Validation of NACA0012 2D results with OpenFOAM

The aim of this report is to report the analysis' results of NACA0012 airfoil for different turbulence models and confront these data with that of NASA **??**. The case is 2D.
The models used are:
- Spalart – Allmaras model (1 equation);
- $k - \epsilon$ model (2 equations);
- $k - \omega$ model (2 equations).

The parameters used for this analysis are reported in table 1.

Table 1: Comparison between 2D and 3D mesh cells.

U_∞	$87.5\mathrm{m\,s^{-1}}$
M_∞	0.26
p_{ref}	0Pa
L	1m
α	10°
Tu	0.052%
Tu_L	1m
ν	$1.5 * 10^{-5}\mathrm{m^2\,s^{-1}}$
ρ	$1.225\mathrm{kg}m^{-3}$
k	$3.1 * 10^{-3}\mathrm{m^2\,s^{-2}}$
ϵ	$1.56 * 10^{-4}m^2s^{-2}$
ω	$5.57 * 10^{-2}\mathrm{s^{-1}}$
μ_T	$0.009\mathrm{kg\,m^{-1}\,s^{-1}}$

Turbulence variables ($k-\epsilon-\omega$) have been calculated using the turbulence tool available in **??**.
For the analysis the software OpenFOAM 3.0.1 have been used. In figg. 1-2 is shown the mesh, with a particular of the refinement around the airfoil. The mesh was created using *snappyHexMesh* tool. The airfoil has 555 points; the boundary layer is expected to be 0.4mm (from the Prandtl's theory applied to thin airfoils), so there are 20 prism layers starting from the surface and ending 0.6mm higher. A refinement with box and sphere regions is also applied around the airfoil and close to leading and trailing edge.

For the analysis were used the *simpleFoam* algorithm for the Spalart-Allmaras model, and the *pimpleFoam* algorithm for the remaining. The reason of this choice is that the first algorithm is not working well for the $k - \epsilon$ and $k - \omega$ model, as it is reported in **??**.

In tab. 2 are reported all the values for lift and drag coefficient for all the models, compared with NASA data. The maximum difference in lift coefficient is about 0.3%. meanwhile in drag coefficient is about 3%.

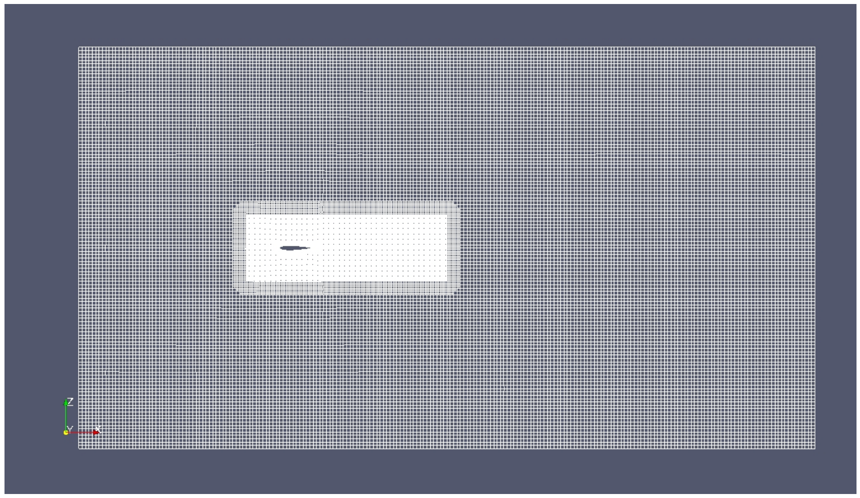

Figure 1: Mesh used for the analysis.

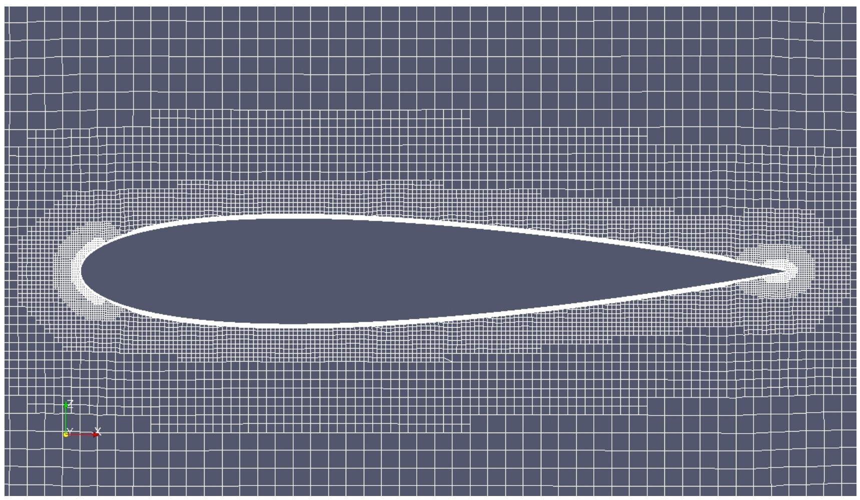

Figure 2: Particular of the mesh around the airfoil.

Table 2: Lift and drag coefficient for all the models and NASA data.

	C_L	C_D
NASA data	1.09	0.0123
Spalart-Allmaras	1.093	0.0126
$k-\epsilon$	1.087	0.0119
$k-\omega$	1.090	0.0122

The pressure field is shown in fig. 3, while in fig. 4 is shown the velocity field.

It can be noted the wake that starts at the trailing edge, approximately around the 90% of the chord, and that is inclined of 10°.
The pressure and friction coefficient were both calculated on the airfoil, and these quantities were used for comparison with that of NASA: the pressure coefficient is experimentally calculated, meanwhile the friction coefficient is numerically calculated, due to the difficul-

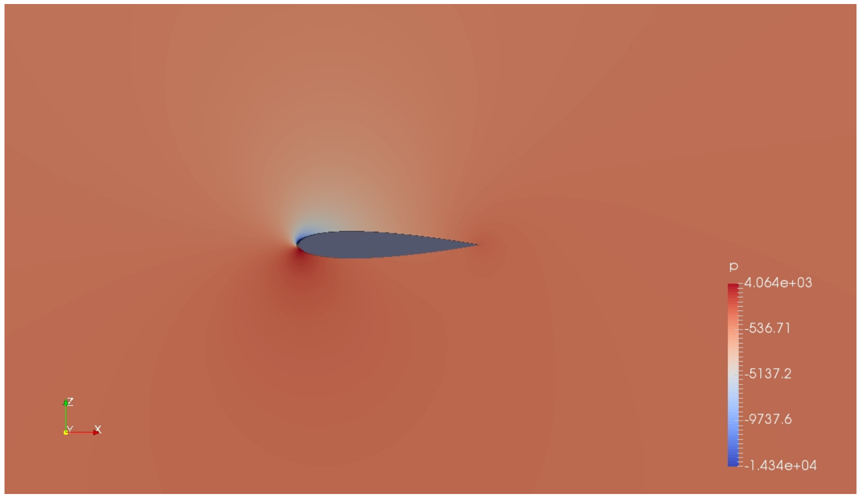

Figure 3: Pressure field around the airfoil (with Spalart-Allmaras model).

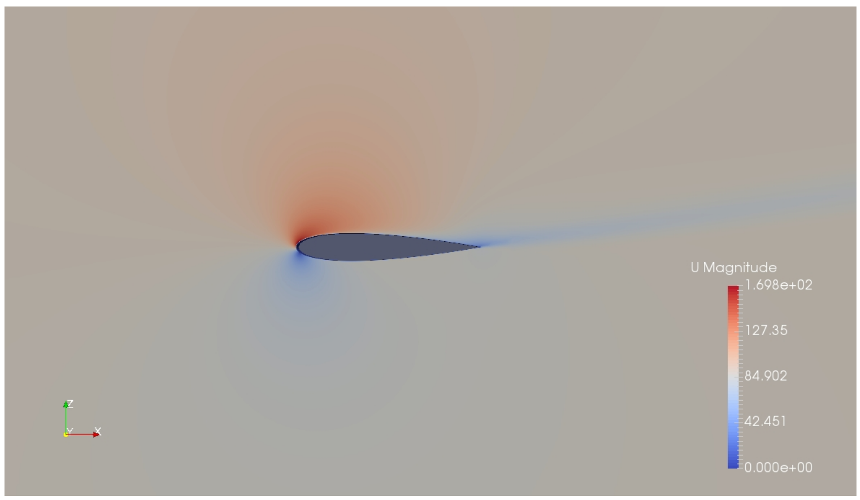

Figure 4: Velocity field around the airfoil (with Spalart-Allmaras model).

ties of experimentation. In **??** is shown the friction coefficient only on the upper surface of the airfoil, so only this surface is taken into account. Results are shown in the following figures.
It is possible to note that all the results are close, with a maximum of difference of around 10% for the $k - \epsilon$ model in friction coefficient.
In fig. 7 is shown a particular of the expansion peak, meanwhile in fig. 8 is shown a particular of the compression peak: it is possible to see that there's a little difference in the former, meanwhile the position of the latter is similar and it is close to one, as it is expected. Finally, in fig. 9 is show a particular of the friction coefficient at the leading edge: it is possible to appreciate little differences between the data, also the $k - \epsilon$ model shows two relative maximum, instead of an absolute one as the others.

From the analysis presented here, we can conclude that the OpenFOAM code is robust: all the models are close each other and the results are comparable to the experimental data.

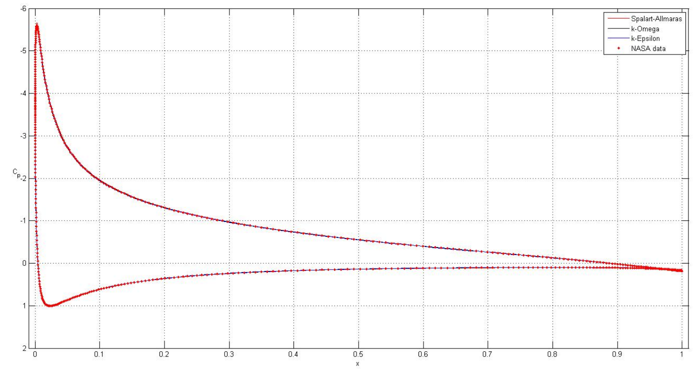

Figure 5: Pressure coefficient for the different models used and experimental data.

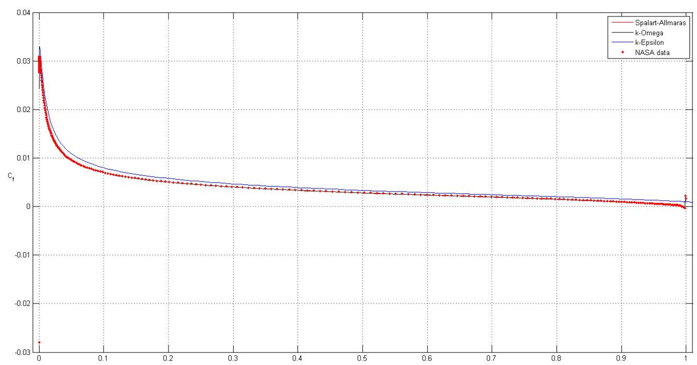

Figure 6: Friction coefficient on the upper surface of the airfoil for the different models used and NASA numerical data.

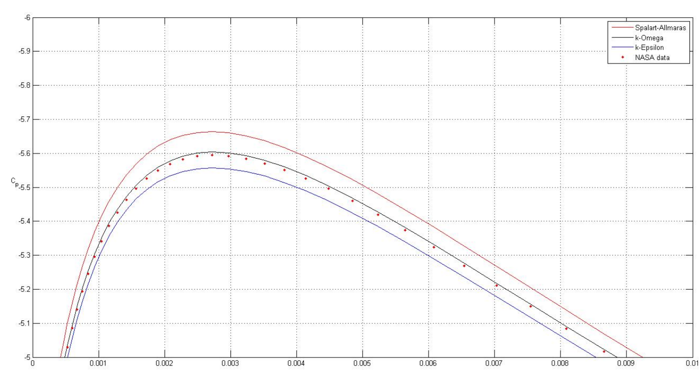

Figure 7: Particular of the expansion peak.

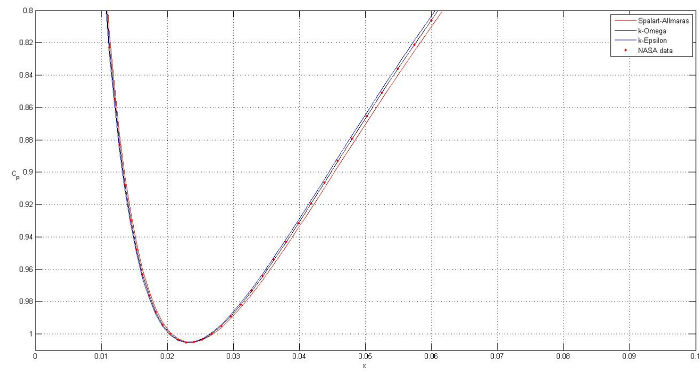

Figure 8: Particular of the compression peak.

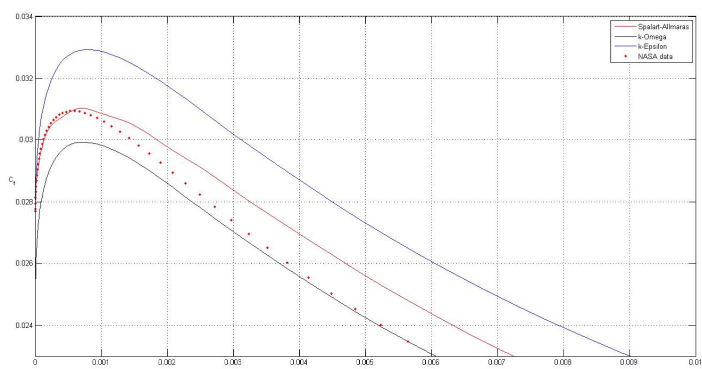

Figure 9: Particular of the friction coefficient at the leading edge.

Bibliography

[1] $http://turbmodels.larc.nasa.gov/naca0012-val.html$

[2] *http://www.cfd-online.com/Tools/turbulence.php*

[3] OpenFOAM Introductory Course