PIR – Project innovation et recherche

Hinged wingtip modelling in NeoCASS based on Airbus AlbatrossONE

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20th may 2020

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The hinged wingtip

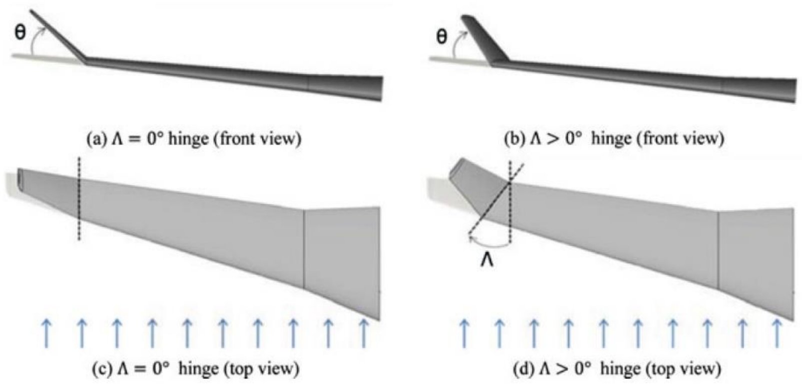
Folding wingtips are well known in aeronautics, they have been mainly expoited to save up space in aircraft carriers.

Even civil aviation is starting to consider them, as the new B777 proves. The challenge is now exploiting this feature to obtain further advantages.

Theoretical research

Much theoretical work has been done during the last years to prove that hinged wingtips could bring load alleviation in case of maneuver and gust or turbulence. Even performance can be enhanced as the hinged device allows an extension in wing span and aspect ratio, which is fundamental to decrease induced drag.

As reported in [1] different configurations of the hinge device have been taken into consideraion. Research proved that a flare angle hinge with a low rotational stiffness was beneficial for loads alleviation



[1] A. Castrichini, V. Hodigere Siddaramaiah, D.E. Calderon, J.E. Cooper, T. Wilson, and Y. Lemmens. Preliminary investigation of use of flexible folding wing tips for static and dynamic load alleviation.

In this study the model was built such that the wingspan was increased by 25% thanks to the folding device. The main presented results were the following:

- a reduction of 30% in the wing-root loads was obtained in the case of a low stiffness 25° hinge with respect to the fixed one;
- the loads were only 4.36% higher than in the baseline model without folding wing tips;
- the gust response proved load reductions for high swept hinge angles, low wingtip mass and stiffness.

Another study [2] covered simulation on an aircraft loosely based on A320 family, extending the span from 36m to 45m, confirming the benefits of a hinged wingtip.

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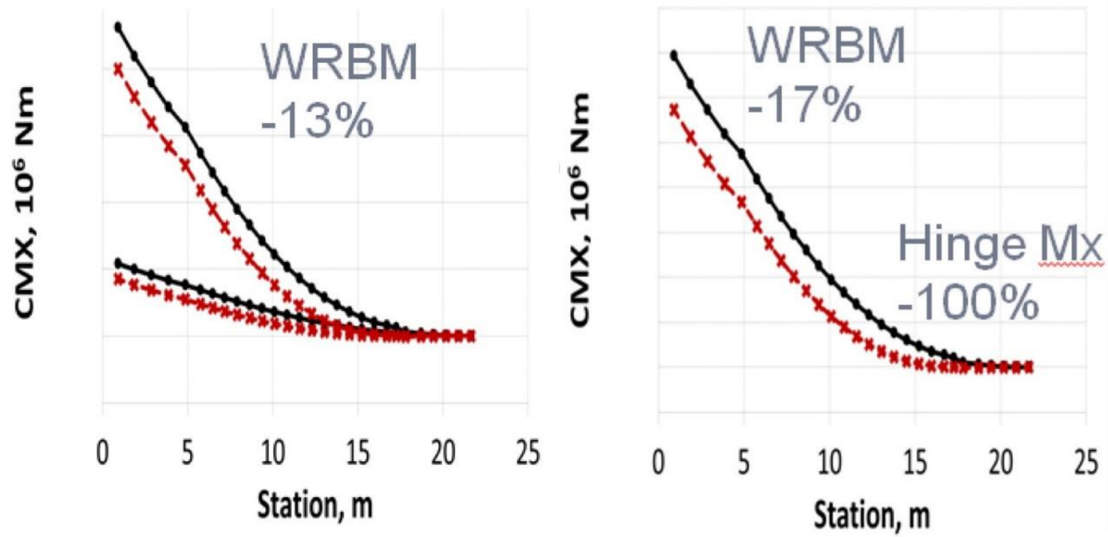
[2] T. Wilson, A. Castrichini, A. Azabal, J.E. Cooper, and M. Herring R. Ajaj. Aeroelastic behaviour of hinged wing tips

It was proved that both for up/down gust (right) and 2.5g maneuver (left) cases the main result was a decrease in the wing root bending moment by comparing free and fixed hinge behaviours.



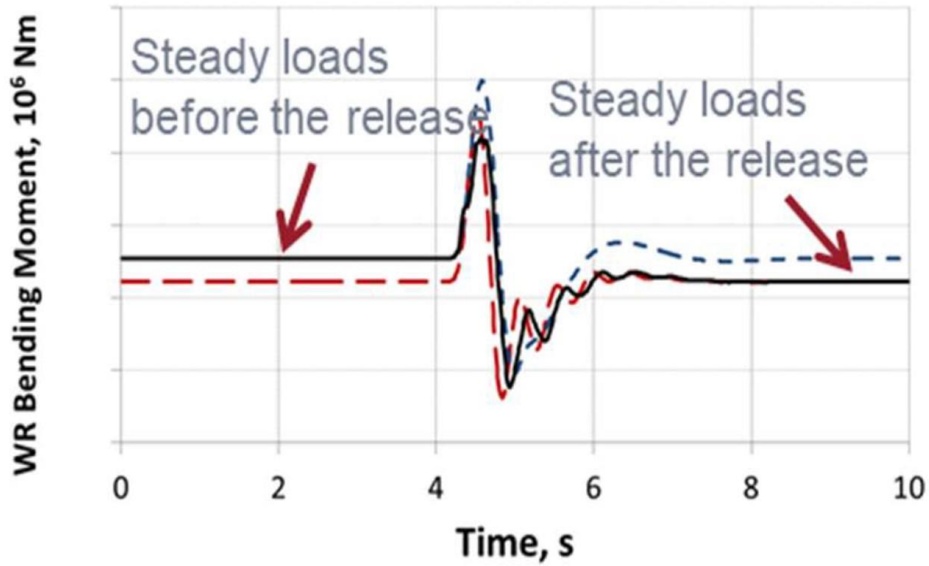
red for free hinge and black for fixed hinge

However, research stated some drawbacks for the free hinge device. During leveled flight, aerodynamic performance can be worsened by constant deflection of the wingtip due to static loads or by oscillating phenomenona due to dynamics loads.

The concept of a nonlinear hinge spring was then introduced ([3],[4]) in order to enable the folding mechanism only when aerodynamics loads were greater than a threshold value M_{max}. Such an idea was realised by applying on the hinge restoring moments ($M_{NL} = -K_\theta \theta$) through a piecewise linear spring whose stiffness varied as follows:

$$\begin{cases} K_\theta = 1.E12Nm/rad & if\ K_\theta \theta \leq M_{NL} \\ K_\theta = 1.E0Nm/rad & if\ K_\theta \theta > M_{NL} \end{cases}$$

[3] A. Castrichini, V. Hodigere Siddaramaiah, D.E. Calderon, J.E. Cooper, T. Wilson, and Y. Lemmens. Nonlinear folding wing tips for gust loads alleviation.
[4] A. Castrichini, T. Wilson, and J.E. Cooper. On the dynamic release of the semi aeroelastic wing-tip hinge device



Special attention was payed to the gust response, the results highlighted how a low threshold value was beenficial for load alleviation, the semi aeroelastic hinge(black) proved to be the most effective compared to the fixed (blue) and free ones (red).

Finally, related work ([5],[6]) to this topic gave a new insight into an active control of the wingtip extension. The device, which was designed such to have a trailing edge control surface, witnessed again beneficial results in load alleviation.

[5] F. Fonte, Francesco Toffol, and Sergio Ricci. Design of a wing tip device for active maneuver and gust load alleviation.
[6] F. Toffol, F. Fonte, and S. Ricci. Design of an innovative wing tip device

Airbus AlbatrossONE

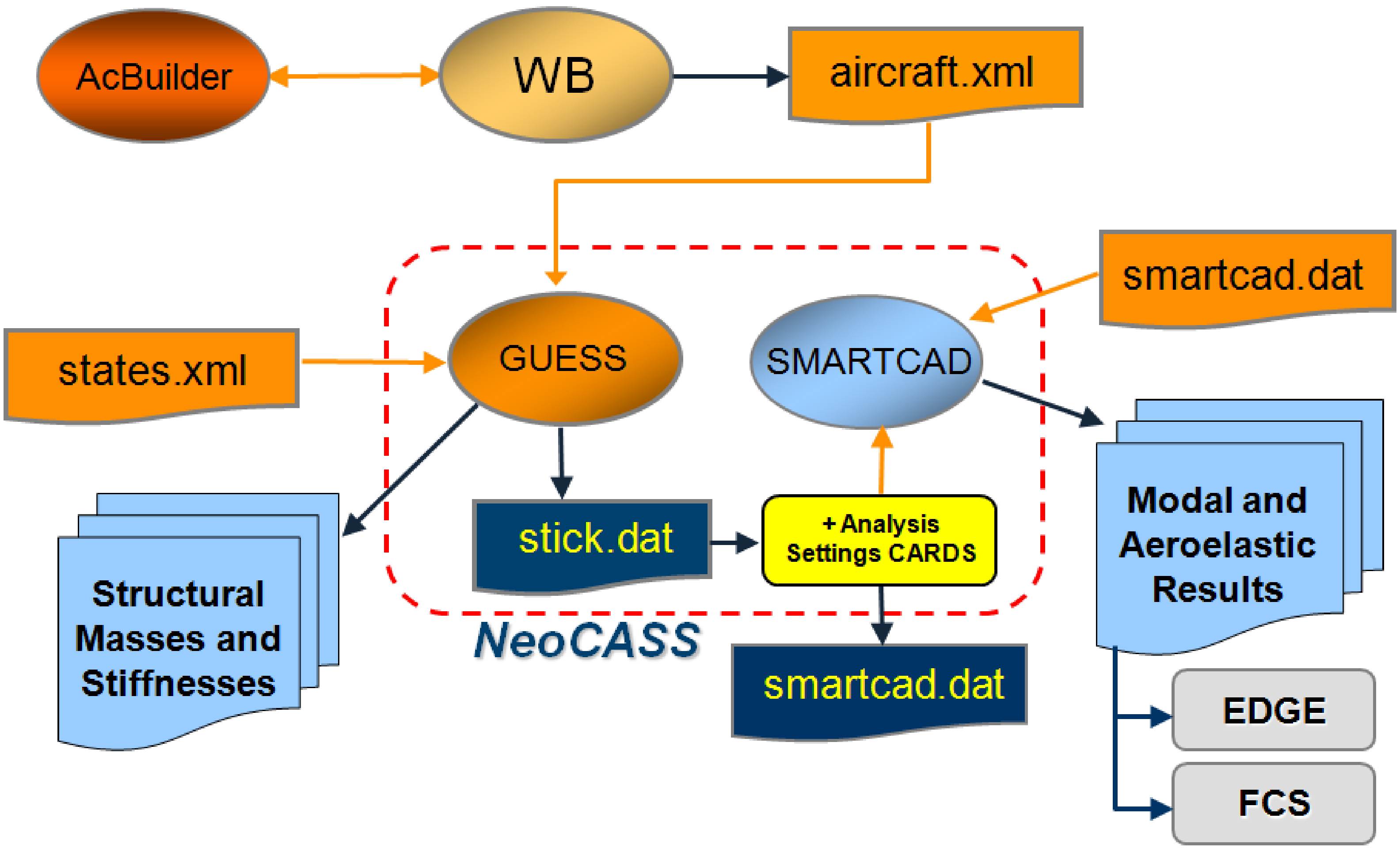
- Small scale remote-controlled aircraft based on the A321
- Embodies the idea of a semi aeroelastic hinge
- Attention to qualitative results
- Increased wingspan of more than 25%
- First flight in 2019, results were satisfactory both for stability and load alleviation

[7] Airbus. The albatross is inspiring tomorrow's aircraft wings
[8] Thomas Wilson, James Kirk, and John Hobday Andrea Castrichini. Small scale flying demonstrator of semi aeroelastic hinged wing tips.

Problem statement

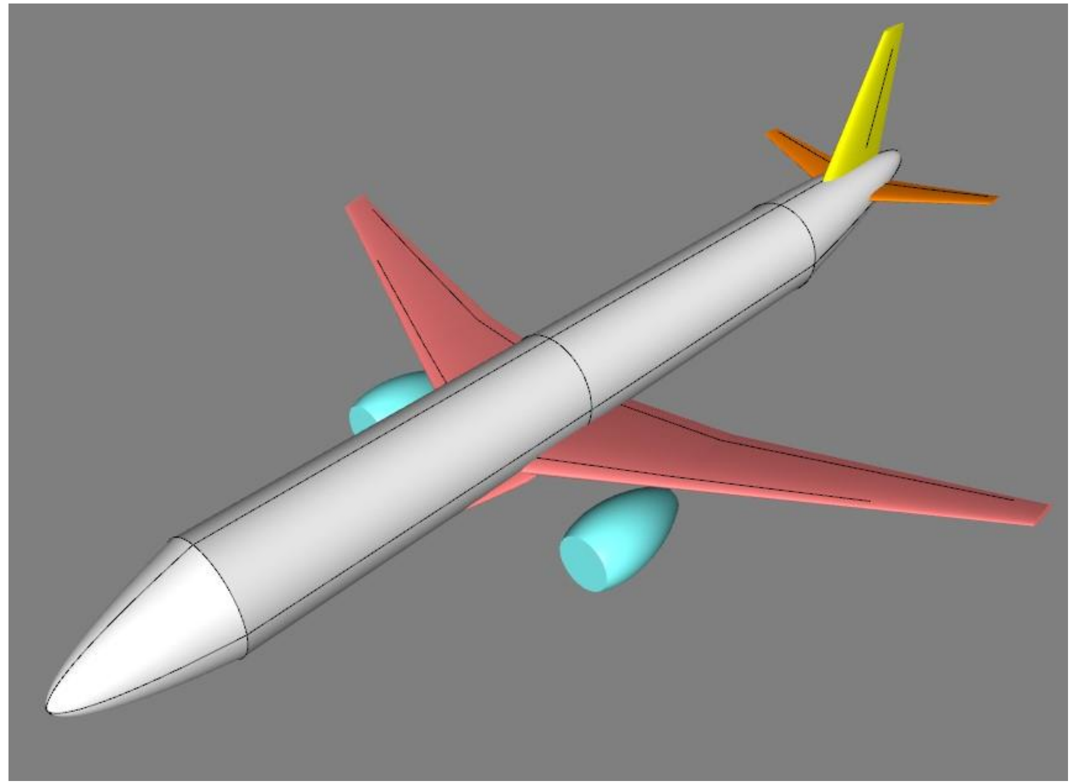
The main purpose is reproducing the effect of a hinged wingtip in a model inspired by AlbatrossONE via NeoCASS, a suite of Matlab modules to to deal with all the aspects of the aero-structural analysis of a design layout at conceptual design stage.

NeoCASS layout



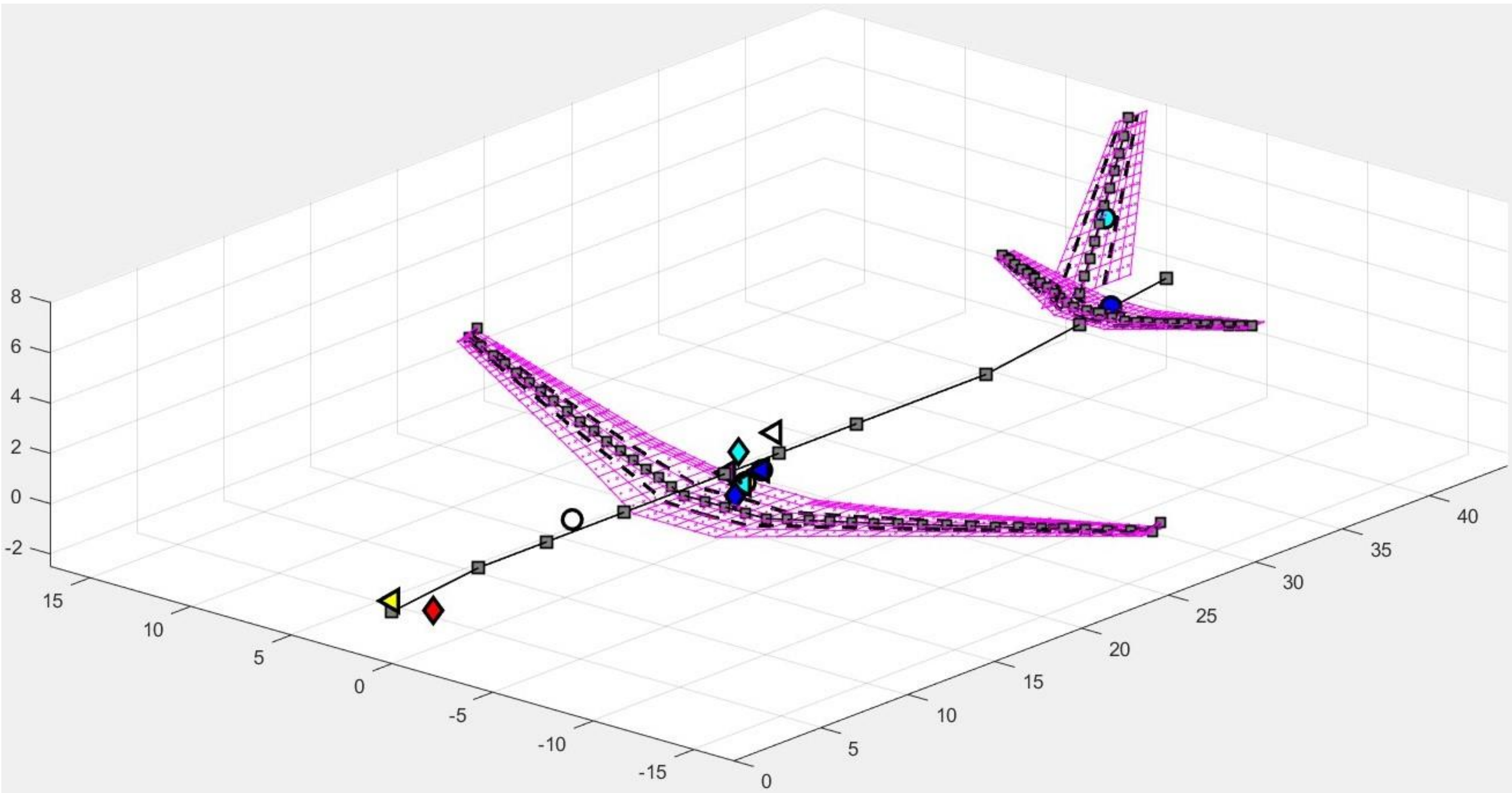
Baseline model

Different sources ([10], [11], …) have been considered to reproduce the main features of an A321 in ACbuilder, where geometry, mass distribution ad material are defined.
Since lack of specific data was sometimes run into, qualitative choices have been made (i.e. airfoil)



[10] Airbus. A321 Aircraft characteristics, airport and maintenance planning
[11] EASA. Type certificate data sheet for Airbus A318-A319-A320-A321

Once exported the model in a *.xml* file, the sizing maneuvers have been defined following EASA standards, the main GUESS outputs are a *beam stick* model and the *aerodynamic mesh.*



Analysis

- NeoCASS offers different types of analysis, for each one a SMARTCAD file is needed.
- Main focus is on trim static analysis and gust dynamic response.
- As this is realised in Matlab environment ad hoc script have been prepared both to run the analysis and to extract the post process results.

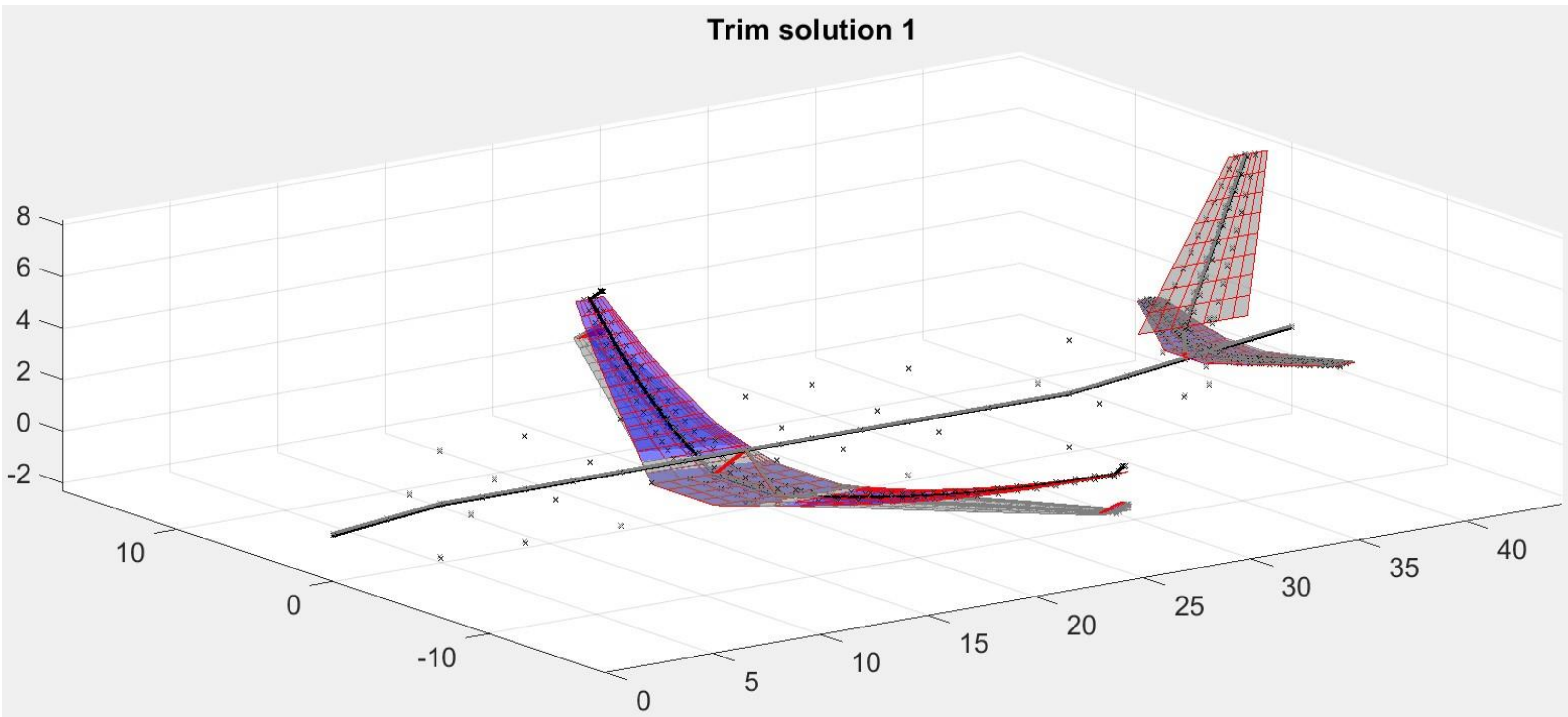
Trim

```
$------2------3------4------5------6------7------8------9------10
$ DATA ADDED AFTER GUESS SIZING
$------2------3------4------5------6------7------8------9------10
$ ADD PAYLOAD
INCLUDE A321CONM_CONF1.inc
$------2------3------4------5------6------7------8------9------10
$ SET TRIM SOLVER
SOL 144
AEROS           0       3.58944 34.1    122.4   0       0
$------2------3------4------5------6------7------8------9------10
$ ADD MANEUVERS
INCLUDE A321_3maneuvers.inc
$
$ INCLUDE MODEL
INCLUDE A321.inc
$
```

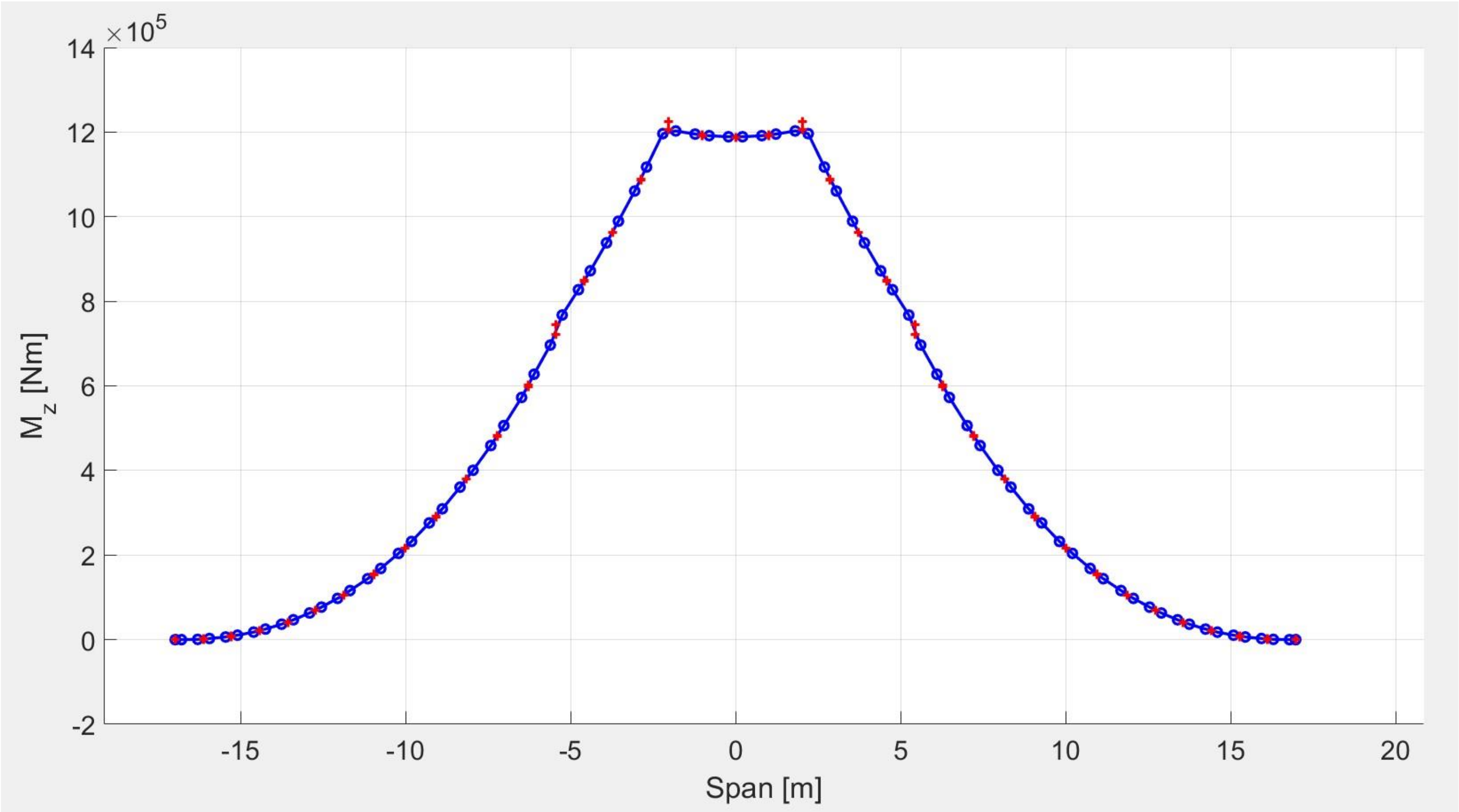
Three maneuvers have been taken into consideration: Cruise, Pull-up and Sideslip, these information are stored in a *.dat* file with other aircraft parameters.

A few code lines

```
global beam_model
input_file = 'A321_input3Trim.dat'
beam_model = load_nastran_model(input_file);
solve_free_lin_trim('INDEX', 1);
plotLinearDispl(beam_model, beam_model.Res, 1, 1)
```



With some post-processing internal forces can be extracted, for example the spanwise bending moment has showed to be of critical importance in this kind of analysis.



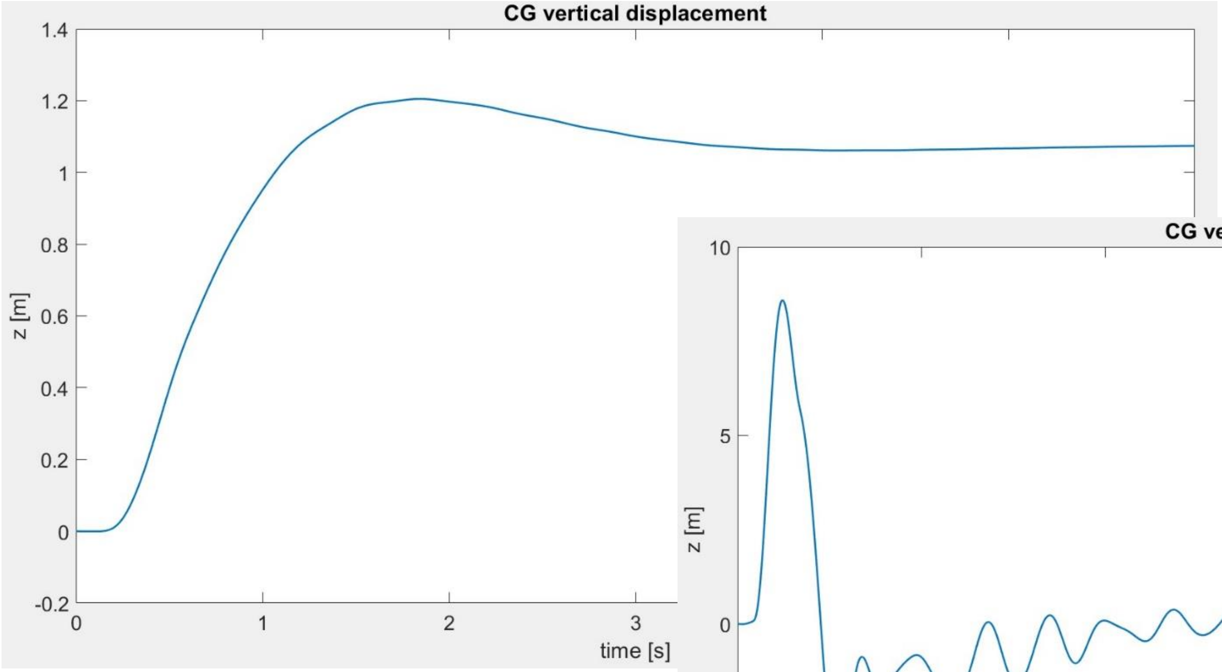
Gust

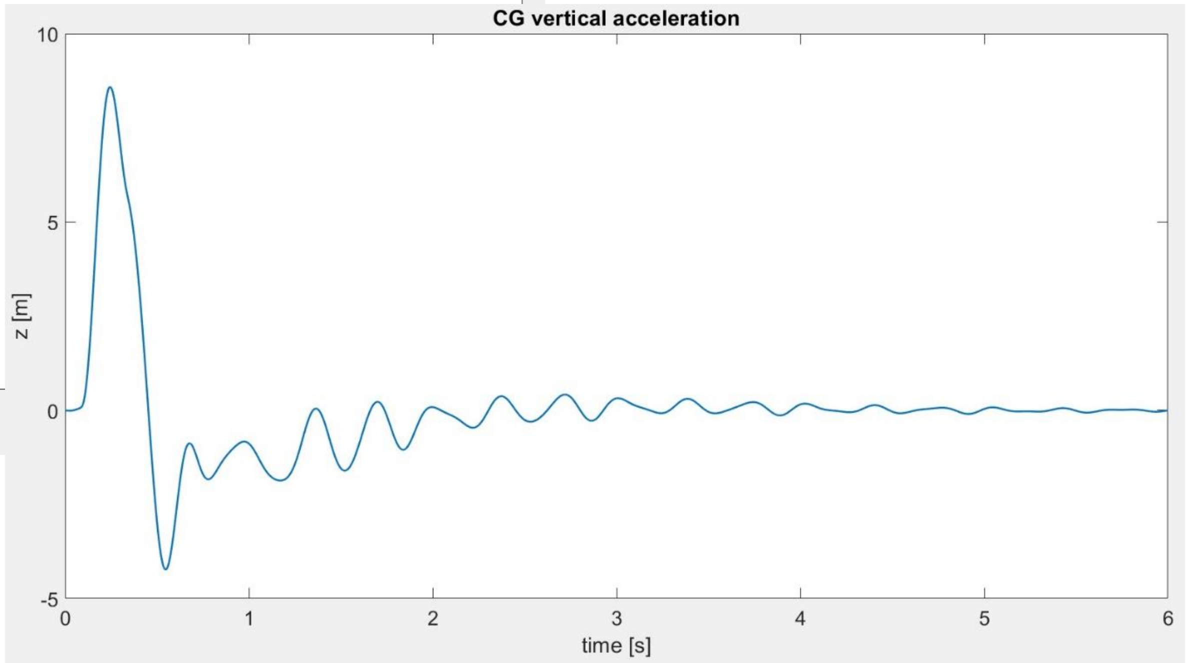
Gust analysis is a little more demanding, but the principles are the same as the trim one, a dedicated SMARTCAD is needed, with all the aircraft features, gust definition (standard 1-cos) and dynamic analysis parameters.

```
$
$-------2-------3-------4-------5-------6-------7-------8-------9-------10
GUST= 1
$-------2-------3-------4-------5-------6-------7-------8-------9-------10
$ Gust input
$-------2-------3-------4-------5-------6-------7-------8-------9-------10
GUST    1       15.07   0.25    0       3               FUN
        1
        (1-cos(2*pi/0.25*t))*0.5
```

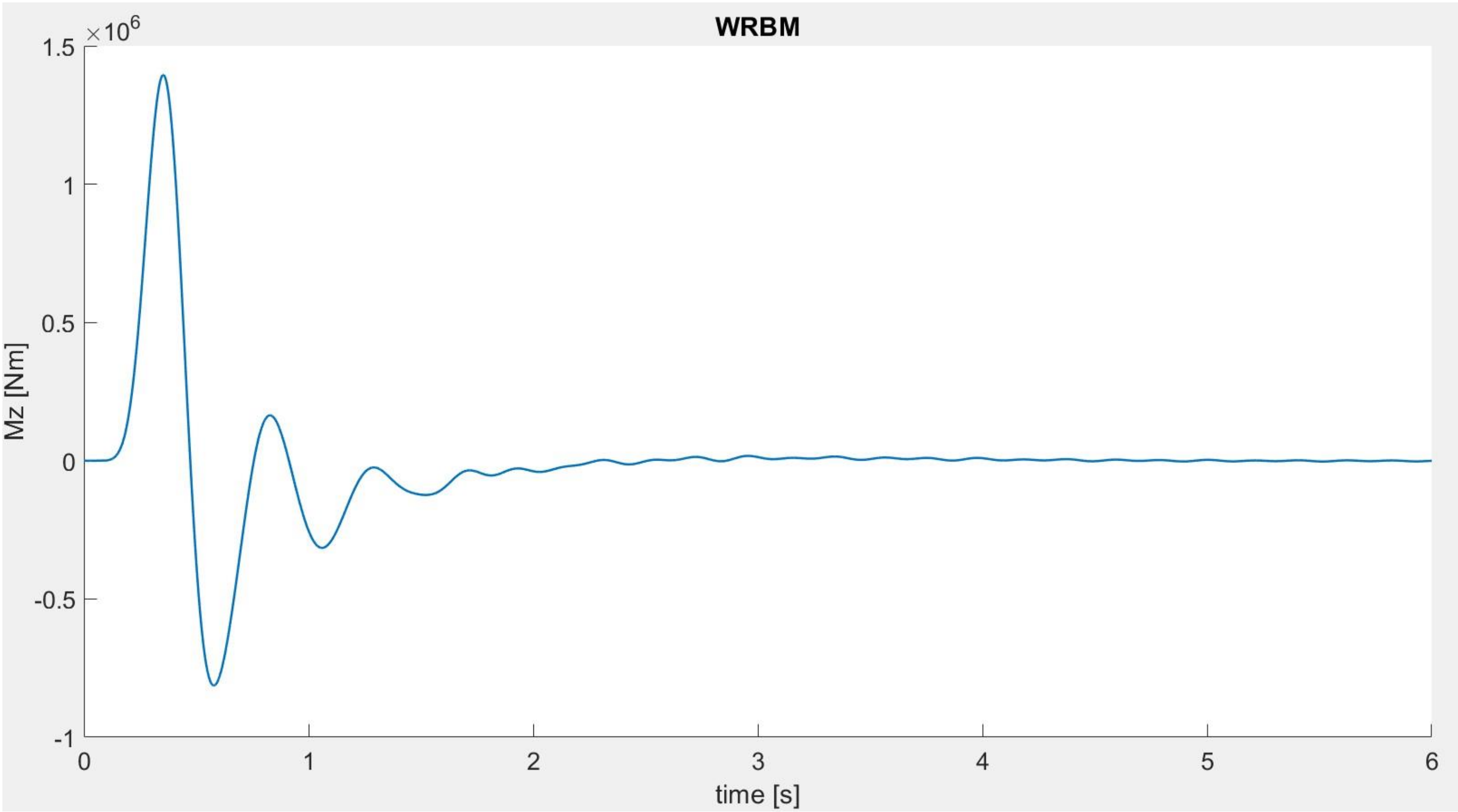
```
global beam_model
global dyn_model
input_file = 'A321_inputGust.dat';
init_dyn_model(input_file)
solve_free_lin_dyn('dT', 5e-3, 'Tmax', 6);
```

Main results can be extracted by post process commands :





Main focus is given on the evolution of wing-root bending moment and its evolution in time :



The hinge device

- A second model has been built to investigate the effects of a increased wingspan (+25%), while the other characteristic have remained the same has the baseline model.

- Once the Guess sizing is completed among the outputs there is a file which contains the stick beam model definition, where nodes and bars are defined.

- The idea to reproduce the hinge behaviour is modifying the definition of the node set in order to introduce an elastic coupling, to make the wing tip free to fold.

Nodes definition

```
GRID    2010    0       22.6648 12.0066 -0.255380       0       0
GRID    2011    0       23.1436 13.2458 -0.123640       0       0
GRID    2012    0       23.6224 14.485  0.0081040       0       0
GRID    2013    0       24.1012 15.7242 0.1398510       0       0
GRID    2014    0       24.58   16.9634 0.2715970       0       0
GRID    8001    0       24.58   16.9634 0.2715970       0       0
GRID    2015    0       25.1303 18.319  0.41318 0       0       0
GRID    2016    0       25.6806 19.6746 0.5547630       0       0
GRID    2017    0       26.231  21.0301 0.6963460       0       0
GRID    2018    0       26.7813 22.3857 0.8379290       0       0
GRID    2000    0       19.2588 0.      -1.3248 0       0       0
```

```
CBAR    2013    2013    2013    2014    0.008225-0.109520.99395 GGG
CELAS2  8001    K1      2014    1       8001    1
CELAS2  8002    K2      2014    2       8001    2
CELAS2  8003    K3      2014    3       8001    3
CELAS2  8004    1.      2014    4       8001    4
CELAS2  8005    K5      2014    5       8001    5
CELAS2  8006    K6      2014    6       8001    6
CBAR    2014    2014    8001    2015    0.008225-0.109520.99395 GGG
```

Next steps

- Validating the idea for the hinge device reproduction with the elastic coupling

- Try to reproduce the flare angle, up to know the model is equipped with a hinge aligned with the x-axis only

- Running the analysis for trim and gust for the new model

- Comparig the results with the baseline model seeking for better performance and loads alleviation

Thank for your precious attention!

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