A demo application of AES=3= for AGARD wing 445.6

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Contents

Introduction

AES=3= solves the thin-airfoil equations using a 3 dimensional panel method for subsonic and supersonic flow conditions about structures composed of planar wings which are modeled by thin lifting surfaces parallel to the supersonic or subsonic free stream. Each wing is composed of planar strips with side edges parallel to the free stream. The app is a general unsteady lifting surface method with an almost unlimited application range with respect to Mach number, frequency and configuration and is very ease to use. The app calculates 3-D air loads and pressure distributions for oscillating thin airframe parts with general unsteady motions characterized by the divergence rate and the reduced frequency. Sinusoidal motions (or gust) characterized by the reduced frequency and exponential growing motions (or gust) characterized by the diverging rate are allowed. The method calculates sectional forces and moment's coefficients (according to AGARD manual on aero elasticity VOL. VI notation) and generalized force coefficients for rigid and flexible displacement modes. Output is possible in text, Excel ™ (one sheet per mode) and Postscript ™ format. A Doublet Lattice like model is applied in subsonic flow. A Potential Gradient or Constant pressure model is applied in supersonic flow. The app uses the GLUI user interface library (Version 2.36).

The objective of this example is to demonstrate **AES=3=** for AGARD wing 445.6. Note that this is a very simple application. **AES=3=** is hardly limited in applications and can easily support design and certification of A/C.

For demonstration purposes a paneling is already hardwired in the app and also vibration mode data is hardwired in the app. The vibration modes are defined on an unstructured mesh and require to be warped to the paneling.

Running the app **AES=3=** ab initio will use the example and generate automatically the preferences file *.prefs_aes=3=* and the configuration file *aes=3=.cnf* in your home directory. These files might serve as templates for your own applications.

The **aes=3=** workbench will show up (see figure 1).

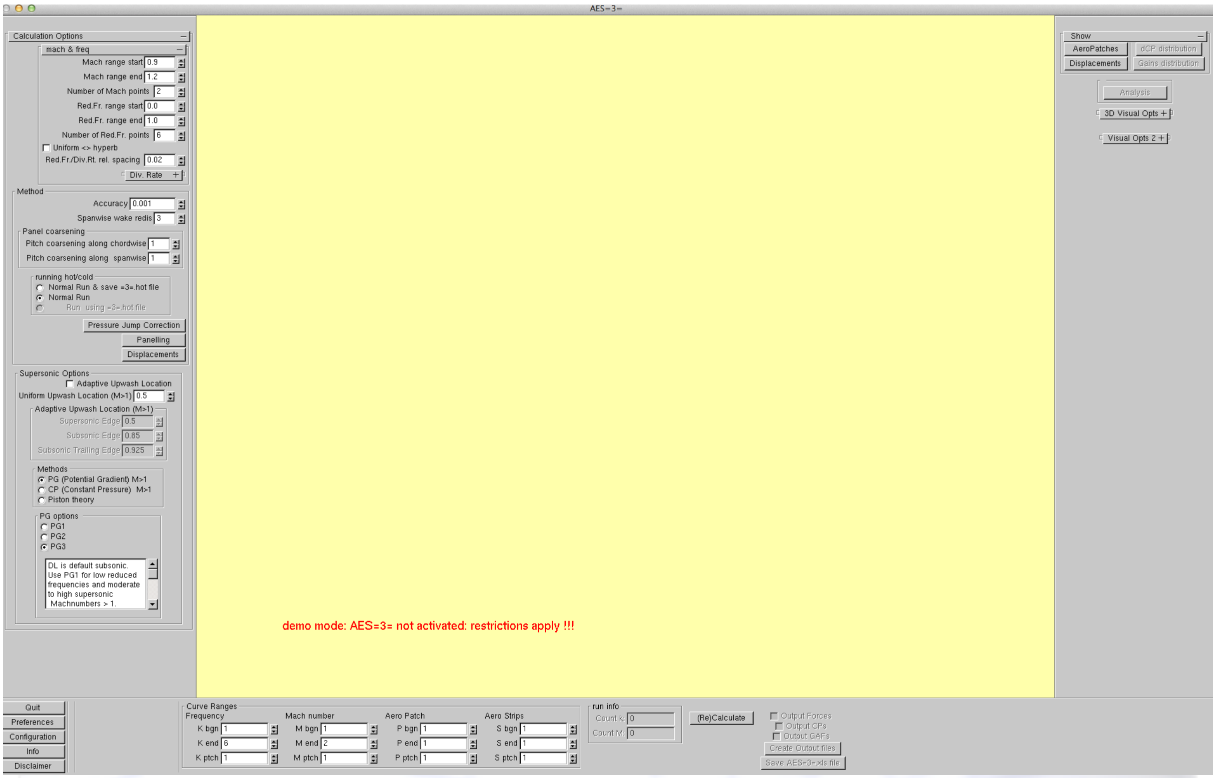

Figure 1 The startup screen of AES=3=

Geometry

Next you can inspect and/or change the geometry/paneling by pressing the paneling button (see figure 2). You can easily change the sweep, the taper and/or dihedral of selected aero patches. Also you can split patches. You can set various symmetry options et cetera.

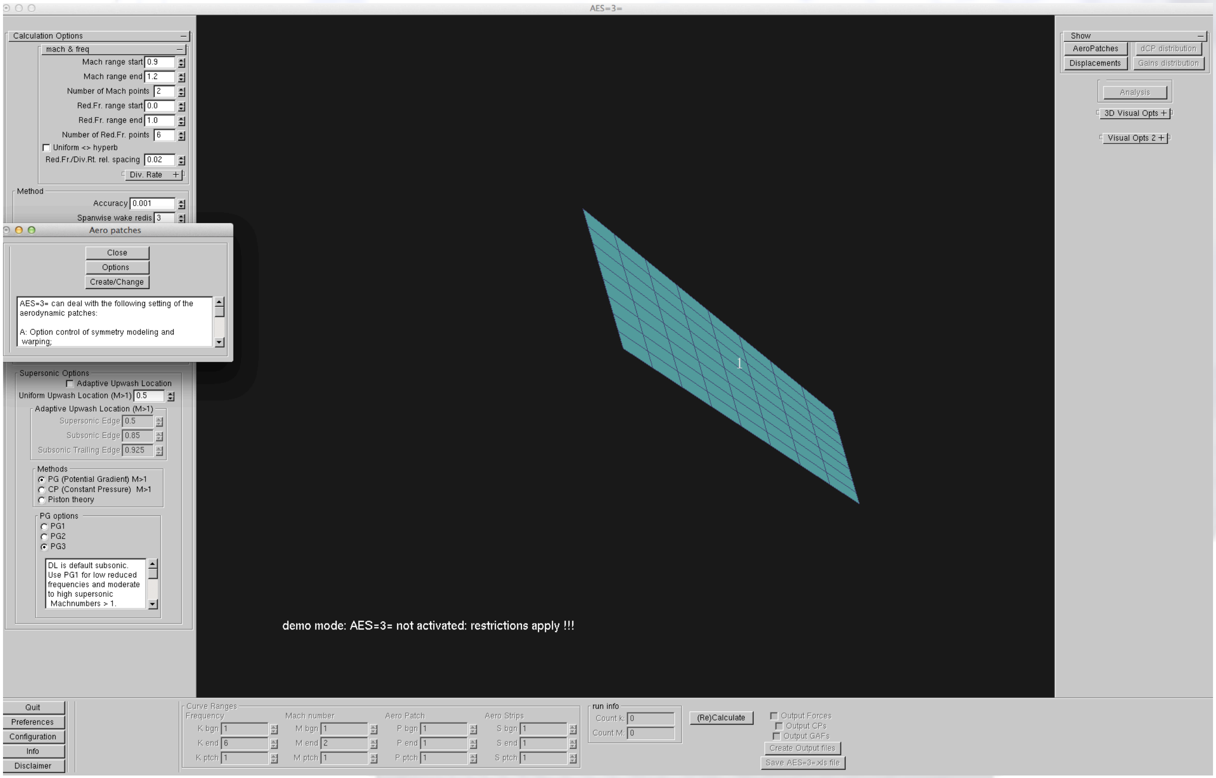

Figure 2 Inspection of the geometry

Inspection of displacement modes

Then you can inspect and/or change the displacement modes by pressing the displacement button. You can activate/create/deactivate rigid, sub-rigid (effectors), regular (warped), polynomial, special (warped) and gust modes (see sections below).

The example uses 4 regular modes, which are warped with the default volume spline to the aerodynamic grid. All the modes can be inspected separately/by group/simultaneously and moreover the regular and special modes can be simply compared to the original support data.

Various warping options for the regular and special modes can be selected to accommodate accuracy and/or efficiency.

Warping's can be stored for reuse accommodating follow on stages of your design cycle (Mach number and/or frequency changes).

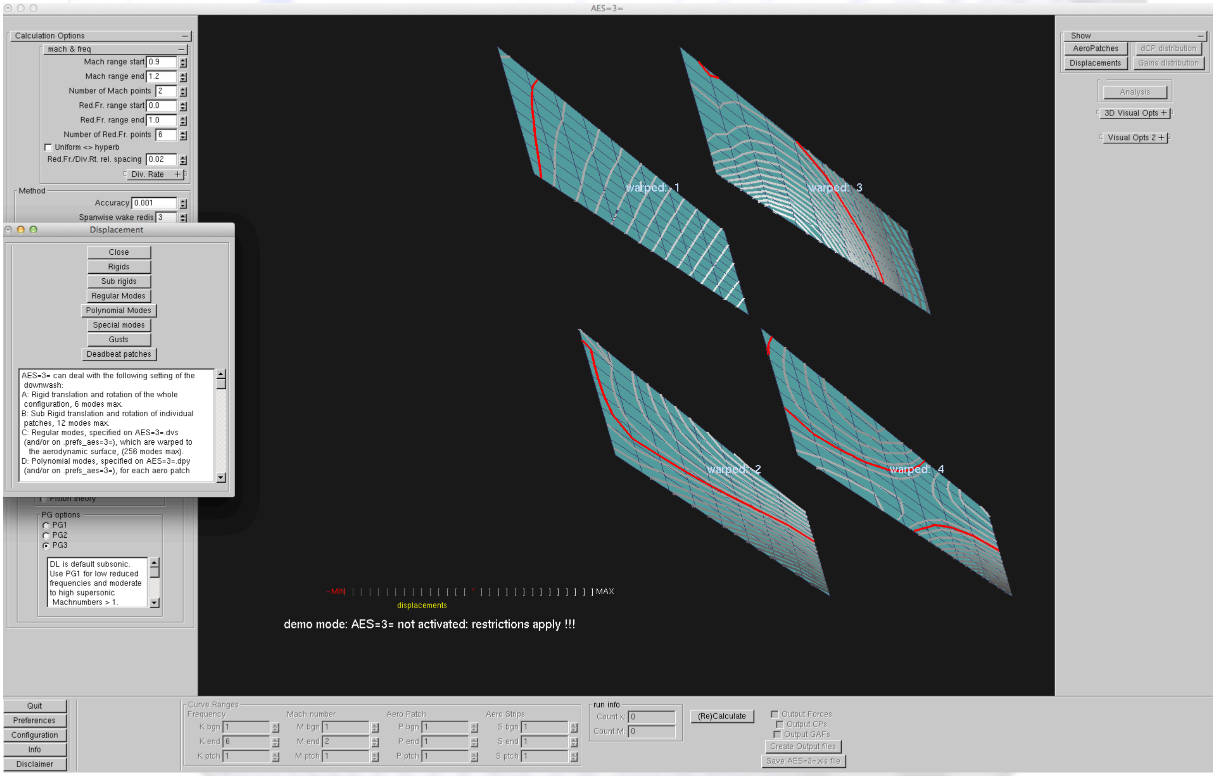

Figure 3 Inspection of the warped vibration modes

Execution

By pressing the calculate button the calculation is performed using the specified Mach number and frequency distribution and activated vibration modes in combination with the selected calculation methods. The solution matrices can be stored for reuse accommodating follow on stages of your design & certification cycle (mode shape changes). Also it is made possible to coarsen the paneling to reduce CPU time.

The results (forces, pressures & applied downwash) can be extensively analyzed by pressing the analysis button (see figures 4 and 5). This data can also be stored in data files, postscript files and *.xls* files (one sheet per vibration mode). The calculated pressure distributions can be visualized simultaneously with the modes shapes! (see figures 6 and 7).

The calculation can also be performed in batch by setting the first parameter on *.prefs_aes=3=* to one, again for easy integration in a design/optimization/certification loop.

Typical examples of the using **AES=3=** are given in the next sections for the paneling, the warping of the vibration modes and the calculated pressure distribution.

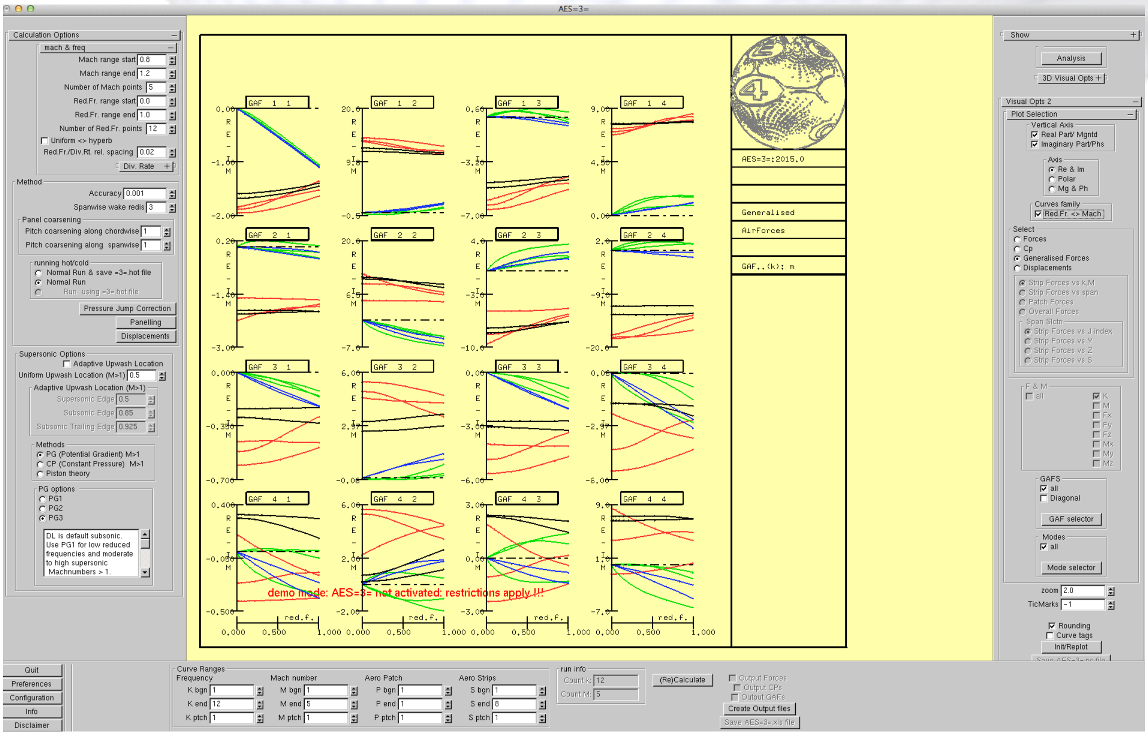

Figure 4 Generalized forces (real and imaginary part) versus frequency for subsonic (black, green) and supersonic (red, blue) Mach numbers

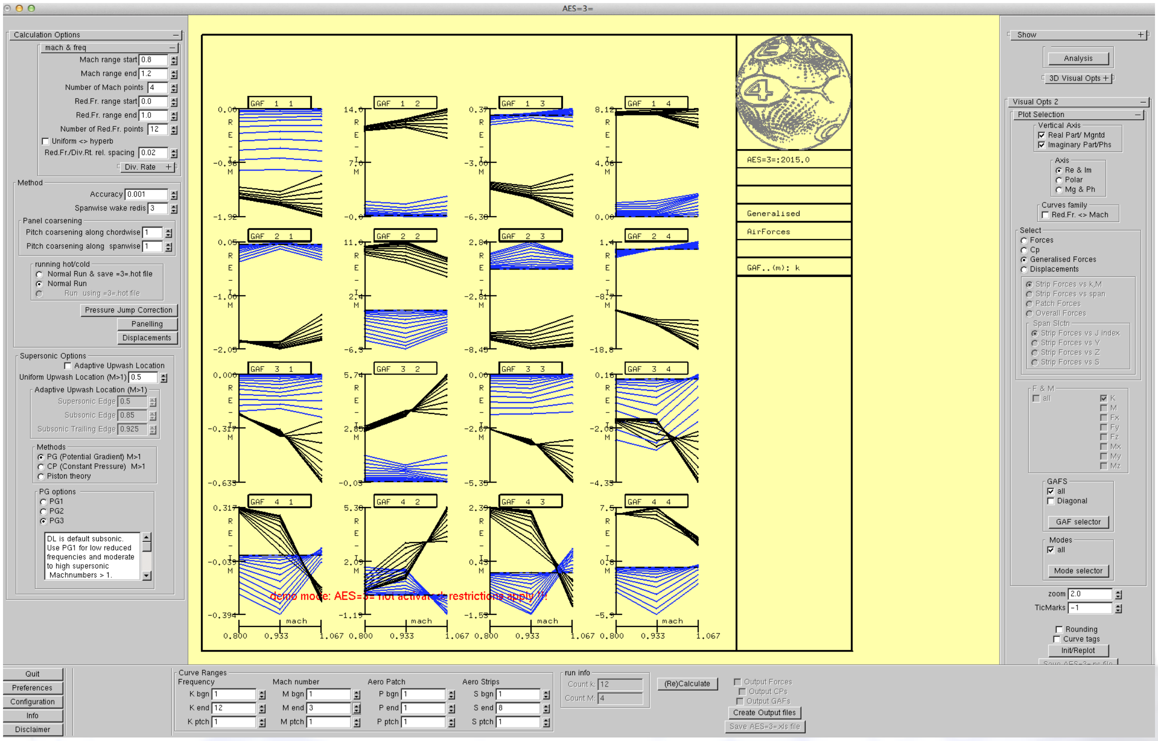

Figure 5 Generalized forces (real and imaginary part) versus Mach number for the reduced frequencies

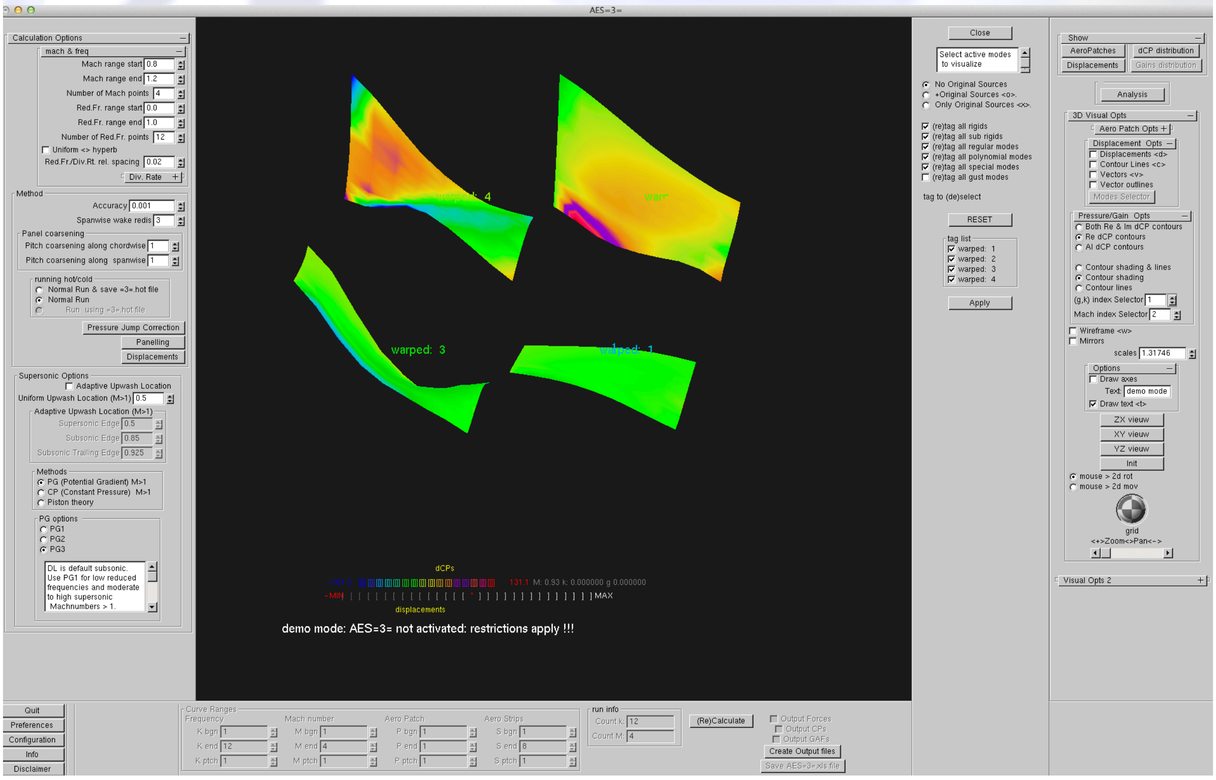

Figure 6 Real part of calculated pressure difference on deformed surface

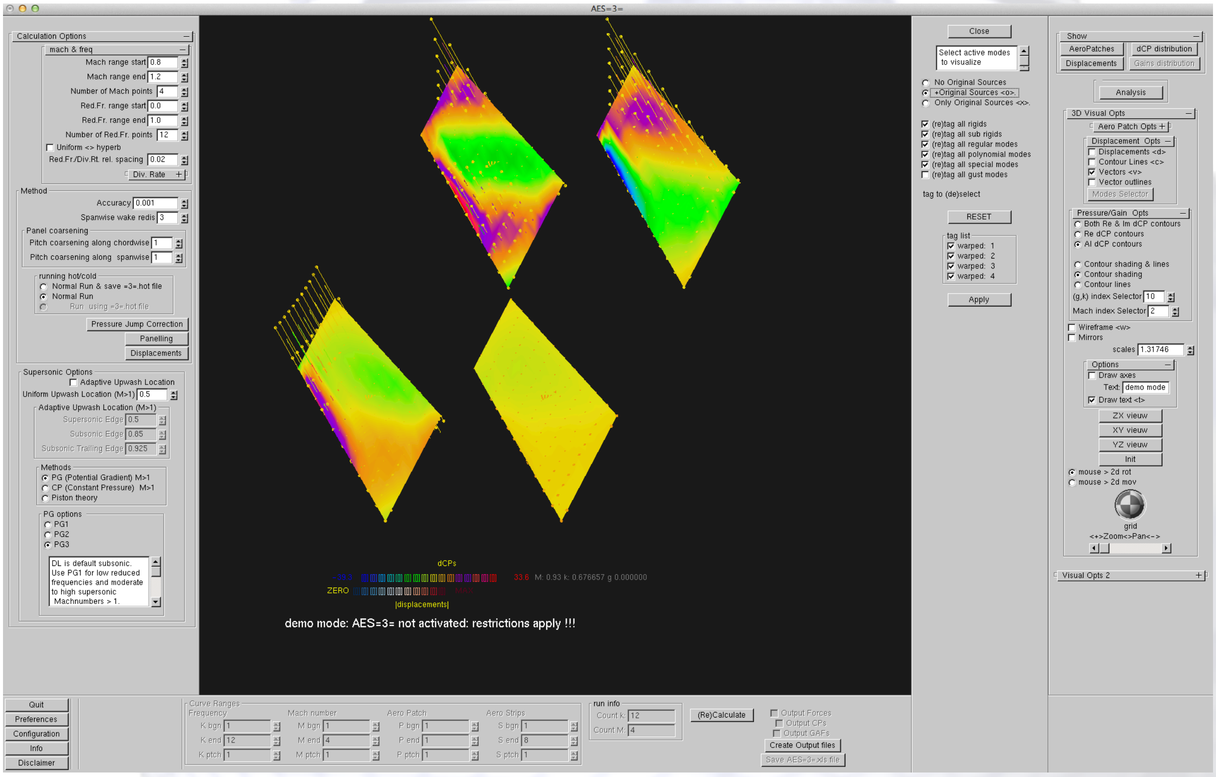

Figure 7 Imaginary part of calculated pressure difference

Examples of AES=3= usage

Typical examples of using **AES=3=** are given in the next sections for the paneling, the warping of the vibration modes and correcting the calculated pressure distribution.

Geometry specification and changes

AES=3= can interactively deal with the following setting of the aerodynamic patches:

- Option control of symmetry modeling and warping;
- Create patches ab initio and or change patches.

The symmetry options of patches with respect to the xz plane and the yx plane can be set. This allows the modeling of half and quarter models provided that displacements are symmetric or anti-symmetric with respect to these planes.
The contribution to the integrated forces of the full configuration can be set. For example when the starboard side of an A/C is only modeled the contribution of the portside of the A/C is obtained by setting the integral factor to 2.
When the displacements modes are obtained from an external dataset (e.g. FEM) the warping can be restricted to selected parts of that dataset

Entering the corner coordinates at the portside and starboard edges can generate additional patches. Note these are parallel to the x-axis. The paneling inside the corners is carried out with the specified numbers and according to a hyperbolic distribution. Also existing patches might be changed or mirrored.

An existing geometry can be easily changed to analyze effects of effectors et cetera. A simple example is given in this section. The 445.6 wing is first split in four patches (see figures 8 and 9), then the tip patches are set to a 60 deg dihedral angle (see figure 10).

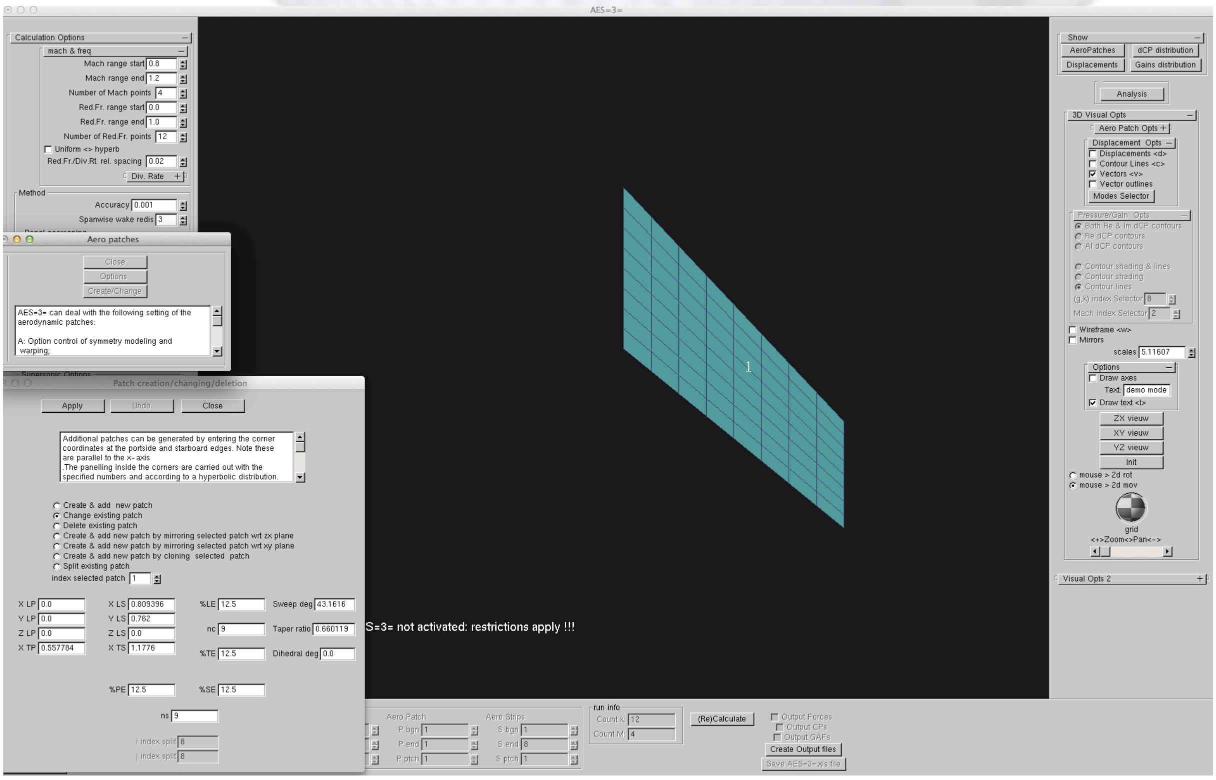

Figure 8 Geometry change window

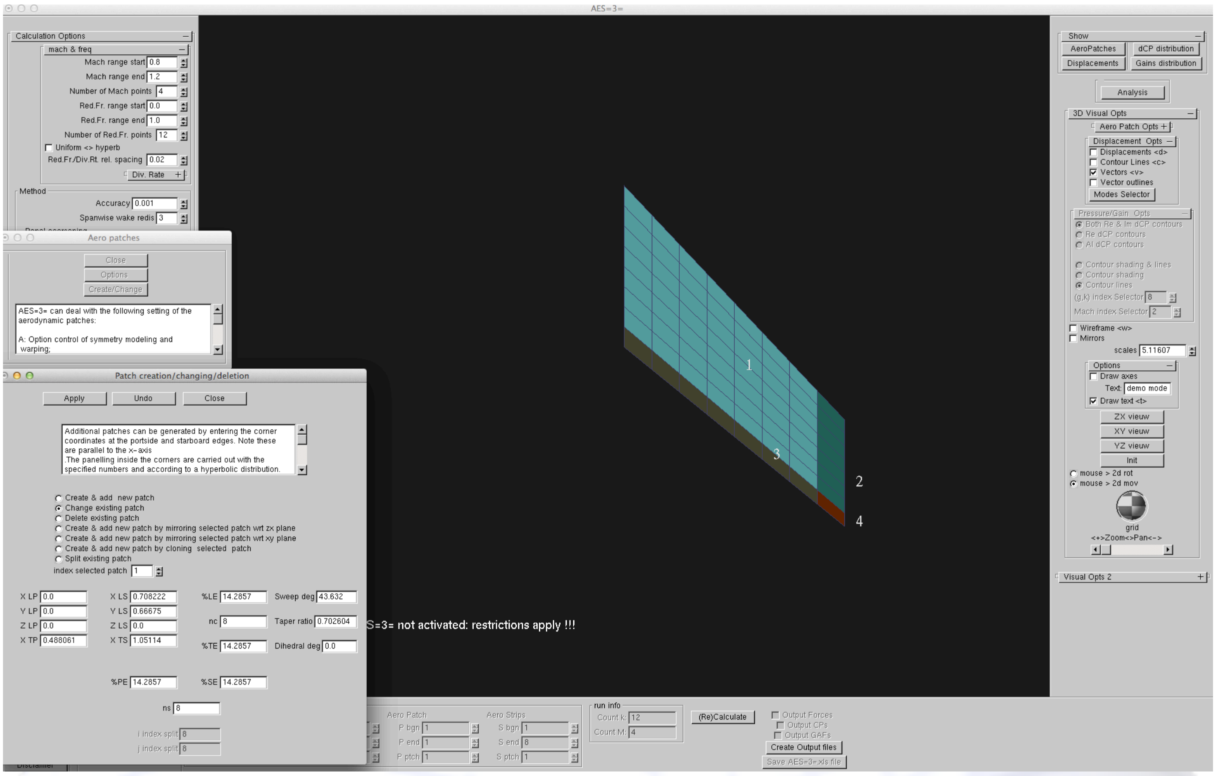

Figure 9 Geometry is split 4 parts

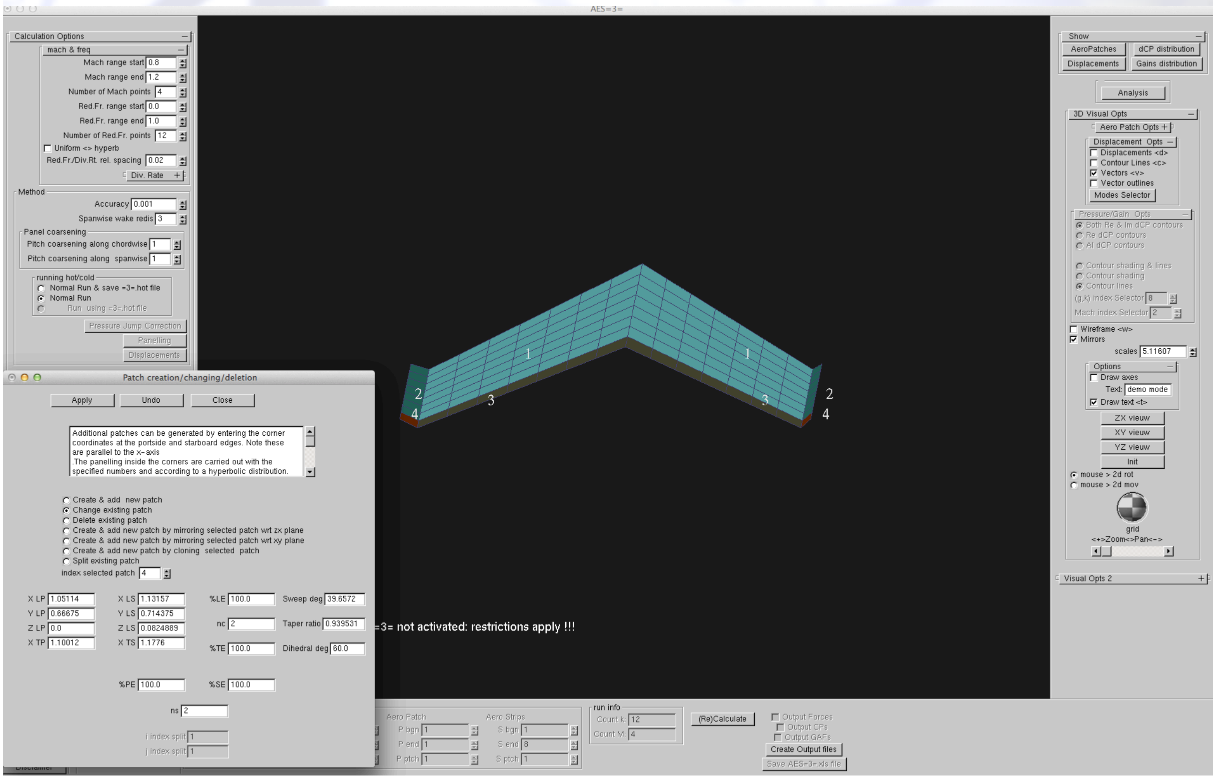

Figure 10 Geometry patches 3 and 4 are rotated 60 deg

Warping specification and changes

After changing the geometry the original structural data is applied to model the vibration modes with respect to the dihedral parts (see figure 11).

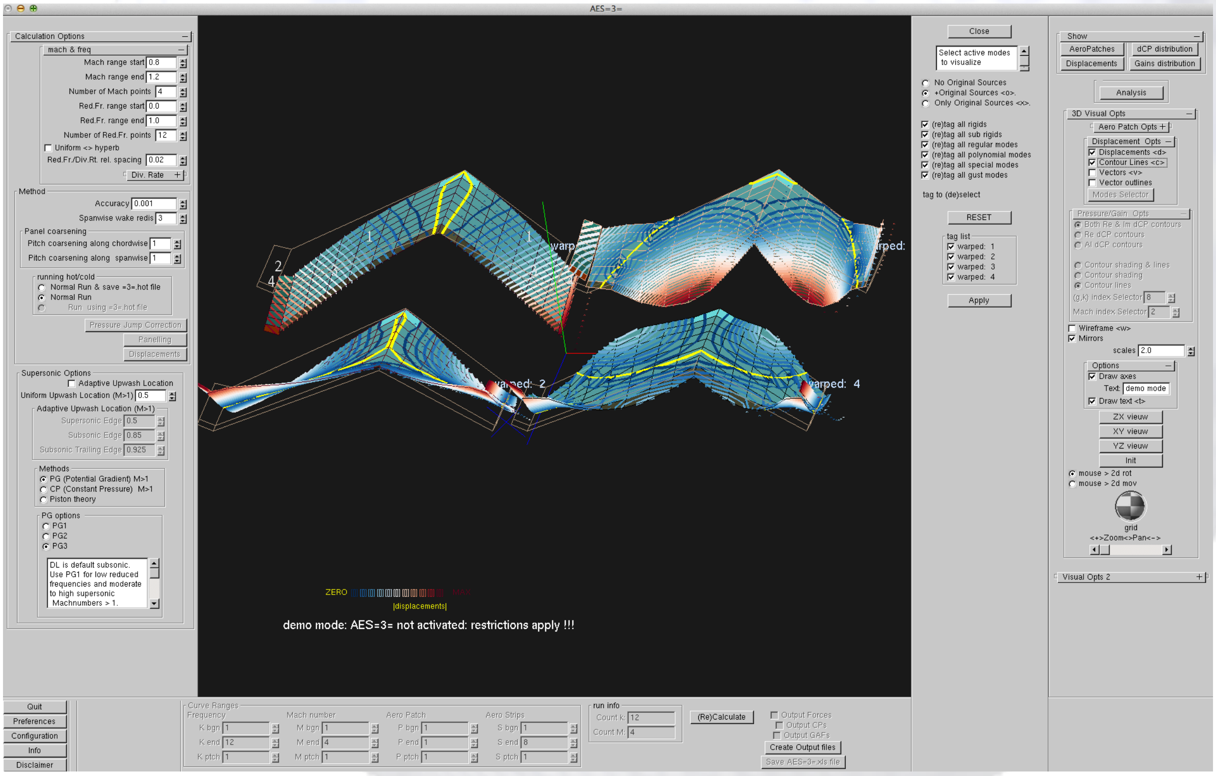

Figure 11 Vibration modes warped on the modified geometry

Execution

By pressing the calculate button the calculation is performed using the specified Mach number and frequency distribution and activated vibration modes for the modified geometry and warping. The real part of the calculated pressure distribution is shown in figure 12. Note that the geometry is deformed according to the mode shapes.

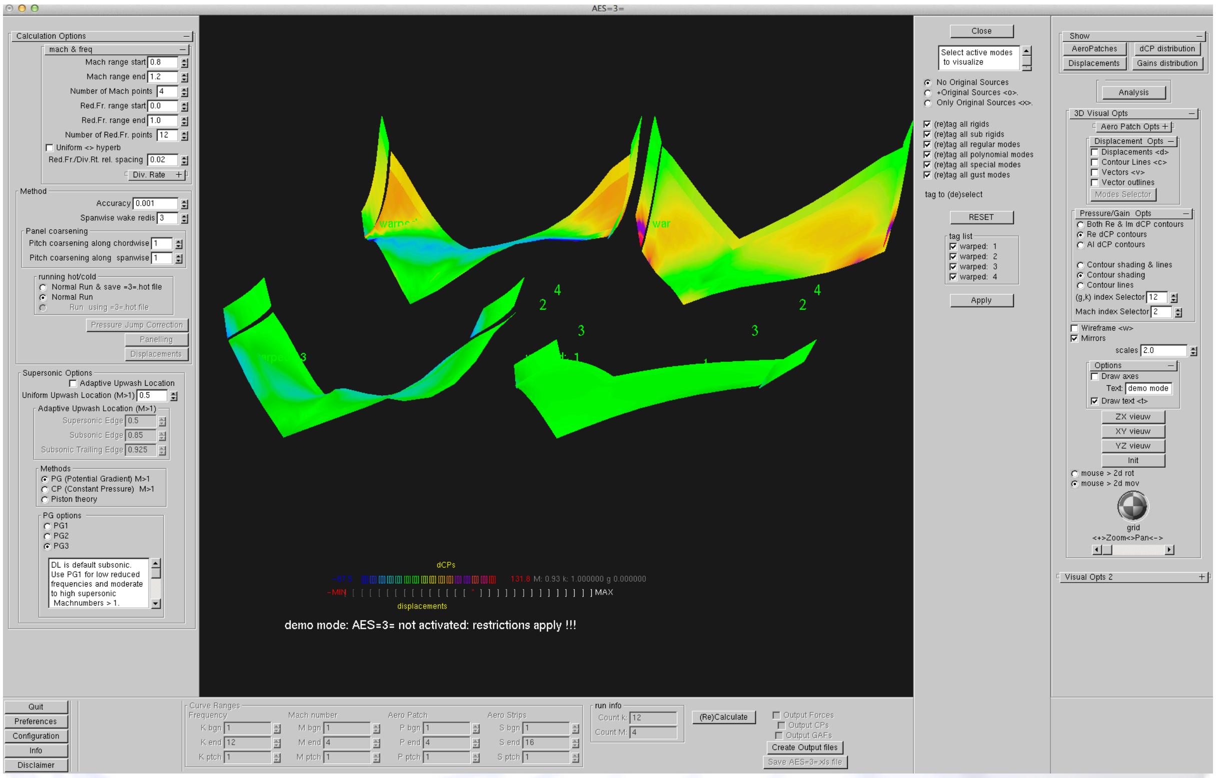

Figure 12 Real part of calculated pressure difference distribution on deformed geometry

Displacements

You can activate/create/deactivate rigid, sub-rigid (effectors), regular (warped), polynomial, special (warped) and gust modes.
All the modes can be inspected separately/by group/simultaneously and moreover the regular and special modes can be simply compared to the original support data. Various warping options for the regular and special modes can be selected to accommodate accuracy and/or efficiency.

AES=3= can deal with the following setting of the downwash:

- Rigid translation and rotation of the whole configuration
- Sub Rigid translation and rotation of individual patches
- Regular modes, specified on *AES=3=.dvs* (and/or *AES=3=.cnf* which are warped to the aerodynamic surface
- Polynomial modes, specified *on AES=3=.dpy* (and/or on *AES=3=.cnf*), for each aero patch
- Special modes, for individual aero patches
- Sinusoidal gust modes
- Patches with zero downwash

Rigid modes

The user can apply 6 modes consisting of rotations and translations (see figures 13 and 14).

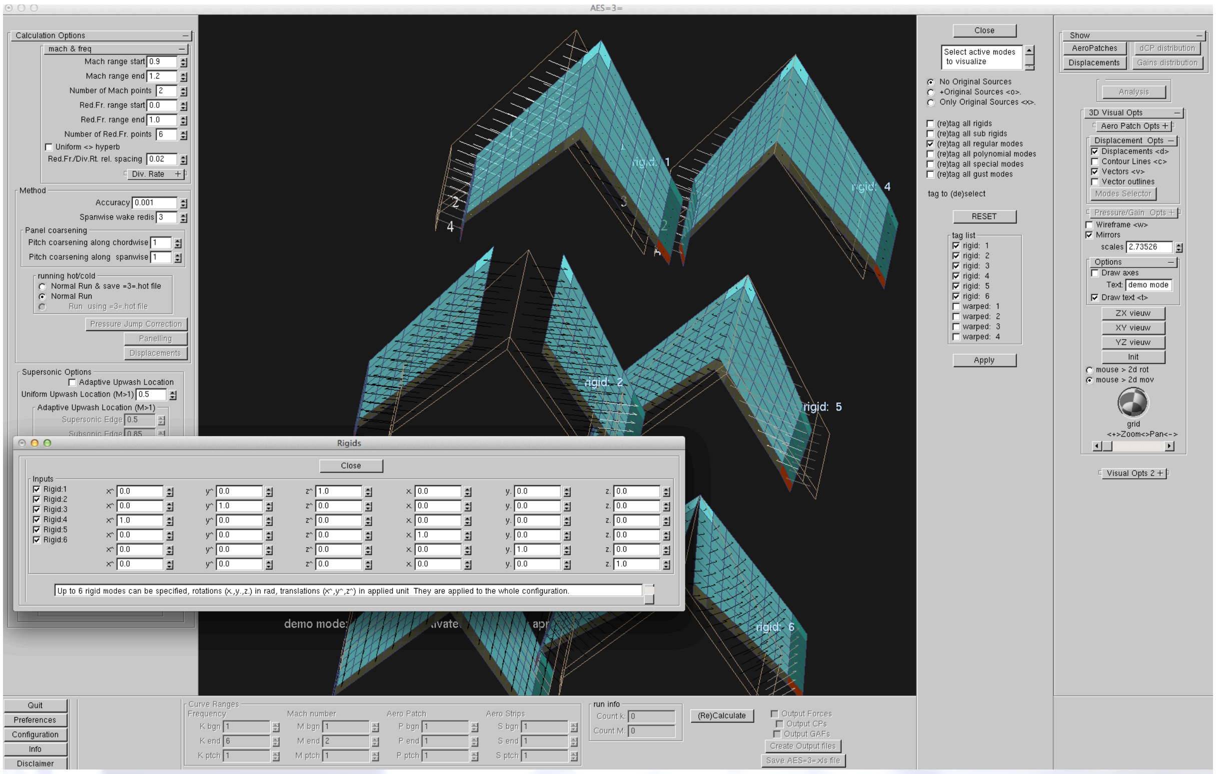

Figure 13 Adding/Creating rigid modes

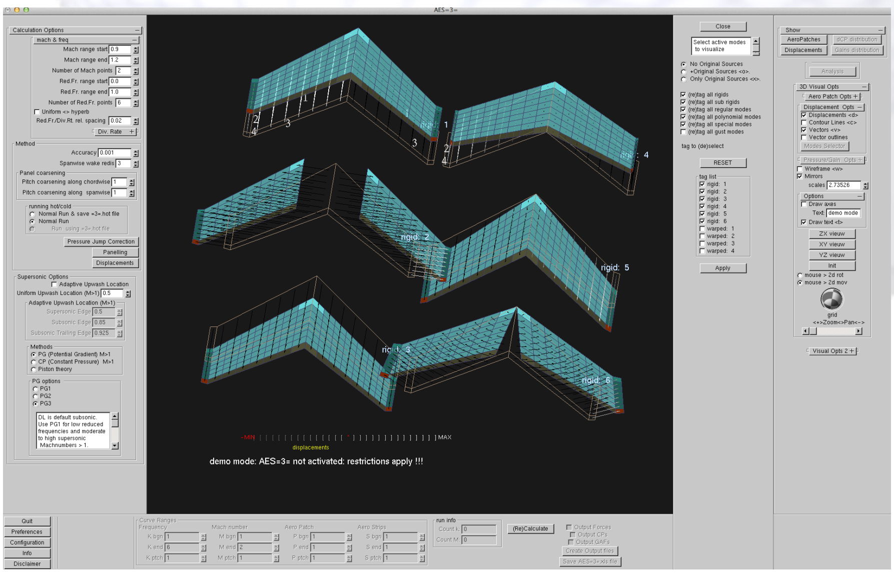

Figure 14 Visualization of rigid modes

Sub Rigid modes

Rigid modes can be applied by specifying the displacements at the 4 corners of the selected aero patch. LP,TP,LS and TS denote the corners at the Leading edge-Portside edge, Trailing edge-Portside edge, Leading edge-Starboard edge and Trailing edge-Starboard edge ,respectively (see figure 15).

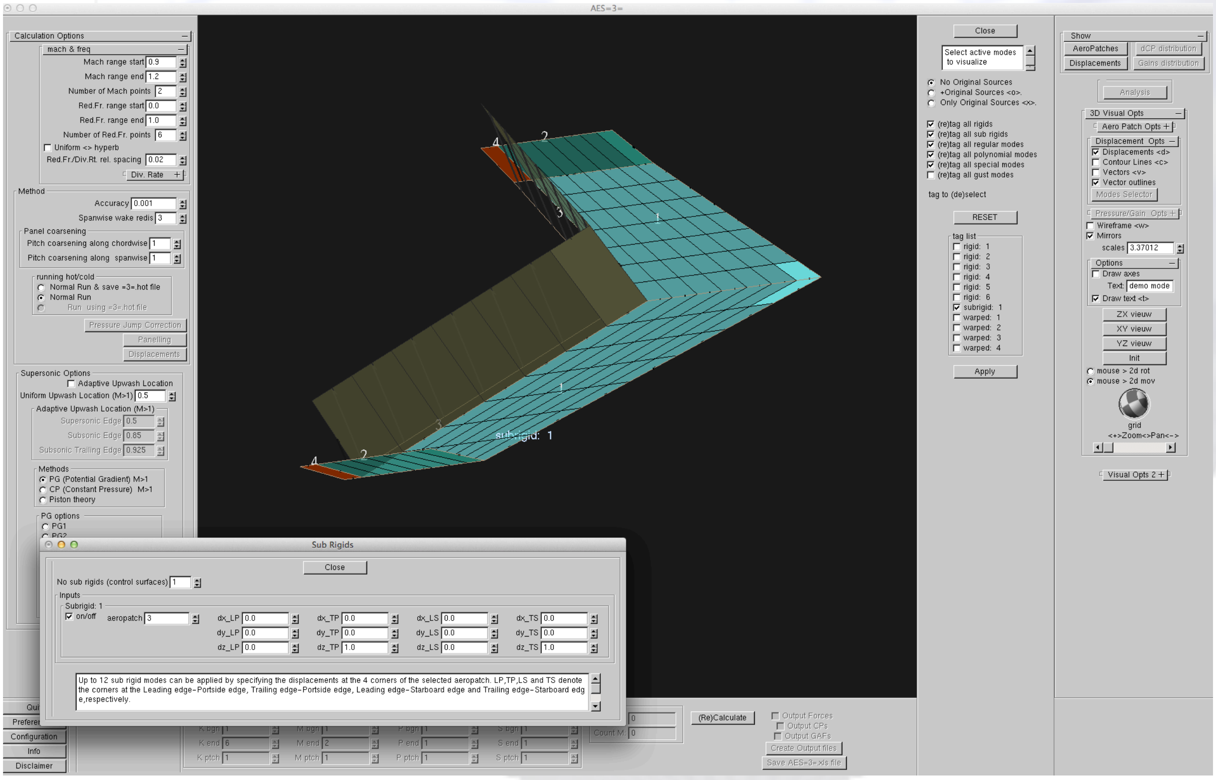

Figure 15 Adding/Creating sub rigid modes

Regular modes

Various warping options for the regular and special modes can be selected to accommodate accuracy and/or efficiency of the warping of the unstructured support data to the aero patches:

1. Hounjet's Volume spline interpolation
2. Planar surface spline interpolation
3. Least Squares Polynomial approximation.

Both approximations 1&2 can be applied in a combined hybrid way with 3 enabling a noise-free interpolation with respect to algebraic type of motions.
Various nearest neighbors strategies are available to reduce computational work.(see figure 16)

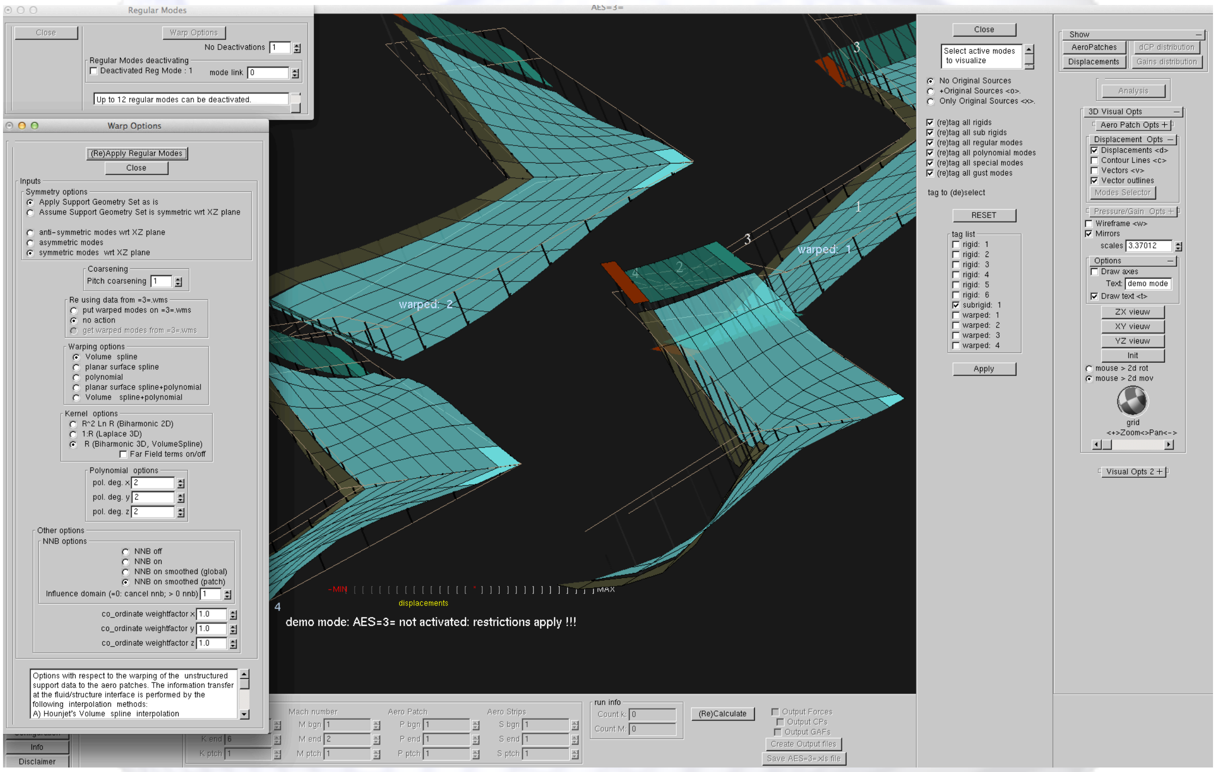

Figure 16 Changing warping modes

Special modes

Special warp modes can be applied by specifying the displacements at arbitrary points. The data is warped to the aerodynamic surface, the warping can be restricted to selected aerodynamic patches. (see figure 17)

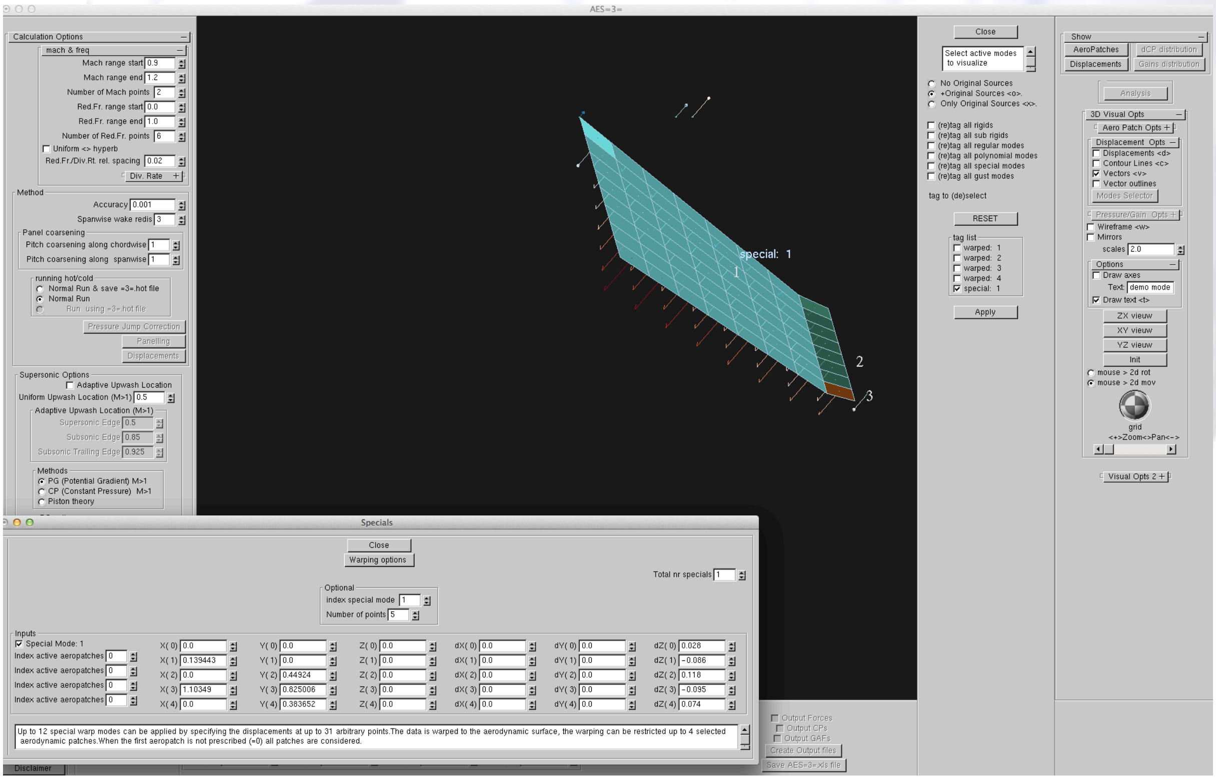

Figure 17 Adding/Creating special modes

Polynomial modes

Polynomial modes can be (de-)activated and interactively prescribed (see figure 18). The polynomials are defined along local patch coordinates.

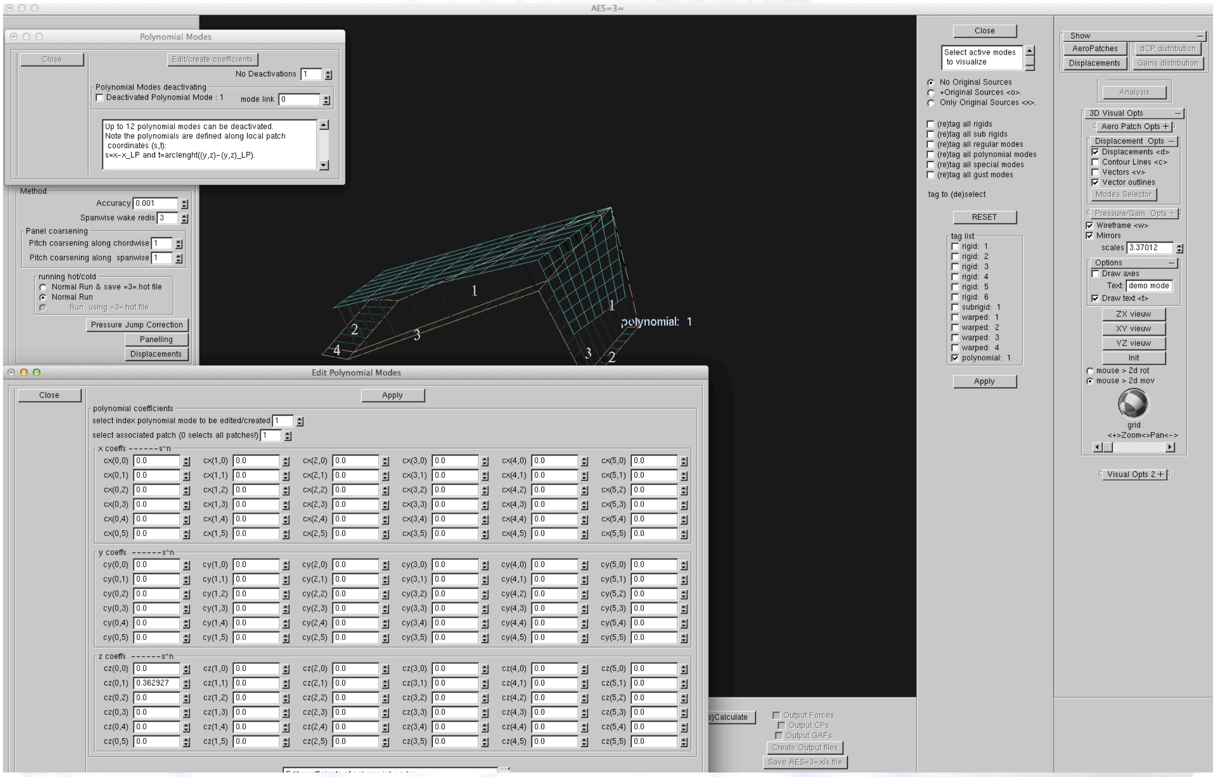

Figure 18 Adding/Creating Polynomial modes

Gust Modes

Sinusoidal gust modes can be applied, sinusoidal variation (red. freq.) in x (invariant in y, z), amplitude is linear varying in |y| and |z|. Figure 19 depicts two gust modes at a reference frequency.

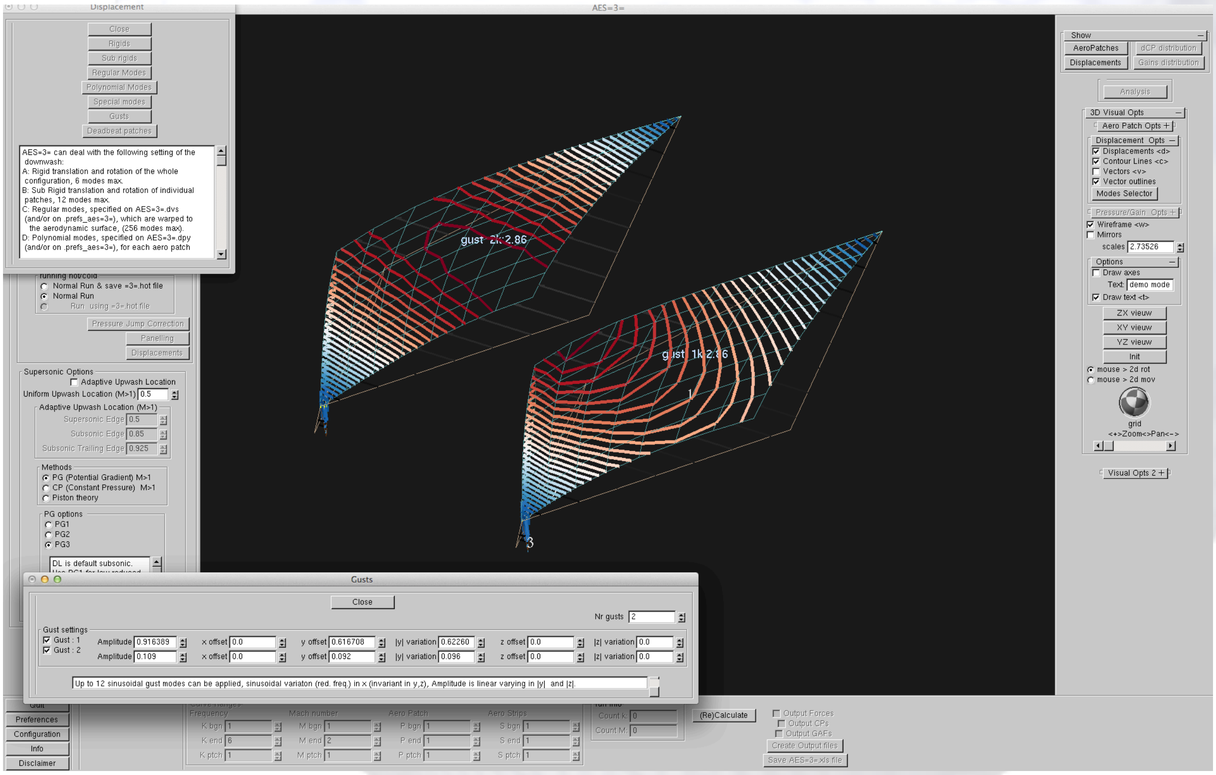

Figure 19 Adding/Creating Gust modes

Correction of pressure difference distribution

The calculated pressure distribution can be factored with a correction (Mach number, frequency and position dependent) to accommodate transonic, boundary layer and edge effects. These corrections are defined on a few support points and will be interpolated to the aerodynamic patches with a hyperspace biharmonic spline. Figure 20 show the input window in which the correction factor is set at the four vertices of the wing. Figure 21 presents the interpolated correction factor distribution.

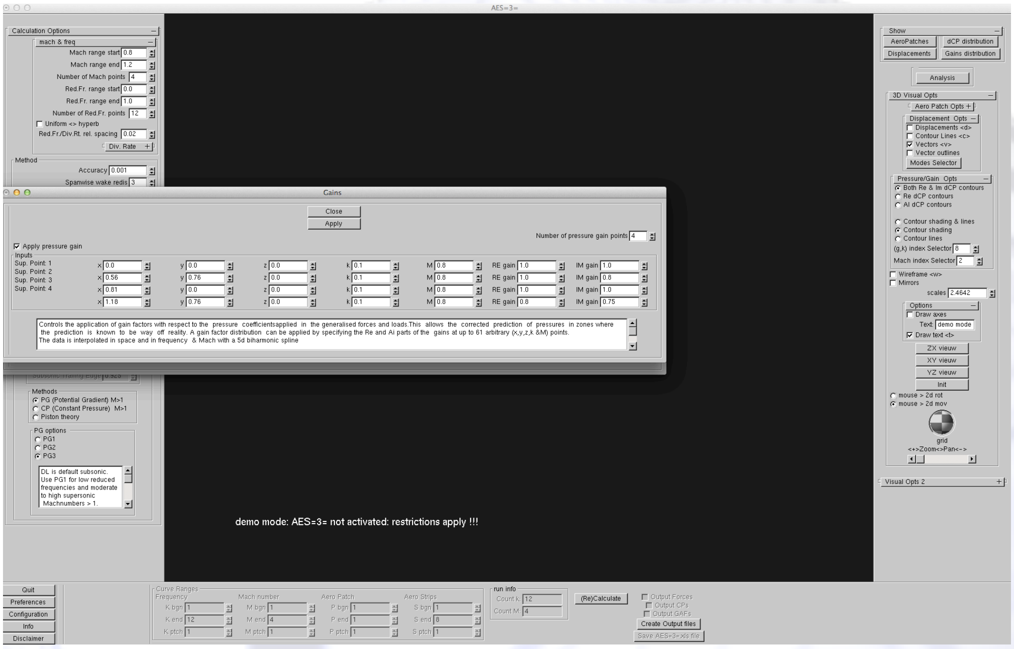

Figure 20 Input window of pressure correction

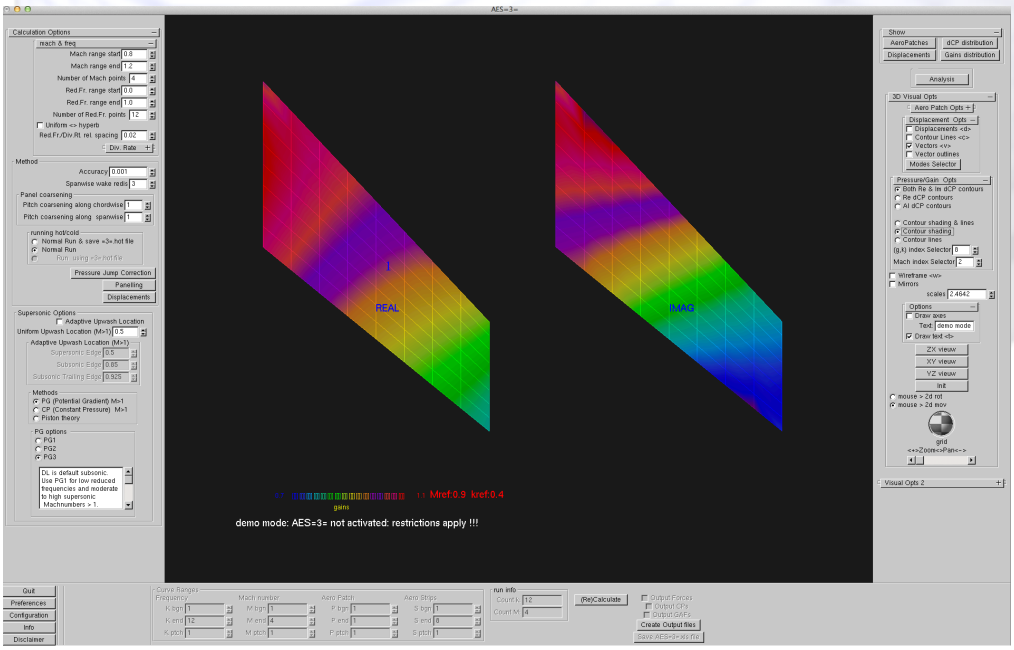

Figure 21 Interpolation of the pressure correction support data