# Blended Wing Body Wingbox Design with Aeroelasticity Constraints

João CRUZ MATOS[1] , Joseph MORLIER[2] , Simone CONIGLIO[2] , Joan MAS COLOMER[2]

1-2: ISAE Supaero, Toulouse - France
1. joao.cruz-ferreira-matos@student.isae-supaero.fr

## Introdution

The project consists in designing an innovative wingbox through topology optimization that accounts for aeroelasticity deformation (Figure 2). This innovative wingbox will be applied to an innovative design, a Blended Wing Body design (Figure 1).

Figure 1: Blended Wing Body. [1]

The project is separated in two parts:

1. First develop a 2D topology optimization implementation in Python of a wing rib.
2. Then build a MDO formulation to design a BWB wingbox and add aeroelasticity constraints

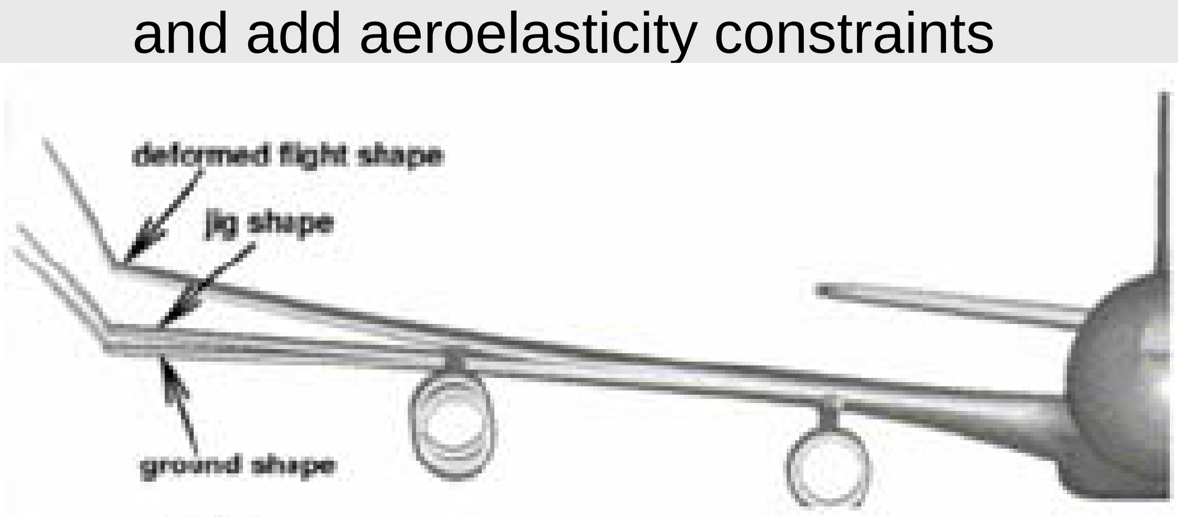


Figure 2: Wing deformation due to the Aerodynamic Forces. [2]

## Topology Optimization

According to Hayoung Chung (2019) [3] topology optimization is a numerical method that computes an optimal structural layout for a set of objectives and constraints with the goal of getting a lighter structure using less material. This structure will have material only in the most critical areas. In Figure 3 it can be seen a basic example of topology optimization in an MBB beam

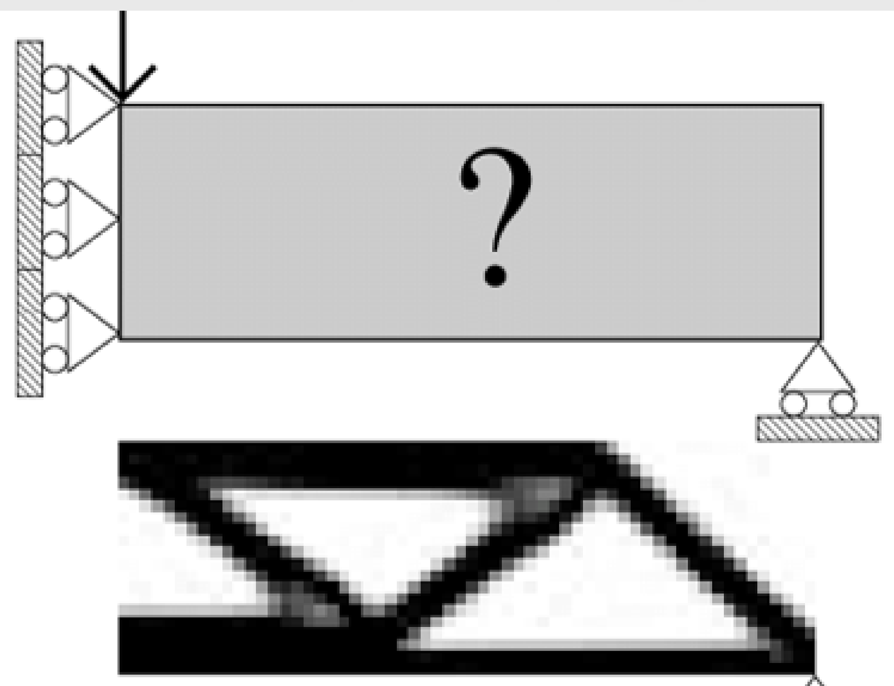


Figure 3: MBB beam example. [4]

There are different formulations in topology optimization. In this project it is used the Solid Isotropic Materials with Penalization (SIMP) method.

The SIMP formulation can be seen in Equation 1 where the goal is to minimize the compliance.

$$\begin{cases} min_{\{x\}} c = U^T F \\ \frac{V(x)}{V_0} \leq f(volfrac) \\ 0 \leq x_{min} \leq x \leq 1 \end{cases} \tag{1}$$

Where $c$ is the compliance, $U$ is the global displacement vector, $F$ is the external forces vector, $V(x)$ is the material volume, $V_0$ is the design domain volume, $f(volfrac)$ is the constrained volume fraction and $x$ is the density of each element.

## Python Implementation

The fist part of the project, completed, consists in developing a topology optimization code in Python with several SIMP approach methods, such as the Moving Morphable Components (MMC) (Guo et al., 2014) [5] and the Generalized Geometry Projection (GGP) by Simone Coniglio.

The optimizer used in the implementation is the Method of Moving Asymptotes (Svanberg, 1987) [6].

In Figure 4 it is displayed the graph of the objective function in terms of the volume fraction constraint and the plots of the optimal structure for each volume fraction. The figure shows well the compromise between light and strong structures. Engineers try to find the perfect equilibrium for each specific structure.

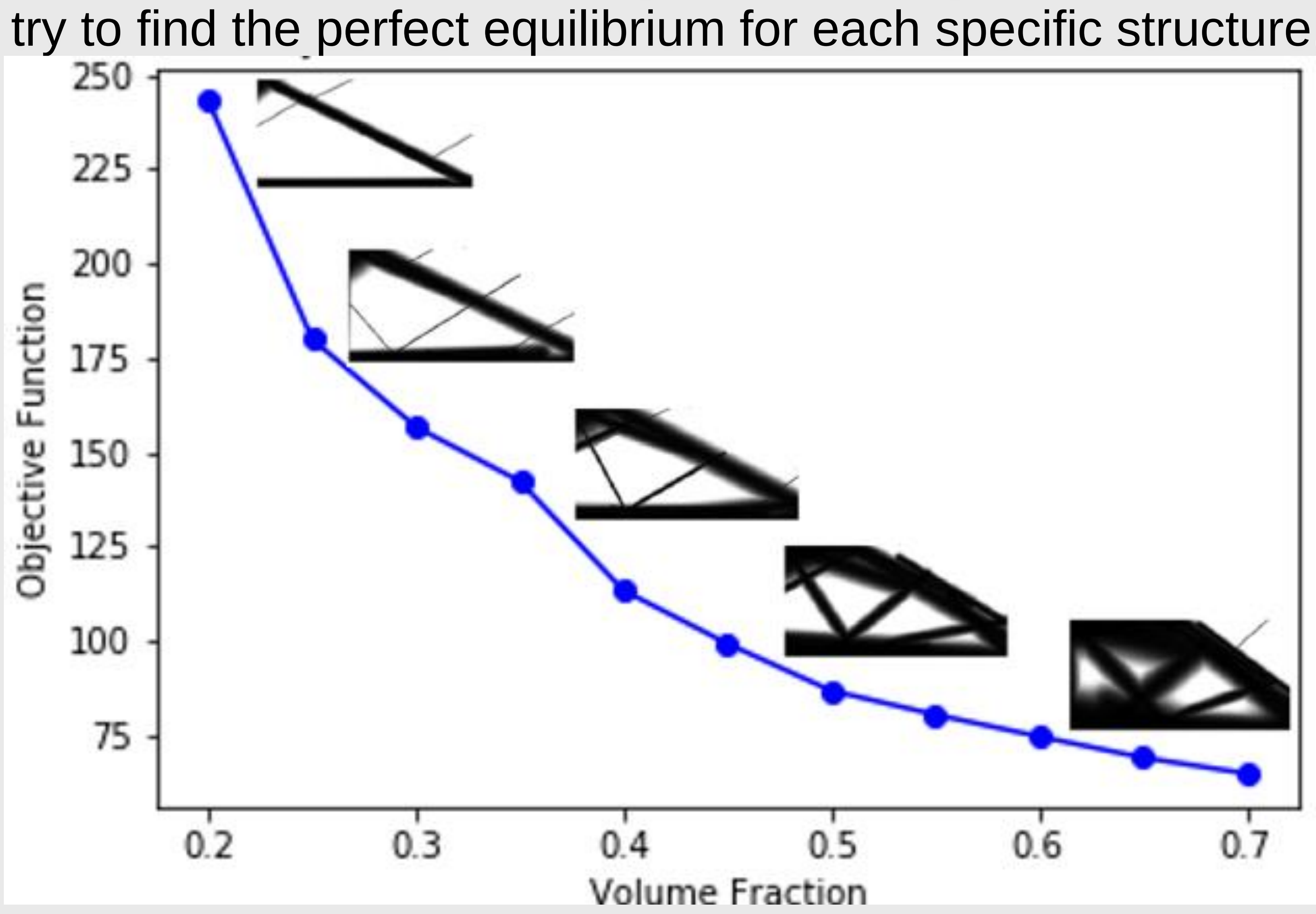


Figure 4: Objective Function in terms of Volume Fraction.

## Next Steps

The next steps on this project are to add to the python implementation a wing rib boundary condition and two more methods: the Moving Node Approach (MNA) by Overveld (2012) [7] and the Geometry Projection (GP) by Norato (2015) [8].

With that concluded, it will be used OpenMDAO to optimize the wingbox ribs (Figure 5) with the different disciplines including the aeroelasticity.

This python implementation might also be expanded to 3D to be used in other projects.

[1]https://aviationweek.com/blog/landmark-nasas-mini-bwb-x-48c
[2]https://www.researchgate.net/publication/260907676_Natural_Laminar_Flow_Transonic_Wing_Design_Applied_to_Future_Innovative_Green_Regional_Aircraft/figures?lo=1
[3] Hayoung Chung, John T, H. J. S. G. H. A. K. (2019). Topology optimization in openmdao.
[4] Sigmund, O.: A 99 Line Topology Optimization Code Written in MATLAB. Structural and Multidisciplinary Optimization 21, 120-127
[5] Guo, X., Zhang, W., and Zhong, W. (2014). Doing topology optimization explicitly and geometrically—a new moving morphable components based framework
[6] Svanberg, K. (1987). The method of moving asymptotes—a new method for structural optimization. International Journal for Numerical Methods in Engineering.
[7] Overveld, J. (2012). The moving node approach in topology optimization. Master Thesis, TU Delft, Delft University of Technology.
[8} Norato, J. (2015). A geometry projection method for the optimal distribution of short fiber reinforcements. ASME 2015 International Design Engineering Technical Conferences and Computers and Information in Engineering Conference.
[9]https://www.researchgate.net/publication/229348018_A_new_procedure_for_aerodynamic_missile_designs_using_topological_optimization_approach_of_continuum_structures/figures?lo=1&utm_source=google&utm_medium=organic

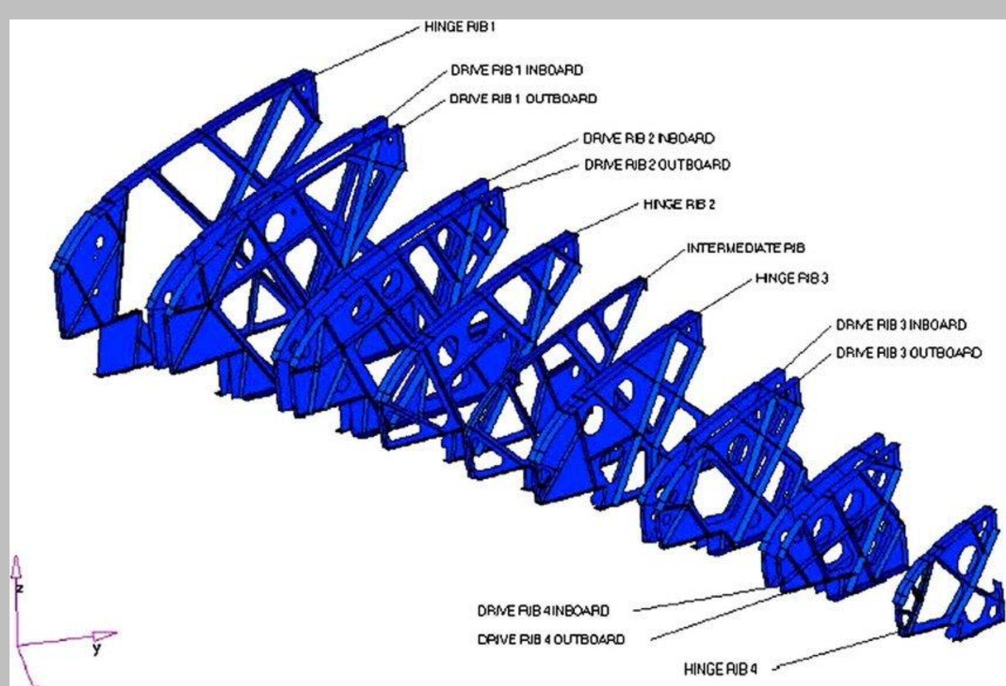


Figure 5: Wingbox ribs [9]