STUDY OF VARIOUS NACA SERIES AEROFOIL SECTIONS AND WING CONTOUR GENERATION USING CATIA V5

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ABSTRACT

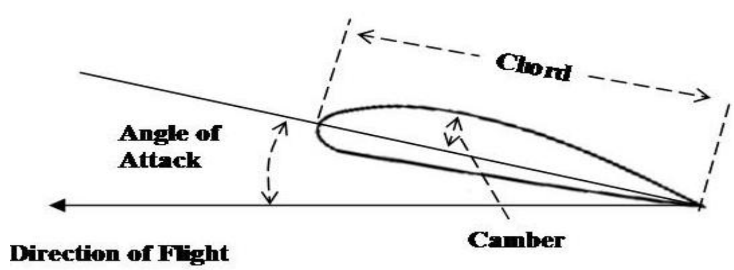
Aerofoil is the basic part to be designed during starting stage of creating a new airplane. It is the part that forms of cross section of the wing. The wing is used to produce lift force that balances the weight which acts downwards. Velocity variation creates pressure difference over top and bottom surface of wing. The pressure difference over top and bottom surface of wing creates lift. In this paper, we studies about aerofoil and its basic types and various NACA series and equation of 4 digit NACA series. In this paper, we come to know how we can export an aerofoil in CATIA from MS EXCEL and how we can design wing contour using CATIA software.

KEYWORDS

Aerofoil, Lift, Wing Contour, NACA Series & CATIA V5.

1. INTRODUCTION

An aerofoil is a shape of an aircraft wing or blade which can produce aerodynamic forces. First patented aerofoil shapes were developed by Horatio F. Phillips in 1884. The standard nomenclature of aerofoil is established by NACA. Consider the aerofoil as sketched in figure 1



Straight line connecting the leading edge and trailing edge is known as chord line. And precise distance between leading and trailing edge is known as chord. Mean camber is the locus of points halfway between upper and lower surface as measured perpendicular to mean camber line itself. The distance between upper and lower surface measured perpendicular to chord line is called thickness.

Force acting upward perpendicular to aerofoil or perpendicular the line of flight is called lift. Force that acts parallel to an aerofoil or force acting in opposite direction to line of flight is called drag. As clearly shown in Figure 2

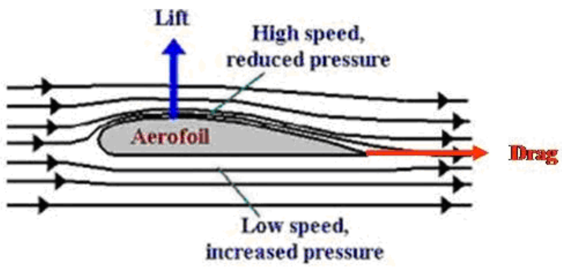


Figure 2. Lift and Drag

Aerofoil mainly produces lift because of its angle of attack and cross sectional shape, where angle of attack is defined as an angle formed free-stream air and chord line of airfoil. Most of the aerofoil has positive angle of attack.

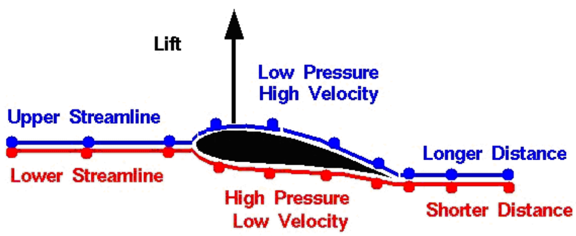


Figure 3. Lift generation on an Aerofoil

On the behave of camber, aerofoils basically divided into two parts i.e. Symmetric aerofoil and Cambered aerofoil. Aerofoil whose mean camber line coincides with chord line is known as symmetric aerofoil as shown in figure 4. In case of symmetric aerofoil, camber is zero.

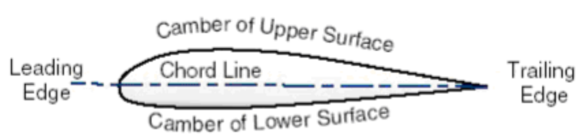


Figure 4. Symmetric Aerofoil

On other hand, aerofoil whose camber line does not coincide with chord line is known as a cambered aerofoil. For subsonic use the aerofoil section has rounded edge. The depth increases smoothly to a maximum which usually occurs between ¼ and ½ way along the profile and thereafter tapers off toward rear of section.

2. DESIGN

National Advisory Committee for Aeronautics developed many designs of aerofoil. These are known as series or NACA series of aerofoil. Some of them are given as follows in detail.

2.1. FOUR DIGIT NACA SERIES

4 digit NACA series developed in 1930s. This defines the profile as first digit is the maximum camber in 100^{th} of chord. 2^{nd} digit is the location of maximum camber along chord from leading edge in 10^{th} of chord. Last two digits give maximum thickness in 100^{th} of chord. For Example:

NACA 2412- Maximum camber is 0.02c located at 0.4c from leading edge and maximum thickness is 0.12c (where c shows chord).

For Symmetrical Aerofoil NACA 00XX, camber is zero. 'XX' indicates aerofoil has a XX thickness to chord length ratio.

2.1.1. EQUATION FOR 4 DIGIT NACA SERIES

To design an aerofoil of 4 digit NACA series, we have a standard equation. By using which we can calculate the points of an aerofoil in 2-D coordinates and easily design an aerofoil.

$$y_t = (t/0.2)\,(0.2969\sqrt{x} - 0.126x - 0.3516x^2 + 0.2843x^3 - 0.1015x^4)$$

Where, c is the chord length, x is the position along chord from 0 to c, y is the half thickness at a given value of x, t is the maximum thickness as a fraction of chord. By putting all these values in equation, we get required points of x and y. Using these points we can form a profile for aerofoil of 4 digit series.

For upper surface {x (U), y (U)} and for lower surface {x (L), y (L)}

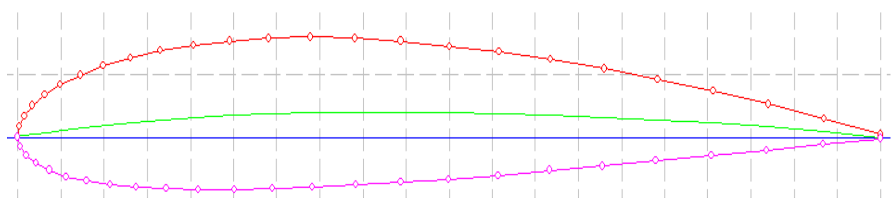


Figure 5. Aerofoil Design using x and y points

But, now day's different kinds of software are used to design aerofoil, which also work on same kind of standard equations computationally.

2.2. FIVE DIGIT NACA SERIES

In five digit NACA series, first digit when multiplied by 3/2 it gives the design lift coefficient in tenths. Next two digits when divide with 2 it gives the location of maximum camber from leading edge in 100^{th} of chord. Last 2 digits give maximum thickness in 100^{th} of chord.

For Example: NACA 23012 is defined as, Design lift coefficient = 2*(3/2)*(1/10) =0.3, Maximum camber located at = (30/2)*(c/100) = 0.15c, Maximum thickness of aerofoil = 12*c/100 = 0.12c.

2.3. SIX DIGIT NACA SERIES

In six digit NACA series, first digit simply identifies the series. Second digit gives the location of minimum pressure in tenths of chord from leading edge. Third digit gives the design lift coefficient in tenths and last two digits give maximum thickness in 100^{th} of chord.

For Example: NACA 65-218 is defined as follows, 6 show the designation of series, minimum pressure occurs at 0.5c from leading edge of aerofoil. Lift coefficient is 0.2c and maximum thickness of aerofoil is 0.18c.

2.4. Seven Digit NACA Series

This series give further advancement in maximizing laminar flow achieved by separately identifying the low pressure zones on upper and lower surfaces of the aerofoil. First digit designates the series. Second digit describes the distance of minimum pressure area on the upper surface in tenths of chord. Third digit gives distance of minimum pressure area on the lower surface in tenths of chord. Fourth letter refers to a standard profile from earlier NACA series. Fifth digit describe lift coefficient in tenths. Last digits two describe maximum thickness as 100^{th} of chord.

For Example: NACA 712A315 has area of minimum pressure 0.1 of chord back on upper surface and 0.2 of chord back on lower surface, uses standard 'A' profile, has a lift coefficient of 0.3 and has maximum thickness of 0.15of the chord.

3. To Export Aerofoil In CATIA V5

CATIA V5 is software, which is used to form three dimensional designs of machines, machine parts, tools etc. To design a wing contour, first need is an aerofoil. In above, we have discussed about the equation for 4 digit NACA series. Using that equation, we generate an excel sheet of x and y points depending upon any desired thickness. And follow the steps given below:-

Step 1: Open the CATIA V5, click on file option and select 'new'. From 'new', select part and part1, then click 'OK'.

Step 2: Minimize the CATIA V5 and Open the MS-EXCEL. We make an Excel sheet (having exporter to CATIA) in which we put x and y coordinates calculated from equation of aerofoil, which are discussed above.

Step 3: Put z-axis coordinates zero, because aerofoil is a two dimensional profile. For Example, we have 4 digit series aerofoil i.e. NACA 2412

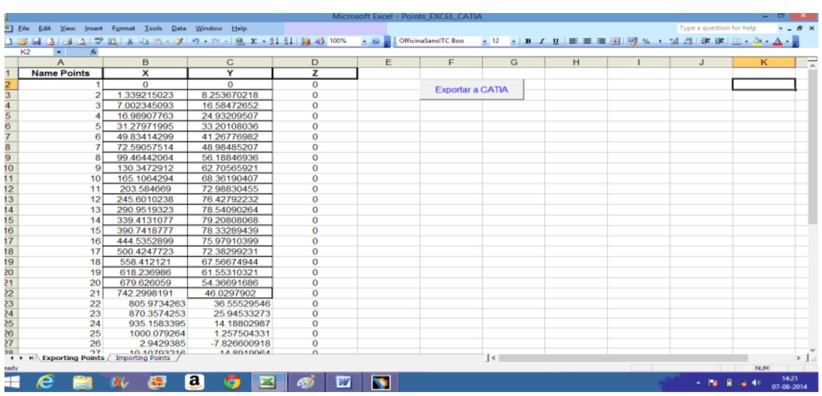


Figure 6. Excel sheet having x, y and z points

Step 4: Click on 'Exporter a CATIA' box to insert all the points in CATIA from Excel sheet. Click 'OK'.

Step 5: Progress screen shown at monitor, then click at EXIT. Close the MS-EXCEL.

Step 6: Open the minimized CATIA folder.

Step 7: Click at 'Fit in all' option. Now, click at 'Spline' command and Join all the points one by one in series.

Step 8: Click at 'Tools' and select 'hide all points' option to hide all the points. And we get a desired aerofoil shape as shown in figure 7

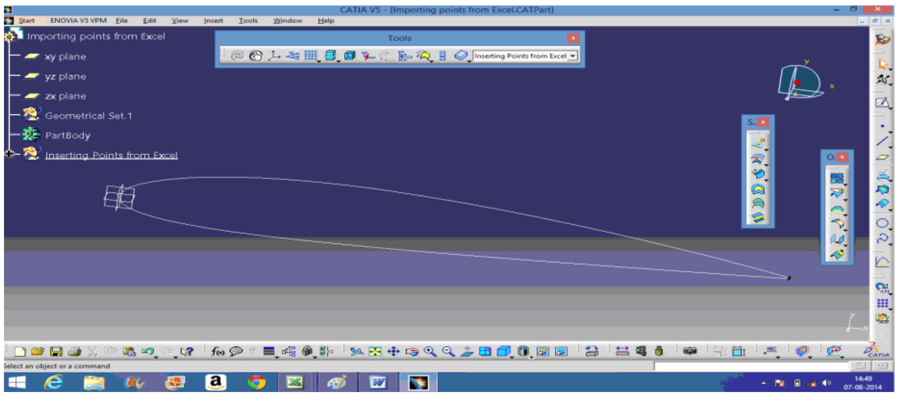


Figure 7. Aerofoil shape exported in CATIA V5

4. To Design Wing Contour Using CATIA V5

After exporting the aerofoil in CATIA V5 follow the steps given below to design a wing contour. Step 9: Select plane command to define a plane. Click at reference plane (xy) and give offset of 3000 and click 'OK'.

Step 10: Select scaling command. Click at aerofoil and then, reference plane zx. After that give ratio 0.6 and click 'OK'.

Step 11: Repeat step 10 to scale new aerofoil with reference plane yz having ratio 0.6 and hide the middle aerofoil by right clicking at that aerofoil and click at hide option.

Step 12: Select translate command to draw wing tip and click at small aerofoil, Select reference plane xy with distance 3000 and click 'OK'.

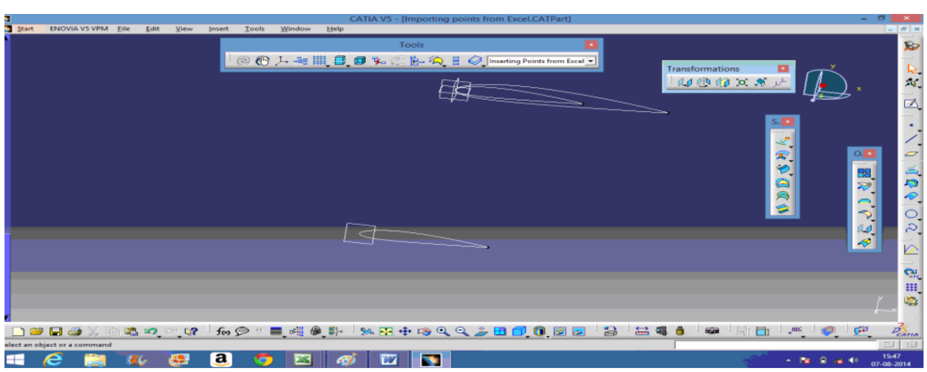


Figure 8. Wing Tip Design

Step 13: Hide the first small aerofoil.

Step 14: Select multi-section command, and click at both aerofoils' one by one, then at 'OK'.

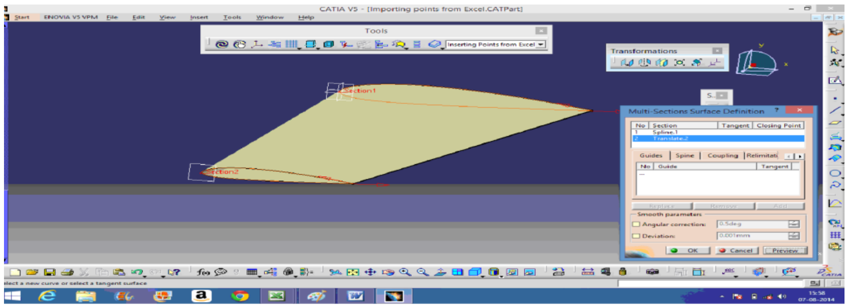


Figure 9. Use of Multi Section Command

Step 15: Select split command. Click at wing surface and zx plane. By keeping both sides, click 'OK'.

Step 16: Zoom in at trailing edge of wing. Trailing edge of wing is not closed, to make it close we extrapolate upper and lower surface one by one.

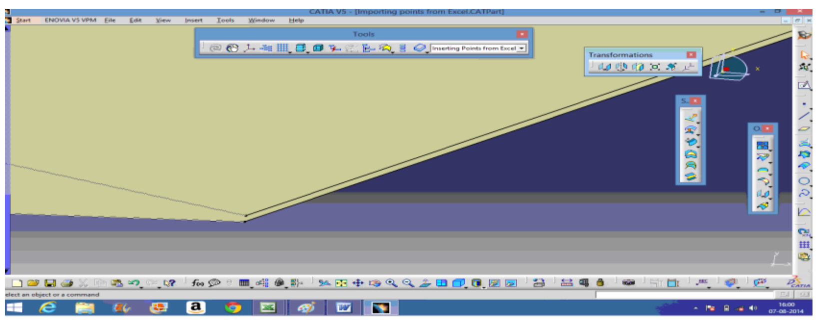


Figure 10. Opened Surface of Trailing Edge

Step 17: To extrapolate, Select 'Extrapolate' command and click at Edge and Surface of upper section, then click at 'OK'.

Step 18: Repeat the Step 17 at lower section of wing.

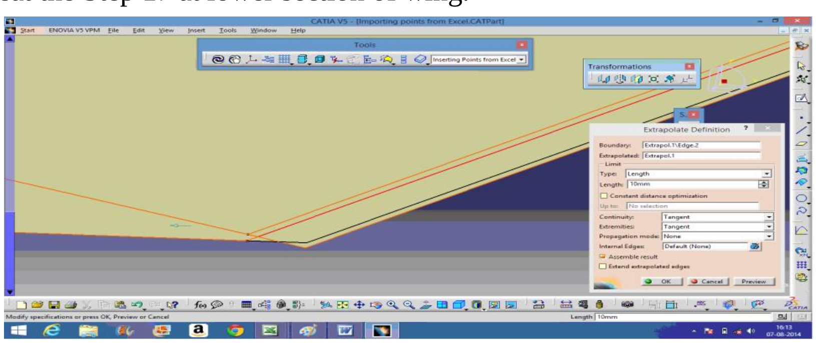


Figure 11. Extrapolation of Wing Surfaces

Step 19: Choose 'Shape fillet' command to put a fillet on intersection of surfaces. For this, Select shape fillet. For support1, click at upper surface and 'inside' arrow direction. Similarly, for support2 click at lower surface and 'inside' arrow direction. Click 'OK'.

Step 20: Select healing command, Click the surface and then click 'OK'.

Step 21: Hide all the planes. Design of wing contour is completed.

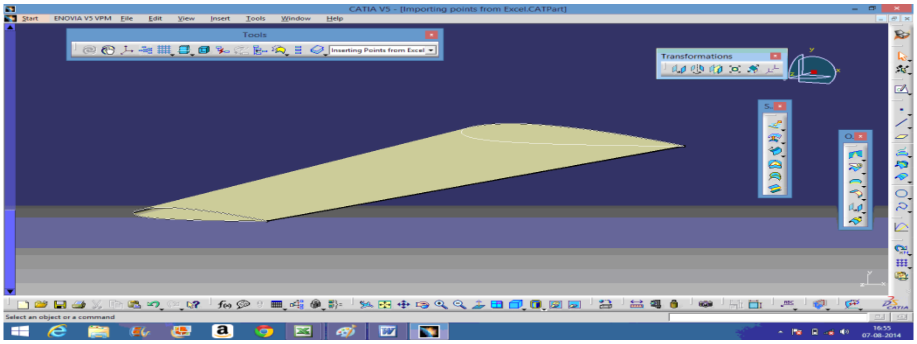


Figure 12. Wing Contour Design

Step 22: For multi-view, Click at multi-view command.

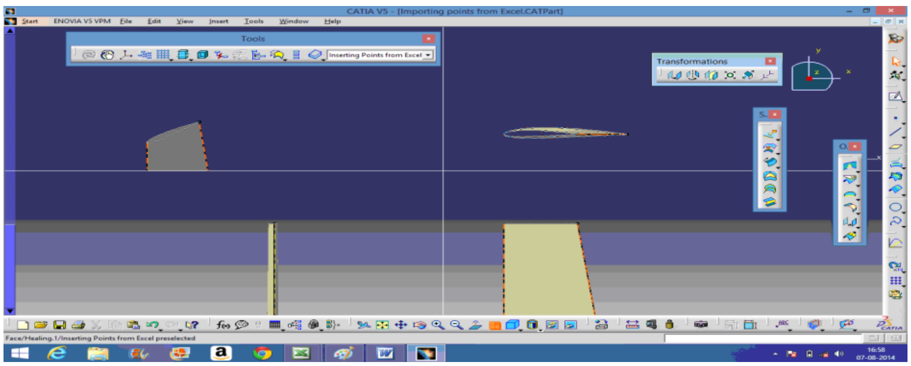


Figure 13. Multi-View of Wing Contour

5. CONCLUSION

Here, we have studied about aerofoil and different types and various NACA series of aerofoil including NACA 4 digit, NACA 5 digit, NACA 6 digit and NACA 7 digit series. We come to know how we can export an aerofoil in CATIA V5. We conclude that we can easily form precise profile of aerofoil with the help of MS EXCEL and CATIA V5. Aerofoil mainly produces lift because of its angle of attack and its cross sectional shape. In this paper, we have studied how easily we can design a wing with the help of CATIA V5 software. We can design different types of wing contours using different-different profiles of aerofoil in CATIA V5. Using this, further modification can be done to design aerofoils and wings. We can modify different aerofoil profiles for different types of wings. For sonic, supersonic and hyper sonic aircrafts different types of airfoils and wings are used depending upon amount of lift needed. Aerofoil shapes used to produce maximum lift. So, aerofoil shapes can be modified according to the need of lift. From these aerofoils, further different types of wings can be designed.

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