PyPAD: a Framework for Multidisciplinary Aircraft Design

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Introduction

Background. The preliminary design of an aircraft is the phase of the project when all the computations regarding aerodynamic performances and structural behavior are executed in order to freeze the optimal configuration and focus on the detailed design of the different parts. It is a complex and iterative task involving a lot of different disciplines and it is becoming more challenging due to the reduced budget, compressed time and new technical challenges.

Aim of the research. PyPAD (Python module for Preliminary Aircraft Design) has been developed to solve the principal issues of the typical approach used during the preliminary project:

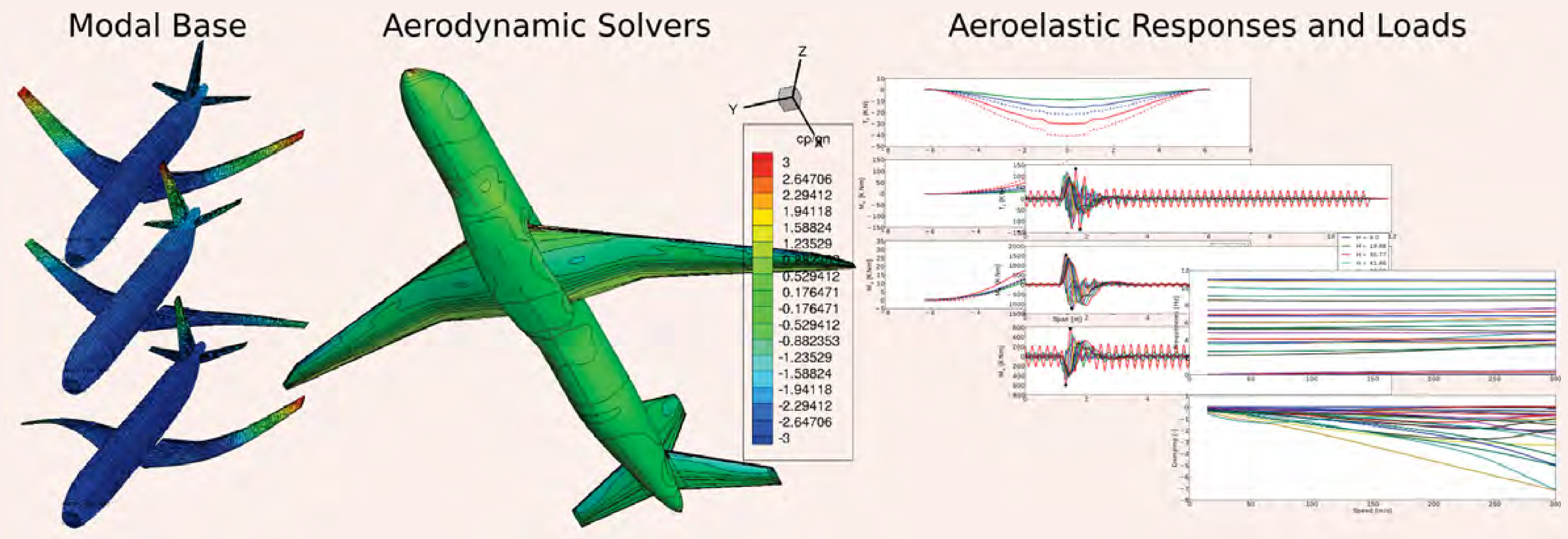
- All the iterations, the models definition, are performed manually;
- Change at the conceptual level are very expensive to analyze;
- The aeroelastic effects (more and more important in modern projects) are used to check the sizing solution not to drive it.

PyPAD (Python module for Preliminary Aircraft Design)

PyGFEM (Python modules for the Generation of Finite Element Models):

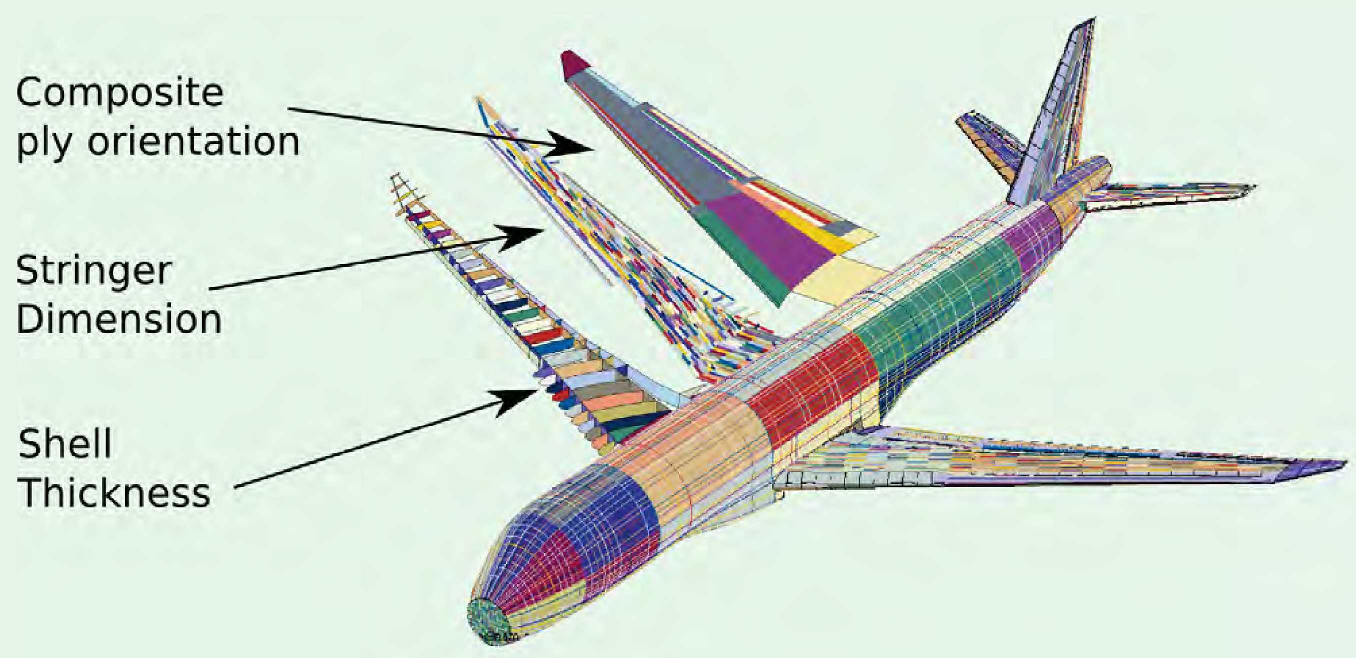
It is a Python object-oriented tool, developed taking advantages of Abaqus-CAE API, able to define structural and aerodynamic models, as the one reported in the figure above, fully automatically. It is also able to handle the different structural property definitions of the FEM and to export a parametric structural model used as input for the optimization module (PySIZE).

PyAERO (Python module for the AEROelastic analysis):



developed to compute all the aeroelastic responses such as Trim, Flutter, Dynamic Analysis, and the sizing loads of the structures; it couples the Abaqus structural model defined by PyGFEM and an aerodynamic solver based on the Morino method. It is written using Python and FORTRAN, exploiting the power of parallel computing using OpenMP.

PySIZE (Python module for multi-disciplinary SIZing):



takes advantages of the Python optimization library *pyOpt*; can handle several kind of structural parameters, like shell thickness and stringer section dimensions. It can compute both the value and the derivative (analytically) of several structural and aeroelastic responses, using Abaqus for the computation of stresses, global stiffness and mass matrices and their derivatives.

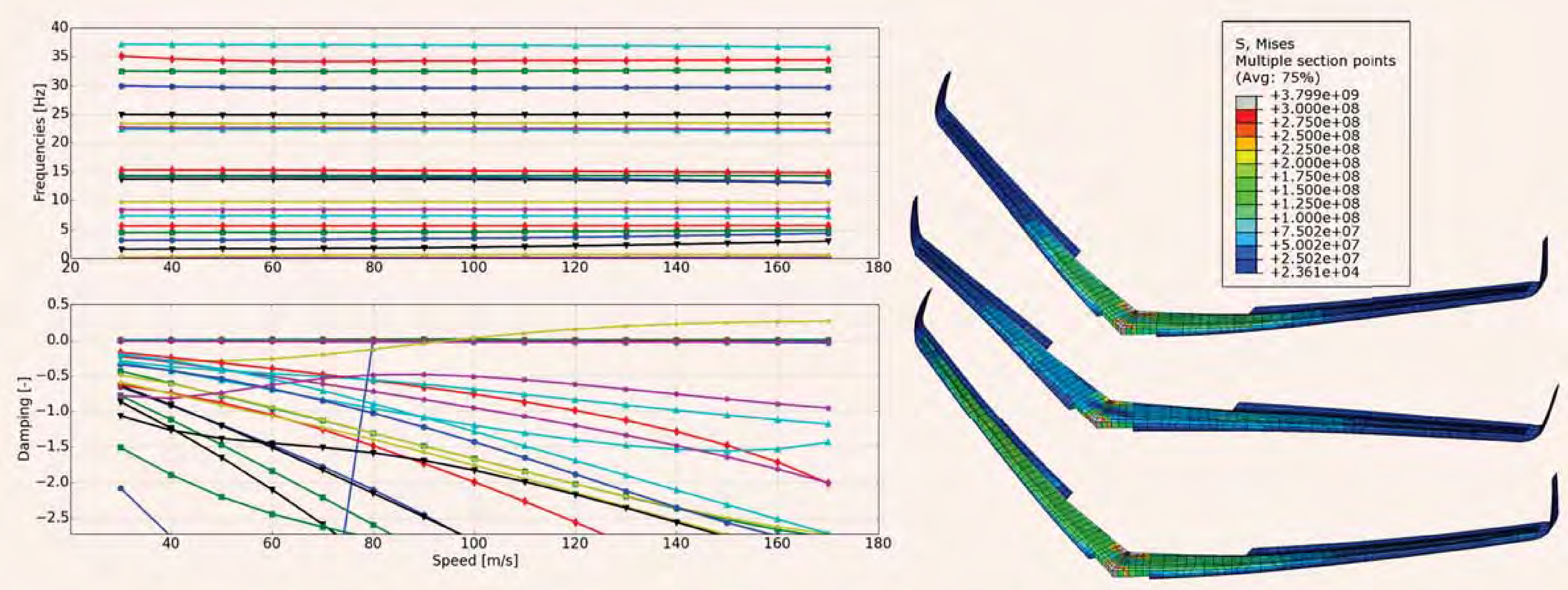
Test Case: *Osprey*

The test case shown here regards the wing structural optimization of *Osprey*, an UAV dedicated for the territory monitoring, having a very particular design without the tail planes. The preliminary informations about the structural properties have been obtained by the sizing performed using NeoCASS (open source tool developed in our department), used as start point for the analysis of PyPAD.

Osprey Model:

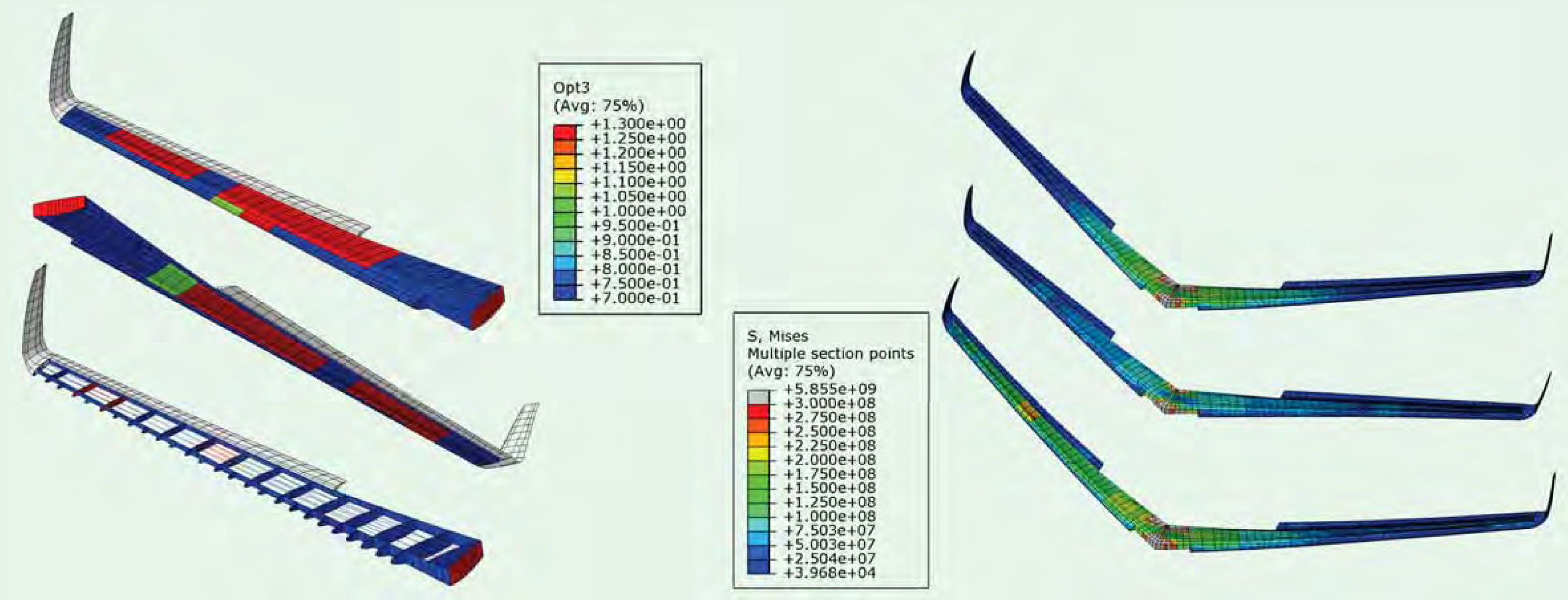
Only the wing is described by the structural model and the fuselage is considered by its inertial properties. The aeroelastic model is assembled using the first thirty modes of the FEM and the aerodynamic one is defined by about 20000 body elements. The total mass of the model is 4900 Kg.

Initial Responses:



Several analysis have been performed to investigated the initial solution. The flutter diagram reported above does not show instabilities except for the one regarding the short period mode (a rigid mode of the full aircraft) that is intrinsic of this type of configuration and cannot be suppressed only by the structural design (a control system could be required). The stress level on the structures is below the 300MPa except for the regions close to the symmetry plane where the fuselage masses are attached. This zone is not considered during the optimization because strongly affected by the constraints.

Optimal Solution:



The optimization is performed to find a better design without loosing the good stability performances. The wing structure is parametrized by 158 variables, describing the aluminum thickness of skins, ribs and webs and the dimension of the stringer sets. The constrains of the optimizations are the Von-Mises stress in three different load conditions, the stability of the first fifteen modes and the efficiency of the aileron under the aeroelastic deformation. As shown by the pictures above, the optimizer reduced most of the variables, adding material in some key regions. As results the model is still stable, the stress level is higher than before but below the 300MPa (maximum limit) and the design is more efficient than the initial one. The total mass at the end of the optimization is 4798 Kg, the mass of the wing is reduced by 8.5%.

Conclusions

The framework takes advantages of Abaqus both for the model definition and for the FEM computations, coupling these informations with an aerodynamic panel method and a full package of aeroelastic solver. The reported test case shows that PyPAD could be a valid tool during the design of an aircraft.