BWB Wingbox Design with Aeroelasticity Constraints

João Matos

S2 Research Project Final Presentation

aviationweek.com

Table of Contents

Context of the Project

1. Topology Optimization

2. Wingbox Design

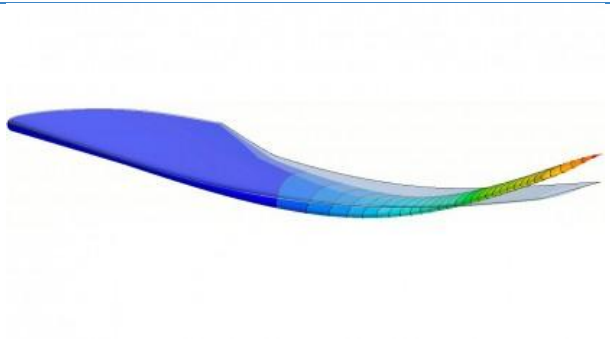
3. MDO

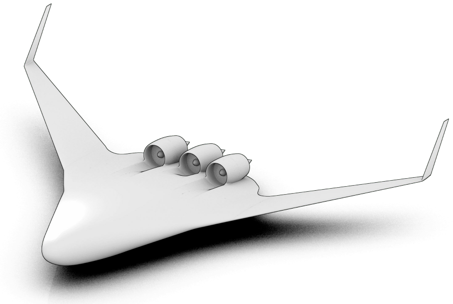
4. BWB

Important Aspects

1. Aerostructural Coupling

2. Blended Wing Body Design





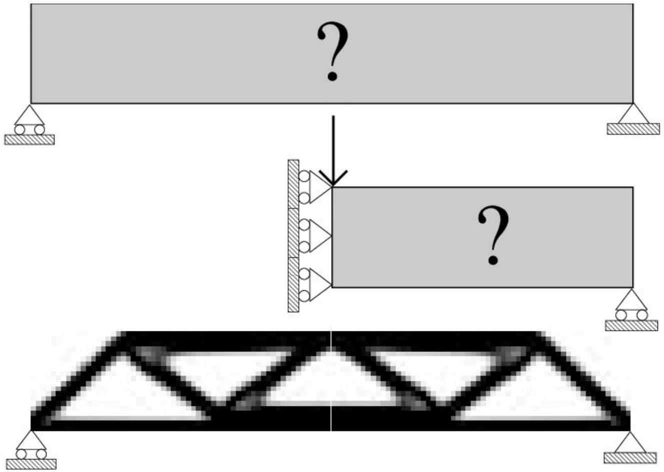
Semester 2 Goals

1. State of the Art.
2. Learn more about Topology Optimization.
3. Understand the MATLAB Topology Optimization codes.
4. Create a Topology Optimization implementation in Python.
5. Add different methods to the code.

Theoretical Background

Topology Optimization with SIMP

$$
\begin{cases}
min_{\{x\}}\ c = U\,F = \displaystyle\sum_{e=1}^{N} (x_e)^p\, u_e^T\, k_e\, u_e \\
\dfrac{V(x)}{V_0} \leq Volume\ Fraction \\
0 \leq\ x_{min} \leq x \leq 1 \\
F = K\,U
\end{cases}
$$



Methods

- Generalized Geometry Projection (GGP) - Coniglio, S. et al (2019)
- Moving Morphable Components (MMC) - Guo et al. (2014)
- Moving Node Approach (MNA) - Overveld (2012)
- Geometry Projection (GP) - Norato (2015)

Topology Optimization Implementations

- A 99 line topology optimization code written in MATLAB - Sigmund, O. (2001)
- Efficient topology optimization in MATLAB using 88 lines of code - Andreassen, E. et al. (2011)
- Generalized Geometry Projection - Coniglio, S. et al (2019)
- Topology optimization codes written in Python

Numerical Implementation

Implementation

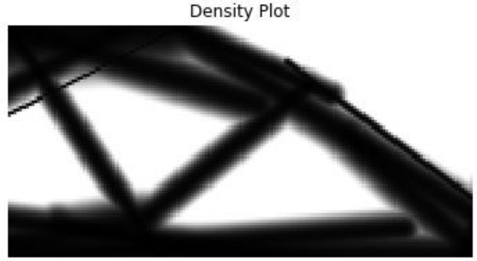
- Python
- SIMP
- Method of Moving Asymptotes - Svanberg, K. (1987)

$$\begin{cases} min_{\{x\}}\ c = U^T K U = \sum_{e=1}^{N} (x_e)^p\, u_e^T\, k_e\, u_e \\ \frac{V(x)}{V_0} \leq Volume\ Fraction \\ 0 \leq\ x_{min} \leq x \leq 1 \end{cases}$$

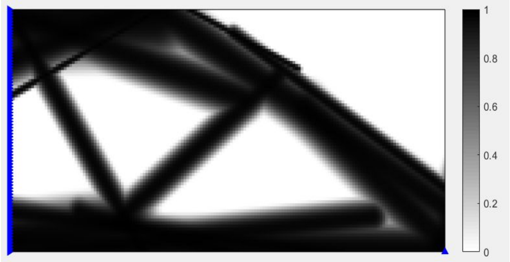
Implementations Comparison

```
it.: 1 , obj.: 113843.451 Vol.: 0.090, kktnorm.: 10.001  ch.: 1.000
it.: 2 , obj.: 8116.545 Vol.: 0.181, kktnorm.: 140.791  ch.: 0.071
it.: 3 , obj.: 2519.770 Vol.: 0.252, kktnorm.: 106.133  ch.: 0.068
it.: 4 , obj.: 1020.707 Vol.: 0.297, kktnorm.: 129.679  ch.: 0.062
it.: 5 , obj.: 573.373 Vol.: 0.331, kktnorm.: 104.725  ch.: 0.059
it.: 6 , obj.: 324.040 Vol.: 0.370, kktnorm.: 173.326  ch.: 0.040
it.: 7 , obj.: 189.456 Vol.: 0.430, kktnorm.: 36.548  ch.: 0.044
it.: 8 , obj.: 159.171 Vol.: 0.452, kktnorm.: 19.003  ch.: 0.043
it.: 9 , obj.: 141.515 Vol.: 0.473, kktnorm.: 11.453  ch.: 0.045
it.: 10 , obj.: 128.585 Vol.: 0.492, kktnorm.: 7.597  ch.: 0.030
```

```
It.:    1 Obj.:1.138e+05 Vol.:  0.090 kktnorm.: 10.001 ch.:  1.000
It.:    2 Obj.:8.117e+03 Vol.:  0.181 kktnorm.:140.791 ch.:  0.071
It.:    3 Obj.:2.520e+03 Vol.:  0.252 kktnorm.:106.133 ch.:  0.068
It.:    4 Obj.:1.021e+03 Vol.:  0.297 kktnorm.:129.679 ch.:  0.062
It.:    5 Obj.:5.734e+02 Vol.:  0.331 kktnorm.:104.725 ch.:  0.059
It.:    6 Obj.:3.240e+02 Vol.:  0.370 kktnorm.:173.326 ch.:  0.040
It.:    7 Obj.:1.895e+02 Vol.:  0.430 kktnorm.: 36.548 ch.:  0.044
It.:    8 Obj.:1.592e+02 Vol.:  0.452 kktnorm.: 19.003 ch.:  0.043
It.:    9 Obj.:1.415e+02 Vol.:  0.473 kktnorm.: 11.453 ch.:  0.045
It.:   10 Obj.:1.286e+02 Vol.:  0.492 kktnorm.:  7.597 ch.:  0.030
```



Python Implementation



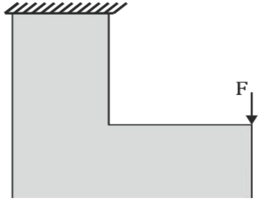
MATLAB Implementation

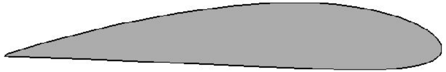
Methods

Generalized Geometry Projection (GGP)

Moving Morphable components (MMC)

Boundary Conditions



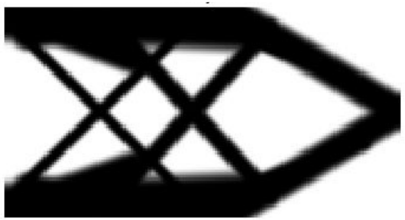


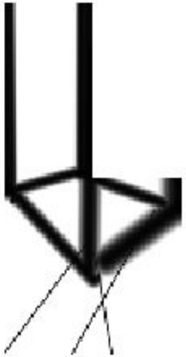
MBB

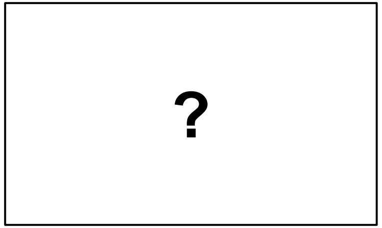
Short Cantilever

L Shape

Wingbox





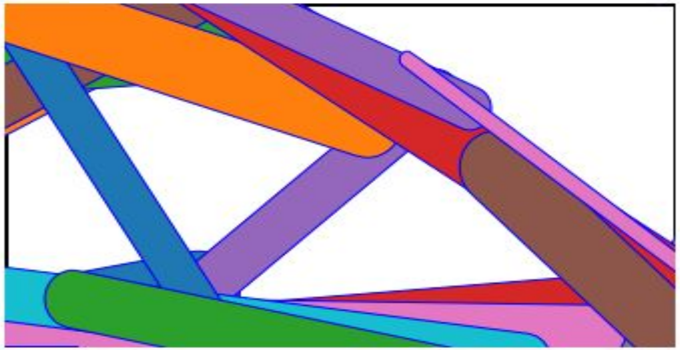


Density and Components Plots

Black → xe = 1 (Fully Material)
White → xe = 0 (Void)

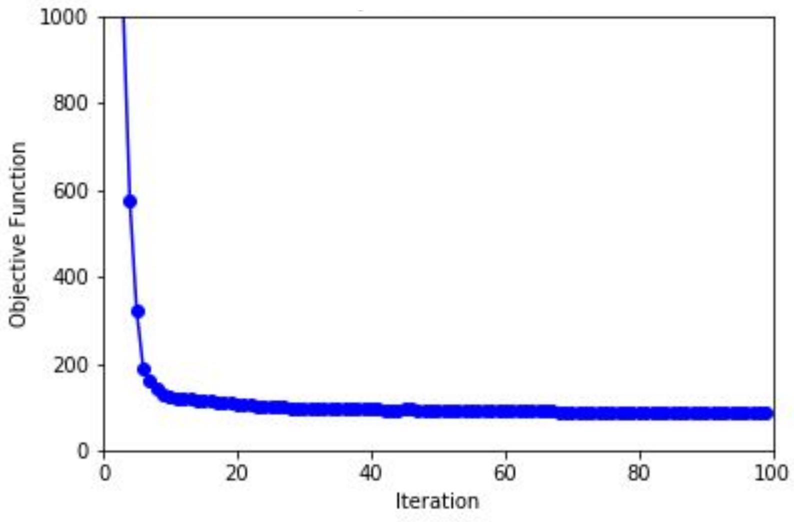
Density Plot

Each component is defined by:
x, y, L, h, ϴ



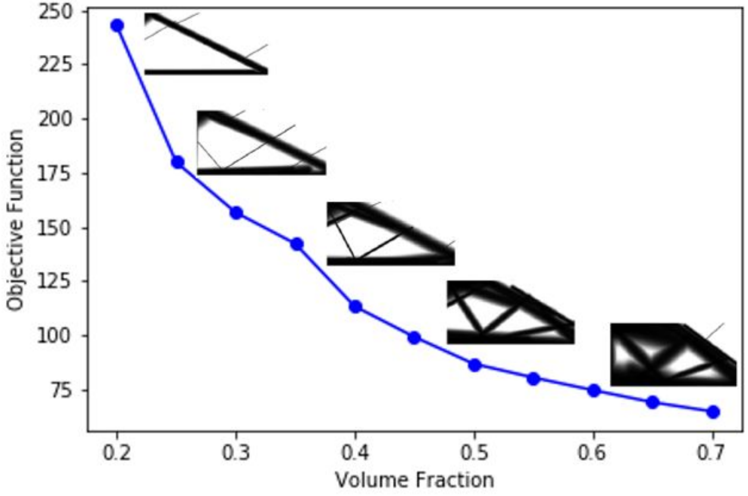
Components Plot

Objective Function

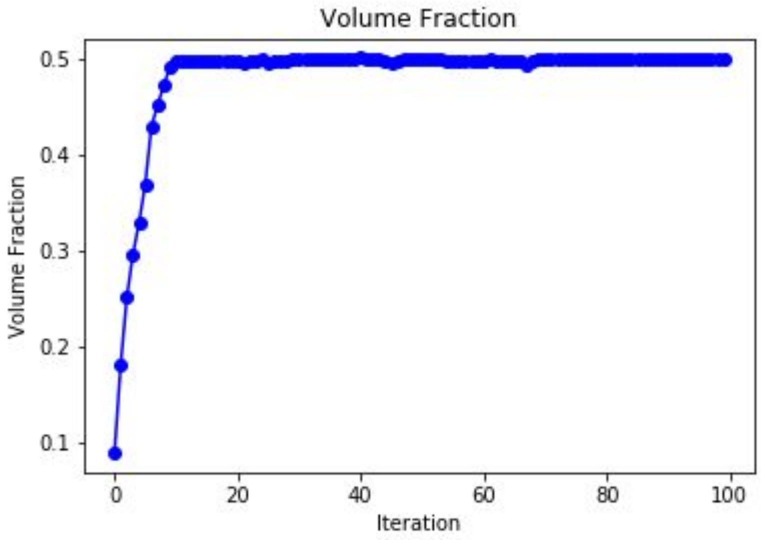


$$min_{\{x\}}\ c = \sum_{e=1}^{N} (x_e)^p\ u_e^T\ k_e\ u_e$$

Objective Function and Volume Fraction



Volume Fraction



Mesh Sizes

40 x 20 elements

80 x 40 elements

120 x 60 elements

160 x 80 elements

Conclusions

Future Work

Goals for Semester 3

Add one more boundary condition:

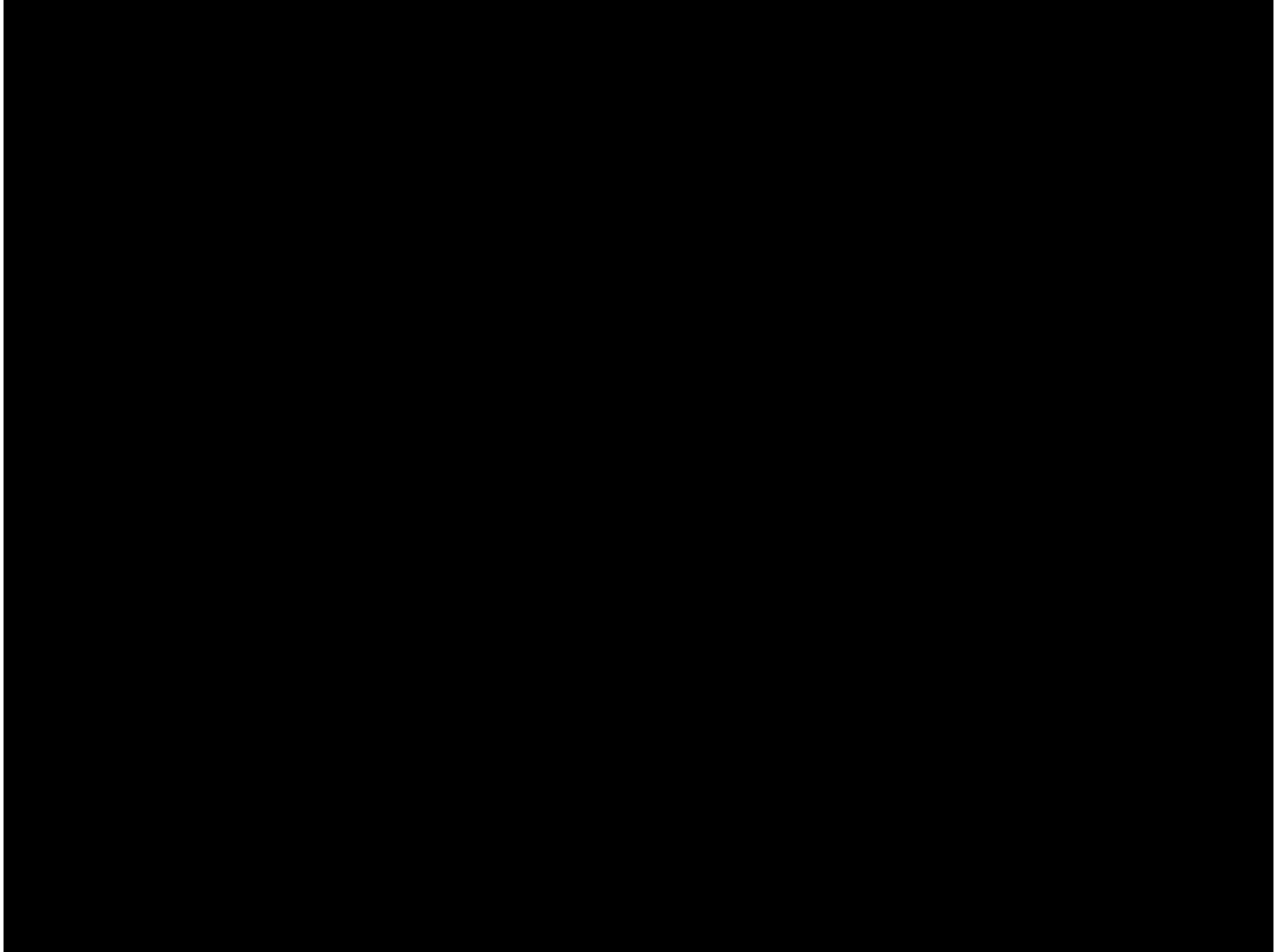
- ❑ Wingbox

Add more methods to the code:

- ❑ Moving Node Approach (MNA)
- ❑ Geometry Projection (GP)

Goals for Semester 3

- Use OpenMDAO to create a wingbox.
- Add aeroelasticity constraints.
- Apply to the wingbox of a BWB.



Any Questions?

Jasa, J.P., Hwang, J.T. & Martins, J.R.R.A. Struct Multidisc Optim (2018) 57: 1815. https://doi.org/10.1007/s00158-018-1912-8

Sigmund, O. (2001). A 99 line topology optimization code written in matlab. Structural and Multidisciplinary Optimization, 21(2):120–127.

Andreassen, E., Clausen, A., Schevenels, M., Lazarov, B. S., and Sigmund, O. (2011). Efficient topology optimization in matlab using 88 lines of code. Structural and Multidisciplinary Optimization, 43(1):1–16.

Guo, X., Zhang, W., and Zhong, W. (2014). Doing topology optimization explicitly and geometrically—a new moving morphable components based framework.

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.

Overveld, J. (2012). The moving node approach in topology optimization. Master Thesis, TU Delft, Delft University of Technology.

Svanberg, K. (1987). The method of moving asymptotes—a new method for structural optimization. International Journal for Numerical Methods in Engineering.

https://mdx2.plm.automation.siemens.com/ko/industries/%ED%95%AD%EA%B3%B5%ED%83%84%EC%84%B1%ED%95%99

https://www.agile-project.eu/use-case-blended-wing-body-bli/

https://www.arxiv-vanity.com/papers/1709.09578/

https://www.researchgate.net/publication/251502916_Stress-related_topology_optimization_via_level_set_approach/figures?lo=1&utm_source=google&utm_medium=organic

http://m2do.ucsd.edu/research/

https://www.symscape.com/downloads?page=1