Front Wing

Vasanth P

July 2024

1 Introduction

This front wing designed consists of 2 different regions/sections - Middle and Side sections . For a simple general aerofoil , the general procedure followed is

1. Aerofoil selection
2. Sequential selection of AoA by 2D CFD
3. 3D Modelling along with endlpates
4. Iterative 3D CFD and final alteration

But for a front wing with different regions and multiple functionality (creating downforce and managing airflow to undertray diffuser , sidepods , pushing air away from front tyres ,etc) the workflow slightly varies towars the end .

The airfoil data is obtained from $airfoiltools.com$.All the CAD work was done in SOLIDWORKS.ANSYS Workbench Mechanical and Fluent were used for managing workflow ,Meshing and performing CFD respectively.

In this , the general procedure followed for 2D and 3D CFD is explained in short, follwed by the sequential workflow followed for this specific design.

2 2D CFD

The spline points for the required aerofoil were downloaded from plotter in .dat format. The curve is imported to CAD software as 3D curve after modifying it in excel , deleting everything else other than data points , and adding another column filled with zeros to represent Z coordinate.Note that some curves may be open at the trailing edge , these are closed by using a tangent arc after importing.The final output of the CAD software must be a surface (which represents the domain) where the airfoil shape is cutout.In addition to this a smaller surface which represents the refinement region is also created to act as construction geometry ,which later helps make the mesh finer at the region surrounding the aerofoil cutout.

Figure 1: Zoomed in image of surface domain prepared

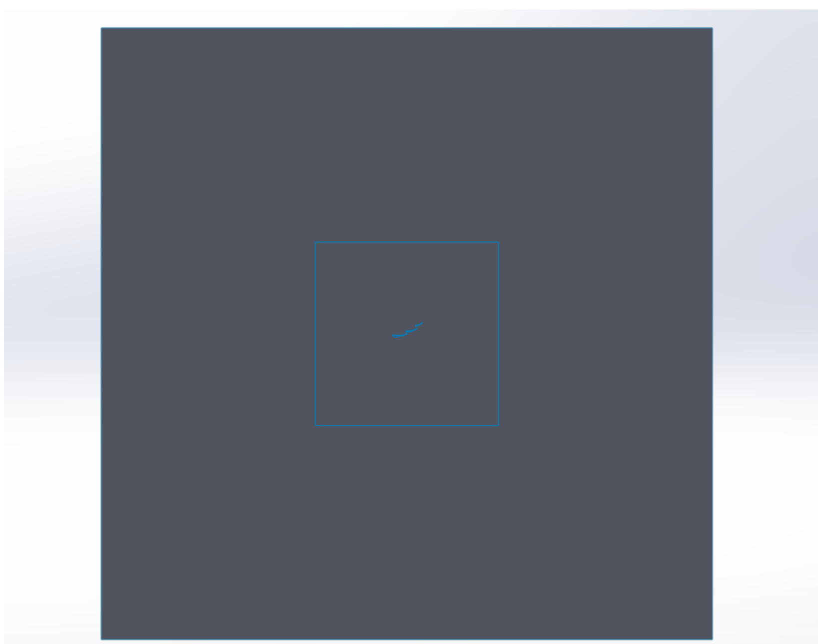

Figure 2: Entire surface domain along with refinement surface

One important plugin which saved a lot of time is the Ansys plugin for SOLIDWORKS.This helps to dynamically update SW file in Ansys workflow as if it were a part of Ansys package.

- Configure Ansys : https://grabcad.com/tutorials/configuring-solidworks-and-ansys
- Configure SW : https://www.youtube.com/watch?v=huPxRsAmxds&list=PLsP1-PKBZiqU6yZCtMOryJZUFlFmAGwC0&index=3&t=51s

Fluid Flow (*Fluent*) workflow was used and meshing was performed in Mechanical since 2D meshing is not supported in fluent.

- A useful meshing guide : https://www.youtube.com/watch?v=BfM8bpowS8o

The CFD was performed in Fluent with boundary conditions of $15ms^{-1}$ at one wall and $0Pa$ Gauge pressure at other walls.Velocity and pressure contours were recorded. Lift , drag , lift coefficient and drag coefficient report definition were created and corresponding valued for both aerofoils were recorded.

3 3D CFD

The procedure for 3D CFD is very similar to that for 2D. The 2D sketch is surface extruded and endplates are added.Care must be taken to trim the suface at the interface of aerofoil and endplate.The final enclosed surface is knit with create solid option checked.In order to reduce computational time , only a symmetric half of the entire wing is used in CFD .The A cuboidal volume representing the domain anlong with a smaller cuboidal volume representing the refinement region is created.The combine tool in subtract mode is used to create a cavity in the shape of the aerofoil along with endplate in the domain volume.This CAD model is imported to Ansys.The workflow and apps used for meshing and CFD are same as in 2D CFD.

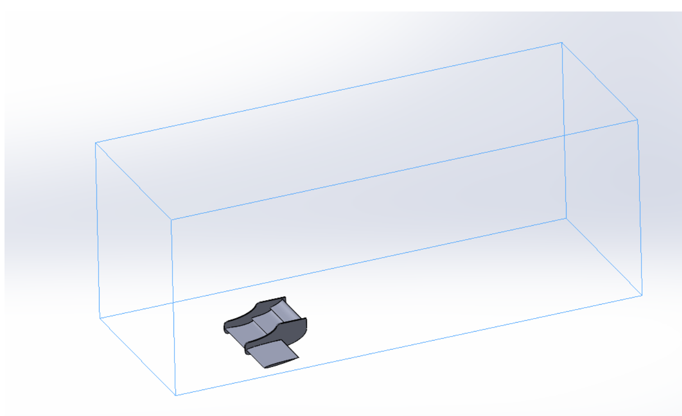

Figure 3: Symmetric half of front wing

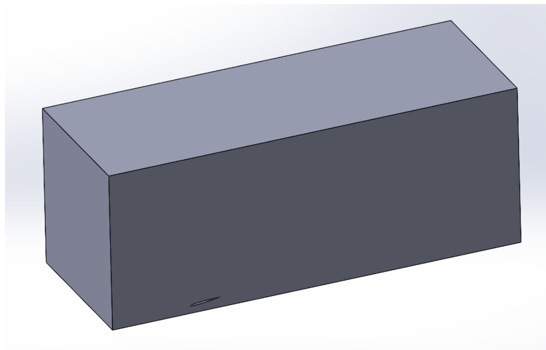

Figure 4: Final domain prepared

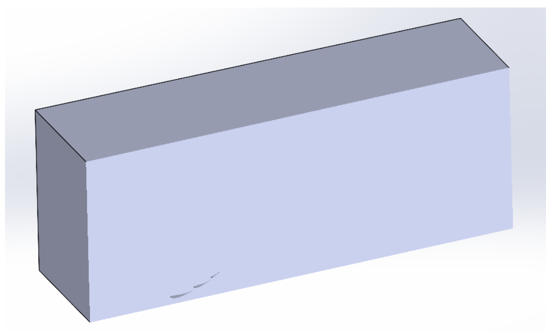

Figure 5: Section view of domain

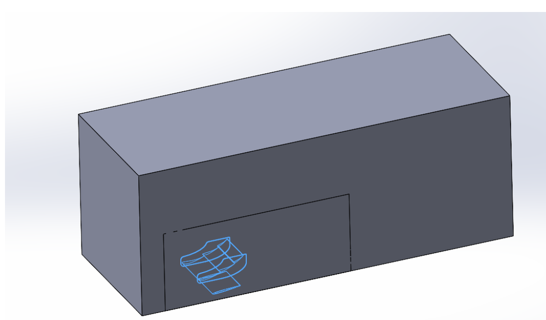

Figure 6: Domain with refinement box

4 Middle Section

The Middle section of front wing lies directly in front undertray. The undertray diffuser has the maximum contribution in downforce generated . Thus , the airflow toward it must be as undisturbed as possible. To achieve this , it is decided to use only a single element and a symmetric airfoil which has very good airflow around it . In order to first find how the thickness of aerofoil affects airflow and lift , two symmetric aerofoils with different thickness ($Naca0006$ and $Naca0024$) were selected and 2D CFD was performed.The data obtained is as in Tables 1 and 2

AoA	Downforce(N)	Drag(N)	Downforce coefficient	Drag coefficient	Efficiency
3^o	13.082	0.453	0.0949	0.0033	28.7575
5^o	21.7092	0.6418	0.1575	0.0047	33.5106

Table 1: NACA0006

AoA	Downforce(N)	Drag(N)	Downforce coefficient	Drag coefficient	Efficiency
3^o	3.3394	1.1659	0.0807	0.0282	2.8617
5^o	4.5397	1.3298	0.1098	0.0321	3.4205

Table 2: NACA0024

The thicker Naca0024 produces very less lift , enormous drag and is very inefficient at the speeds relevent to the event and they are better suited for high speed aviation applications.So the thinner Naca0006 is selected for its high efficiency and lift generated at the smaller AoAs . The Angle of attack is finalized as 5^o . The AoA is kept small so that airflow to undertray diffuser remains relatively undisturbed.Chord length is fixed at 30cm

Figure 7: Naca0006 at 5^o AoA - Pressure contour

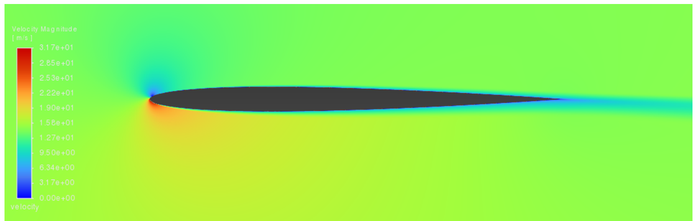

Figure 8: Naca0006 at 5^o AoA - Velocity contour

5 Side Section

For the region which lies directly in front of wheels , a multielement profile with steeper overall AoA was decided to be created .This is to push the airflow above and away the front tyres as the turbulence created at the tyress is the single major source of drag . Higher AoA also helps in generating the required downforce. S1223 was choosen for this section due to its impressive downforce generation capabilities at lower speeds and AoA.It was analysed at various angles between 0 and 13 deg with a chord length of 24cm.

AoA	Downforce(N)	Drag(N)
0^o	45.03	0.95
6^o	68.42	1.39
7^o	71.67	1.5
8^o	74.63	1.63
9^o	77.27	1.78
10^o	79.5	1.97
11^o	81.18	2.2
12^o	82.12	2.52
13^o	81.67	2.99

Table 3: s1223

The AoA of 6^o turned out to be highly efficient and manages airflow better.Higher AoA may provide more downforce but it will increase the height , and hence it is avoided considering height restrictions (front wing must be within 25cm from ground).

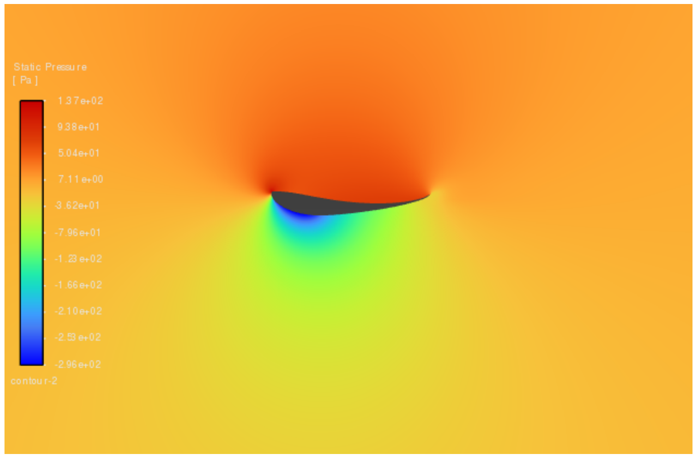

Figure 9: s1223 at 6^o AoA - Pressure contour

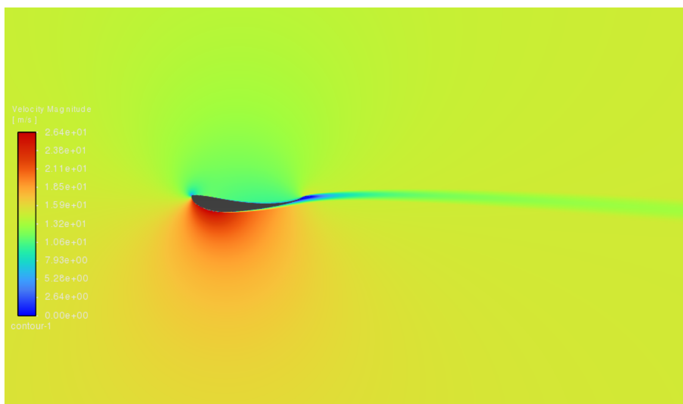

Figure 10: s1223 at 6^o AoA - Velocity contour

The chord length of 18cm is fixed for the second element and CFD is performed for AoAs in range 12 to 20.Gap between elements was temporarily fixed as 2cm.The AoA of secondary element is finalized as 15^o.

AoA	Downforce	Drag	Downforce Coefficient	Drag Coefficient	Efficiency
12	113.83996	2.59547	0.82604	0.01883	43.86829527
14	121.81609	2.78349	0.88392	0.02019	43.78008915
15	125.25617	2.87708	0.90888	0.02087	43.54959272
16	129.19713	3.00824	0.93748	0.02182	42.96425298
18	135.43466	3.20224	0.98274	0.02323	42.3047783
20	142.39947	3.47091	1.03328	0.02518	41.03574265

Table 4: s1223 2^{nd} element AoA data

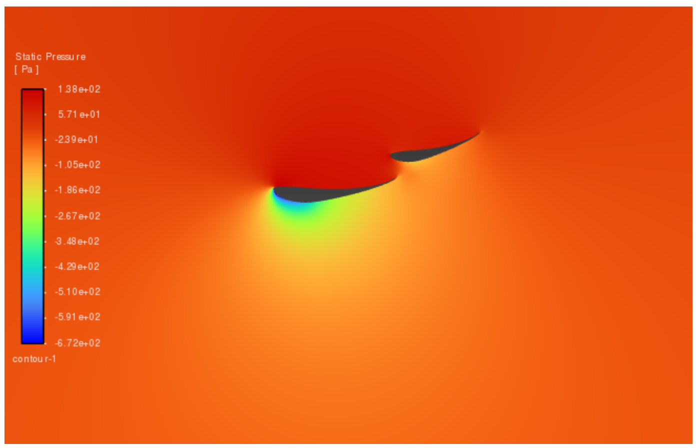

Figure 11: First two flaps of front wing at AoAs 6^o and 15^o - Pressure contour

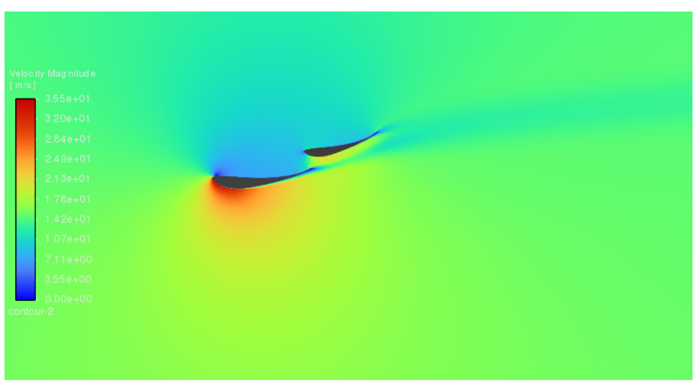

Figure 12: First two flaps of front wing at AoAs 6^o and 15^o - Velocity contour

For the third element ,CFD was performed with AoAs between 19^o and 25^o with chord length 12cm.The AoA for 3rd element was decided as 24^o(changed later).

AoA	Downforce	Drag	Downforce Coefficient	Drag Coefficient	Efficiency
19	176.83568	4.90109	1.28316	0.035563	36.08132047
20	178.93288	5.0827	1.29837	0.03688	35.2052603
21	181.82755	5.1071	1.31938	0.03705	35.61079622
22	184.95369	5.25824	1.34206	0.03815	35.1785059
23	186.8414	5.42796	1.35576	0.03938	34.42762824
24	189.54073	5.49136	1.37535	0.03984	34.52183735
25	191.34497	5.646158	1.38844	0.04096	33.89746094

Table 5: Third element AoAs data

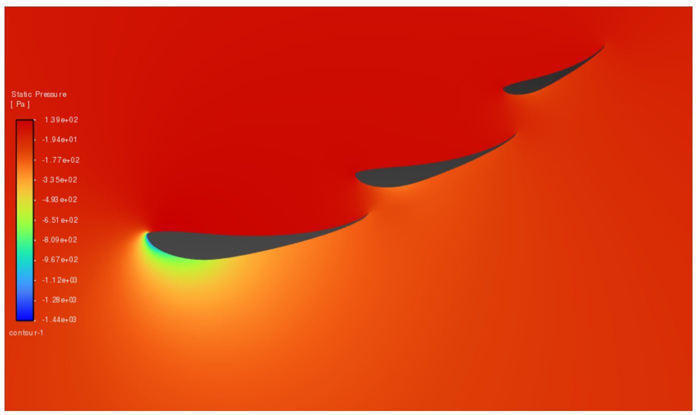

Figure 13: All three flaps - Pressure contour

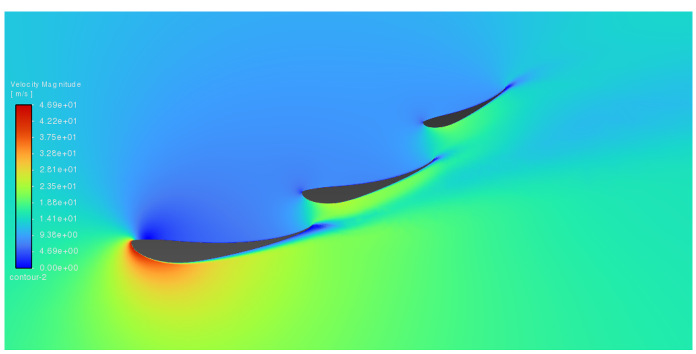

Figure 14: All three flaps - Velocity contour

The plan for fourth element was abondoned as it increases the height of front wing beyond the restricted value.

The gap between the elements too were varied and the following data were obtained.

Vertical Gap	Downforce	Drag	Downforce coefficient	Drag Coefficient	Efficiency
4	189.54073	5.49136	1.3753523	0.03984	34.52189508
2	187.97247	5.65875	1.36397	0.04106	33.21894788
1	179.96494	5.61721	1.30586	0.04075	32.04564417
0.5	175.34626	5.52073	1.27235	0.04005	31.7690387
1 and 2	186.04587	5.63851	1.34999	0.04091	32.99902224
1 and 1.5	186.00194	5.6387704	1.34967	0.04091	32.9912002

Table 6: Gap between elements *vs* performance