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An Investigation on NACA 2312 Aerofoil With Curved And Straight Leading Edge Wing

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***Abstract*— The Theoretical and experimental investigation to explore better aerodynamic performance by incorporating curvature at the leading edge of a wing. A model with straight leading and trailing edge i.e. rectangular planform and another model with curved leading edge and straight trailing edge are prepared with NACA 2312 airfoil in equal length (span) and surface area. Both the models are tested in a wind tunnel at air speed of 23.71 m/s (0.07 Mach) i.e. at Reynold's number 1.82 x 10^5. The lift coefficient, drag coefficient and lift to drag ratio of both the models are analysed. The Theoretical investigation to explore better aerodynamic performance by incorporating the leading edge of a wing. A NACA 2312 Airfoil is designed and modelled by using SOLIDWORKS. Modelled the NACA 2312 airfoil with the straight leading edge wing and curved leading edge wing by using SOLIDWORKS and analyse the two wings by using SOLIDWORKS-Flow simulation. After analysing the results by using experimental and theoretical investigation the NACA 2312 airfoil with curved leading edge wing having higher lift to drag ratio than the NACA 2312 Airfoil with straight leading edge wing. After comparing the theoretical results and experimental results there is a 20% of deviation exists. The theoretical results are 20% better than the experimental results..**

***Keywords*— Aerofoil, Solid works, Wind tunnel, 3D printing, Lift, Drag, Force, Pressure**

I. INTRODUCTION

In the previous days, when person was yet living in the piece of creation, the principle technique for speed was his legs. Thusly, we have built up quicker and more abundant strategies for voyaging, latest including the air movement. Since, its development planes have been receiving more notoriety as it is the speediest strategy for transport open. It has moreover gotten distinction as a war machine since World War II. This conspicuousness of air transport has incited various developments and investigation to become snappier and more moderate planes. This work is an endeavour to mediate how we can derive most extraordinary execution from an aerofoil fragment.

An aerofoil is a cross area of wing of the flying machine. Its essential occupation is to offer lift to a plane in the midst of take- off remembering of direction. However, it has a part of resultant power called weight – shape drag which limits the development of the plane. The measure of coefficient of lift and its power required by a flying machine depends on upon setup and get together of different parts to the concerned airplane. Heavier one suit more lift while lighter oblige less contrasted with heavier ones. In like manner, dependent upon the usage of plane, aerofoil region is settled. Lift however apply extra expectation to the inspire raising rate of the airplane, which in turns relies upon the plane regarding level speed. Subsequently, the coefficient of lift and coefficient of weight is the main factor to find out how the lift reacts according to the speed and different parameters.

Flying machine wings which are even and vertical stabilizers, helicopter rotor sharp edges, propellers, fans, compressors turbines all have aerofoil outlines. Indeed, even sails, swimming and flying animals utilize airfoils. An airfoil-formed ribs is adequate to get down the power on a car parts or other engine passing on gadget so to enhance the glue erosion that is footing.

A wing following the laminar stream has a biggest partiality of thickness in the middle piece of camber line. It exhibits a negative weight slant along the stream has an indistinguishable effect from diminishing the rate when we analyse the Navier– Stokes scientific proclamations in the straight organization. So if we keep up most prominent camber in the middle, a laminar stream over a greater rate of the wing at a higher speed can be accomplished. In any case, with particles on the wing, this does not work. Since such a wing backs off more successfully than others. .

II. THEORETICAL INVESTIGATION

Design

Theoretical investigation is done by using SOLIDWORKS software. It consists of both design and analysis modules. For the design of straight and curved leading edge wings NACA 2312 Aerfoil is selected and then Aerfoil is designed on SOLIDWORKS. After that the straight and curved leading edge wing 3D models are developed as those two wings are having same surface area and span. The size and shape of wing is shown in below figure.

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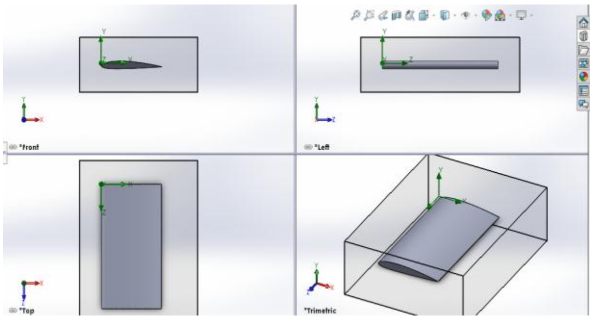

Figure 1: Straight leading edge wing

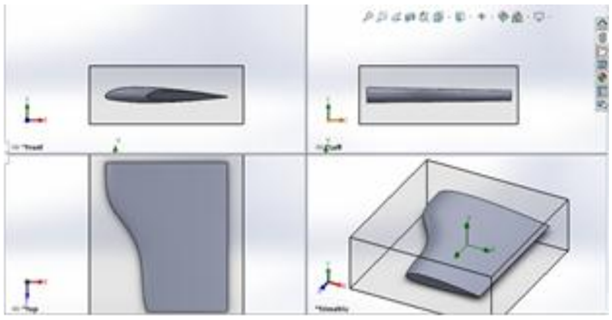

Figure 2:Curved leading edge wing

Analysis

The designed wings are analysed on SOLIDWORKS for pressure distribution, shear stress Distribution, vorticity, lift and drag characteristics over a straight and curved leading edge wings at different angle of attack. The wings are analysed at the boundary conditions of inlet Temperature =35^{0}C, inlet velocity=23.71m/s and inlet pressure=1.01325bar and at outlet are temperature=38^{0}C, Pressure=1bar and velocity=18m/s. the results are shown on results and conclusion.

III. PREPARATION OF WING MODELS

The preparation of wing models is done by using the 3D PRINTER. 3D printing is a form of additive manufacturing technology where a three dimensional object is created by laying down successive layers of material. It is also known as rapid prototyping, is a mechanized method whereby 3D objects are quickly made on a reasonably sized machine connected to a computer containing blueprints for the object. The 3D printing concept of custom manufacturing is exciting to nearly everyone. This revolutionary method for creating 3D models with the use of inkjet technology saves time and cost by eliminating the need to design; print and glue together separate model parts. Now, you can create a complete model in a single process using 3D printing. The basic principles include materials cartridges, flexibility of output, and translation of code into a visible pattern.

The wing model is first designed on the SOLIDWORKS and then imported to the 3D Printer. The 3D Printer is analyse the design and then generate the G-code. We need to give the input details such as speed of the bed, feed of the material and sintering Temperature. The thermoplastic material is used as a raw material

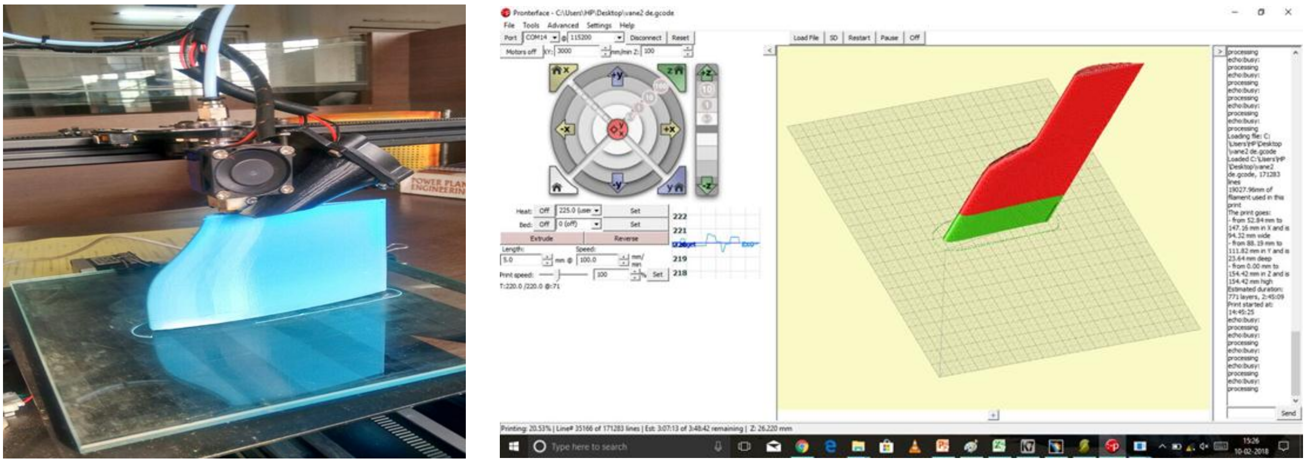

Figure 3: Preparation of curved leading edge wing with 3D printer

IV. EXPERIMENTAL INVESTIGATION

In this dissertation a model of NACA 2312 AIRFOIL being considered inside the wind tunnel and various test has been performed to achieve the objective. In these experiments, the response of flow behaviour over the airfoil was taken as paramount importance. From Aditya College and Engineering and Technology various facilities were taken and the airfoils profiles of below mentioned dimensions were 3d printed to be tested on wind tunnel flow to certain level.

The fan motors are powered by AC.3ph, 440V, 32 Amps power supply through motor speed controller. The experiment is carried out in a Test section of 150mm×150mm open circuit wind tunnel available at Thermal Engineering laboratory of Department of Mechanical Engineering, Aditya College and Engineering and Technology. The wind speed is created by the 700mm counter rotating fan. At the discharge of the fans there is a silencer to reduce the sound level. From the silencer air flow passes through the flow controlling butterfly valve, diffuser and the plenum chamber to stabilize the sound. Thus the wind speed in the tunnel can be varied both by controlling the fan motor speed as well as by controlling the butterfly valve. To facilitate the present experiment in the open air condition the diffuser at the end of the test section is taken out and the discharge side of the test section is fitted with a discharge duct and a bell mouth entry is added at the return duct to have smooth entry. Thus the open flow field created between the discharge duct and bell mouth entry become the experimental space where desire velocity is obtained.

All the experimental data were taken at room temperature of 35˚C and at air speed of 23.71 m/s (85.35 kph) and the air flow was considered incompressible throughout the experiment. The static pressure at different AOA (-4˚, 0˚,4˚, 8˚, 12˚, 16˚, 20˚ & 24˚) are measured from surfaces of the wing models through different pressure tapings by using a multi-tube water manometer. The lift and drag characteristics of a straight and curved leading edge wing. Specific density of both air and water corresponding to room temperature was assumed to be 1.145 kg/m3 and 994 kg/m3 respectively

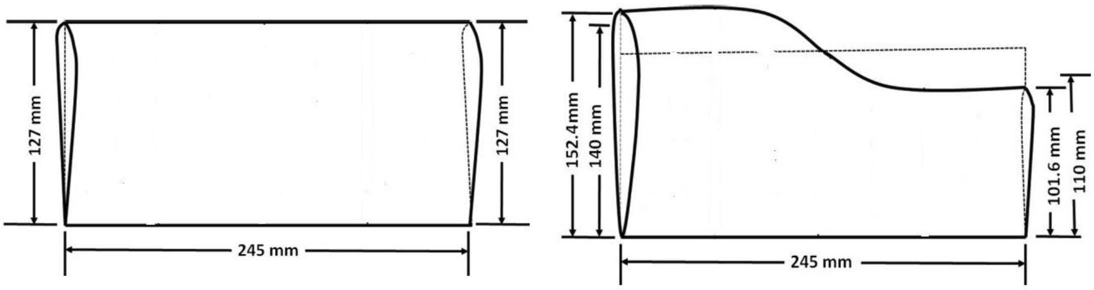

Figure.4: Straight and Curved leading edge wing

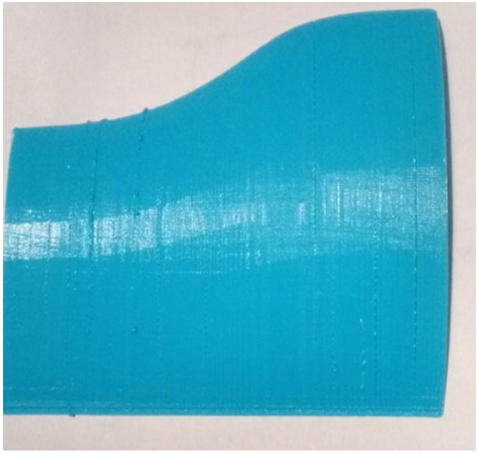

Figure.5: curved leading edge wing

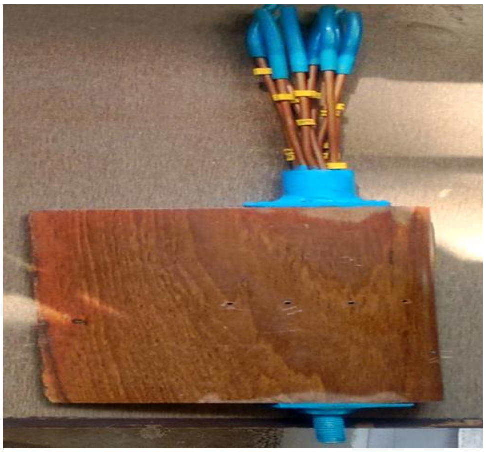

Figure.6: Straight leading edge wing

Figure 7: Wind Tunnel

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In the Thermal Engineering Laboratory to study the desired stream flow over the airfoil experimentally and analytically. This dissertation depicts how the complete research been proposed and carried out in the wind tunnel placed in the Thermal Engineering Lab of the Mechanical Department, at the Aditya College of Engineering and Technology, Surampalem. The basic objective behind these experiments is to Compute the lift and drag force acting on an airfoil under varying Angle of Attack and configurations (shape and size) of airfoil.

Table 1: Lift and Drag characteristics of a straight leading edge wing

S. NO	Angle of Attack(Degree)	Lift Force(N)	Drag Force(N)	Velocity(m/s)	Theoretical Force(N)	Coefficient of Lift	Coefficient of Drag
1	-4^{0}	0.02	0.04	23.71	1.2254955	0.016	0.032
2	0^{0}	0.58	0.08	23.71	1.224956	0.47	0.07
3	4^{0}	0.74	0.15	23.71	1.224955	0.60	0.12
4	8^{0}	0.97	0.33	23.71	1.224952	0.79	0.27
5	12^{0}	1.22	0.49	23.71	1.224947	0.9959	0.4
6	16^{0}	1.22	0.52	23.71	1.224941	1	0.43
7	20^{0}	0.71	0.62	23.71	1.224933	0.58	0.51
8	24^{0}	0.69	0.67	23.71	1.224923	0.56	0.55

Table 2: Lift and Drag characteristics of a curved leading edge wing

S. NO	Angle of Attack(Degree)	Lift Force(N)	Drag Force(N)	Velocity(m/s)	Theoretical Force(N)	Coefficient of Lift	Coefficient of Drag
1	-4^{0}	0.24	0.01	23.71	1.224955	0.2	0.01
2	0^{0}	0.73	0.03	23.71	1.224956	0.6	0.03
3	4^{0}	0.85	0.12	23.71	1.224955	0.7	0.1
4	8^{0}	1.20	0.24	23.71	1.224952	0.98	0.2
5	12^{0}	1.34	0.36	23.71	1.224947	1.1	0.3
6	16^{0}	1.47	0.47	23.71	1.224941	1.2	0.39
7	20^{0}	0.85	0.49	23.71	1.224933	0.7	0.4
8	24^{0}	0.73	0.61	23.71	1.224923	0.6	0.5

V. RESULTS AND DISCUSSIONS

Solidworks outcomes the mesh of an airfoil with c mesh domain. The mapped meshing is created on entire c-domain. The cross section is developed to be fine at areas near to the airfoil and coarser more remote far placed irrespective to the position of airfoil. For this particular airfoil a quadratic formation of an element was utilized. The mesh has to be smooth and fine also in some regions away from the airfoil. Various edge sizing has been adopted to accomplish the task.

Lift and Drag characteristics

The NACA 2312 straight curved leading edge wings are tested against a various angle of attacks such as 0 to 20degree. The lift and drag characteristics of a straight leading and curved leading edge wings are shown in below figures.

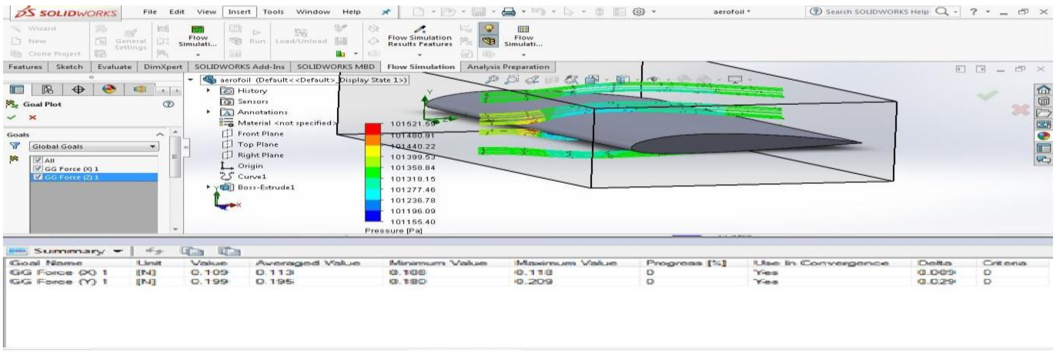

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Fig 8: Force distribution over straight leading edge wing at 0^0 AOA

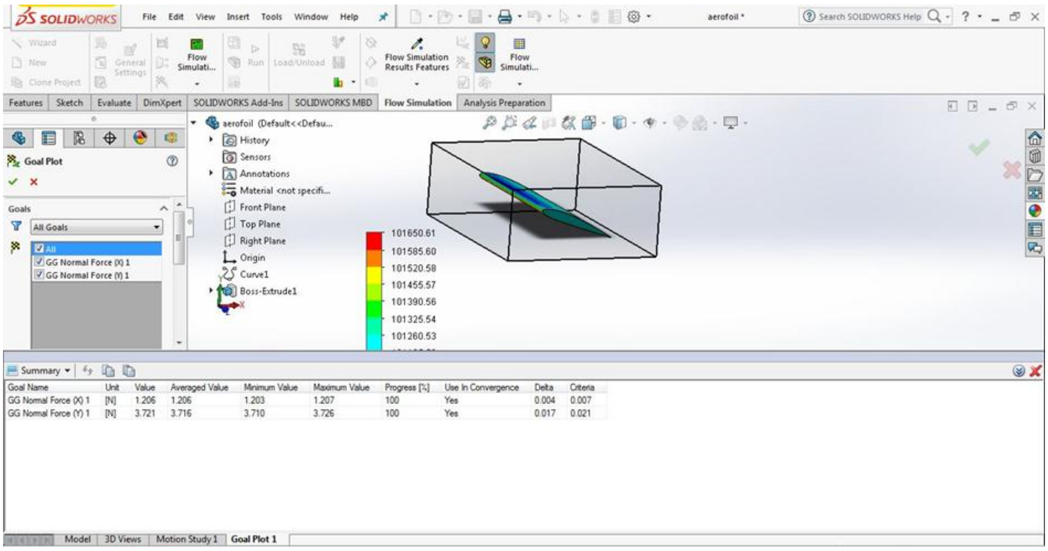

Figure 9: Force distribution over straight leading edge wing at 20^0 AOA

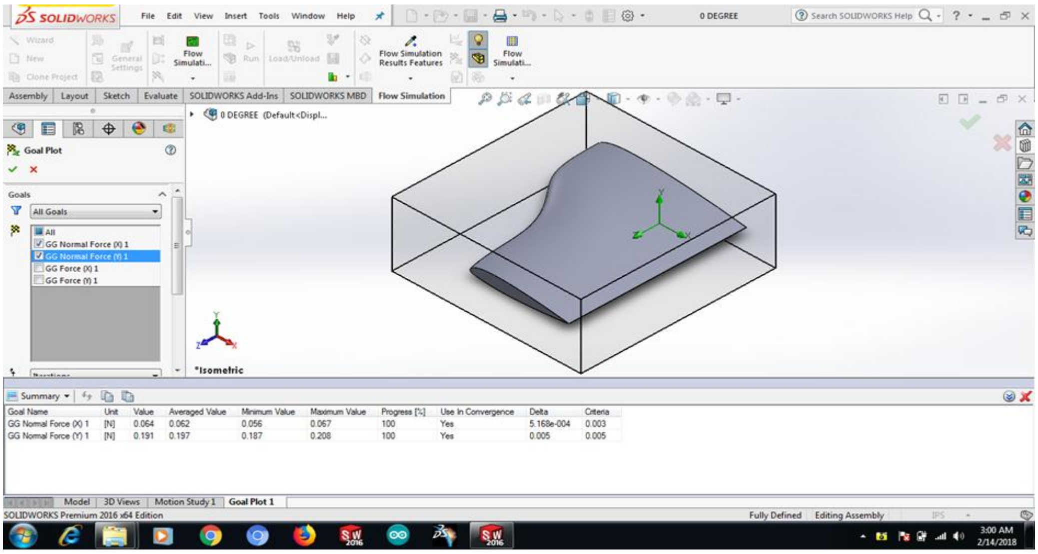

Figure 10: Force distribution over curved leading edge wing at 0^0 AOA

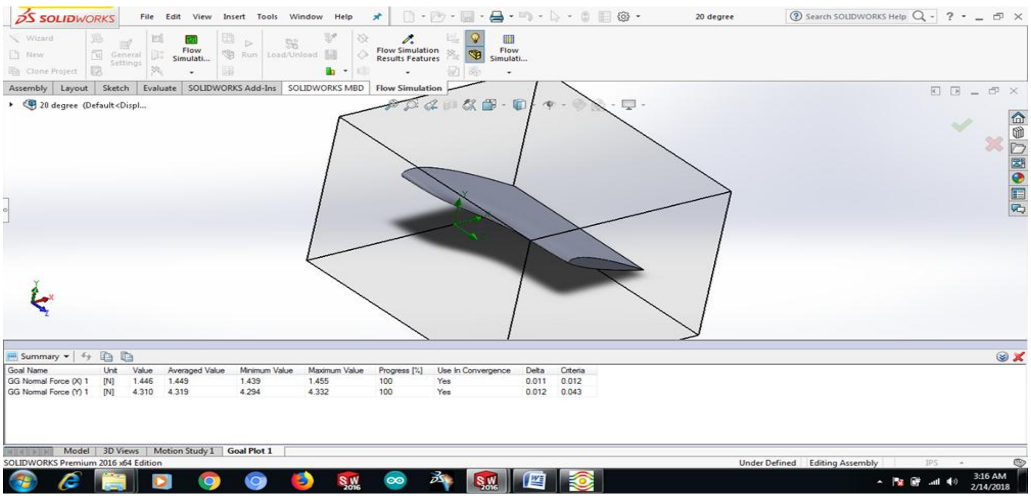

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Figure 11: Force distribution over straight leading edge wing at 20^0 AOA

Experimental Results

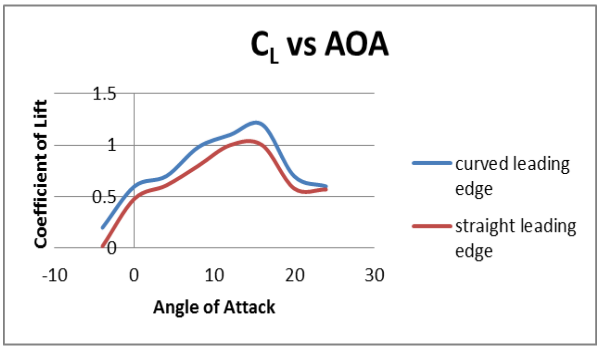

Fig.12: Graph between CL versus AOA

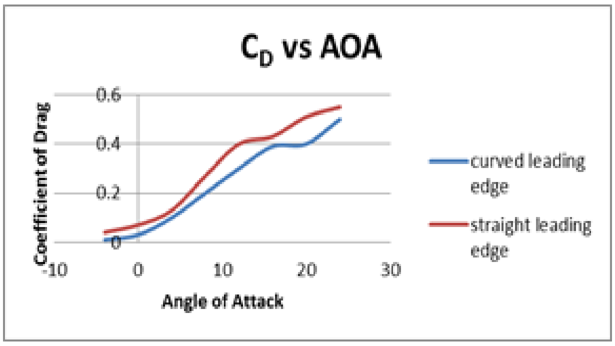

Fig.13: Graph between CD versus AOA

V. Conclusions

The Coefficient of lift will be higher at an angle of 15 degree. As the angle of attack increase the amount of lift created by the airfoil also increases A lowering of pressure on the upper surface results in developing pressure gradient. Coefficient of pressure show better results at 23.71m/s

After comparing from the experimental data conclusion arise that stalling effect will occur after 20 degree angle of attack.

The curved leading edge is preferred due to the superior lift and inferior drag force. In both practical and CFD analysis

- In CFD ANALYSIS normal forces in case of curved vane is observed to be greater than straight vane under same boundary conditions indicating the curve edge to be superior
- In practical study as shown in graphs lift force is observed to be greater in case of curved edge
- Both the results justify each other in support of curved edge aerofoil.

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