



MESH ATTACHMENT

- Degree in aerospace vehicles engineering
- Final work title:
 - Study of supercritical airfoils by means of computational fluid dynamics
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- ETSEIAT (UPC)



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1 Airfoil coordinates

(x/c)	$(y/c)_u$	$(y/c)_l$	(x/c)	$(y/c)_u$	$(y/c)_l$
0.00	0.00000	0.00000	0.260	0.06700	-0.06720
0.002	0.01077	-0.01077	0.270	0.06750	-0.06770
0.005	0.01658	-0.01658	0.280	0.06790	-0.06810
0.010	0.02240	-0.02240	0.290	0.06830	-0.06850
0.020	0.02960	-0.02960	0.300	0.06860	-0.06880
0.030	0.03460	-0.03450	0.310	0.06890	-0.06910
0.040	0.03830	-0.03820	0.320	0.06920	-0.06930
0.050	0.04140	-0.04130	0.330	0.06940	-0.06950
0.060	0.04400	-0.04390	0.340	0.06960	-0.06960
0.070	0.04630	-0.04620	0.350	0.06970	-0.06970
0.080	0.04840	-0.04830	0.360	0.06980	-0.06970
0.090	0.05020	-0.05010	0.370	0.06990	-0.06970
0.100	0.05190	-0.05180	0.380	0.06990	-0.06960
0.110	0.05350	-0.05340	0.390	0.06990	-0.06950
0.120	0.05490	-0.05490	0.400	0.06990	-0.06930
0.130	0.05620	-0.05620	0.410	0.06980	-0.06910
0.140	0.05740	-0.05740	0.420	0.06970	-0.06880
0.150	0.05860	-0.05860	0.430	0.06960	-0.06850
0.160	0.05970	-0.05970	0.440	0.06950	-0.06810
0.170	0.06070	-0.06070	0.450	0.06930	-0.06770
0.180	0.06160	-0.06160	0.460	0.06910	-0.06720
0.190	0.06250	-0.06250	0.470	0.06890	-0.06670
0.200	0.06330	-0.06330	0.480	0.06860	-0.06610
0.210	0.06410	-0.06410	0.490	0.06830	-0.06540
0.220	0.06480	-0.06480	0.500	0.06800	-0.06460
0.230	0.06540	-0.06550	0.510	0.06760	-0.06370
0.240	0.06600	-0.06610	0.520	0.06720	-0.06270
0.250	0.06650	-0.06670	0.530	0.06680	-0.06160

Table 1: NASA SC(2)-0714 airfoil coordinates

(x/c)	$(y/c)_u$	$(y/c)_l$	(x/c)	$(y/c)_u$	$(y/c)_l$
0.540	0.06630	-0.06040	0.780	0.04270	-0.01320
0.550	0.06580	-0.05910	0.790	0.04110	-0.01130
0.560	0.06530	-0.05770	0.800	0.03940	-0.00950
0.570	0.06470	-0.05620	0.810	0.03760	-0.00790
0.580	0.06410	-0.05460	0.820	0.03580	-0.00640
0.590	0.06350	-0.05290	0.830	0.03390	-0.00500
0.600	0.06280	-0.05110	0.840	0.03190	-0.00380
0.610	0.06210	-0.04920	0.850	0.02990	-0.00280
0.620	0.06130	-0.04730	0.860	0.02780	-0.00200
0.630	0.06050	-0.04530	0.870	0.02560	-0.00140
0.640	0.05970	-0.04330	0.880	0.02340	-0.00100
0.650	0.05880	-0.04120	0.890	0.02110	-0.00080
0.660	0.05790	-0.03910	0.900	0.01870	-0.00090
0.670	0.05690	-0.03700	0.910	0.01620	-0.00120
0.680	0.05590	-0.03480	0.920	0.01370	-0.00170
0.690	0.05480	-0.03260	0.930	0.01110	-0.00250
0.700	0.05370	-0.03040	0.940	0.00840	-0.00360
0.710	0.05250	-0.02820	0.950	0.00560	-0.00500
0.720	0.05130	-0.02600	0.960	0.00270	-0.00670
0.730	0.05000	-0.02380	0.970	-0.00020	-0.00870
0.740	0.04870	-0.02160	0.980	-0.00320	-0.01100
0.750	0.04730	-0.01940	0.990	-0.00630	-0.01360
0.760	0.04580	-0.01730	1.000	-0.00950	-0.01650
0.770	0.04430	-0.01520			

Table 2: NASA SC(2)-0714 airfoil coordinates

2 Mesh 1

All the experimental data was extracted from Jenkins, R. V. *Aerodynamic performance and pressure distributions for a NASA SC(2)-0714 airfoil tested in the Langley 0.3 meter transonic cryogenic tunnel*. USA: NASA, 1988.

2.1 Generation

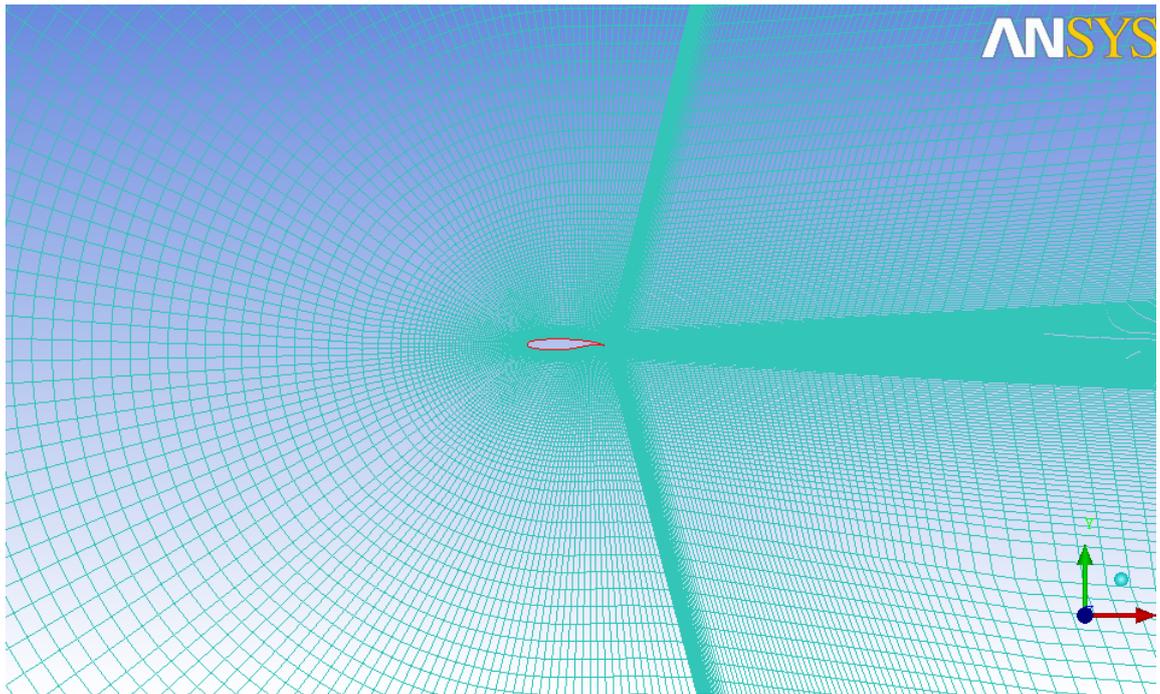


Figure 1: Mesh 1, smooth variation of the cells size

This is the base for the other meshes, that will be generated using the refinement function.

Several blocks have been created to better control the refinement. As Fluent can not bear with two neighboring cells with a refinement ratio greater than two, the blocks just after the boundary layer have been split into more blocks to gradually change the refinement (in the direction normal to the airfoil) of the boundary layer and the zone downstream from level 8 to level zero (figure 3).

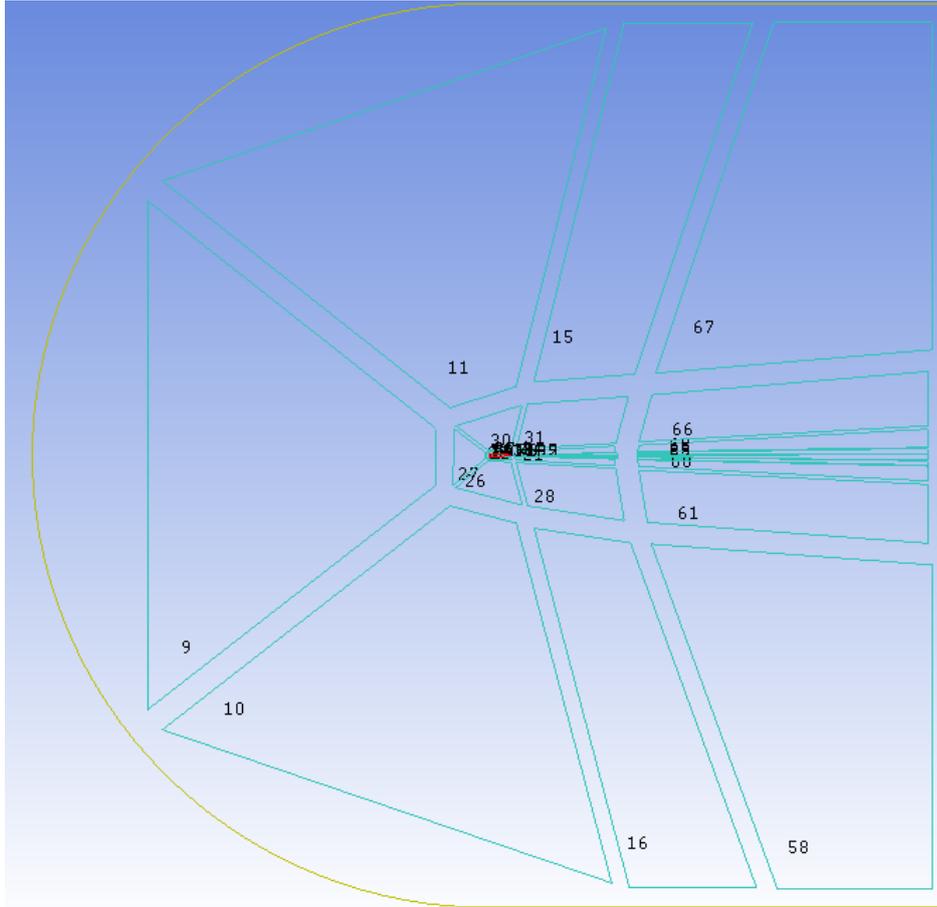


Figure 2: Mesh blocks

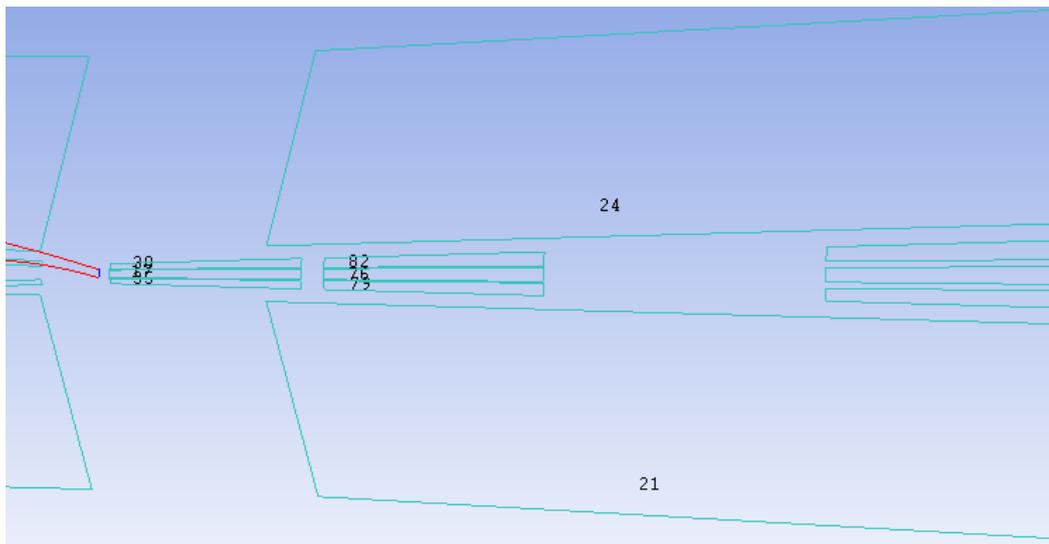


Figure 3: Block zoom

This division of blocks has been made to refine the wake just after the airfoil, and to use less cells when further from the airfoil.

Mesh 1 has 49036 cells (after the gradient adapt, this number will slightly increase). They are concentrated in the boundary layer, the part of the wake near the airfoil and the zone at a radius of distance from the airfoil.

2.2 Quality

2.2.1 Determinant 3x3x3

It computes the deformation of the cells. A value of 1 is a perfect square, while a value of 0 would be a negative volume. The minimum acceptable value for Fluent is 0.3. For the first mesh, the minimum value is 0.73, while the maximum is 1. The distribution of the values is shown in figures 4 and 5. As it can be observed, the less-quality cells are situated far from the airfoil.

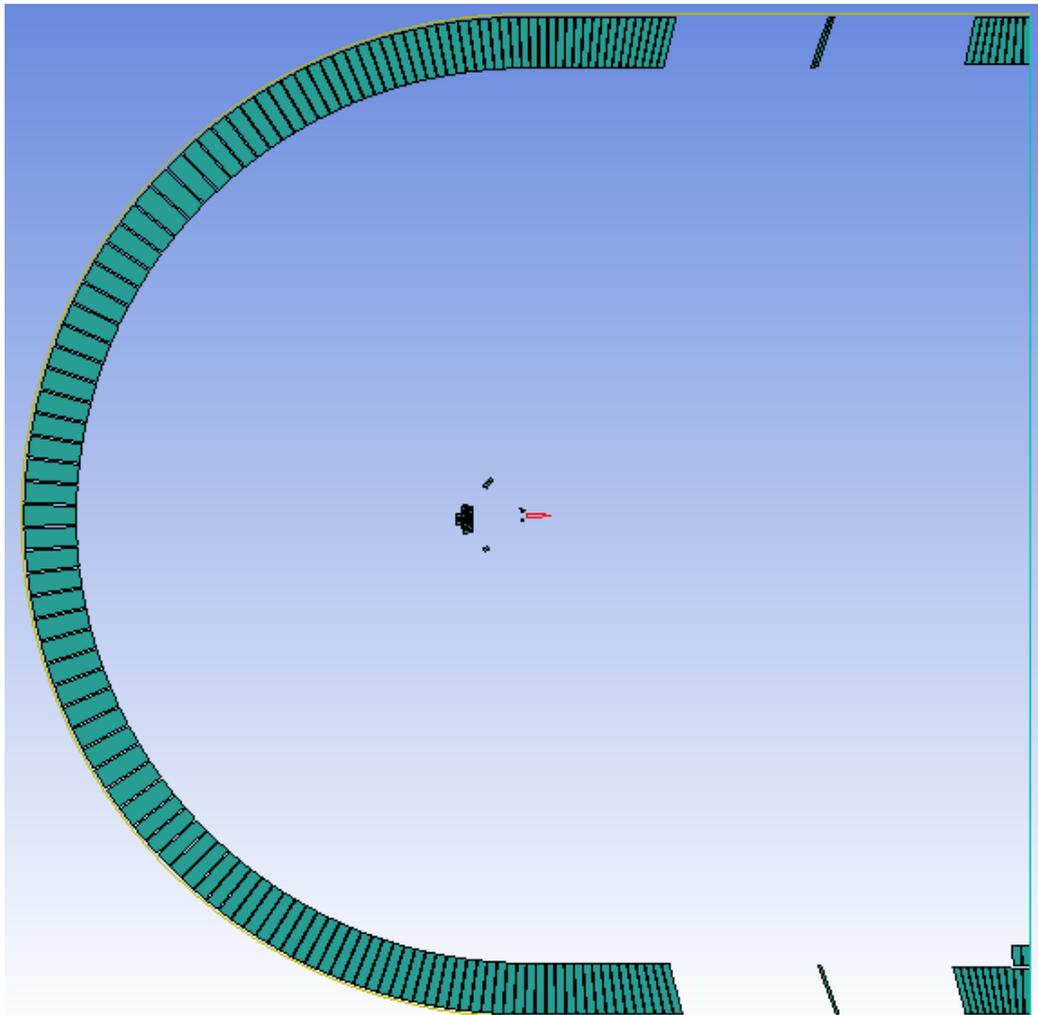


Figure 4: Mesh 1, determinant values until 0.9

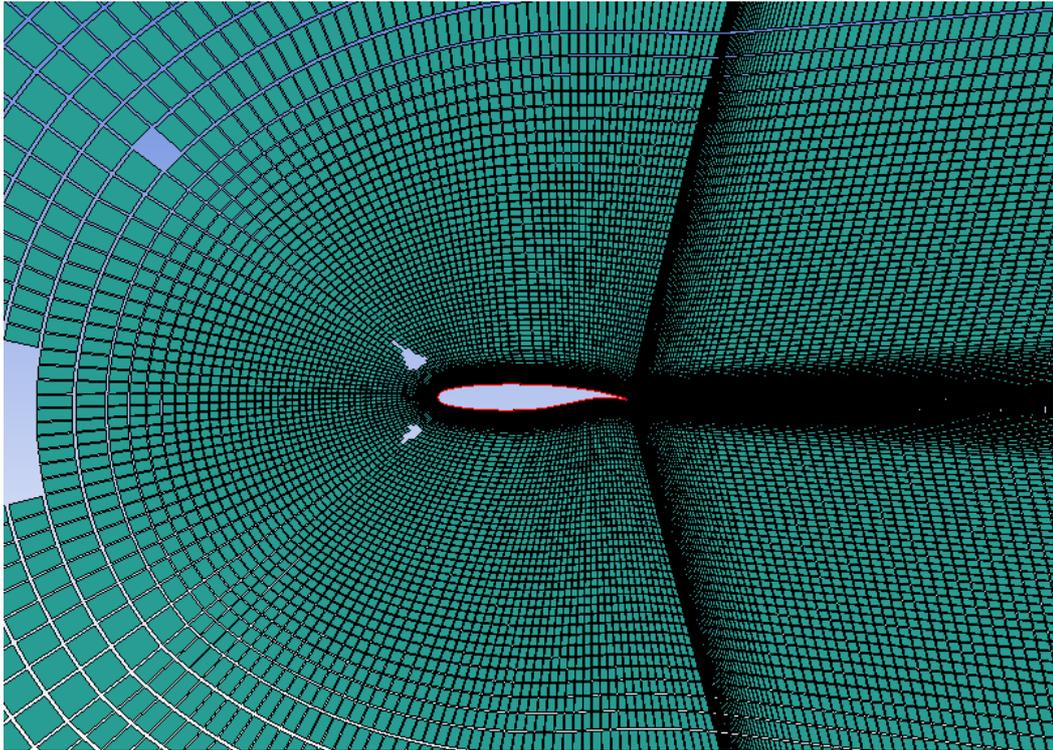


Figure 5: Mesh 1, determinant values from 0.9 to 1

2.2.2 Angle

If the elements are distorted and the internal angles are small, the accuracy of the solution will decrease. It must be greater than 18° , but at 9° it might be accurate in Fluent (the more it approximates to 90° , the better). For the first mesh, the minimum value is 50.4° , situated in the first layers of the airfoil.

2.2.3 Volume

The minimum volume is $1.65 \cdot 10^{-7} m^3$, positive, so there are no conflicting cells in the grid.

2.2.4 Quality

It must be greater than 0.3 in order the mesh to be acceptable. For the first mesh, the minimum value is 0.73. The quality of each cell near the airfoil is shown in figure 6.

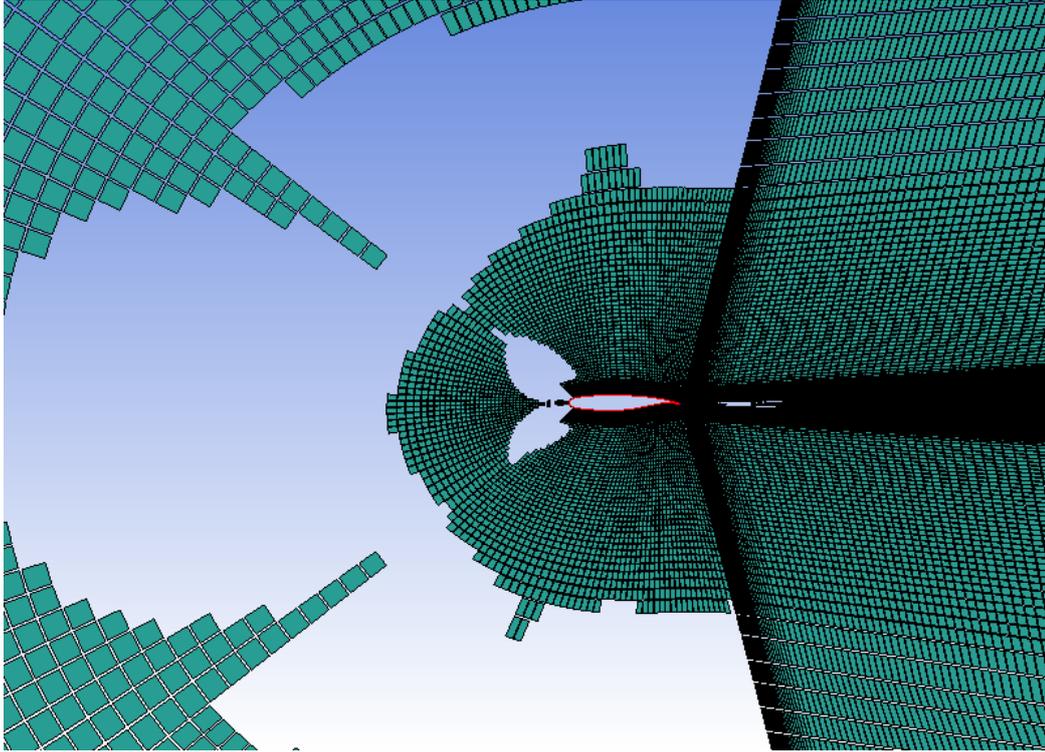


Figure 6: Mesh 1, quality values from 0.95 to 1

2.3 Validation

All tests are with a Re of $4 \cdot 10^6$.

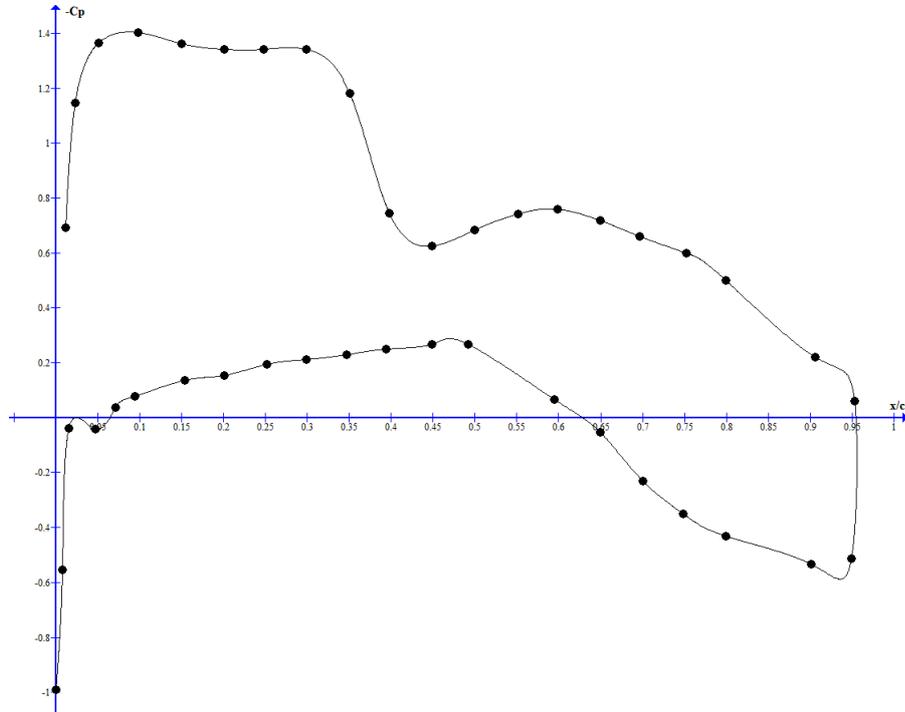


Figure 7: Experimental data at $M=0.710$ and $\alpha=2.00^\circ$

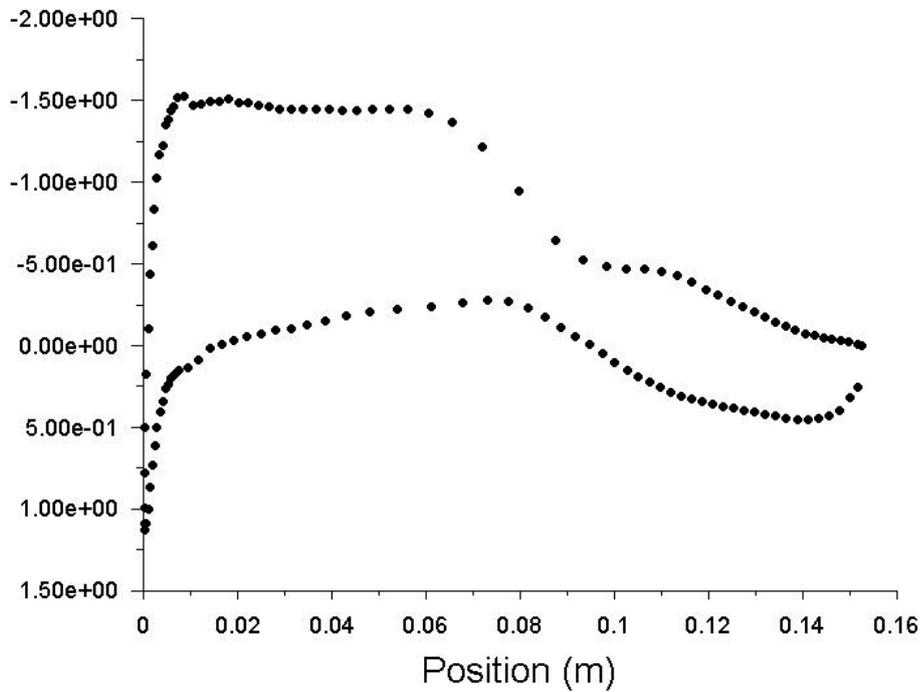


Figure 8: Mesh 1 at $M=0.710$ and $\alpha=2.00^\circ$

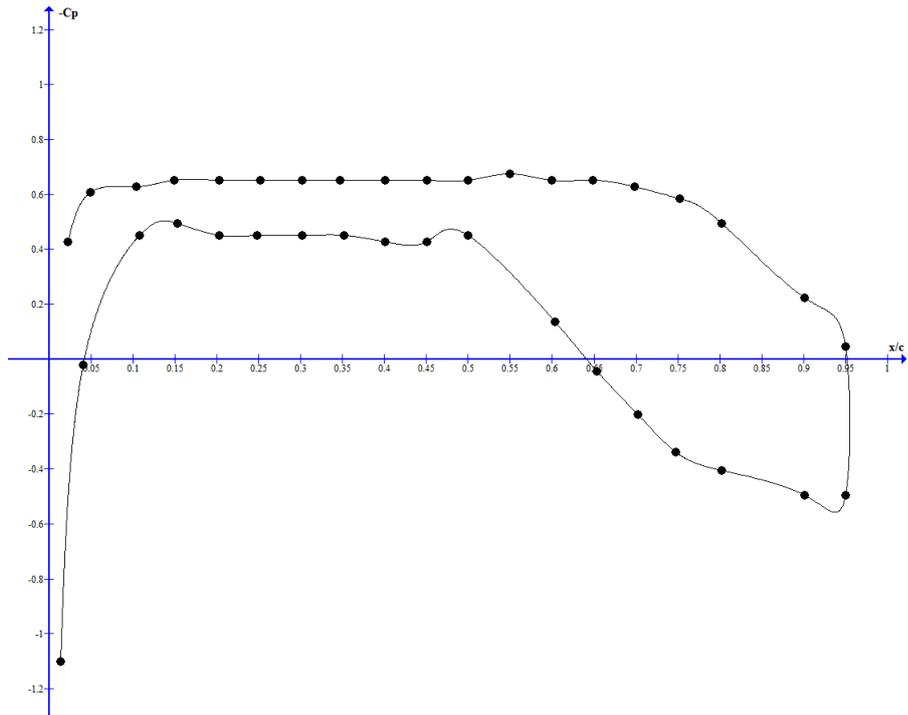


Figure 9: Experimental data at $M=0.720$ and $\alpha=-1.00^\circ$

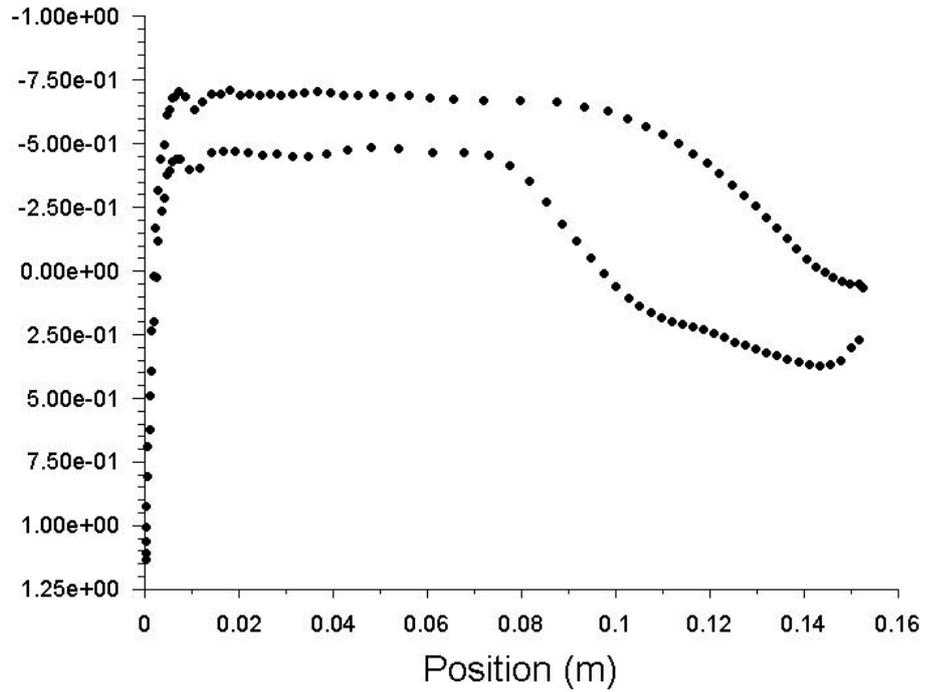


Figure 10: Mesh 1 at $M=0.720$ and $\alpha=-1.00^\circ$

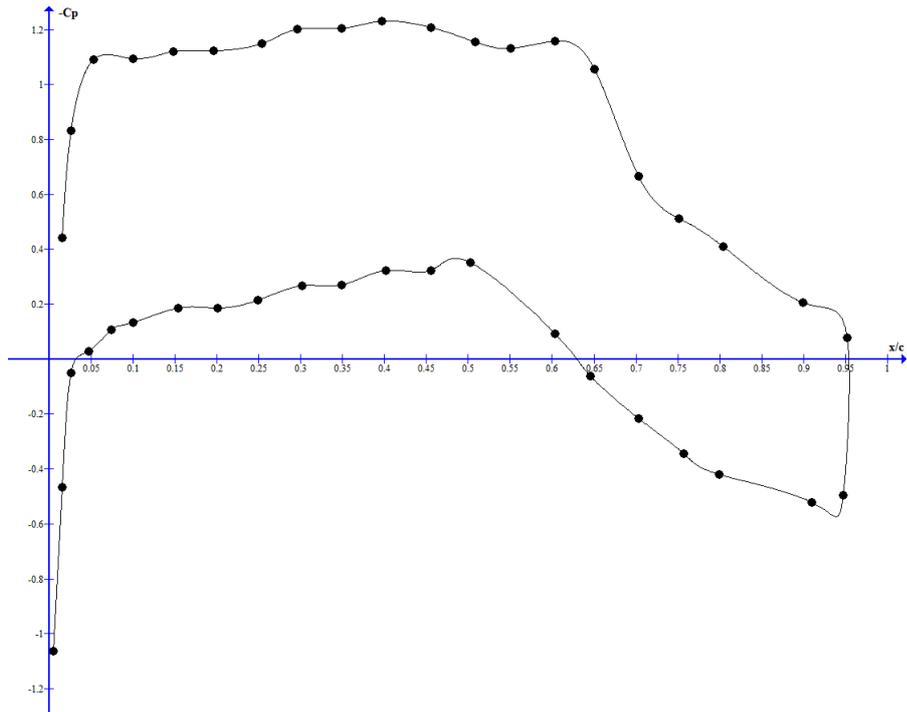


Figure 11: Experimental data at $M=0.750$ and $\alpha=1.51^\circ$

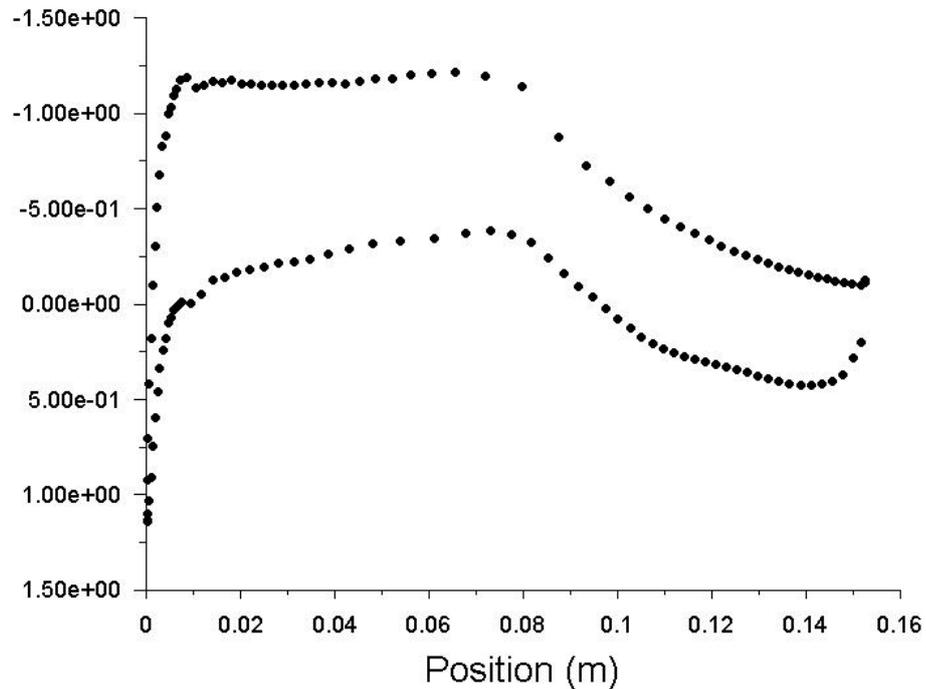


Figure 12: Mesh 1 at $M=0.750$ and $\alpha=1.51^\circ$

As it can be observed, the mesh performs well in both upper and lower surfaces. A slight difference in the shockwave location can be due to the low mesh refinement in the upper surface; this will be compensated through the refinement in

the next meshes, but this mesh is validated and it will be useful for the mesh sensitivity process. Note that the differences are always in the upper surface, where the shockwave develops.

3 Mesh 2

3.1 Generation

For the rest of the meshes, refinement of certain blocks has been performed. The selected blocks must be carefully chosen, as if the block is refined with level two, its number of cells will be multiplied by four. In this mesh, the blocks near the airfoil (at a distance of a chord) and part of the wake have been refined at level 2 in both directions, shown in figure 13. The number of cells has increased to 114800 cells. The huge increment compared with the first mesh is due to the refinement in the blocks with higher number of cells. Concerning the quality of the mesh, as the unique change is the division of each cell, the quality is the same, but the proportion of cells might change. In conclusion, the quality is the same of that of the first one.

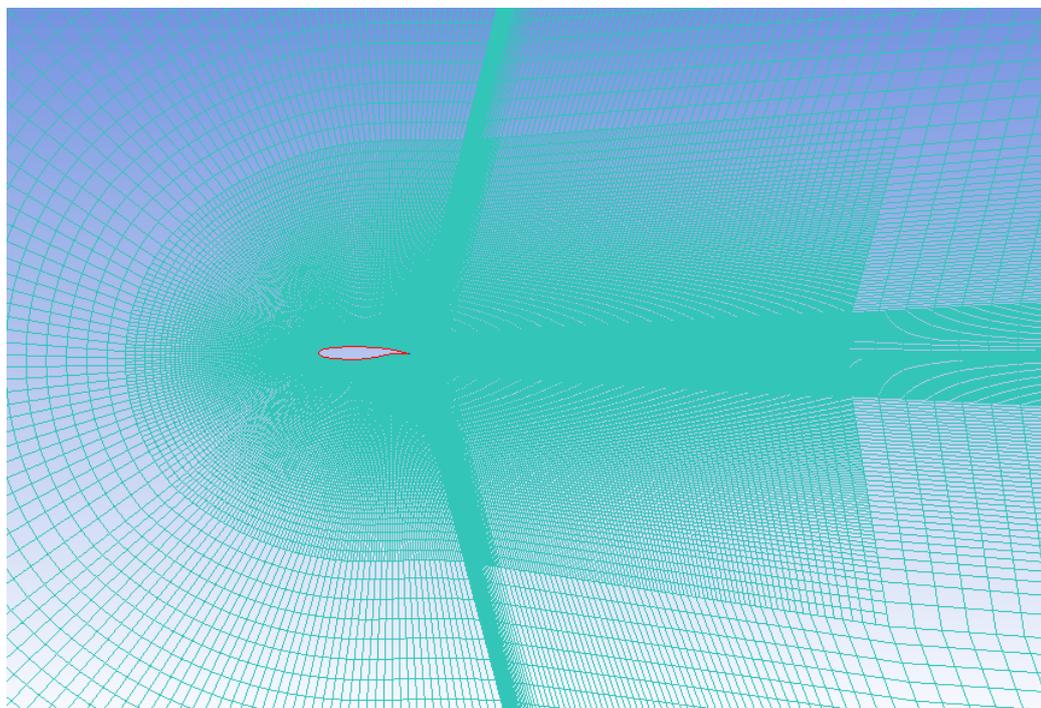


Figure 13: Mesh 2 refinement

3.2 Validation

The process of validation is the same as in the first mesh.

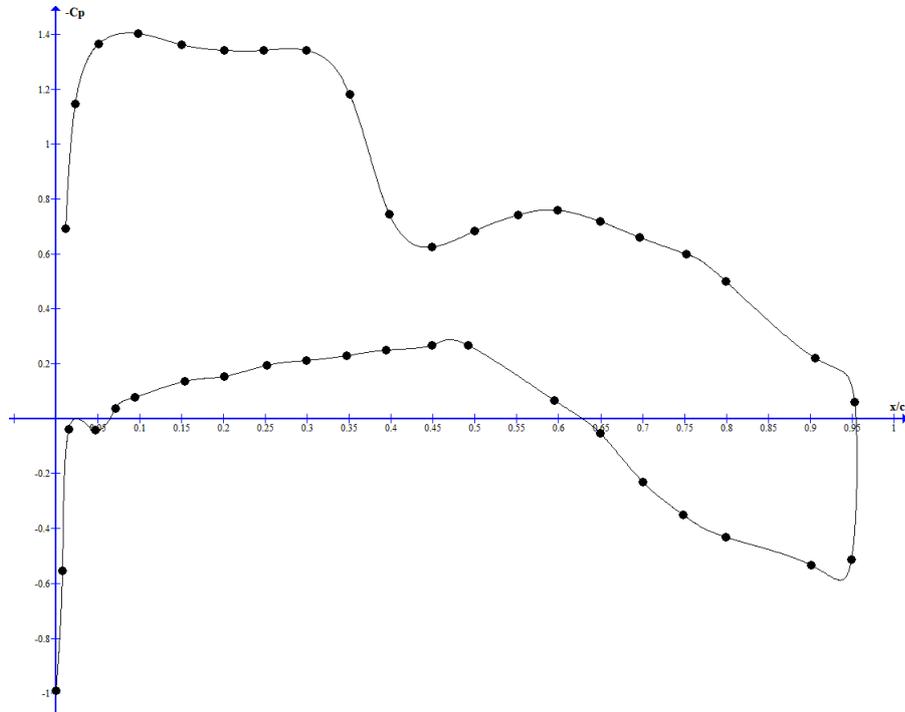


Figure 14: Experimental data at $M=0.710$ and $\alpha=2.00^\circ$

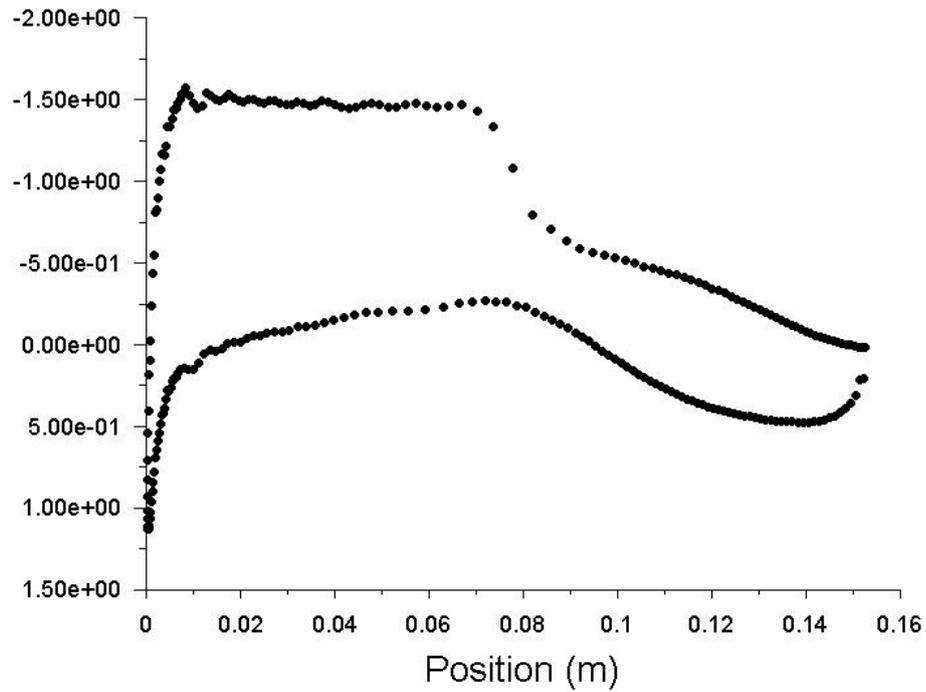


Figure 15: Mesh 2 at $M=0.710$ and $\alpha=2.00^\circ$

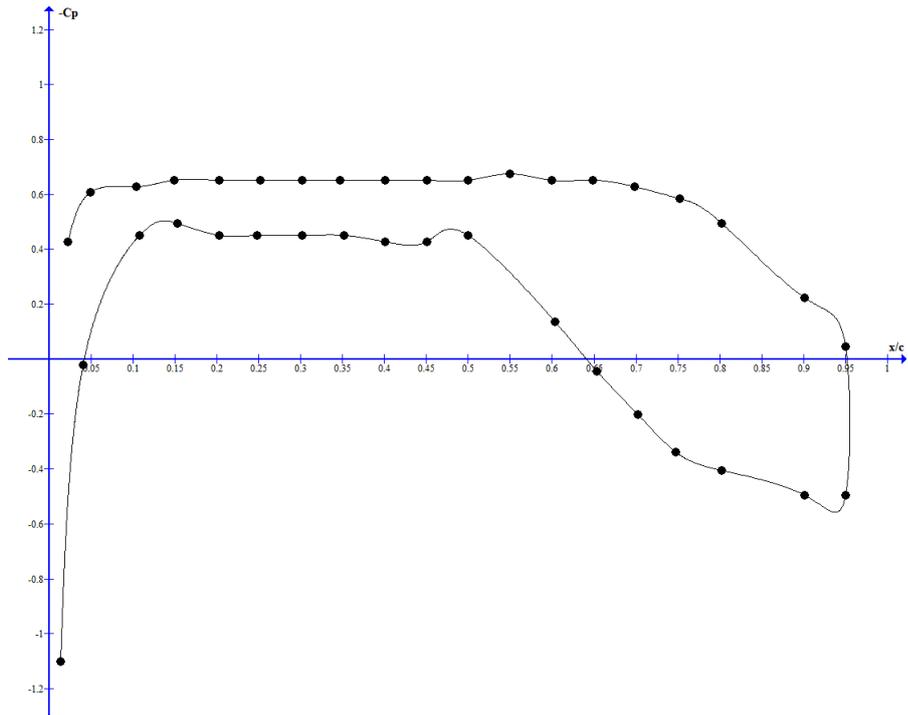


Figure 16: Experimental data at $M=0.720$ and $\alpha=-1.00^\circ$

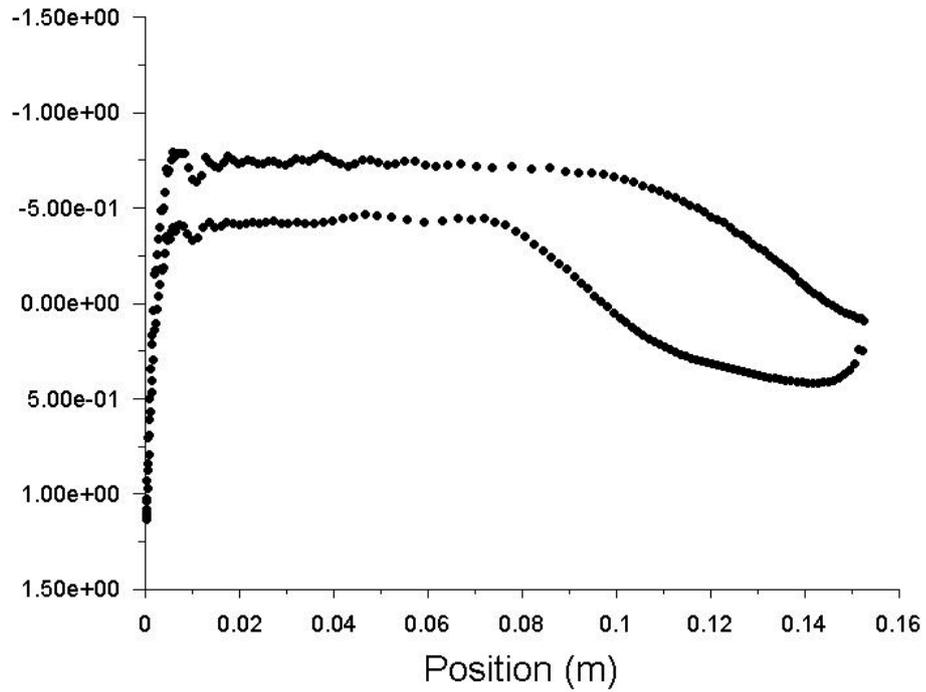


Figure 17: Mesh 2 at $M=0.720$ and $\alpha=-1.00^\circ$

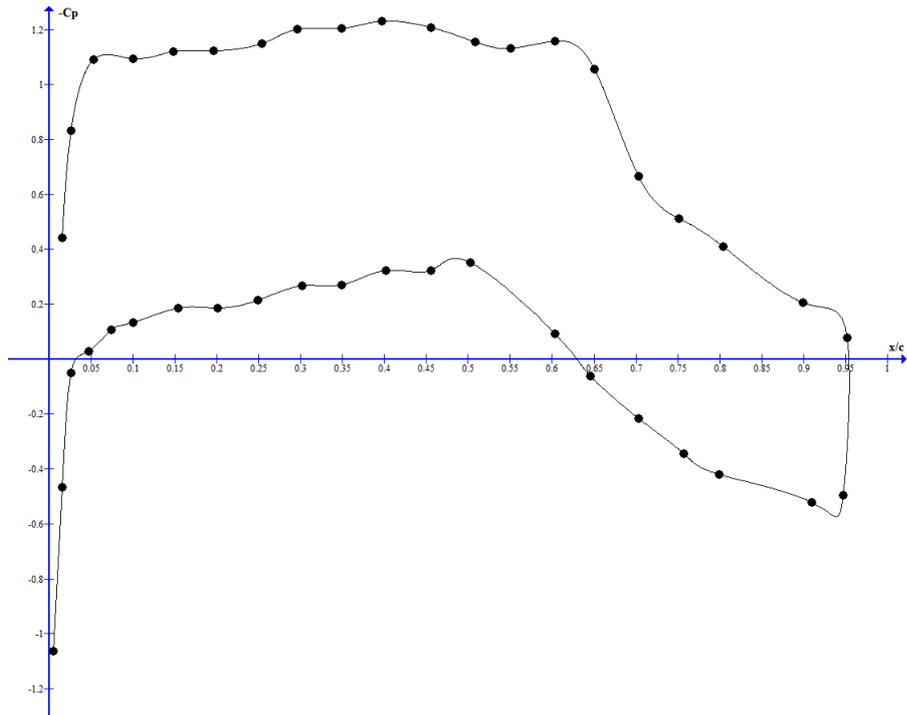


Figure 18: Experimental data at $M=0.750$ and $\alpha=1.51^\circ$

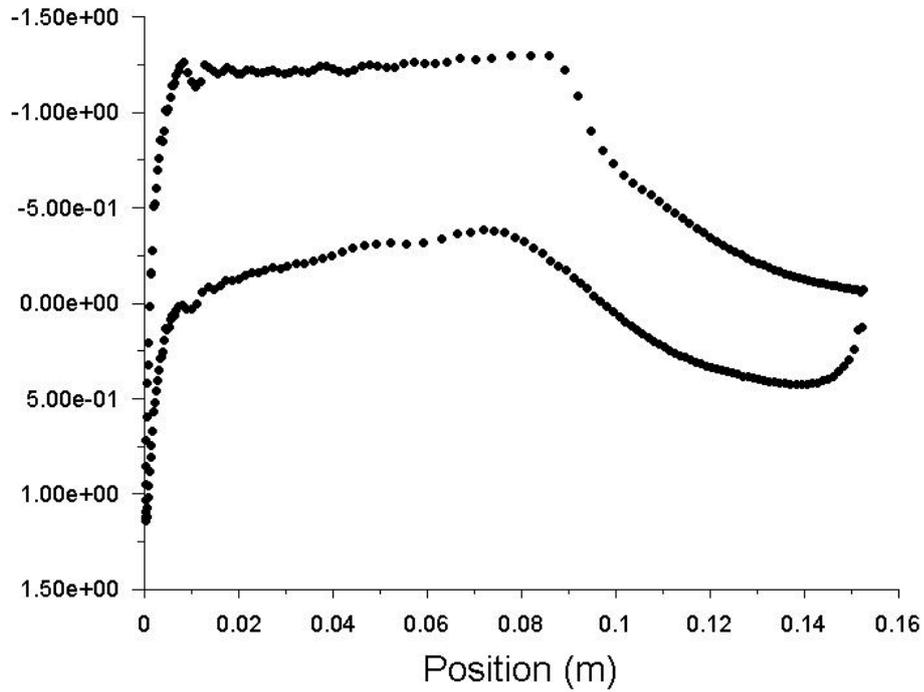


Figure 19: Mesh 2 at $M=0.750$ and $\alpha=1.51^\circ$

As it can be observed, the numerical results approximate to the experimental ones, so the mesh is validated. Note that the location of the shockwave in the last test ($M=0.75$ and $\alpha=1.51^\circ$) has improved with respect to the first mesh.

4 Mesh 3

4.1 Generation

For this mesh, all the flow field has been refined to level 2 except the part downstream the airfoil out of the wake, figure 20. The mesh has 156107 cells.

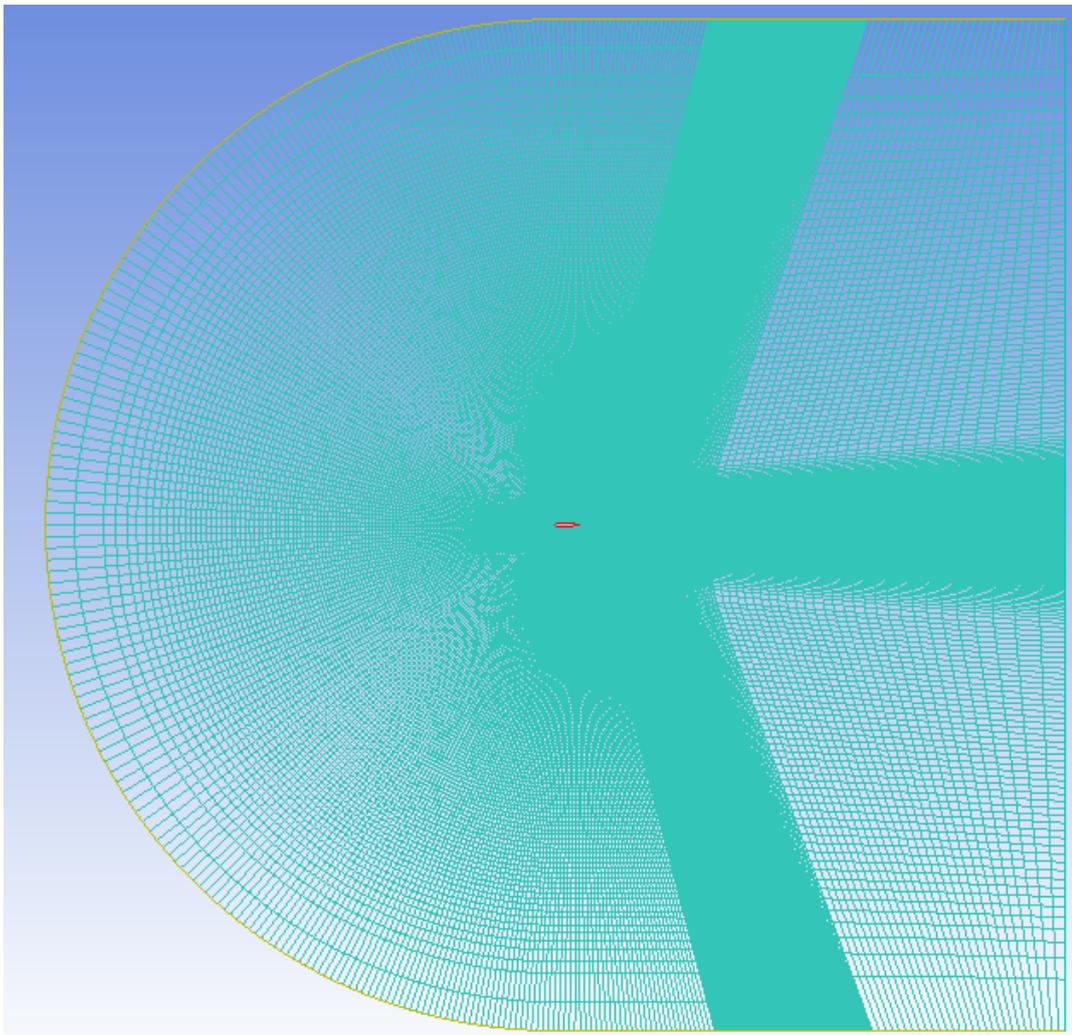


Figure 20: Mesh 3

4.2 Validation

The shockwave location is nearer to the experimental values than the other meshes. The mesh has been validated.

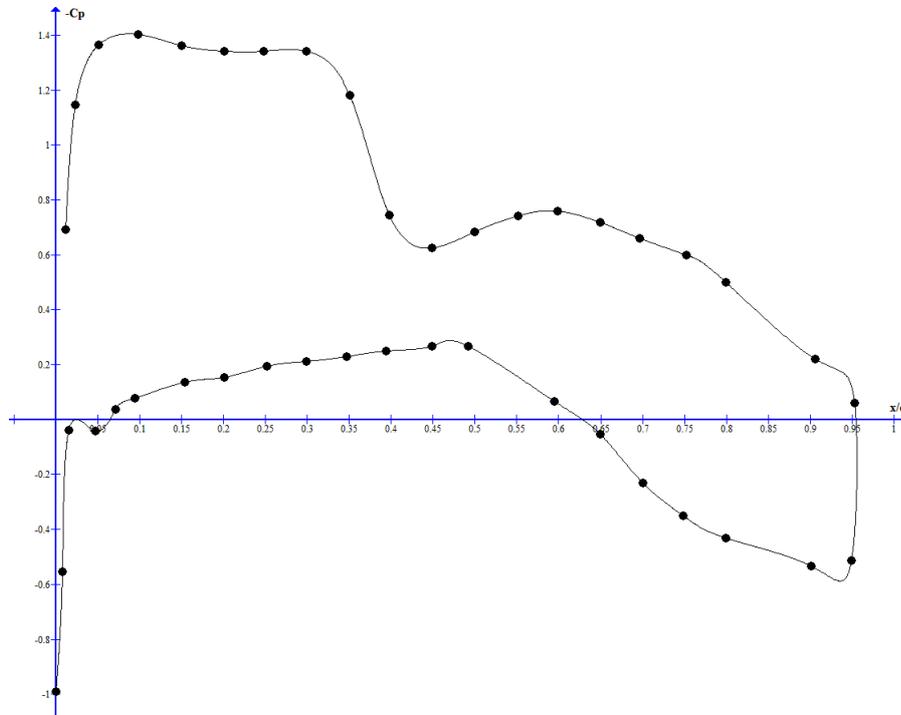


Figure 21: Experimental data at $M=0.710$ and $\alpha=2.00^\circ$

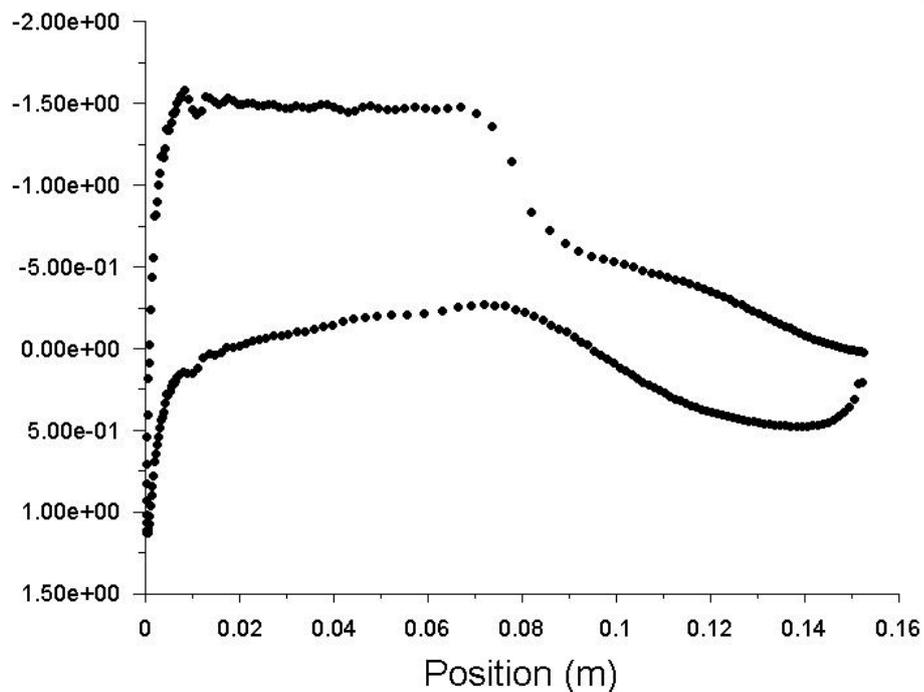


Figure 22: Mesh 3 at $M=0.710$ and $\alpha=2.00^\circ$

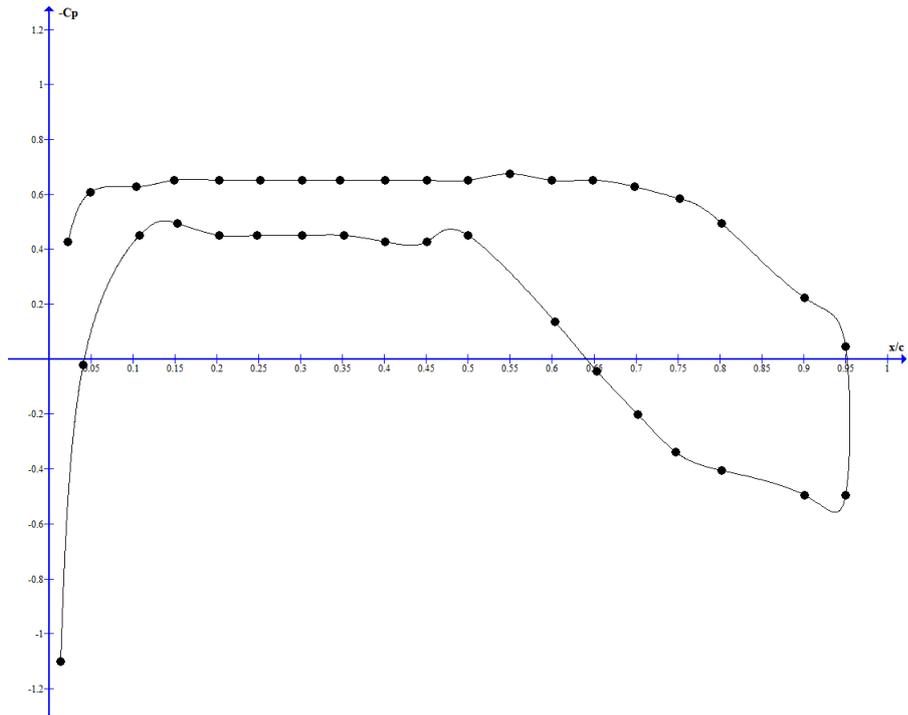


Figure 23: Experimental data at $M=0.720$ and $\alpha=-1.00^\circ$

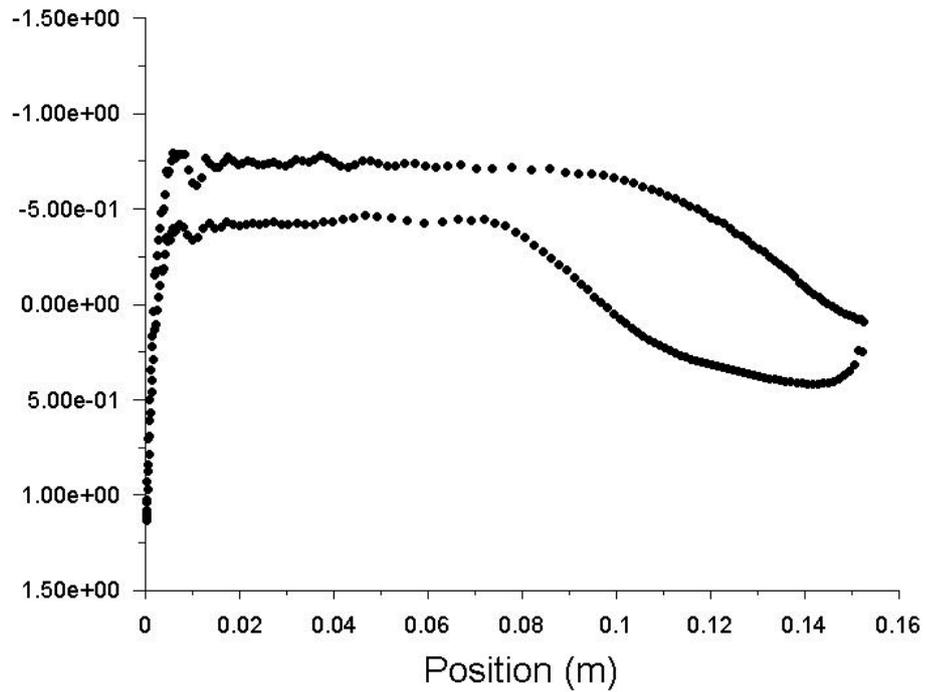


Figure 24: Mesh 3 at $M=0.720$ and $\alpha=-1.00^\circ$

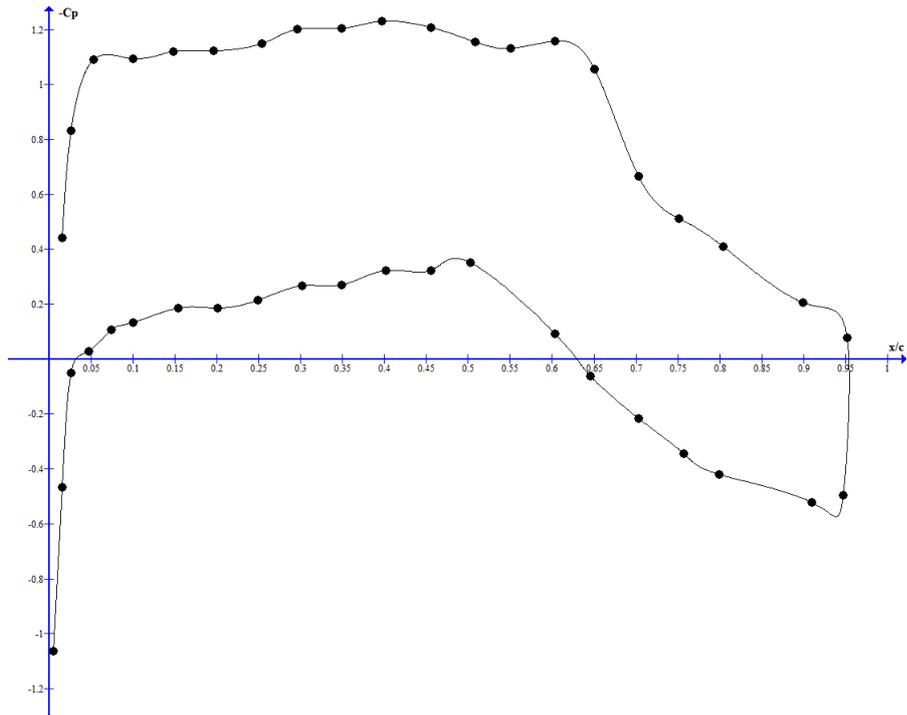


Figure 25: Experimental data at $M=0.750$ and $\alpha=1.51^\circ$

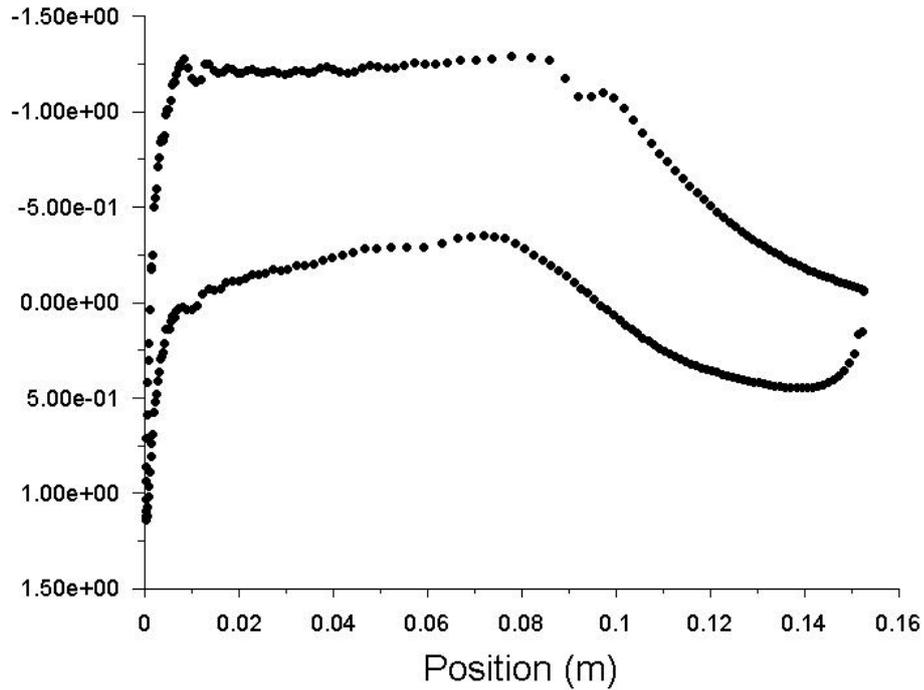


Figure 26: Mesh 3 at $M=0.750$ and $\alpha=1.51^\circ$

As mesh 3 has the same number of cells in the nearby of the airfoil as mesh 2, it is not likely to be used unless strange results of the mesh 2 exist.

5 Mesh 4

5.1 Generation

The mesh 4 has been refined to level 4 in the zone at a chord of distance until just the zone downstream the airfoil, figure 27. The number of cells is 202335, in the limit of the computational resources.

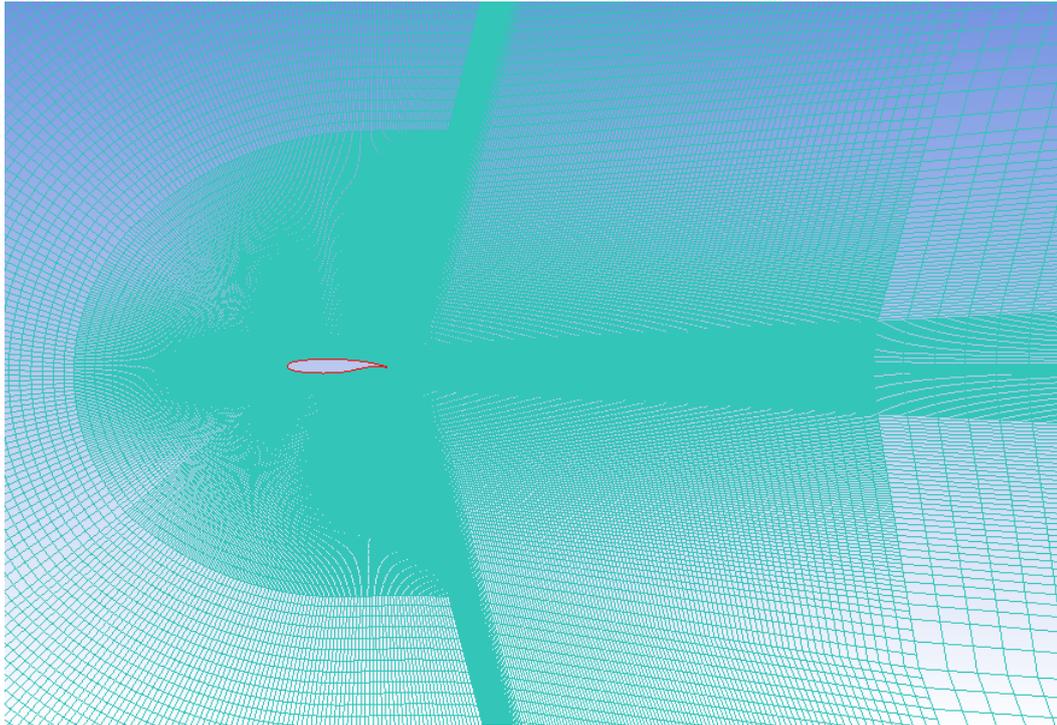


Figure 27: Mesh 4

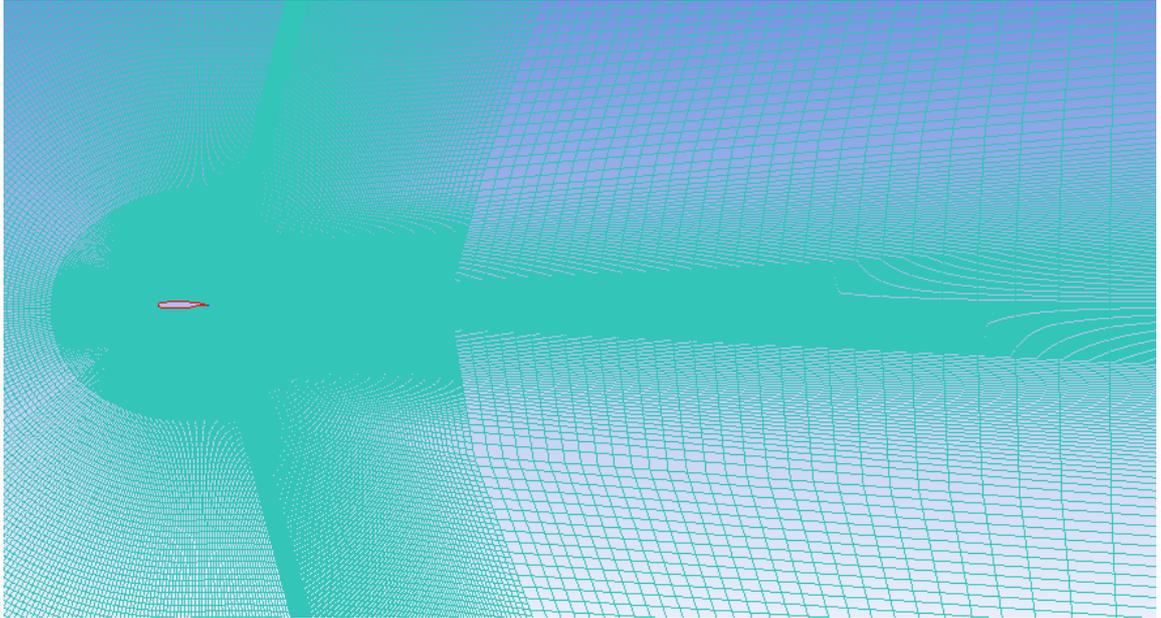


Figure 28: Wake thickening

5.2 Validation

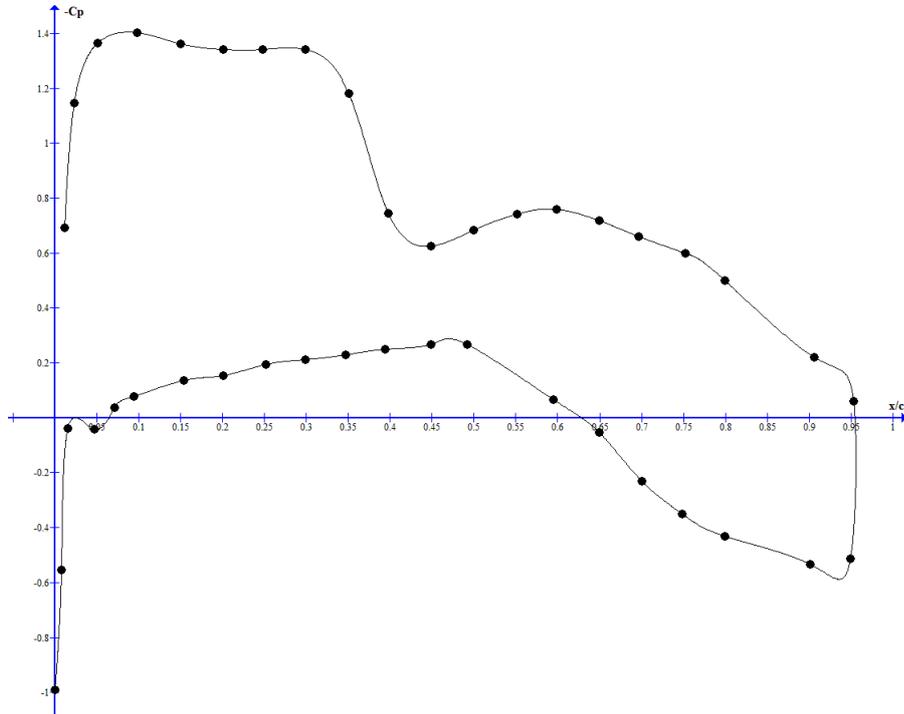


Figure 29: Experimental data at $M=0.710$ and $\alpha=2.00^\circ$

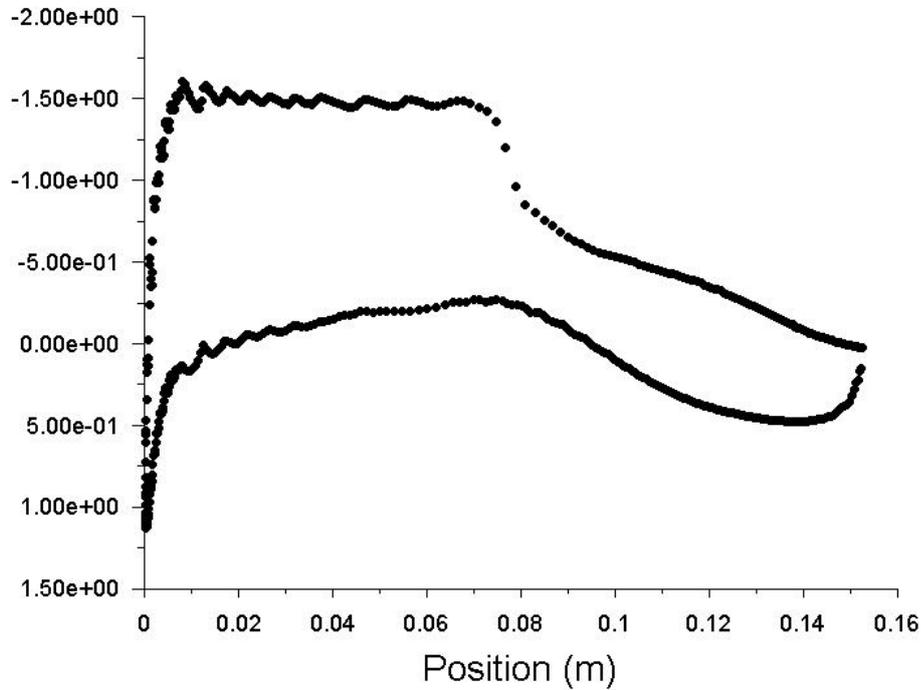


Figure 30: Mesh 4 at $M=0.710$ and $\alpha=2.00^\circ$

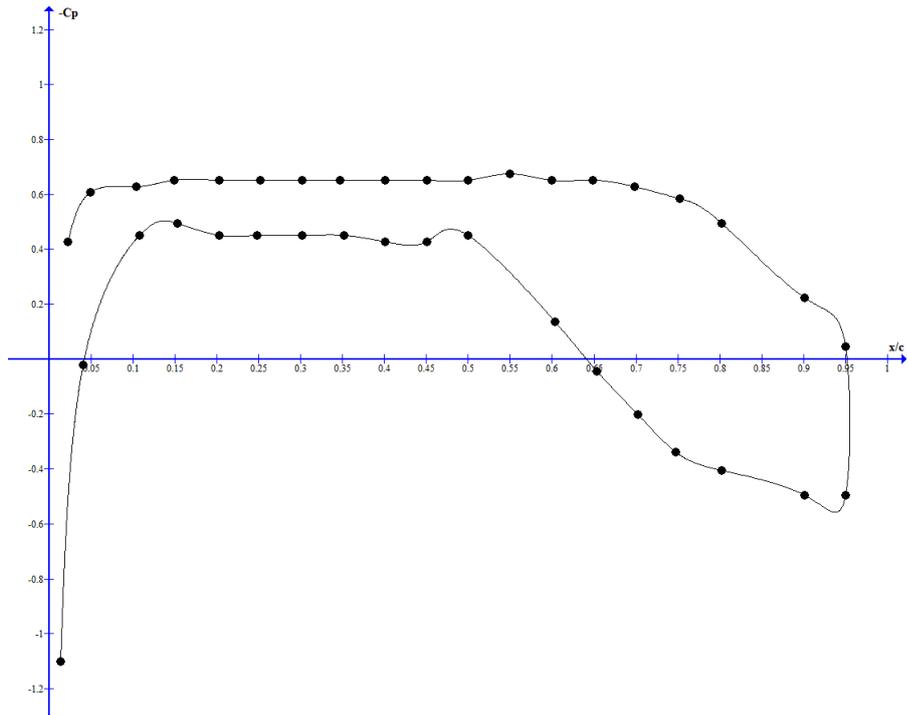


Figure 31: Experimental data at $M=0.720$ and $\alpha=-1.00^\circ$

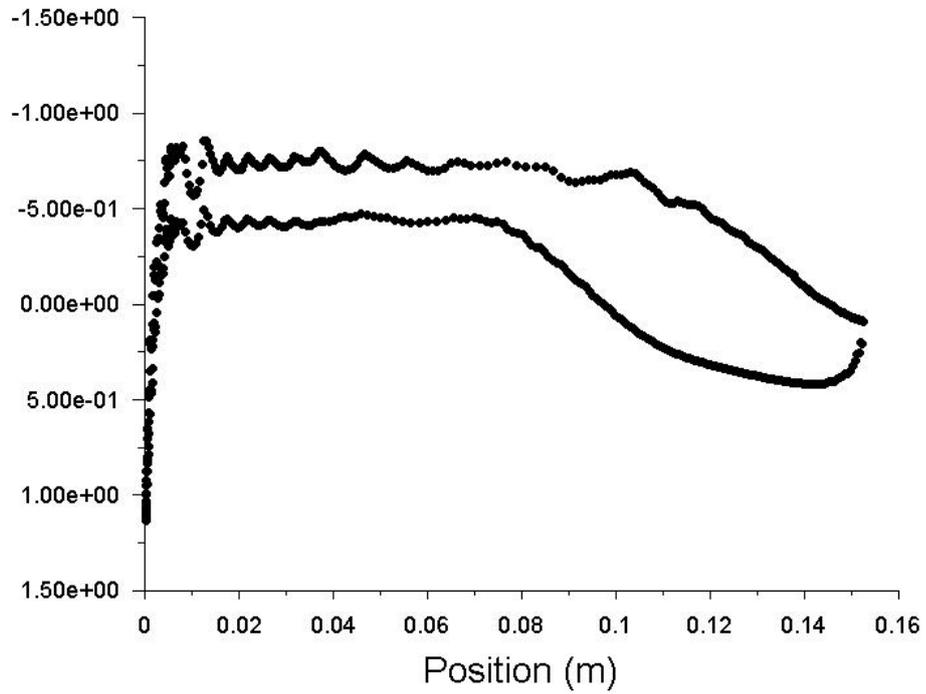


Figure 32: Mesh 4 at $M=0.720$ and $\alpha=-1.00^\circ$

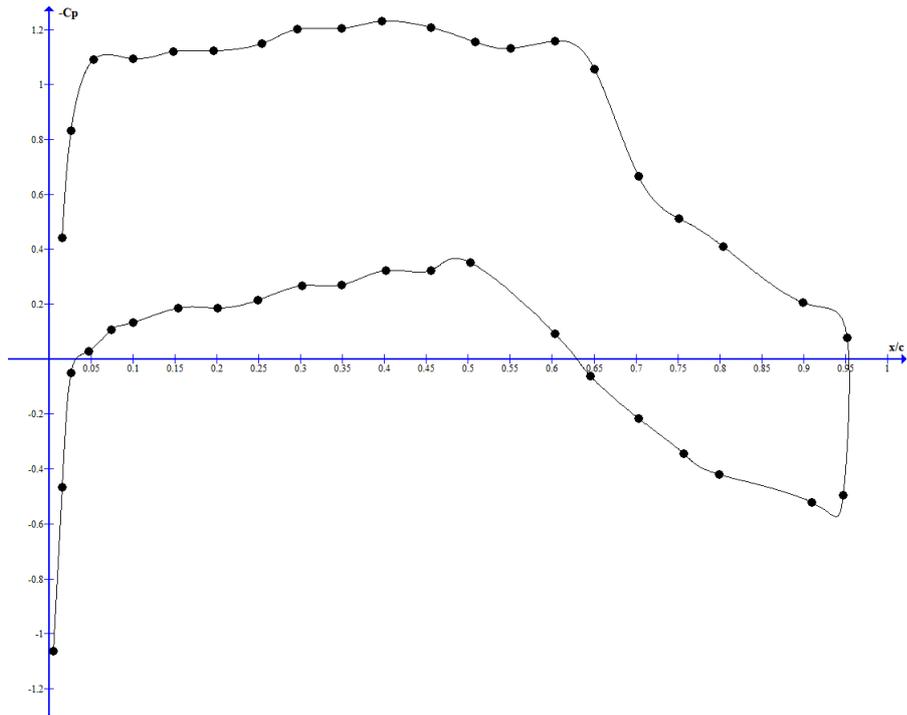


Figure 33: Experimental data at $M=0.750$ and $\alpha=1.51^\circ$

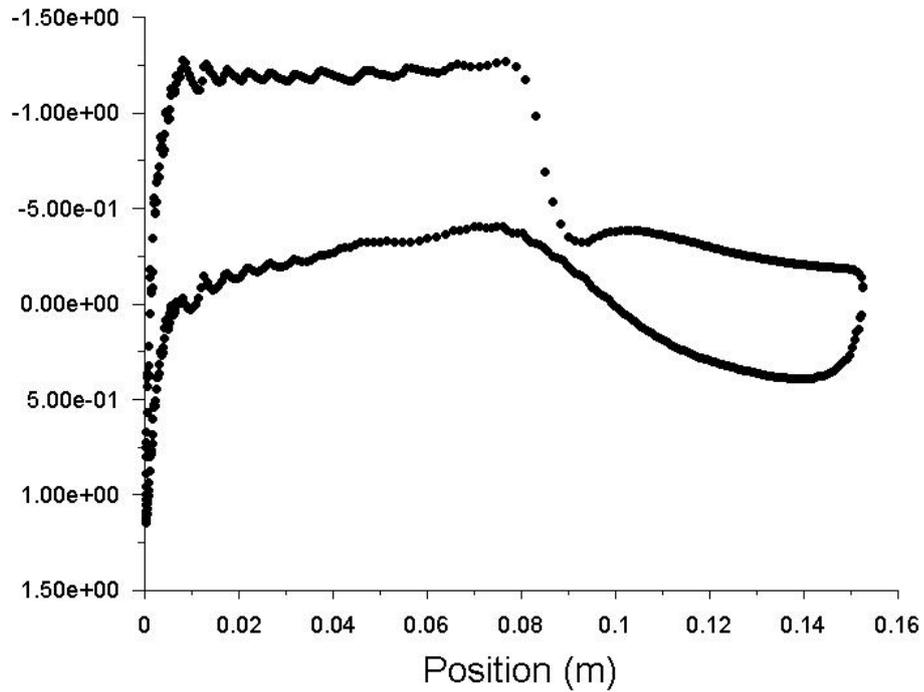


Figure 34: Mesh 4 at $M=0.750$ and $\alpha=1.51^\circ$

Although the shockwave intensity is higher than the experimental values in the last test, the mesh is validated.