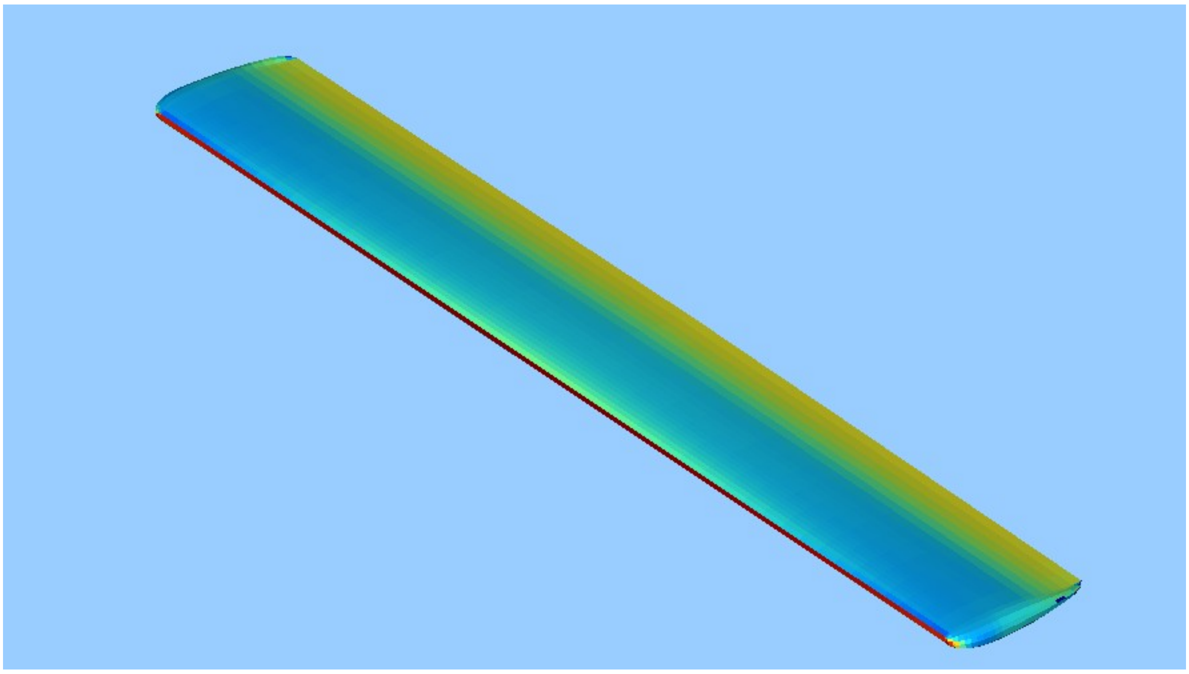
Wing analysis with APAME



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Author: *Etienne Vandame*

Signature: ....

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1 Log of revisions

Revision	Date	Author(s)	Notes
R0	26 July 2011	E. Vandame	Initial issue

2 Shortcuts & definitions

GUI	Graphical Interface Unit
AOA	Angle of attack

3 References

[1] APAME 3D panel method, by Daniel Filković, Dipl. -Ing, www.3dpanelmethod.com

[2] www.salome-platform.org

[3] NASA-TN-D-8524 Aerodynamic characteristics of wing-body configuration with two advanced general aviation airfoil sections and simple flap systems. By Harry L. Morgan Jr and John W. Paulson Jr. August 1977

[4] Engauge Digitizer http://digitizer.sourceforge.net/

4 Introduction

This tutorial is intended for beginners with APAME, a low-order 3D panel method. The theory of this software is not described, but the pathway to compute a wing is explained step-by-step. The reader learns how to set APAME, import a mesh, generate the wake, set the variables and parameters, launch the computation and process the results. The computation results are compared with the wind-tunnel results from the NASA.

5 Generalities about APAME

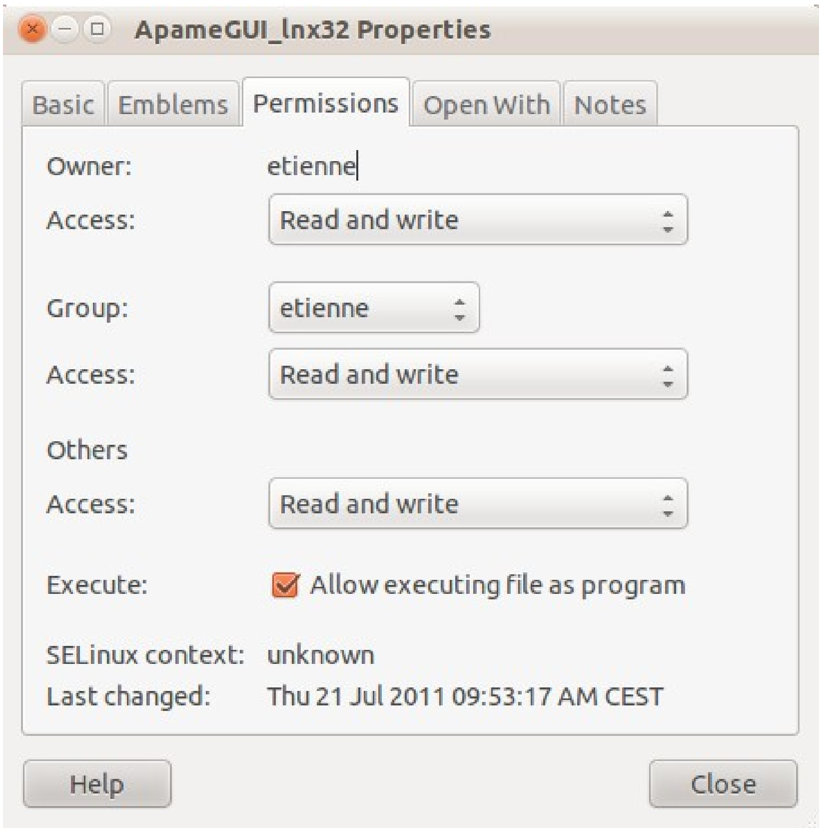
5.1 Installation

Apame is made of two main software: The GUI and the solver. They are shipped in two different GUI, so just unpack them.

You must save them in a folder where you have full right access, because APAME needs to create and modify files. In Linux it is recommended to use you *home* folder.

5.1.1 Linux

After unpacking, you have to change the rights of the files. Right-click on **ApameGUI_lnx32 (**or 64, depending on you OS architecture). You have to check the **Allow executing file as program** in order to allow the program to launch.



Do the same for the solver (Apame_lnx32 or Apame_lnx64).

Very important: If you use Ubuntu 11.04, you must remove the package **appmenu-gtk** in order to see the menubar.

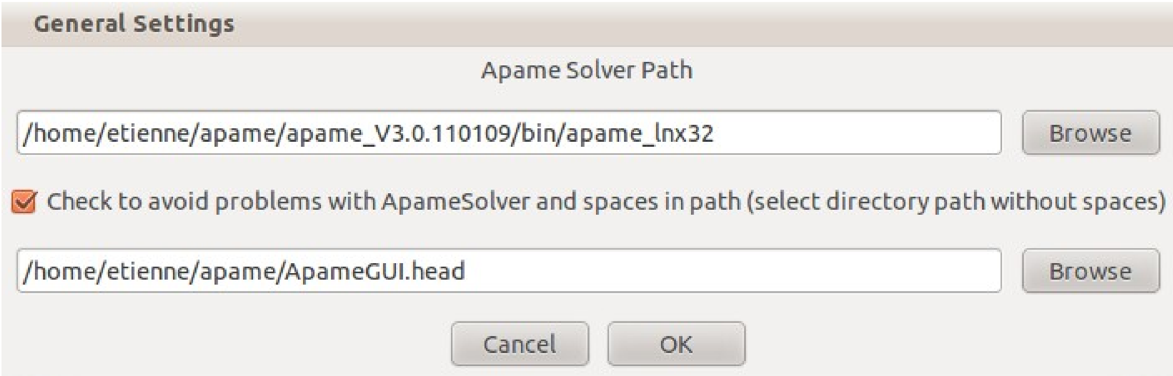
5.2 Settings

Launch ApameGUI

Go to the menubar, **Settings, General.**

You have to set two paths.

- The first one is for the Apame solver, so you have to select a *file*.
- The second one is the *folder* where the Apame files will be created. As previously noticed, you must have a read & write access to this folder, otherwise Apame will crash because it will not be allowed to create the required files



6 Preparing the computation

6.1 Geometry & mesh

6.1.1 Create a new study

In the menubar, **file, new**

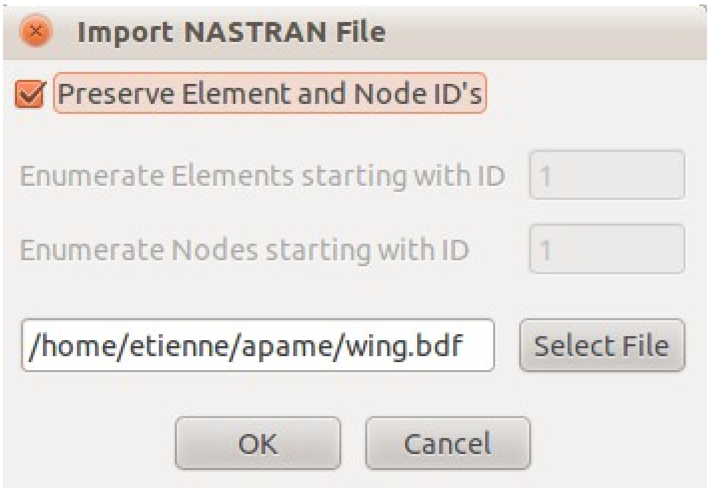
or click to this icon: 

6.1.2 Import the mesh

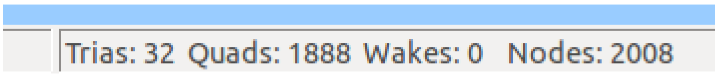
In this tutorial we will work with the mesh created in the SALOME tutorial.

In the menubar, **file, import, Nastran file...**

And choose the BDF file...



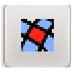
The mesh appears. On the lowest bar of the Apame windows, you can see informations about the mesh, and hence check if it was imported correctly.

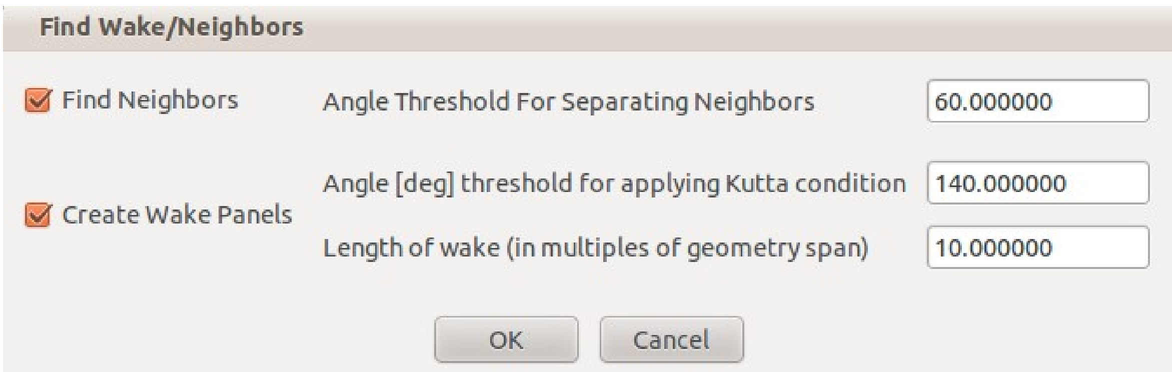


6.1.3 *Generate the wake*

Apame has an automatic procedure for wake generation. It recognize the angle at the trailing edges. This was the reason why in the previous tutorial I used a modified trailing edge for the airfoil section.

On the menubar, **grid, wake/neighbors generator,**

or press the following icon 

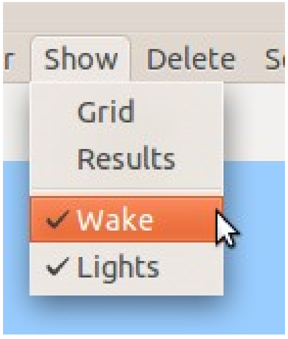


You can let the angle for applying the Kutta condition to the default value of 140 deg. When you will be creating your own geometries, you will have to always have in mind how you defined the trailing edges before setting this value.

You can let the length of the wake to the default value of 10. Click OK to generate the wake

6.1.4 Show the wake

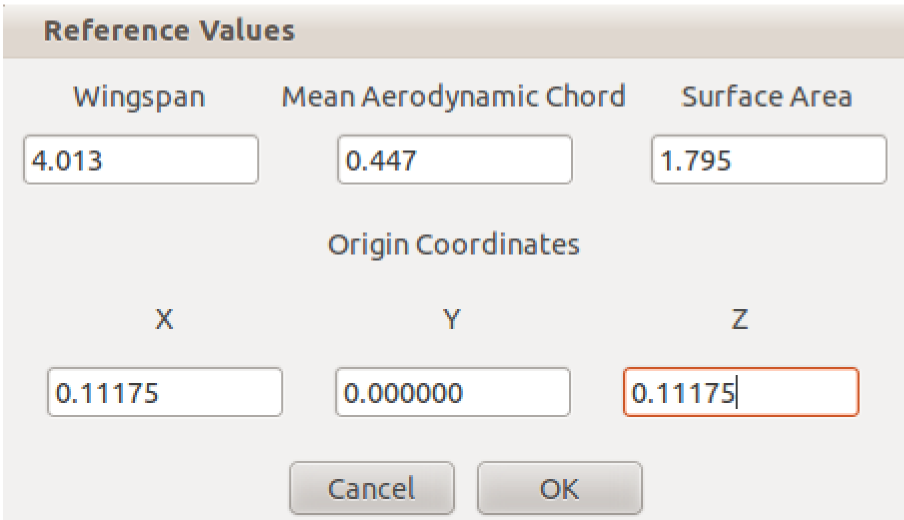
On the menubar, **show, and check the wake**



6.2 Solver settings

6.2.1 Set the references values

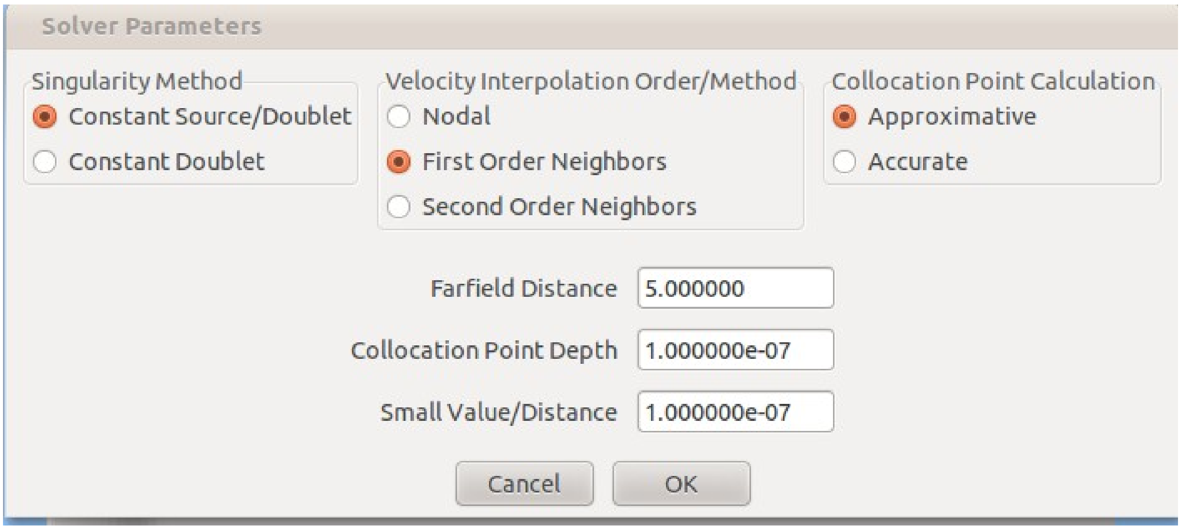
On the menubar, **Define, Reference Values.**



Those values are found directly form the NASA report of [ref 3]. The wingspan, MAC and Area are in the Symbols chapter at the beginning of the report, but the position of the balance for the forces is found page 20. You can notice that the balance is not aligned with the wing on the Z axis.

6.2.2 Set the solver parameters

On the menubar, **Define, Solver parameters.** You can leave the defaults values



6.2.3 Set the required results

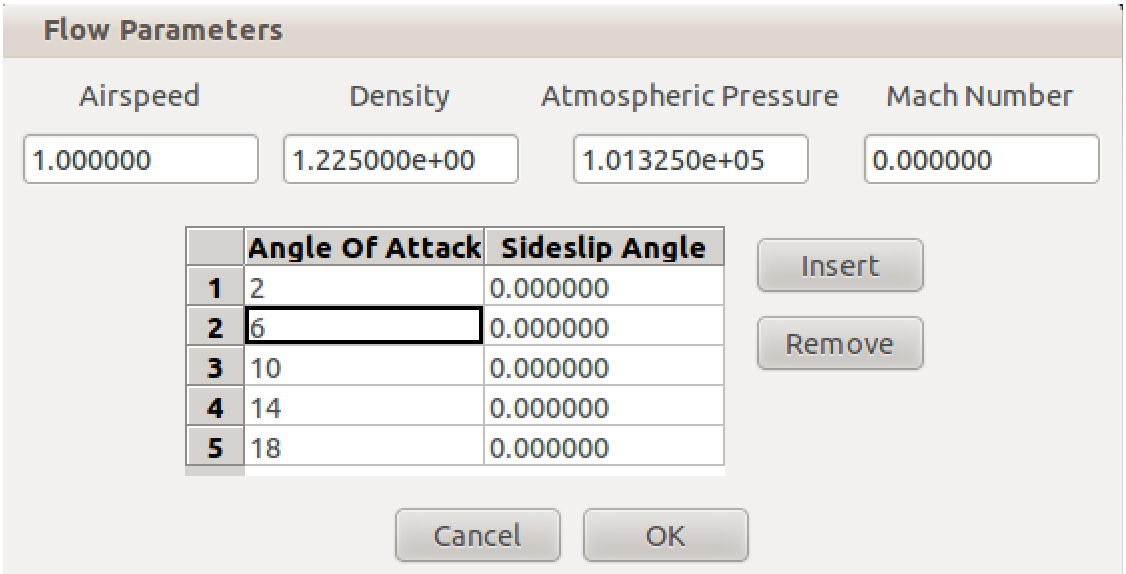
On menubar, **Define, Results Request,** you have to select the outputs you want to have. Verify that the **Write results file** is check, and select your outputs.

6.2.4 Set the flow parameters

On the menubar, **Define, flow parameters**. As Apame is a potential flow solver, the airspeed, density, athmospheric pressure and Mach number don't influence the computation, but only the magnitude of the results. In this tutorial we will only make use of the coefficients results, so we can let the defaults values for those inputs.

On prime importance for us are the angles. We will just study symmetric cases, so the **sideslip angles** will remain at zero. The wing is set to an angle of incidence of 2 degrees. So we will have to add those 2 degrees to each angle of attack in order to have comparable angle with the NASA reports.

Click several times the Insert button and fill the angles of attack column as described. Press OK to apply the changes.



6.3 Save you study

On the menubar, **file, save as** and in the name field, enter *wing_8542.apame.*

7 computation

7.1 Solver

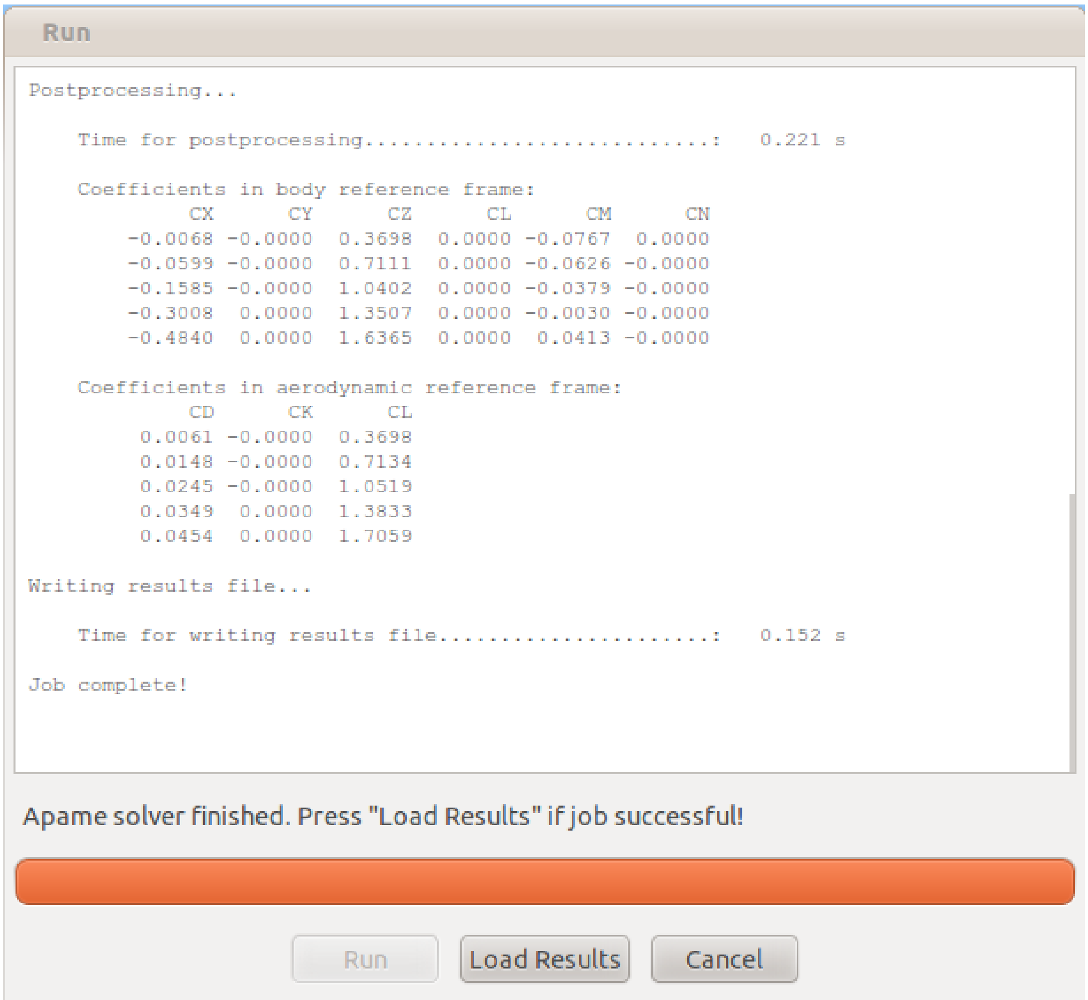
7.1.1 Launch the solver

On the menubar, **solver, run,** or press this icon 

The Solver windows opens. Press **Run** to launch the computation.

7.1.2 Grab the results

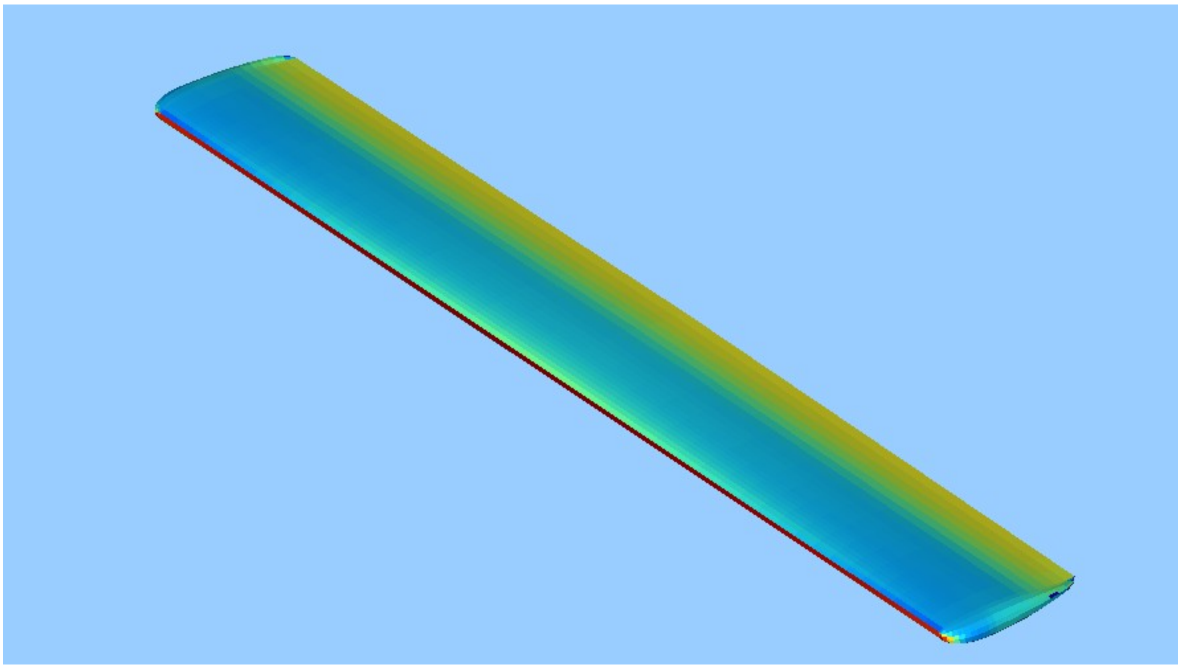
If the computation is successful, the solver windows now shows the following:



Press **load results** and the **close** to go back to the Apame GUI.

7.1.3 Show the results in APAME Gui

On the menubar, **show, results.** Choose **Pressure coefficients,** and the angle of attack you want to see. Press OK, and turn off the visibility of the wake.



7.2 Visualization in Salome

7.2.1 Export to VTK

On the menubar, **file, export, VTK file.**

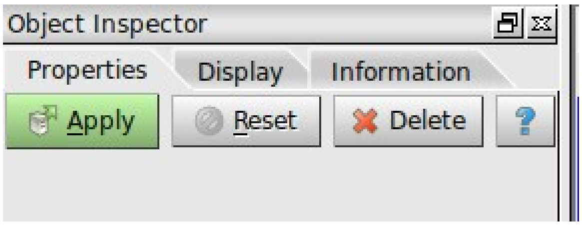
7.2.2 Import in Salome

From release 6 of Salome, the module Paraview is integrated in Salome and offers great possibilities for post processing and displaying the results.

Open Salome. Create a new study, and switch to the **ParaVis** module.

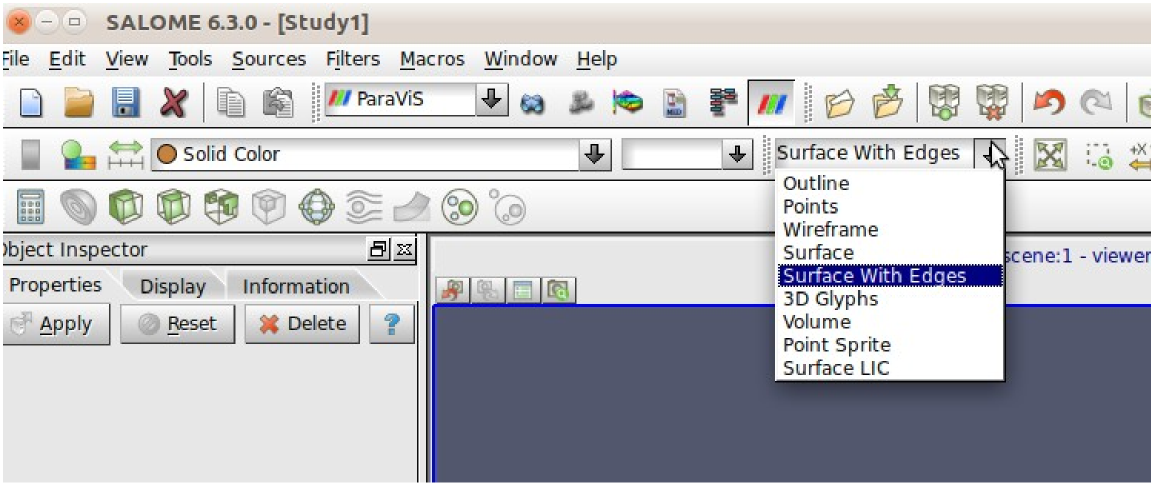
Then on the menubar, **file, Open Paraview file**, and select the VTK file you've just created.

In the Object inspector, check the **Apply** button to validate the import.

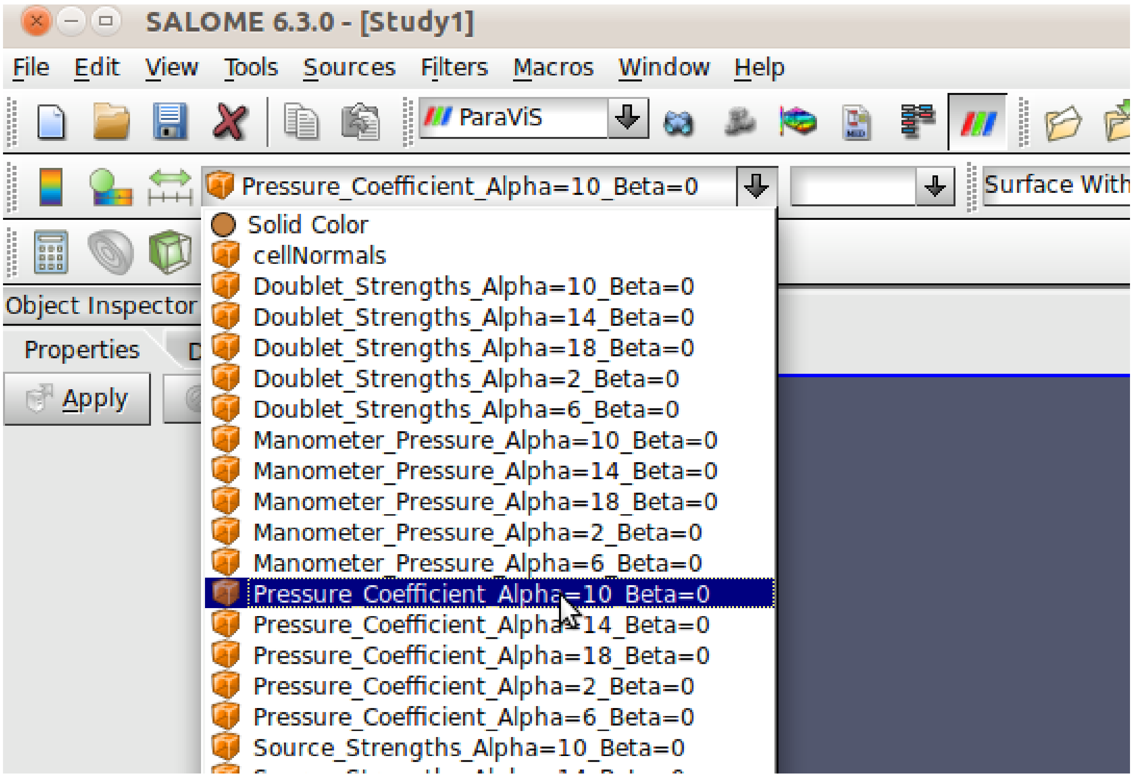


7.2.3 Display the cases

On the toolbar, select **surface with edges**



Then choose which case and parameter you want to display. We choose to display the **pressure coefficients** at the angle of attack of 10 degrees.



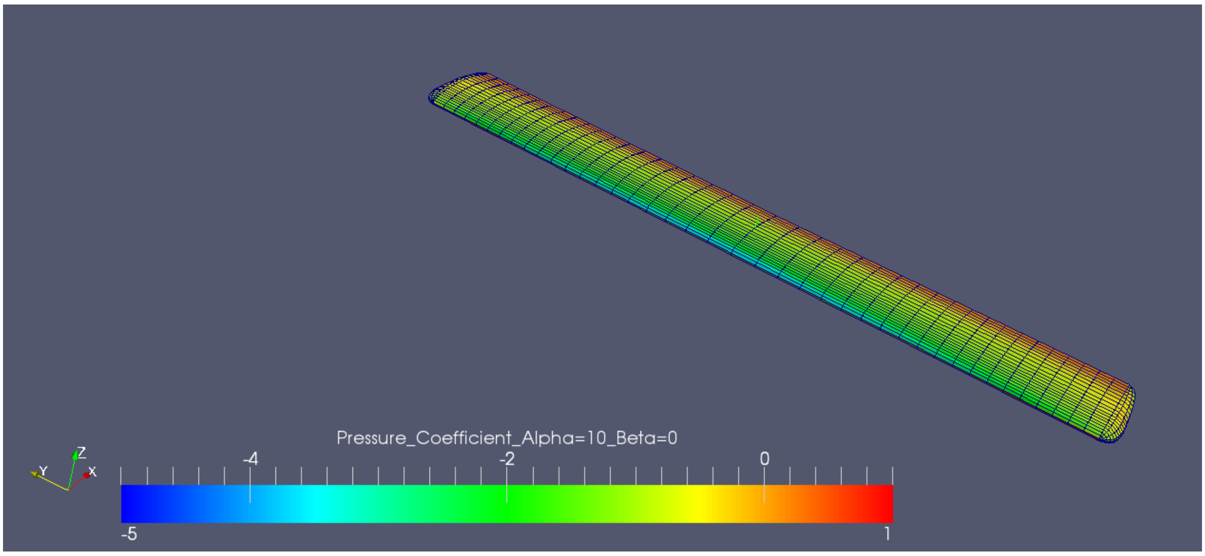
7.2.4 Adjust the display

Press the icon  in order to display the legend. You can move the legend by left-cliquing on it, and holding press the left button move the mouse.

Then, press the icon  in order to be able to adjust the settings of the display. It opens a windows with two tabs.

The **color Scale** tabs allow you to tune the colors of the display. For example click on **Choose preset** in order to load a more friendly color palet. Choose **blue to red**, and press OK. You can choose if you want to have an automatic computation of the scalar range of if you want to set it manually. For a manual input, uncheck the automatic range box, then click on the circles on the color range, and set values for each of them.

The **Color Legend** tab allow you to tune the size of the legend, its font, colors,...



8 Comparison of results

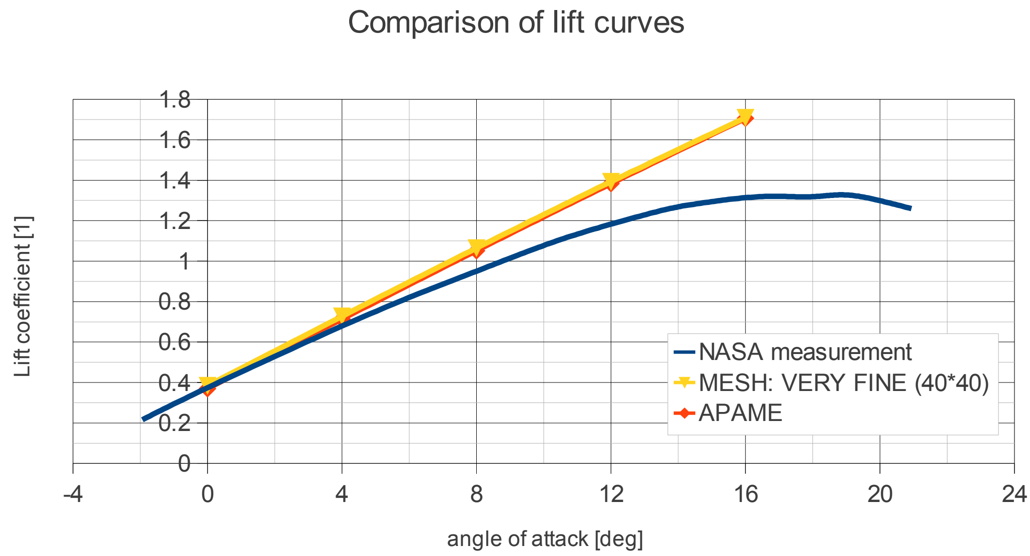
8.1 Introduction

Using the digitizer of [ref 4], the results of the NASA report were digitized *(blue curves on the following figures),* and compared with the results form APAME *(orange curves).* In order to test APAME to the sensitivity of the mesh, the analysis was also done with a mesh two times finer (40 cells on half span and 40 on half profile, *yellow curves*).

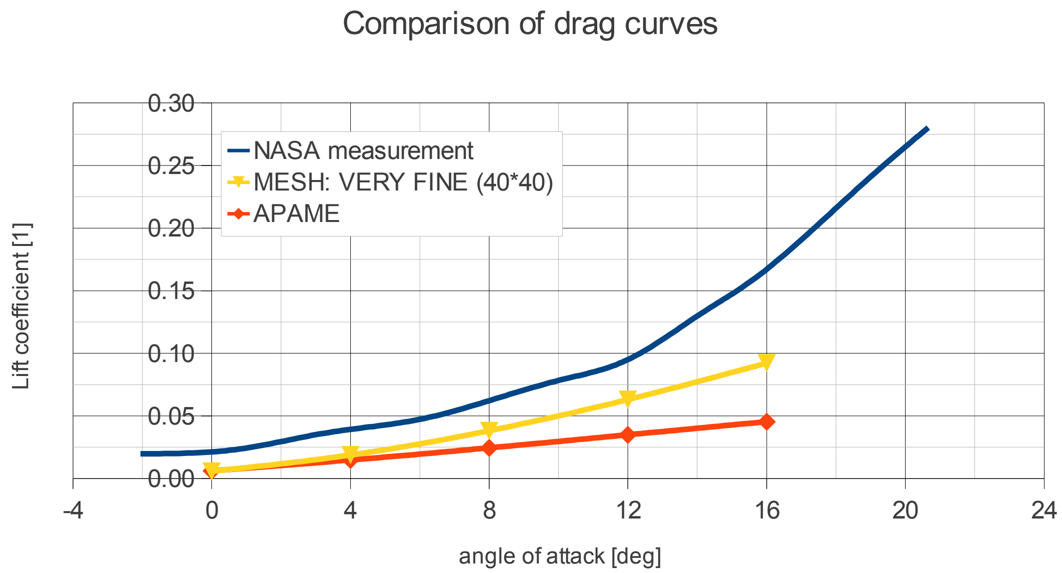
The increase in mesh density has nearly no effect in the lift curves, a slight influence on the pitch curves, and a very strong influence on the drag curves. At no angle of attack, the lift and pitch curves fit extremely well with the tunnel measurement.

8.2 Coefficients comparison

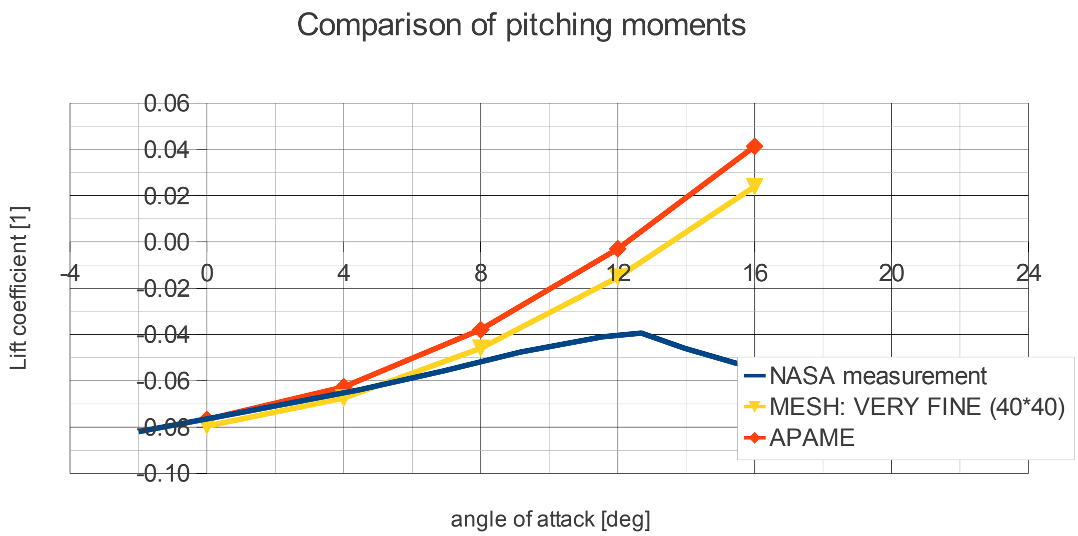
8.2.1 Lift



8.2.2 Drag



8.2.3 Pitch



8.3 Mesh rotation

Apame always define the wake as aligned with the X axis. In order to check the influence of the wake angle, the mesh was rotated in Salome by an angle of 14 degrees, in order to simulate an angle of attack of 12 degrees, and computed in Apame. The numerical results are presented in the next tab:

	NASA measurement	Original mesh, angle of attack 14 degrees	Mesh rotated by 14 deg, AOA 0 deg.
Lift [1]	1.18	1.3927	1.4137
Drag [1]	0.095	0.063	0.0677
Pitch [1]	-0.040	-0.0153	-0.0193

The only noticeable difference is in the pitching moment.

8.4 Mach correction

The original NASA rapport doesn't explicitly mention the mach number during tunnel measurements. However this one can be computed easily.

The Reynolds number used during testing varied from 1.21e6 up to 1.92e6. There were no noticeable difference in the results, so the highest will be used.

$\Re = \frac{c.V}{\upsilon}$ With υ the kinematic velocity, 1.46e-5 m2/s

It gives a speed V = 62.7 m/s, and given a speed of sound of 340 m/s, the maximum mach number during the testing was 0.18. We made a test at an angle of attack of 10 degrees (8 deg in the NASA reference), with and without mach correction. We used the *fine* mesh.

	NASA measurement	Mach =0	Mach = 0.2
Lift [1]	0.95	1.0645	1.0865
Drag [1]	0.0622	0.0382	0.0389
Pitch [1]	-0.052	-0.046	-0.0469

As expected the mach correction increase the lift curve slope of the wing. However for this case, this correction is negligible.,