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Analysis of Aerodynamic Characteristics of Various Airfoils at Sonic Speed

Nishant Singh
B.E Aeronautical Enginnering
Dayananda Sager Collage Of Enginnering
Karnataka

***Abstract*:- The important approach of this paper is to analysis the aerodynamic characteristics of the various airfoils .i.e NACA 6 digit ,TsAGI 'B' series ,Hortex brothers . .In this the main aim is to analysis and suggest the performance of an airfoil in terms of CL and Cd .The main aim is to increase the lift coefficient and decrease the drag and his improve the aerodynamics performance of the aircraft.**

The computational analysis of the airfoil are done using JAVA FOIL software.in this analysis thickness of the airfoil and the chord to thickness ratio has kept constant and the value of CL and Cd are found for different angle of attack .The area of focus include : Cl, Cd, CM/4 and flow field and lift to drag curve . The test is conducted at high speed I,e at Mach 1 and the values are tabulated for different flow condition .the Hortex brother airfoil series has a increased Cl by 25% compared to different airfoil models.

Key words :Cl lift coefficient ,CD drag coefficient .

INTRODUCTION

The most primitive solemn work on the improvement of airfoil sections began in the late 1800's. Even though it was known that flat plates would produce lift when set at an angle of incidence, some mistrusted that shapes with curvature,that more closely bear a resemblance to bird wings would produce more lift or do so more efficiently. At almost the alike time Otto Lilienthal had parallel ideas. After cautiously measuring the shapes of bird wings, he confirmed that airfoil less than 7m diameter "whirling machine". Lilienthal implicit that the key to efficacious flight was wing curvature or camber. He also investigated with unalike nose radii and thickness scatterings. Airfoils used by the Wright Brothers closely bear a resemblance to Lilienthal's sections: thin and highly cambered. This was quite possibly because early tests of airfoil sections were done at extremely low Reynolds number, where such sections perform far restored than thicker ones. The mistaken belief that efficient airfoils had to be thin and extremely cambered was one cause that some of the first aircrafts were biplans.Thus this paper represents the basic airfoil design and the stimulation of various airfoils.

1.2 Scope and Objective of the Present Work

In the current work, first of all we have investigated the effect of number of airfoils to decrease the drag. We analysis flow over the wing with different configurations of supercritical airfoils.The four configurations of models are (NACA 6 digit ,TsAGI **'B' series, Hortex brothers, jouskousky airfoils**) airfoil results have been compared to the experimentally reported results from the literatures hortex brother is good performance for Cl, Cd and the flow distribution over the airfoil.

2. LITERATURE REVIEW

A determined effort within the researchers during the 1960's was fixed toward increasing practical airfoils with two- dimensional transonic turbulent flow and improved lift and the performance of the aircraft numbers while retaining acceptable low- speed maximum lift and stall appearances and attentive on a concept discussed to as the supercritical airfoil. This distinctive airfoil shape, based on the concept of local supersonic flow with isentropic recompression, was characterized by a large leading-edge radius, reduced curvature over the middle region of the upper surface, and substantial.

3. COMPUTATIONAL MODELLING OF FLUID FLOW:

JAVAFOIL comes with a set of profile authors for a assortment of airfoils which is easy to get to from this card. These airfoils represent conventional airfoil sections for which methodical metaphors exist or which can be constructed from geometrical constraints (e.g. wedge sections). Notwithstanding their age, many usual airfoil sections are still applicable to many problems or form a good starting point for new developments.

Today, new airfoil sections are typically reputable for specific purposes and their shapes are consistently not distributed.Supplementary contemporary elaborations lead towards the direct scheme of three dimensional wing shapes, eliminating the orthodox steps of two-dimensional airfoil design and three-dimensional wing lobbing. In most cases, modern airfoil sections are not termed anymore by inquisitorial formulas, just by a set of themes.

AIRFOIL NOMENCLATURE:

1) **NACA 6 DIGIT (NACA 64010)**
2) **TsAGI "B" SERIES (TsAGI "B" 10%)**
3) **HORTEX BROTHERS (HORTEX t/c 10%,f/c 0.0%)**

4. FLOW PROPERTIES OF EACH AIRFOIL:

4.1 NACA 6 DIGIT :

These airfoils were the first NACA airfoils which had been methodically industrialised with the converse intention process by Theodore. The conformal mapping process was able to distribute a shape for a given pressure circulation. This means that no shut form equations re-counting the thickness disseminations exist.

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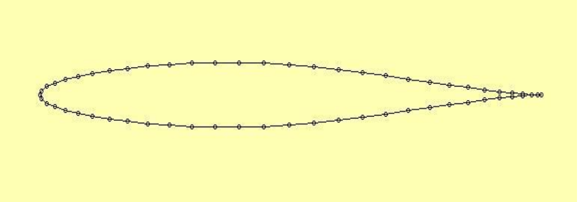
NAMING SCHEMES:

1^ST^Digit indicates the series i.e 6
2nd digit indicates the minimum pressure point .
3rd digit indicates C_l design
4th and 5th digit indicates maximum thickness .

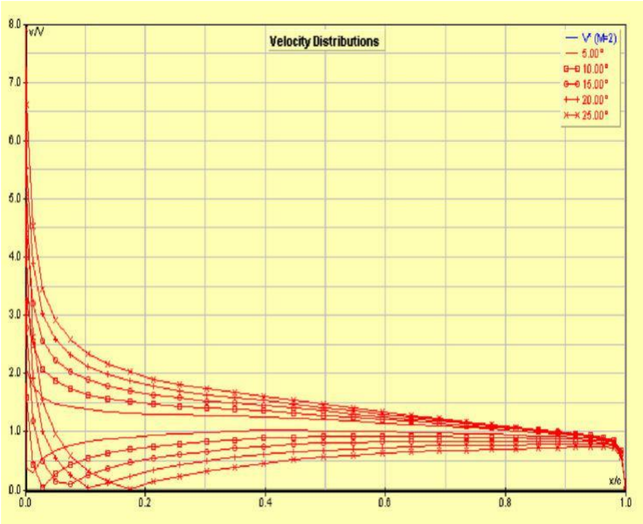
AERODYNAMIC CHARACTERS :



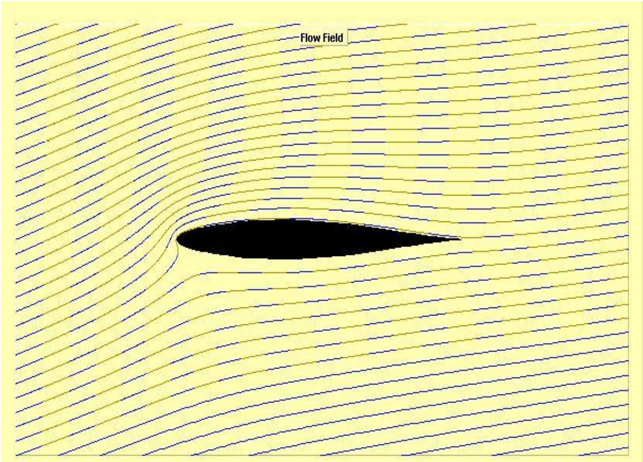
SHAPE OF THE AIRFOIL :NACA 6 DIGIT 10% thickness

VELOCITY AND C_l AND C_d:

α	CL	CD	Cm(0.25)	Cp*	Mcr
5	0.348	0.02812	-0.029	-2.173	0.472
10	0.665	0.06910	-0.058	-5.258	0.332
15	0.697	0.15802	-0.086	-9.25	0.258
20	**0.515**	**0.37874**	**-0.1133**	**-14.57**	**0.209**
25	0.366	0.59357	-0.138	-24.93	0.161



VELOCITY DISTRIBUTION OVER AN AIRFOIL

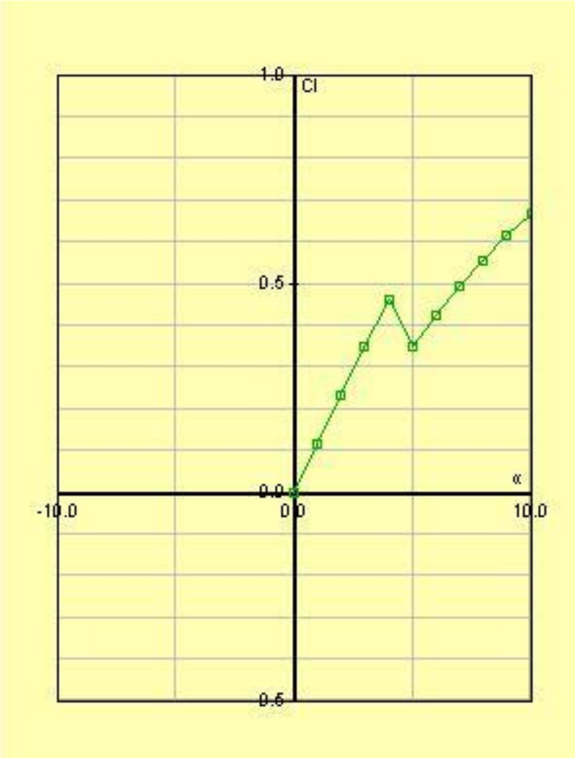


FLOW FIELD OVER AN NACA AIRFOIL AT 10 ANGLE OF ATTACK

The flow over a wing for Reynolds number 100000 is computed using JAVA FOIL simulating in NACA 6 series aairfoil. The variation of lift coefficient Vs angle of attack shown. As well as the variation of drag coefficient has shown Vs angle of attack shown in and C_L Vs C_D in below figure

CL VS CD CURVE :

Cl VS Cd CURVE FOR NACA 6 SERIES AIRFOIL



Cl VS AOA CURVE

Cl vs curve is plotted for the NACA 6 series airfoil.The curve starts for 0 as it is a symmetrical Airfoil .for this the maximum lift is or the stall angle is referred at 8 angle of attack. The angle more than 8 results in stalling of the airfoil .

α	Cl	Cd	Cm 0.25	T.U.	T.L.	S.U.	S.L.	L/D	A.C.	C.P.
[°]	[-]	[-]	[-]	[-]	[-]	[-]	[-]	[-]	[-]	[-]
0.0	-0.000	0.01686	-0.000	0.507	0.507	0.983	0.983	-0.000	0.265	0.250
1.0	0.115	0.01679	-0.002	0.482	0.534	0.982	0.983	6.859	0.265	0.265
2.0	0.231	0.01619	-0.003	0.461	0.567	0.983	0.984	14.299	0.265	0.265
3.0	0.347	0.02009	-0.005	0.025	0.601	0.981	0.984	17.256	0.266	0.265
4.0	0.459	0.02109	-0.007	0.013	0.636	0.976	0.984	21.771	23.180	0.265
5.0	0.348	0.02992	-0.029	0.009	0.672	0.013	0.986	11.619	-0.514	0.335
6.0	0.423	0.03639	-0.035	0.006	0.706	0.010	0.986	11.610	0.330	0.333
7.0	0.492	0.04440	-0.041	0.006	0.739	0.009	0.986	11.082	0.336	0.333
8.0	0.556	0.05271	-0.047	0.006	0.771	0.008	0.986	10.547	0.344	0.334
9.0	0.614	0.06518	-0.052	0.005	0.802	0.007	0.985	9.424	0.355	0.335
10.0	0.665	0.07808	-0.058	0.004	0.838	0.006	0.985	8.513	0.362	0.337

4.2 TsAGI "B" SERIES:

The TsAGI (also ZAGI, CAGI) was and is Russia's leading aeronautical research organization. Not abundanty recognised about later airfoil development, but the existing fiction [6], [9] shows that similar to additional nation-states Russia has developed airfoil folks based on analytical shape expressions. The TsAGI series-B is just one such airfoil family. The very simple shape picture is using just the extreme thickness. The resulting sections have a reflexed camber line and hence low pitching moment.

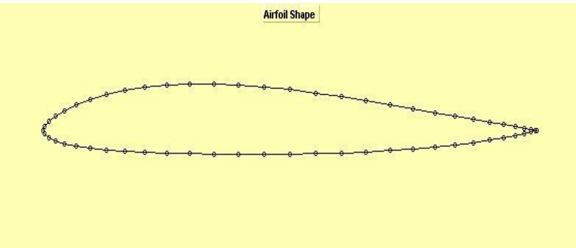
PARAMETERS :

- **Free: t/ c**
- **Fixed t x / c = 0.3388 ,** extreme (positive) camber

at f x / c = 0.3018 minimum (negative) camber at f x / c = 0.9204 .

● **The maximum camber is linked to the thickness by** the expression.

f / c = 0.168 t/ c .

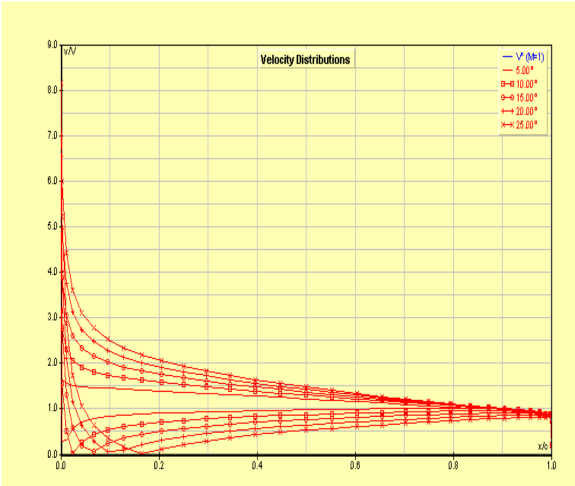


TsAGI "B" SERIES airfoil design for 10% thickness

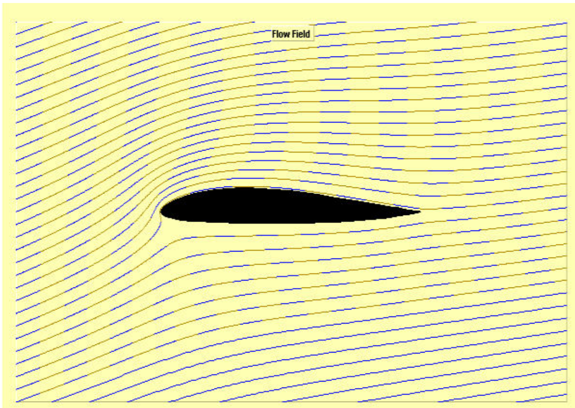
α	C_L	C_D	$C_{m(0.25)}$	C_{p*}	Mcr
5	0.627	00.0147	-0.05	-1.445	0.542
10	0.735	0.05728	-0.058	-4.350	0.360
15	**0.742**	**0.15192**	**-0.090**	**-8.269**	**0.271**
20	0.515	0.24842	-0.121	-15.21	0.205
25	0.319	0.39242	-0.152	-26.29	0.157

Table for lift and drag coefficient.

From this table it can be inferred that as angle of attack increases the lift increases and then it reaches the stall angle . the maximum lift is at 15 and then the lift decreases and lift increases.



VELOCITY DISTRIBUTION OVER AN AIRFOIL



FLOW FIELD OVER AN TsAGI "B" SERIES: AIRFOIL AT 10 ANGLE OF ATTACK

The flow over a wing for Reynolds number 100000 is computed using JAVA FOIL simulating in **TsAGI "B"** series aairfoil. The variation of lift coefficient Vs angle of attack shown. As well as the variation of drag coefficient has shown Vs angle of attack shown in and C_L Vs C_D in below figure From this cl vs cd and and from cl vs this can be notted that as the lift and drag curve is more better than naca series . the lift and drag has higher value when compared with NACA series airfoil .

International Journal of Engineering Research & Technology (IJERT)
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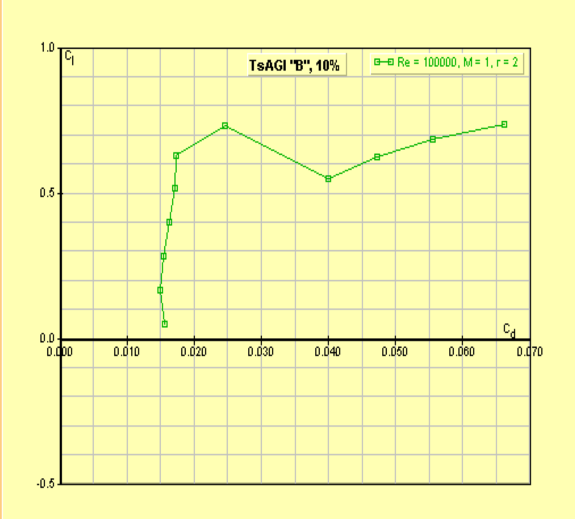
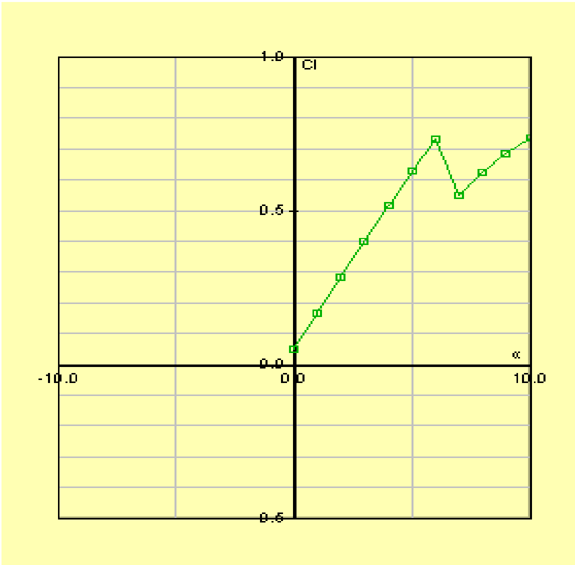


Cl VS Cd CURVE FOR TsAGI "B"SERIES AIRFOIL



Cl VS AOA CURVE

α	Cl	Cd	Cm 0.25	T.U.	T.L.	S.U.	S.L.	L/D	A.C.	C.P.
[°]	[-]	[-]	[-]	[-]	[-]	[-]	[-]	[-]	[-]	[-]
0.0	0.049	0.01557	0.005	0.443	0.803	1.000	0.990	3.148	0.266	0.139
1.0	0.166	0.01493	0.004	0.408	0.834	0.997	0.990	11.094	0.266	0.228
2.0	0.283	0.01549	0.002	0.374	0.854	0.996	0.990	18.286	0.267	0.244
3.0	0.400	0.01624	-0.000	0.338	0.874	0.993	0.990	24.633	0.268	0.251
4.0	0.516	0.01717	-0.003	0.300	0.889	0.991	0.991	30.059	0.271	0.255
5.0	0.628	0.01731	-0.005	0.256	0.905	0.983	0.990	36.281	0.281	0.258
6.0	0.730	0.02468	-0.009	0.010	0.915	0.960	0.991	29.565	-0.187	0.262
7.0	0.551	0.03998	-0.039	0.007	0.927	0.011	0.992	13.783	-0.084	0.321
8.0	0.622	0.04727	-0.045	0.004	0.936	0.008	0.993	13.152	0.343	0.323
9.0	0.686	0.05550	-0.051	0.002	0.943	0.004	0.994	12.366	0.361	0.325
10.0	0.735	0.06625	-0.058	0.001	0.951	0.002	0.996	11.096	0.380	0.329

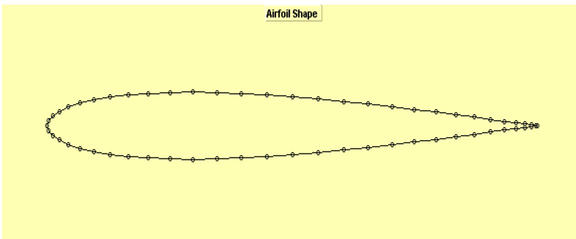
4.3HORTEN BROTHERS:

The *H*orten brothers are well recognised for their expansion of airborne annex aircrafts. For maximum of their annexes, they used airfoil sections with a reflexed camber line. These were based on a camber line of low or zero pitching moment (following the thin airfoil theory of Birnbaum) to which a breadth circulation was added.

PARAMETERS :

- Free: t/c , f/c
- Fixed $x_t/c = 0.293$, maximum camber at $f_X/c = 0.25$.

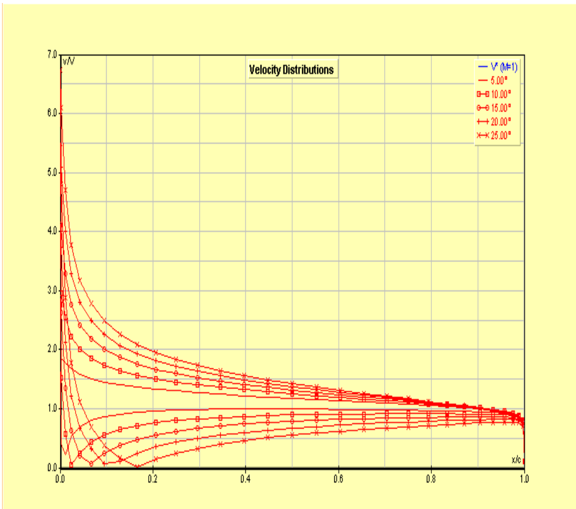
AERODYNAMIC CHARACTERS:



Horten brothers airfoil design for 10% thickness

α	C_L	C_D	$C_{m(0.25)}$	C_p*	Mcr
5	0.581	0.01362	-0.006	-2.180	0.471
10	0.690	0.05913	-0055	-5.486	-0.326
15	**0.861**	**0.12615**	**-0.081**	**-9.830**	**0.251**
20	0.761	0.24650	-0.107	-15.07	0.205
25	0.56	0.46658	-0.131	-21.93	0.179

Table for lift and drag coefficient



International Journal of Engineering Research & Technology (IJERT)
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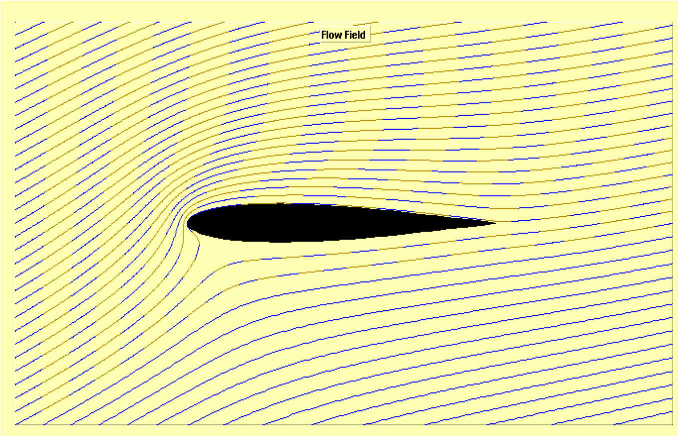
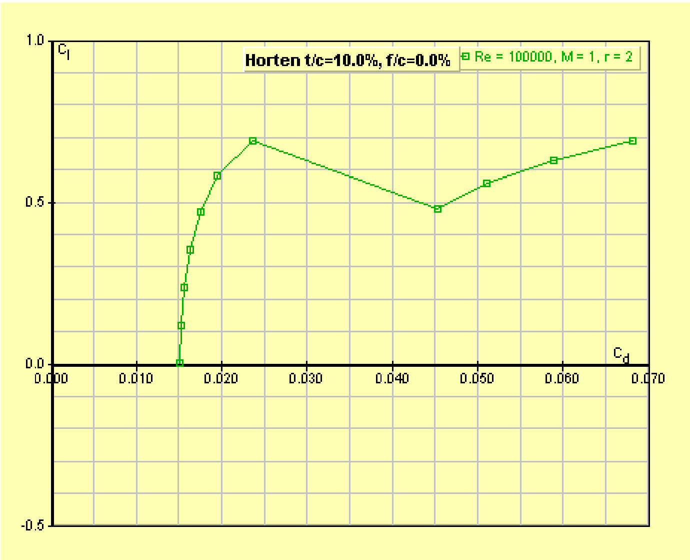
Vol. 5 Issue 09, September-2016

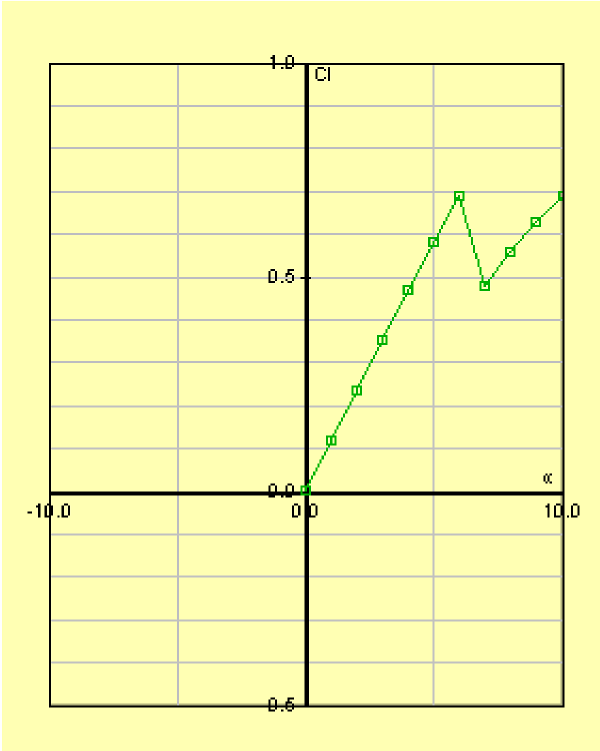


FLOW FIELD OVER HORTEN BROTHER: AIRFOIL AT 10 ANGLE OF ATTACK



Cl VS Cd CURVE HORTEN BROTHER AIRFOIL

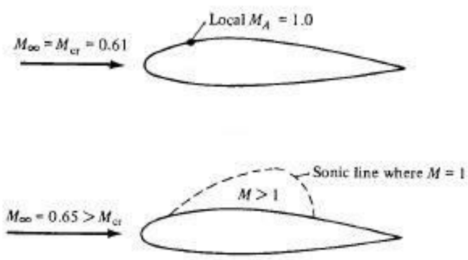
α	Cl	Cd	Cm 0.25	T.U.	T.L.	S.U.	S.L.	L/D	A.C.	C.P.
[°]	[-]	[-]	[-]	[-]	[-]	[-]	[-]	[-]	[-]	[-]
0.0	0.000	0.01514	-0.000	0.482	0.482	0.996	0.996	0.000	0.260	0.250
1.0	0.117	0.01521	-0.001	0.408	0.554	0.996	0.997	7.692	0.260	0.260
2.0	0.235	0.01559	-0.002	0.328	0.622	0.995	0.997	15.047	0.260	0.260
3.0	0.352	0.01637	-0.004	0.241	0.686	0.994	0.997	21.480	0.261	0.260
4.0	0.468	0.01758	-0.005	0.144	0.748	0.992	0.996	26.605	0.262	0.261
5.0	0.581	0.01947	-0.006	0.024	0.802	0.990	0.995	29.859	0.265	0.261
6.0	0.689	0.02358	-0.008	0.017	0.847	0.981	0.994	29.233	-0.067	0.262
7.0	0.477	0.04535	-0.039	0.009	0.884	0.037	0.993	10.526	-0.026	0.332
8.0	0.559	0.05104	-0.044	0.007	0.912	0.017	0.993	10.944	0.317	0.329
9.0	0.628	0.05885	-0.050	0.006	0.934	0.010	0.991	10.679	0.331	0.329
10.0	0.690	0.06814	-0.055	0.006	0.946	0.009	0.991	10.125	0.337	0.330



Cl VS AOA CURVE

4.4 CRITICAL MACH NUMBER:

Critical mach number of an airfoil is the free stream mach number of the flow for which at the minimum pressure location on the airfoil sonic flow is observed i.e. Mach number corresponding to that particular location tends to unity. Critical mach number play a vital in the determining the drag characteristics of the airfoil as there is a dramatic increase in the value of drag as the free stream mach number of the flow is increased beyond critical mach number. If the free stream mach number if further increased there will be a formation of supersonic bubble over the airfoil surrounding the area of minimum pressure location.

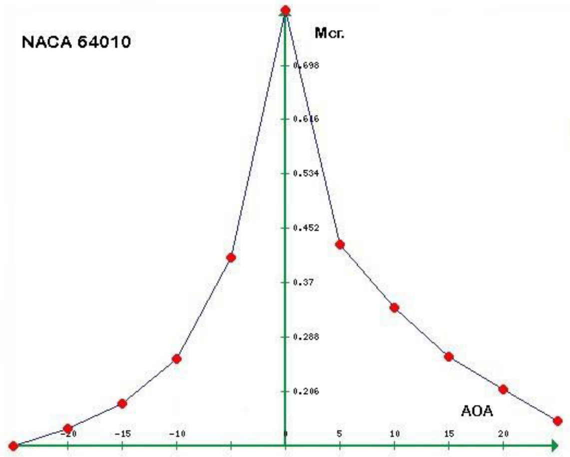


International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 5 Issue 09, September-2016

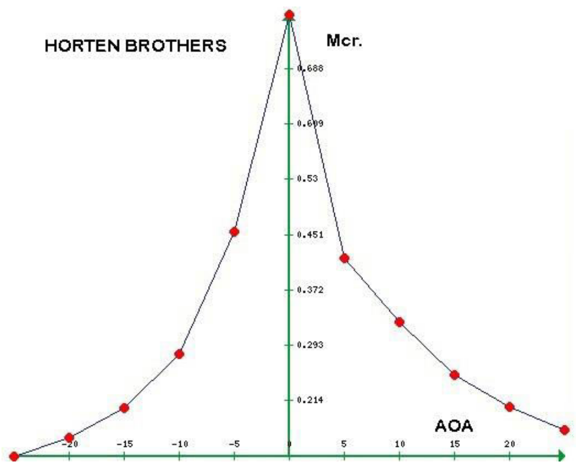
The figure above shows the variation of mach number above the airfoil.
We can estimate the value of critical mach number for particular airfoil using different compressibility correction rule such as Prandtl-Glauert rule,Karman-Tsien rule etc.

Critical mach number also depends on the thickness of the particular airfoil .Thicker the airfoil the less will be its value for critical mach number because of the perturbation the comes from the freestream.

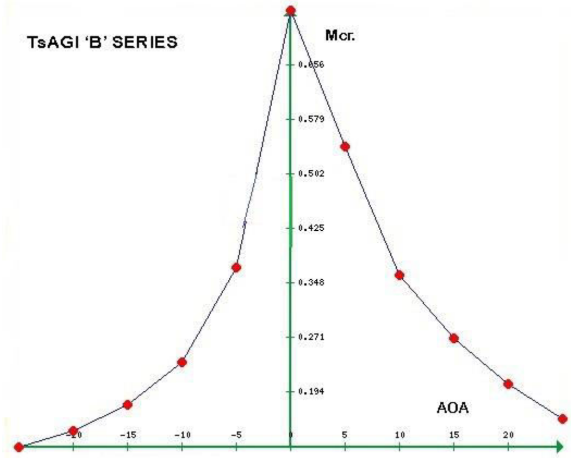
As the angle of attack deviates from zero the critical mach number of the airfoil decreases from its value which means any airfoil has its highest value of critical mach nuber at zero degree.The three airfoil that we are discussing in this script i.e, NACA 64010 ,Horten brothers , TaAGI 'B' series and variation of their Mcr. With angle of attack is showed below.



Fig(a)



Fig(b)



Fig(c)

Fig a ,b and c represenrs the variation of Mcr. wrt angle of attack(AOA). The highest value of Mcr. for each of the airfoil occurs at zero angle of attack and the thickess is taken as 10%.

AIRFOIL	HIGHEST Mcr.
NACA 64010	0.783
HORTEX BROTHERS	0.764
TsAGI "B" SERIES	0.733

From these observations it can be inferred that any airfoil can flow with high mach number at zero angle of attack withless drag associated with it in compared to angle of attack that deviates from zero. In addition to this there is formation of SUPER CRITICAL AIRFOIL by Richard Whitcomb in 1965 which as its Mcr. as high as 0.79.

6. CONCLUSIONS

Computational investigations have been achieved to scrutinize the effectiveness of the various series of airfoil equestrian at fluctuating angle to recover the performance of a wing in sonic flow. Coalescing the Computational analysis measurement results with the untried result, the following are presented for analysis performance due to various series of airfoils. This distinctive airfoil shape, based on local supersonic flow with isentropic recompression, was characterized by a large leading-edge radius, reduced curvature over the middle region of the upper surface, and substantial aft camber. This report has summarized the series airfoil development program in a chronological fashion, discussed some of the airfoil design guidelines, and presented coordinates of a matrix of family-related airfoils with thicknesses of 10 percent and design lift coefficients from 0 to 1.0.the hortex brother airfoils produces more lift and lesser drag compare to the other airfoil.

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AUTHOR

Nishant Singh
BE Aeronautical Engineering
Banglore

CO-AUTHOR

Mohammed Imran Tk
BE Aeronautical Engineering
Bangalore