Flow Simulation of 3d Printed Unsymmetrical Naca 4412 Airfoil

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Abstract: Now a day aircraft industry is very growing industry. Aircraft use in both passenger and war purpose. Design and testing of aircrafts and their components are very complex and need skill, this makes design and testing of aircraft and its component are expensive. So very less organization manufacture the aircraft wings like BOEING and NACA. Many researchers and small industrialist try to invent the new wing design which should be simple and test, and access easily like bicycle. For complete these goal try to flow simulation of airfoil wing on advance software like ANSYS. For validate the result use 3D printed airfoil. Complex 3D airfoils are easily makes in 3D printing machine, which is easily access in engineering colleges. So for the initial verification selects unsymmetrical airfoil, because it will give the lift forces even zero angle of attack. A lot of 3D print methods are available in this time. Small size of airfoils crated in 3D printing machine. So for testing of 3D airfoil need a small wind tunnel. So create a small wind tunnel for testing of 3D airfoil and validate the result. Airfoil should be smooth and easy manufacturing for flow simulation use 3D printing technology. For obtain smooth result and compare the result uses of three analysis software. All the tree software has different advantage like modeling analysis drawing. These   solvers compare   better and more accurate result.

Index terms: NACA airfoil SOLIDWORKS, NX UNIGRAPHICS, ANSYS, FDM technology.

I.   INTRODUCTION

Fused deposition modeling (FDM) is an additive manufacturing technique, which work by heated nozzle layering down molten material in layer to produce a desired shape or product. FDM is one of the most common technique used to 3D printer and has become one of the most popular rapid prototype technique.

Wings are the most essential parts of an aircraft's structure like airplane helicopters, it shapes that lift and sustain the whole weight of aircraft in the air. Without wings, the aircraft will not fly. It has other advantage other than providing necessary lift to fly. During flight lower pressure on top surface and higher pressure on bottom pressure because of COANDA effect which in turn sucks the airplane into the air with follow the application of Newton third law [1]. An airfoil is a cross section of any wing [2].The main functions of the wing to produce enough lift (L). Drag (G) and nose-down pitching moment. The main aim of wing designs to maximize the lift and minimize the drag and nose-down pitching moment.

The wing design depends on many factors for example dimension, load, and application of the aircraft, required landing speed and desired rate of climb. In some aircraft wing are used to store fuel as fuel tank. The wings are designed as left and right wings based on the pilot seated on aircraft. Based on use there are different type of wings for example traditional, blended, rectangular wing, elliptical wing, swept wing, delta wing symmetric and skew symmetric wing. Airfoil selection is based on geometry and aerodynamic. There are some force acts on airplane body for example thrust, drag lift and gravity. There are two dimensionless parameters which affect significantly for example lift coefficient and drag coefficient. Geometry of plane wings depends upon chord line, thickness of wings, chamber of wings, aspect ratio. National advisory committee of aerospace (NACA) define different type of wings for example NACA0012 NACA4412. Airfoil material is very limited because material should be light weight and high strength [5]. Some airfoil design on the basis of speed for example subsonic and supersonic airfoil.

II.   OBJECTIVE

- The purpose of this study the method of FDM technology to print complex airfoil with the help of CAD software, GRABCAD software, STRATSYS F270 machine, and support clean apparatus machine.
- Complete simulation in ANSYS software and design in CAD software for process make simpler and get the advantage of different CAD software in design and drafting.

- Make a small wind tunnel to verify the lift force in 3Dprinted airfoil at different speed of air.

III. DESIGN AND METHODOLOGY

The airfoil design is a very complex and time consuming process. The knowledge of aerodynamic should require of expertise and well trained. Most expensive testing process is available in airfoil aerodynamic properties. So the limited company makes have aircraft production firm for example BOEING and AIRBUS. Designation their own airfoil is not economical for small aircraft manufacturing companies.

Rapid prototypes of fuse deposition modeling give alternate and easy solution for flow simulation study at low speed. Raid prototype materials are generally polymer, which have low strength.
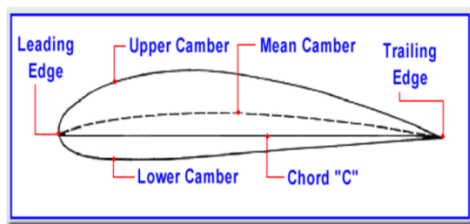

Figure1: Shows the terminology associated with Airfoil

NACA airfoil 4digit describe geometry information

Table 1: Shows the Geometry parameters of NACA 4412 airfoil

NACA 4412 Airfoil		
S. No	Digit number	characteristics
1.	4	4% is maximum camber in percentage of chord
2.	4	40% is the location of maximum camber in percentage of chord
3.	12	12% is the maximum thickness in percentage of chord

Airplane exerts 4 forces when plane fly. Names of forces are lift force, drag force, thrust force, and gravity forces. These all force has own significance use light material for reduce the gravity force. Polish the surface of airfoil reduce the drag force. Use super charger to increase thrust force and lastly use suitable angle for increase the lift force. Foe designing of airfoil the main aim to maximize the lift force and minimize the drag force. During starting of airplane need of lift force is more, this is achieved by tilting of airfoil up to angle of stall.
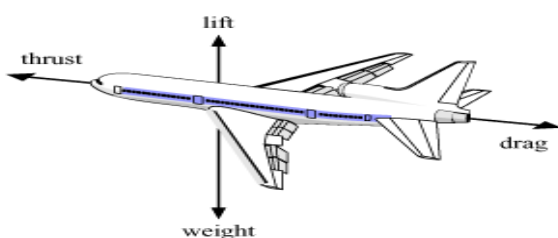

Figure 2: shows the force associated with airplane

Airfoil is printed by 3D printer by follows several step. Firstly the airfoil model have generated in the airfoil generator [10]. The generator output excel file was given in term of x and y coordinates. It was converted to notepad by adding z coordinate as zero.

Figure 3: Shows the profile of NACA 4412 Airfoil

After drawing of airfoil in cad file with the help of coordinate, convert into STL file format for 3D print.
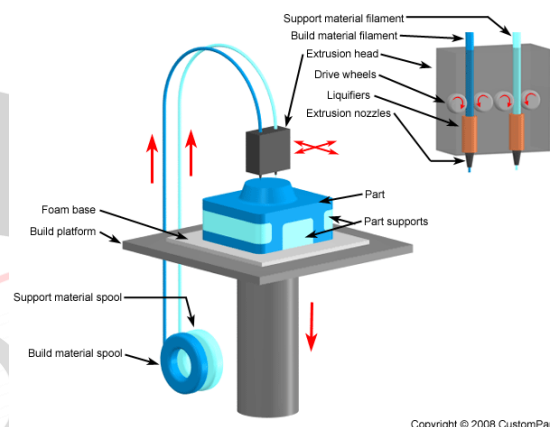

Figure 4: shows that basic method of FDM

Use Grab cad software for print the airfoil. Grab cad is a advance software which have a lot of advantage like accept all format of file and can impart numerous method like WIFI USB BLUTOOTH etc. Size is also controlled by this software without disturbing the geometry of specimen. Use STRATSYS F123 series machine for print airfoil by fused deposition method

Figure 5: Shows the STRATSYS f270 series 3d printed FDM machine

FDM printers use two kind of materials, a modeling material, which constitute the finished object, and a support material which act as scaffolding to support the object as it's being printed. During printing, these materials take the form of plastic thread, or filaments which are unwound from a coil and fed through an extrusion nozzle. The nozzle melts the filament and extrusion onto the base, sometimes called a build platform or table. Both the nozzle and the base are controlled by a computer that translates the dimensions of an object into X, Y and Z coordinate for nozzle and the base to follow the printing.
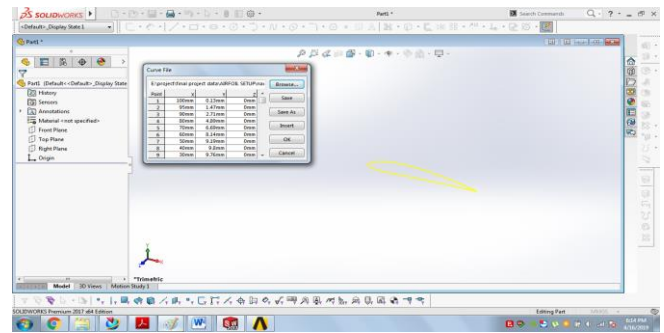

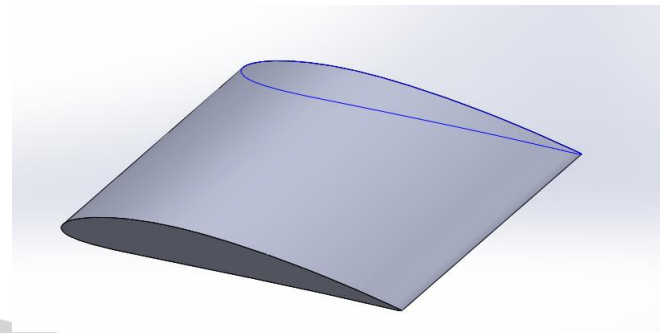Figure 8: shows that coordinate is impart to make airfoil geometry

Figure 9: shows that 3D shape of airfoil in cad

Generate 3D airfoil from these curves in cad file. Then after files is converted in to step file. This file will further impart in ANSYS solver file for checking lift force generation.

NX UNIGRAPHICS, formally known as, "UG". In 2000 UNIGRAPHICS purchased SDRC I-DEAS and began an effort to a integrate aspect of both software package into a single product with UNIGRAPHICS NX or NX is an advance high-end CAD/CAM/CAE, which has been owned since 2007 by SEIMENS PLM software
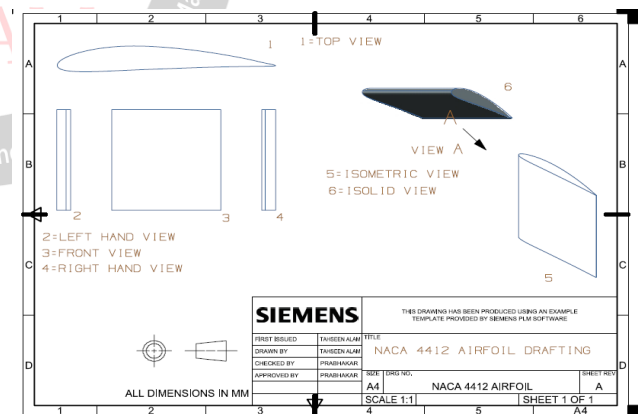

Figure 6: Shows that support cleaning apparatus machine

After print of airfoil through FDM method need a support cleaning apparatus machine which separate the support material

Figure 7: Shows that NACA 4412 airfoil

IV.   EXPERIMENTAL SET UP

BY SOFTWARE

SOLIDWORKS is a solid modeling computer-aided designed computer aided engineering that runs on Microsoft windows. SOLIDWORKS   published by DASSAULT systems. According to publishers, over two million engineers and designers used this software

Draw in cad file from coordinate impart NACA 4412 from NACA website. Copy this coordinate into excel file and add extra column for Z coordinate and put zero in entire column. These file is further converted into word format for accept cad file

Figure 10: shows 4412 airfoil drafting

ANSYS offers engineering simulation solution set in engineers simulation that a design process requires. Companies in a wide variety of a industries use ANSYS software. It used CFD and FEM and various other programming algorithm for simulating and optimize various design problem.

Meshing process is done after imparting of airfoil shape. Meshing is process in which solid part is divided into small parts. Increase the number of parts more fine result will obtain.
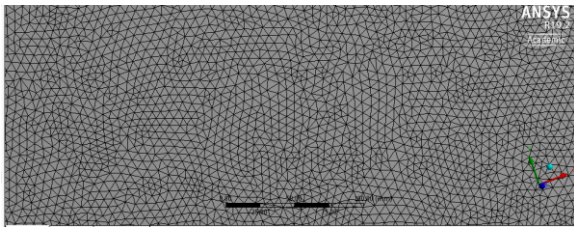
Figure 10: shows meshing of airfoil surrounded body

For 2D CFD analysis firstly create 2D design in either CAD file or direct in ANSYS file. 2D design draw in CAD file make simple, quick and easy. While draw in ANSYS is not easier than CAD file. ANSYS accept file format in which CAD software create otherwise change the format which accept the ANSYS.
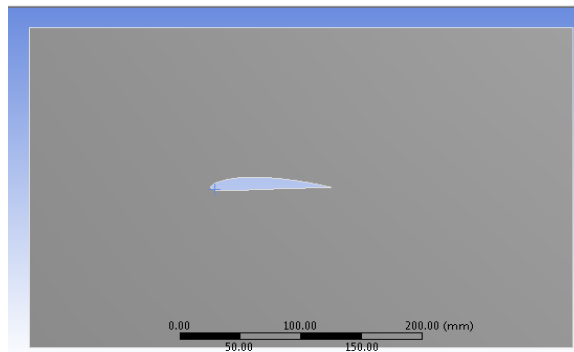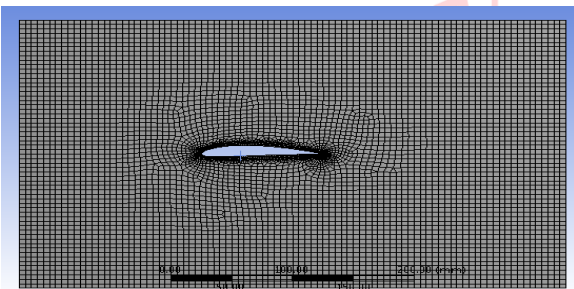

Figure 11: shows that 2D airfoil geometry

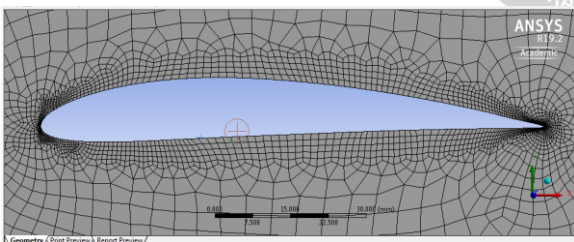**Figure 12: shows that 2D airfoil meshing**

Figure 13: Shows that zoom view of 2d meshing

Table2: shows the input parameters for CFD analysis of airfoil

Input parameter	
Inlet velocity(air)	10 m/s
Density(air)	1.2 kg/m^3
No of iteration	500

Table 3: shows the Size of computational domain

X max	250 mm
X min	-250 mm
Y max	250 mm
Y min	-250 mm
Z max	250 mm
Z min	-250 mm

Calculate lift force drag force for calculating the lift coefficient and drag coefficient. Change angle of attack to find angle of stall. Change of angle 2 degree for smooth or more exact result of stall. Finally draw the graph for angle of attack verses lift coefficient for more detail of stall.
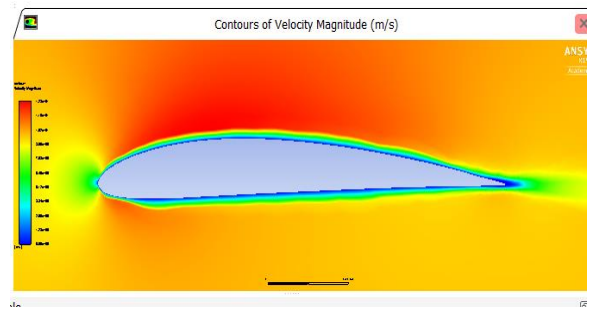

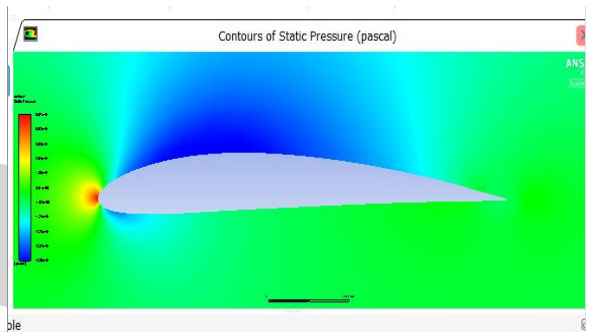**figure 14: Shows the velocity distribution across length**

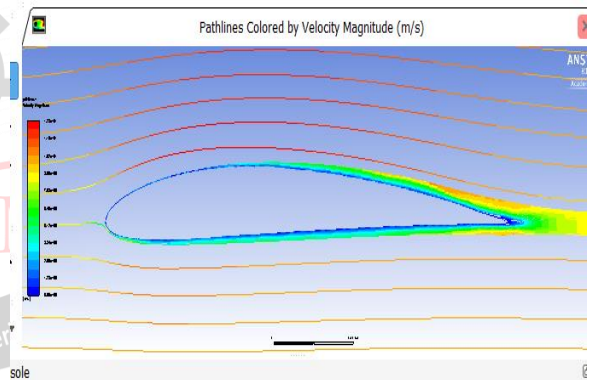**Figure 15: Shows the pressure distribution across length**

Figure 16: Shows that stream path across length

Table 4: Parameter at zero angle of attack

|	formula	value
Lift force	L.C*.5*d*A*V^2	2.347963E-03
Drag force	D.C*.5*d*A*V^2	7.18557E-05
Lift coefficient	L.F/(.5*d*A*V^2)	9.5446E-3
Drag coefficient	D.F/(.5*d*A*V^2)	2.92E-5

WHERE

L.C = LIFT COEFFICIENT
D.C = DRAG COEFFICIENT
L.F = LIFT FORCE
D.F = DRAG FORCE
A = PROJECTED AREA
D = DENSITY OF AIR
V = VELOCITY OF AIR

From the above formula lift force, drag force, lift coefficient, and drag coefficient don't depend on material and its property. Density and area is nearly constant so all of the value of force and coefficient depend on velocity. Because in all the formula velocity is in square form so less change in velocity large change in all the four values.

Table 5: shows that lift and drags coefficient at different angle of attack

Angle of attack	Lift coefficient	Drag coefficient
0	9.5446E-3	2.92E-5
2	10.1898E-3	2.374E-5
4	10.81E-3	1.756E-5
6	11.45E-3	1.052E-5
8	12.1374E-3	.02197E-5
10	13.3194E-3	1.044E-5
12	14.5653E-3	2.6598E-5
14	15.6599E-3	4.311E-5
16	17.0283E-3	6.597E-5
18	18.1341E-3	8.15E-5
20	17.57E-3	9.186E-5
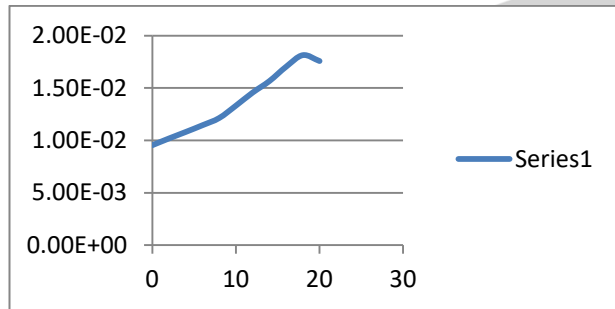
Graph 1: show the stall angle of NACA 4412 airfoil

V.   EXPERIMENTAL SETUP

For varify result need a wind tunnel. For small size of airfoil need a small wind tunnel. So use a home made wind tunnel for testing. Materials use for making wind tunnel are small direct current fan, firect current battery, swittch, plastic tap, paper sheet, and small weighting machine. Calcaulate mass before air start and calculate mass after fan start. Also calculate the mass at different speed.

Figure 17: shows homw made wind tunnel

Table 6: shows that mass of airfoil during experiment

	Mass of airfoil in gram
Without air	68
Air at low speed	61
Air at moderate speed	57
Air at high speed	52

VI.   RESULT

The coefficient of lift and drag ware calculated and compared at different angle of attack at all three software. The results are shown in table. The pressure and velocity contours show the reason of increasing lift at different angle of attack, pressure at the bottom of airfoil surface increases. It also increases at the top but not is significant as compared to bottom surface. Due to this, there was an increase in the pressure difference between the surfaces. This resulted in increased net force, whose vertical component is lift and   horizontal is drag. Thus there was an increase in coefficient of drag and lift (figure). The area of airfoil, velocity and density of air were kept constant over various angle of attack. By experimental set up mass of airfoil decreases when speed of air increases.

VII.   CONCLUSION

From above report complex airfoil is made quickly shape is made by 3d printing and testing of low simulation give pressure distribution, velocity distribution, streamline and lift force and drag force. From experiment mass decrease due to air this decrease mass due to lift force.

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