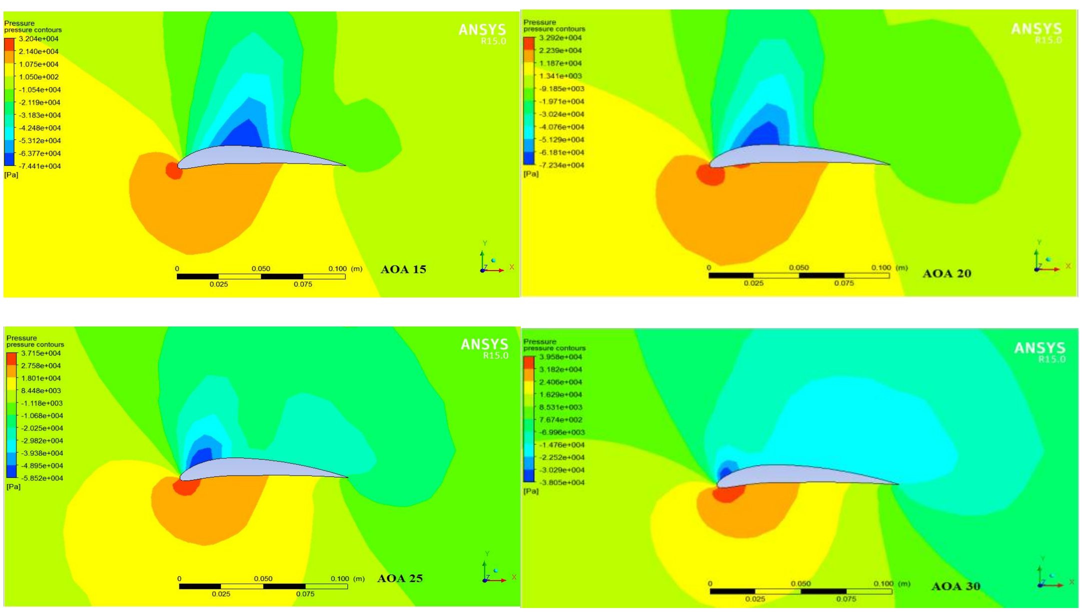

Fig: 4 shock wave location on NACA 8412 aerofoil for various angles of attack

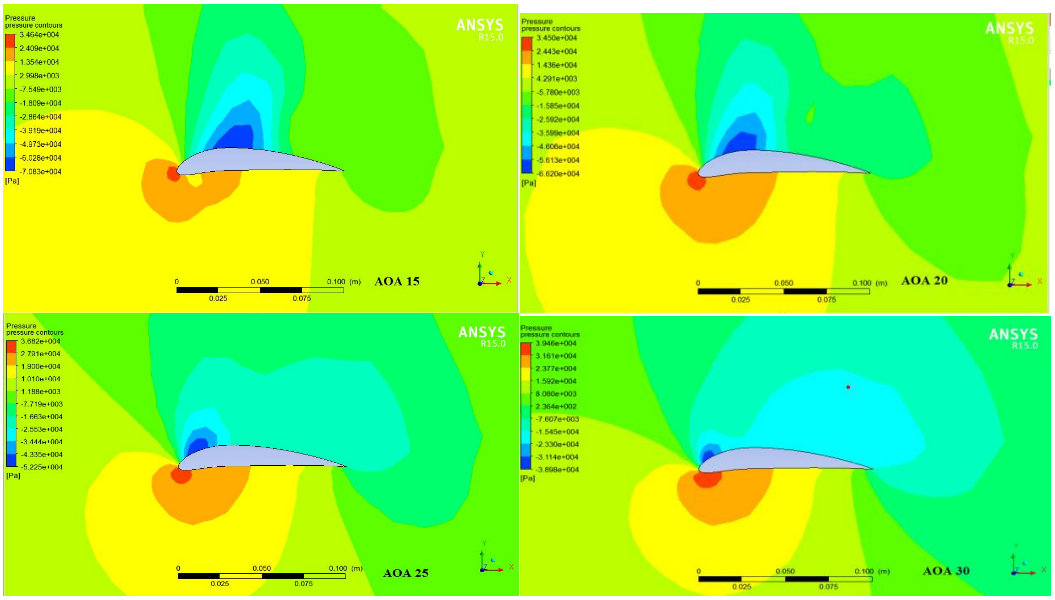

Fig: 5 Shock wave location on NACA 8413 aerofoil for various angles of attack

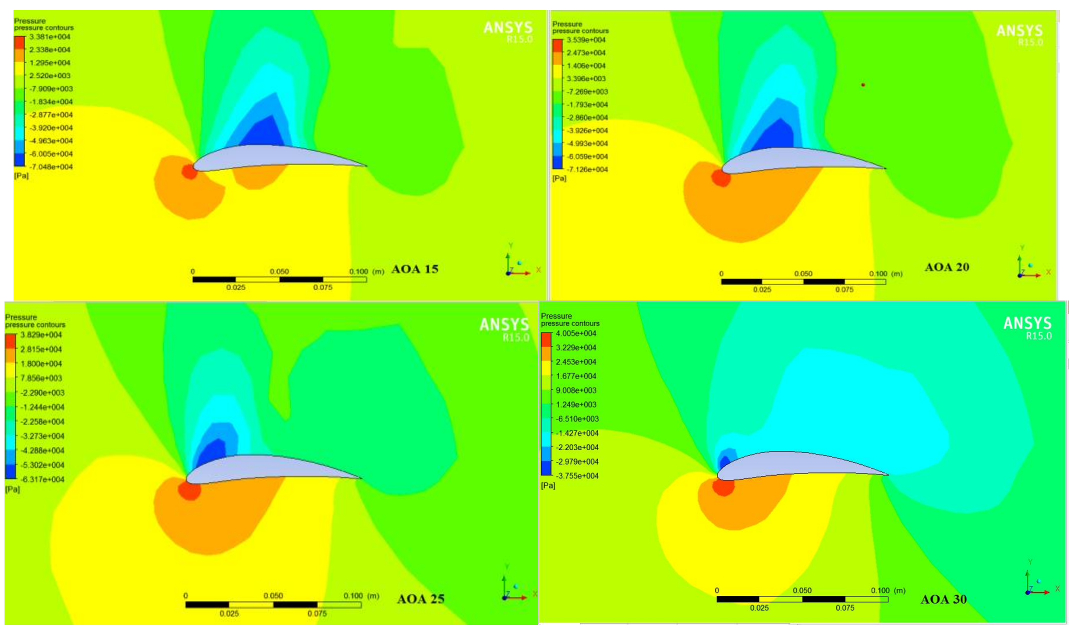

Fig: 6 Shock wave location on NACA 8414 aerofoil for various angles of attack

After performing the iteration for various non critical aerofoils the values of coefficient of drag and lift has been obtained also a derived parameters ration of lift to drag can also be obtained so as to get a better visualization of which is most suitable aerofoils which has been analyzed in our work.

Table 3 : Comparison of coefficient of drags of non critical aerofoil with reference

Cd				
AOA	**RAE2282**	**NACA8412**	**NACA8413**	**NACA8414**
0	0.0111	0.02206	0.023315	0.02042757
5	0.03818	0.02449	0.050429	0.04807726
10	0.123	0.132315	0.132833	0.0131
15	0.2468	0.263543	0.3635436	0.2625303
20	0.33555	0.42249	0.4224585	0.42255459
25	0.4591	0.574338	0.57525499	0.5740471
30	0.54	0.6889468	0.68874011	0.68978

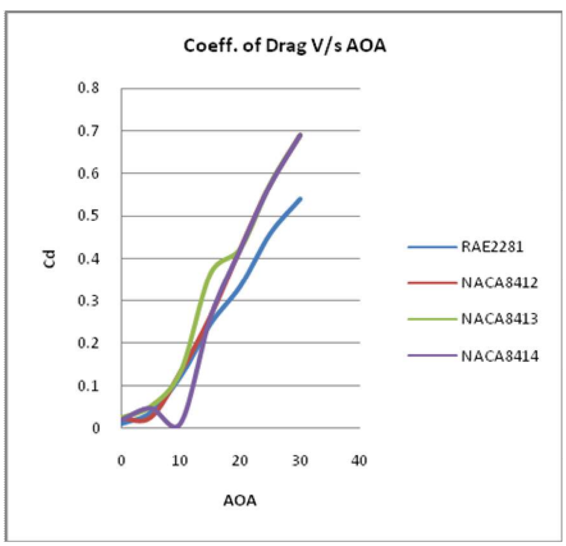

Fig: 7 comparison of coefficient of drag of all selected aerofoils

The result shows that the best suitable aerofoil considering over all minimum coefficient of drag is NACA 8414.

Table 4: Comparison of coefficient of lift of non critical aerofoil with reference

Cl				
AOA	**RAE2282**	**NACA8412**	**NACA8413**	**NACA8414**
0	0.00698	0.02861	0.0281731	0.02263889
5	0.3414	0.030742	0.35555	0.353405
10	0.6535	0.670527	0.66763665	0.6685788
15	0.8873	0.9502519	0.94724414	0.95054
20	0.8976	1.153737	1.1489945	1.1560971
25	0.9712	1.2324614	1.2296566	1.2351153
30	0.95388	1.191695	1.1904706	1.1922397

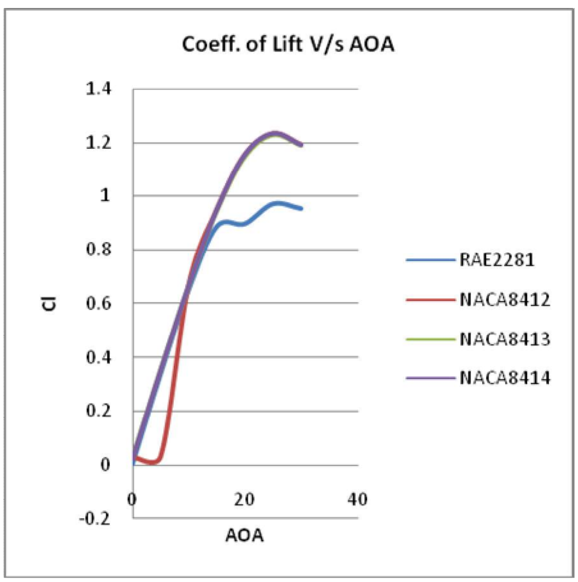

Fig 8 comparison of different aerofoil's lift coefficient at various angle of attack

It is evident from above plot that NACA8414 is giving maximum value of coefficient of lift as this component of force will help us to rotate the turbine shat thus for now we can say the NACA 8414 aerofoil is most suitable aerofoil.

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Table 5: Comparison of coefficient of lift over drag of non critical aerofoil with reference

Cl/Cd				
AOA	**RAE2282**	**NACA8412**	**NACA8413**	**NACA8414**
0	0.628829	1.2969174	1.2083680	1.1082517
5	8.941854	1.2552878	7.0505066	7.3507724
10	5.313008	5.0676567	5.0261354	51.036549
15	3.595219	3.6056806	2.6055860	3.6206868
20	2.675011	2.7308030	2.719780	2.7359709
25	2.115443	2.1458816	2.1375852	2.1515922
30	1.766444	1.7297344	1.7284757	1.7284347

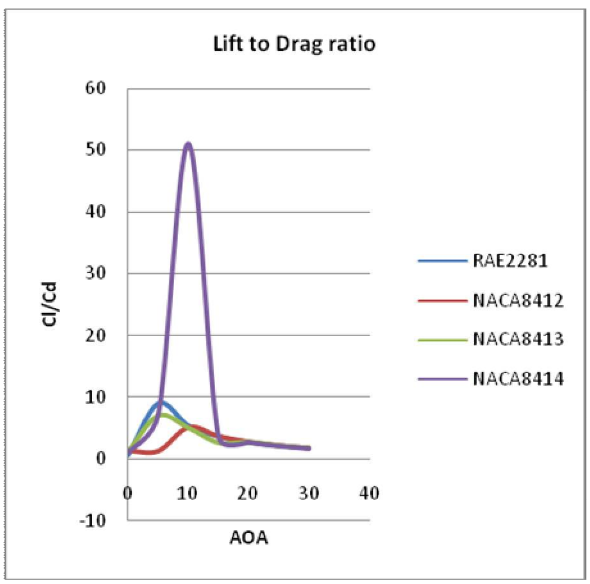

Fig 9 comparison of lift to drag ratio for various angle of attack of different aerofoil.

In the plot obtained above the comparison of lift to drag ratio of the different aerofoil for different operating condition has been shown which clearly shows that NACA8414 airfoil shows best characteristics among all selected aerofoils.

Table 6 Coefficient of lift to Drag for all non supercritical and super critical aerofoil's.

Cl/Cd							
AOA	**RAE2281**	**NACA4415**	**NACA4418**	**NACA6409**	**NACA8412**	**NACA8413**	**NACA8414**
0	0.628828829	2	1.44077961	3.133858268	1.2969175	1.208368	1.1082517
5	8.941854374	8.125572039	6.17670886	8.599964466	1.2552879	7.05050665	7.3507725
10	5.31300813	5.248411215	3.76281825	5.412188612	5.0676567	5.02613545	51.03655
15	3.595218801	3.716339869	3.61992965	3.720546361	3.6056807	2.60558607	3.6206868
20	2.675011176	2.752274607	2.72352433	2.774137115	2.7308031	2.71978076	2.735971
25	2.115443259	2.125254065	2.12880374	2.146211921	2.1458817	2.13758528	2.1515923
30	1.766444444	1.717882266	1.72025414	1.727877287	1.7297344	1.72847578	1.7284347

4. Conclusion

In this paper we've obtained various parametric results related to coefficient of lift and coefficient of drag also shock position of a critical aerofoil REA2282 and other three supercritical aerofoils. While considering the drag coefficient individually NACA 8414 aerofoil was showing least value of the drag which is desirable condition for the gas turbine blade profile also in case of lift coefficient NACA 8414 show the best result but when it comes to compare both result in well proportionate manner i.e lift to drag coefficient ratio the NACA 8414 aerofoil shows the best result which was highly expected while comparing critical and non critical aerofoils in transonic zone condition.

References

[1] Rahman, M. Rizwanur, ABM Toufique Hasan, and M. Itmam Labib. "Numerical investigation of aerodynamic hysteresis for transonic flow over a supercritical airfoil." Procedia Engineering 105 (2015): 368-374.

[2] O. N. Khatuntseva, Analysis of the reasons for aerodynamic hysteresis in the flight tests of the Soyuz re-entry capsule at the hypersonic segment of its descent, Journal of Applied Mechanics and Technical Physics , 52 (2011) 544-552.

[3] Biber, K., and G. W. Zumwalt, Hysteresis Effect on Wind Tunnel Measurements of a Two-Element Airfoil, 31 (1993) 326-330.

[4] Mueller, T. J., The influence of laminar separation and transition on low Reynolds number airfoil hysteresis, Journal of Aircraft, 22 (1985) 763-770.

[5] I. V. Kolin, V. G. Markov, T. L Trifonova, and D. V. Shukhovtsov, Hysteresis in the Static Aerodynamic Characteristics of a Curved Profile Wing, Technical Physics, 49 (2004) 263-266.

[6] Hoffmann, J. A., Effects of Freestream Turbulence on the Performance Characteristics of an Airfoil, AIAA Journal, 29 (1991) 1353-1359.

[7] Mittal, S. and Saxena P., Prediction of hysteresis associated with static stall of an airfoil, AIAA Journal, 38 (2002) 933-935.

[8] Zifeng Yang, Hirofumi Igarashi, Mathew Martin and Hui Hu, An Experimental Investigation on Aerodynamic Hysteresis of a Low Reynolds Number Airfoil, 46th AIAA Aerospace Sciences Meeting and Exhibit ,Reno, Nevada , 2008.

[9] Spalart, P. R. and Allmaras, S. R., A One-Equation Turbulence Model for Aerodynamic Flows, AIAA Paper 92-0439.

[10] Cook, P.H., McDonald, M.A., and Firmin, M.C.P., AEROFOIL RAE 2822 Pressure Distribution and Boundary Layer and Wake Measurement, AGARD Advisory Report. 138 (1979)

[11] T.Yu, J.J.Wang,P.F.Zhang, Numerical Simulation of Gurney Flap on RAE 2822 Supercritical Airfoil, Journal of Aircraft, 48 (2011) 1565-1575.