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CFD Analysis of Two Dimensional Subsonic Flow Over S1223RTL Airfoil

Gargi Sharma, P.C. Gupta, S. Kant

***Abstract:** This paper defines Computational assessment for S1223RTL airfoil based totally totally completely genuinely sincerely in truth without a doubt totally on CFD approach. In experimental technique thru wind tunnel trying out, the evaluation challenge gives extra accurate results however is a lot more time eating and is more steeply-priced than the CFD method. consequently, after analytical approach it can be installation with the useful beneficial beneficial useful useful useful useful resource of experimental finding out. The assessment of the 2 dimensional subsonic go together with the go together with the go with the flow over a S1223RTL airfoil at numerous angles of assault and taking walks at a Reynolds huge shape of .165XE+05 is offered the use of an inviscid laminar model. The aerodynamic tendencies which incorporates coefficient of growth and coefficient of drag are evaluated from -eight.5o to 14.25o using FLUENT 15. The geometry of the airfoil is superior in Catia V5.*

***key phrases:** go together with the go with the flow over airfoil; strain coefficient; CFD evaluation; mind-set of assault; boom Coefficient*

I. INTRODUCTION

Creation: it's miles a truth of commonplace revel in that a body in movement thru a fluid recollections a resultant pressure which, in maximum times is in particular a resistance to the motion. a category of frame exists, however for which the element of the following stress ordinary to the course to the motion is many time extra than the detail resisting the movement, and the possibility of the flight of an plane is primarily based definitely simply upon on the use of the body of this beauty for wing form [1]. Airfoil is such an aerodynamic form that after it movements via air, the air is split and passes above and under the wing. Airfoils shapes are designed to offer immoderate deliver values at low Drag for given flight conditions.CFD has been examined as an economically viable method of desire within the vicinity of severa aerospace, car and business enterprise additives and techniques in which a notable function is finished via fluid or gas flows. It allows to envisage the behavior of geometry subjected to any form of fluid go with the flow vicinity. it's miles been installation as an economically feasible technique of preference inside the vicinity of severa aerospace, vehicle and business company business company additives and techniques wherein a immoderate feature is achieved through fluid or gas flows [3]. Nomenclature of an airfoil: at the same time as a strong frame is located in a fluid go with the float because of which a nonsymmetrical scenario takes place such that the route of the pressure on the body does now not coincide with the course of the (undisturbed) waft. This precept makes flying possible. Airfoils have a top area and a trailing thing, and are commonly designed with top and bottom floor curvatures to promote the go along with the drift introduced on stress distinction that reasons decorate [5]. The clean geometry of an airfoil is set up in decide 1.

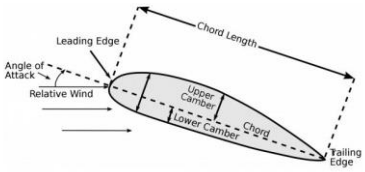

Fig1: Airfoil Geometry [2]

1. Chord period: it's miles drawn from the primary area to the trailing vicinity.
2. mean Camber Line: it's far created with the useful aid of the locus of things midway a number of the higher and reduce surfaces of the airfoil measured perpendicular to the chord line.
3. maximum Camber: it's far the upward push of the camber line from the chord line.
4. Thickness: it's far the height of airfoil profile measured perpendicular to the chord line.
5. mind-set of assault (AoA): angle among direction of wind and chord line.
6. number one thing (LE): earlier edge of the airfoil.
7. Trailing aspect (TE): Rearer fringe of the airfoil .
8. Camber: it's far the Asymmetry the severa top and backside floor of the airfoil.

Aerodynamic Forces On Airfoil: Aerodynamic forces surrender result from the strain distribution over the floor. For growth the pressure distribution is in the vertical direction, while for drag the horizontal stress distribution is important.

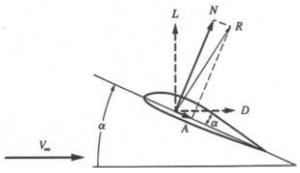

Fig 2: Forces on an airfoil [4]

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Supply pressure: The supply is defined because of the truth the stress normal to the free-flow into route and the drag parallel to the free-motion course. The increase is determined with the beneficial beneficial useful resource of the use of the static-strain distinction maximum of the better and reduce surfaces. If, the airfoil is tilted at an thoughts-set to the free go with the flow, the pressure distribution symmetry a number of the top and reduce surfaces no longer exists and a boost stress effects. this is very nice and the primary feature of the airfoil phase [2].L=0.5*ρ*CL*S*V^2 ... (1) Mechanisms are used to generate decorate. the primary is an uneven profile (approximately the chord). that is regularly used for subsonic flight applications. the second one is to incline the airfoil at an thoughts-set relative to horizontal, it in fact is usually the "relative wind mind-set". For low values of this mind-set (AoA) the go with the go with the go together with the float stays related on every surfaces. For higher angles of assault separation takes region on the manner to boom drag and reduces beautify. ultimately, the airfoil reaches a stall situation, wherein the stress distribution at the pinnacle and bottom are equal [5]. The coefficient of growth will increase linearly with mind-set of assault. Above a first rate mind-set, the beautify coefficient reaches a pinnacle after which declines. The attitude at which the growth coefficient (or deliver) reaches a maximum is referred to as the stall thoughts-set. The coefficient of maintain at the stall mind-set is the most deliver coefficient CLmax past the stall mind-set, one can also furthermore u . s . that the airfoil is stalled and a great exchange inside the drift pattern has took place as examined in fig three.

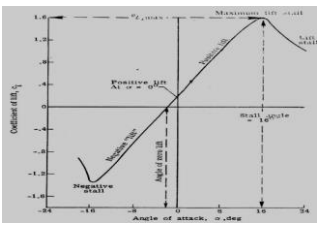

Fig 3: Coefficient of lift as a function of angle of attack [2]

Drag Force: This force arises from the flow of air around the airfoil but is the component of the resultant aerodynamic force along the line of motion.

$$D = 0.5 * CD * \rho * V^2 * S \quad (2)$$

The minimum drag coefficient occurs at a small positive angle of attack corresponding to a positive lift coefficient and builds only gradually at the lower angles. As one nears the stall angle, however, the increase in c_d is rapid because of the greater amount of turbulent and separated flow occurring [2].

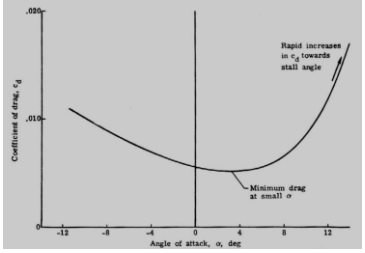

Fig 4: Coefficient of drag as a function of angle of attack [2]

Reynolds number: Reynolds defined a dimensionless parameter, which has since been known as the Reynolds number, to give a quantitative description of the flow [2].

$$\text{Reynolds Number} = \frac{\text{Inertia Force}}{\text{Viscous Force}} \quad (3)$$

$$Re = \frac{\rho V l}{\mu} \quad (4)$$

The viscous forces upward push up because of the internal friction of the fluid. The inertia forces represent the fluid's natural resistance to acceleration. In a low Reynolds big variety go with the flow the inertia forces are negligible in assessment with the viscous forces at the equal time as in immoderate Reynolds variety flows the viscous forces are small relative to the inertia forces three-D Modeling in CATIA: Airfoil model have grow to be prepared With the help of Catia V5 layout software program program software the use of coordinates from airfoiltools [6].

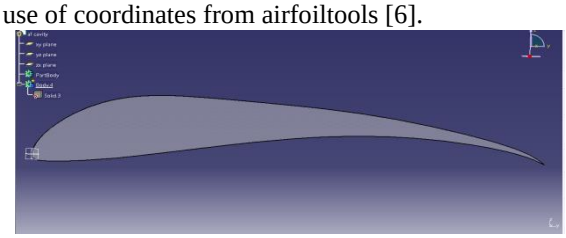

Fig 5: Catia 3-D Modeling of S1223RTL

CFD evaluation way: on this paper, the S1223RTL Richard T. LaSalle exchange of S1223 to S1223RTL grow to be finished. The S1223RTL airfoil is asymmetrical. the airfoil has a 13.five% max thickness at 19.9% chord and max camber of eight.three% at fifty 5.2% of chord. Reynolds amount for the simulations modified into Re=2.16xE5, equal with the reliable experimental facts from S. Selig and A. Lyon [7], a high-quality way to validate the prevailing simulation. For this Reynolds large range, the go with the drift may be described as incompressible. that is an assumption near fact and it isn't crucial to treatment the electricity equation. A segregated, implicit solver have end up done (ANSYS Fluent 15). Calculations had been completed for angles of attack starting from -four.5o to 14.25o .The airfoil profile modified into created in CATIA V5, boundary situations and meshes were all created within the pre-processor ANSYS Fluent model. The pre-processor is a software that may be hired to deliver fashions in and three dimensions, using set up or unstructured meshes, that might encompass a diffusion of factors, which embody quadrilateral, triangular or tetrahedral factors. the selection of the mesh become extra in areas in which more computational accuracy have emerge as desired, along side the location near the airfoil.

II. RESULTS & DISCUSSIONS

Table 1: General procedure for CFD analysis [1]

Sl. No.	Steps	Process
1.	Problem statement	Information about the flow
2.	Mathematical model	Generate 3D model
3.	Mesh generation	Nodes/ cells, time instants
4.	Space discretization	Coupled ODE/DAE systems

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5.	Time discretization	Algebraic system Ax=b
6.	Iterative solver	Discrete function values
7.	CFD software	Implementation, debugging
8.	Simulation run	Parameters, stopping criteria
9.	Post processing	Visualization, analysis of data
10.	Verification	Model validation / adjustment
11.	Saving case and data	Save all the obtain data
12.	Comparing	Comparing the outcome values with real practical values

The first step in performing a CFD simulation want to be to investigate the effect of the mesh length on the answer effects. normally, a numerical answer becomes more accurate as more nodes are used, but the use of extra nodes furthermore will growth the popular laptop memory and computational time. the proper huge shape of nodes can be decided with the beneficial aid of growing the quantity of nodes until the mesh is satisfactorily exceptional in reality so in addition refinement does no longer change the effects. in this take a look at a C-kind grid topology with 15000 quadrilateral cells can be enough to installation a grid impartial solution (determine 6). The place top have come to be set to about 20 chord lengths on the equal time because the width of area modified into set to fifteen chord lengths.

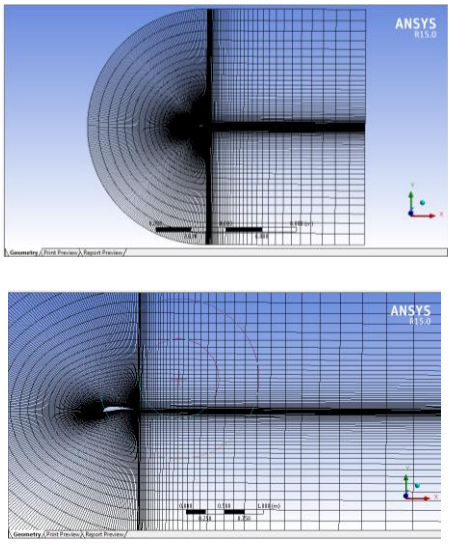

Fig 6: Mesh of the computational domain around S1223RTL airfoil (top) and closed detail to the airfoil (bottom)

Table2: Meshing Details

Mesh Element Type	Elements	Nodes	Mesh Orthogonal quality
Quad4	15000	15300	0.16724

Inputs and Boundary condition: The problem considers flow around an airfoil at various AoA between -4.5 to 14.25. For that we take some initial inputs and boundary condition as shown in the table 3 and Fig 7.

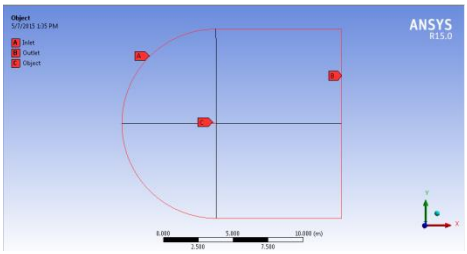

Fig 7:Applied Input and boundary Conditions.

Table 3: Input and Boundary conditions used in the analysis

Sl. No.	Input	Value
1.	Fluid	Air
2.	Flow Velocity	6.4 m/s
3.	Operating Temperature	300 K
4.	Operating Pressure	101325 Pa
5.	Model	Inviscid
6.	Density of fluid	1.223 kg/m^3
7.	Dynamic viscosity	1.7894e-05 kg/m-s
8.	Chord length	0.45 m

Validation of the Simulation approach: To validate the computational approach, outcomes received with the beneficial beneficial beneficial aid of the second simulation of S1223RTL are in evaluation with S. Selig and A. Lyon [7]. The growth curve, drag polar, curve (AoA amongst -4.five to fourteen.25 ranges) for gift have a check is acquired and overlapped on the same antique curves provided in airfoiltool's net internet internet internet web page [6] to have a have a study the in shape of contemporary-day study facts. version of supply coefficient (CL) with mindset of attack (α) for the simulation can be decided from fig. 8. From -four.5 degree AoA to 14.25 degree AoA the enhance curve is shape of linear. at some point of this regime no separation takes region and go together with the float stays connected to the airfoil. At stall AoA boom coefficient is decreased notably due to immoderate go with the flow separation generation. Fig. 10 depicts the conformation of drag polar of c-day validation test with Airfoiltool's facts [6], fig 11. moreover, gift look at depicts higher stress than S. Selig and A. Lyon [7]. at the lower ground on the principle edge of the

airfoil in most instances due to assuming 0 floor roughness of the wall.

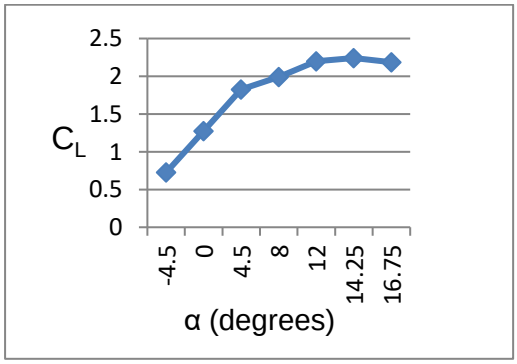

Fig 8: Simulated coefficient of lift (C_L) Vs AoA (α)

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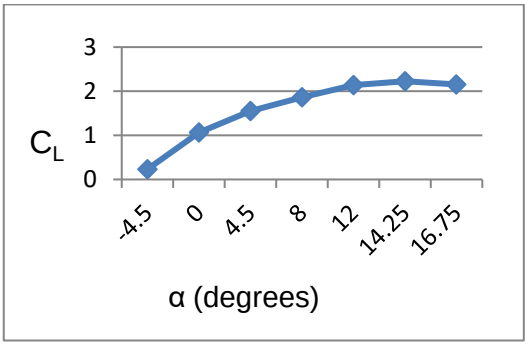


Fig 9: Experimental Data for Coefficient of lift (C_L) and AoA (α) [6]

Close to stall, battle of words between the statistics have become shown. The carry coefficient peaked and the drag coefficient improved as stall prolonged. The anticipated drag coefficients (fig 10) were higher than the experimental information (fig eleven). This over prediction of drag have become predicted.

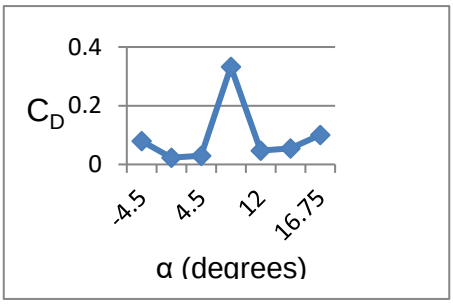


Fig 10: Simulated Coefficient of drag (C_D) Vs AoA (α)

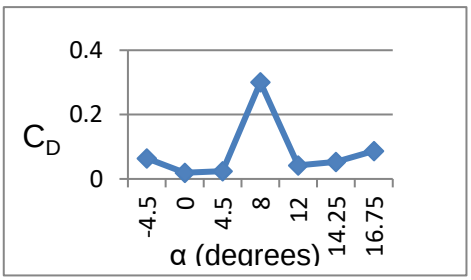


Fig 11: Experimental Coefficient of drag (C_D) Vs AoA (α) [6]

Maximum aerodynamic efficiency for S1223RTL is obtained at AoA equal to 4.5 degrees, as shown in fig 12 and 13.

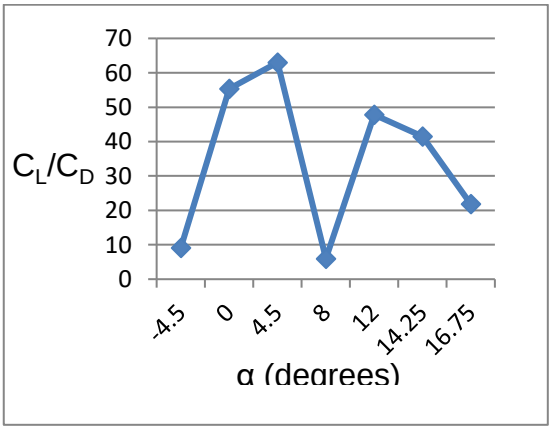


Fig 12: Simulated Aerodynamics Efficiency (C_L/C_D) Vs AoA (α)

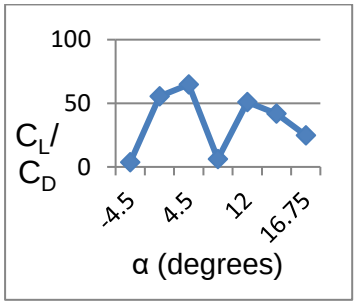
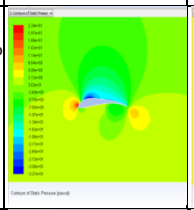
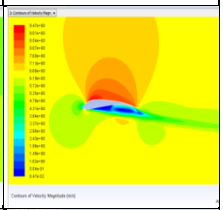
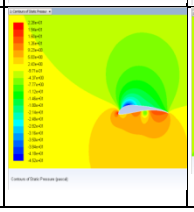
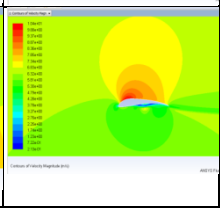


Figure 13: Experimental Aerodynamic Efficiency of S1223RTL (C_L/C_D) Vs AoA (α) [6]

Results and speak: strain and pace contours for AoA (α) are furnished in desk four. As S1223RTL is an uneven airfoil, for zero AoA it may be positioned that pace profile and pressure profile are not identical on pinnacle ground and decrease floor of the airfoil. because of this, decorate technology is likewise a non- zero for this example. but, with converting AoA the place of stagnation element moreover modifications. At stagnation issue strain is maximum and pace is zero this is characterised through manner of exceptional purple problem on the strain contour plots. it is also obvious that with immoderate tremendous AoA stagnation problem moves inside the course of trailing side on the decrease ground of the airfoil. This pressure deviation on the better and decrease ground of the airfoil basically creates quantity of increase. furthermore, separation of go together with the go along with the flow is likewise obvious at excessive mind-set of assault (α). In flip this drift separation phenomenon creates some precise deliver of aerodynamic drag, referred to as strain drag due to separation. this is why immoderate supply normally pals with excessive drag. critical significances of separated low over the airfoil can be cited. the number one is the dearth of deliver. The aerodynamic boom is derived from the internet hassle of a pressure distribution inside the vertical path. at the same time because of the truth the go along with the flow is separated higher strain is created on the top floor pushing the airfoil downward, consequently growing an awful lot an entire lot masses plenty masses much much less deliver.

Table 4: Velocity, pressure contours and streamlines formed around S1223RTL airfoil for different AoA

AOA	Pressure Contour	Velocity Contour
- 4.5°		
0		

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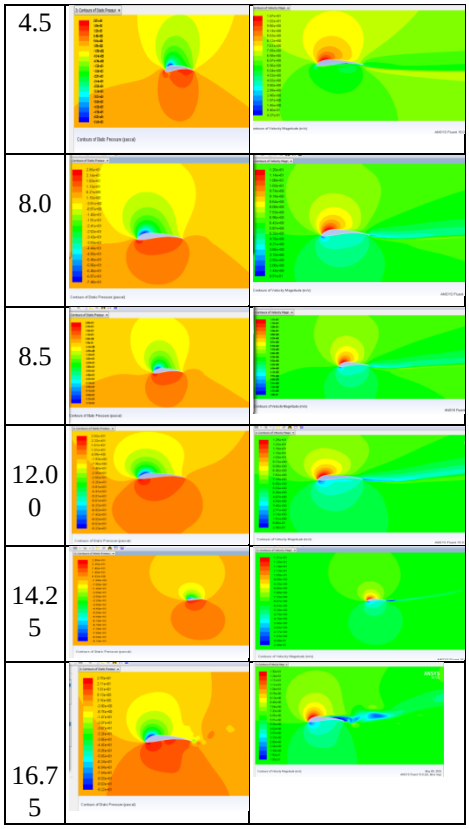

Beneath the stall thoughts-set, the separation factors on the airfoil glide in advance slowly but stay quite near the trailing element. close to the stall mind-set the separation elements skip in advance and the strain drag rises . beyond the stall mind-set, the outcomes of the significantly prolonged sepaextremely goodd drift are to decrease the increase. strain recuperation is while the pressure will growth from its minimum charge to the fee at the trailing detail. This area is known as the place of horrible stress gradient. the damaging strain gradient is related to boundary layer transition and likely separation, if the gradient is in reality too immoderate [2].

save you: it's far located that there can be a near agreement a number of the computational and experimental outcomes. The deviation of computational CL and CD from experimental art work is interior ± 1.five%. those findings highlight the capability of CFD as a tool for the general commonplace fashionable typical performance length of Airfoils for numerous applications life aircrafts and wind generators. The conduct of the airfoil from α fee of -4.5 to 16.75 close to the CL version shows a comparable pattern in assessment to its experimental counterpart. destiny plan is to use S1223RTL in Vertical axis wind turbines and estimate its ordinary performance. This model may be used to are seeking out to a quantity the positioned up stall inclinations of the airfoil.

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