Master of Aerospace Engineering - Research Project

HALE AEROECODESIGN

S2 Project Report – 26/06/2020

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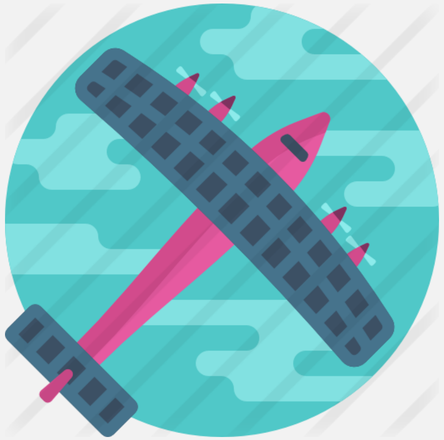
OUTLINE

- STATE OF THE ART
- GOAL OF THE PROJECT
- MILESTONES OF THE PROJECT
- RESULTS
- CONCLUSIONS
- FUTURE WORK



STATE OF THE ART

- HALE ➤ High-Altitude Long Endurance Drone
  - Atmospheric satellites or atmosats
  - Services conventionally provided by space satellites
  - Environment-friendly ➤ Powered by solar energy
  - CO_2 emissions ➤ Manufacturing and materials

Fig. 1: Airbus-built HALE Zephyr

- MDO ➤ Multidisciplinary Design Optimization
  - Optimum for the interaction of disciplines
  - OpenAeroStruct (based on OpenMDAO) ➤ Aerostructural optimization

GOAL OF THE PROJECT

- Refine a modified version of OpenAeroStruct presented in [1]
- CO_2 footprint optimization of a HALE
- Compromise solution between:
  - Convergence of the optimization ➤ Efficiency
  - Complexity of the model ➤ Realistic
- Validation with Facebook's single-boom HALE [2]

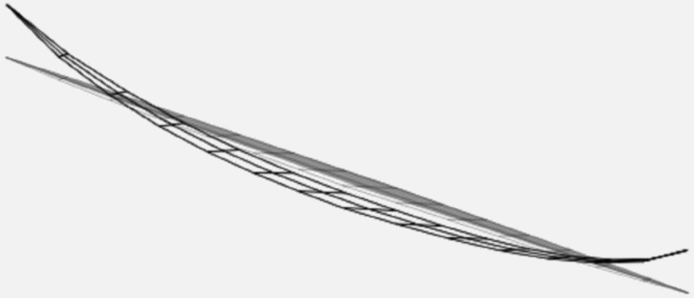


Fig. 2: Optimal HALE wing structure [1]

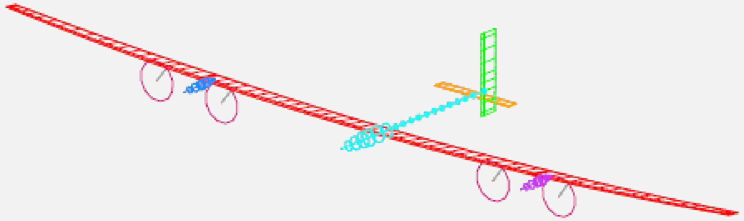
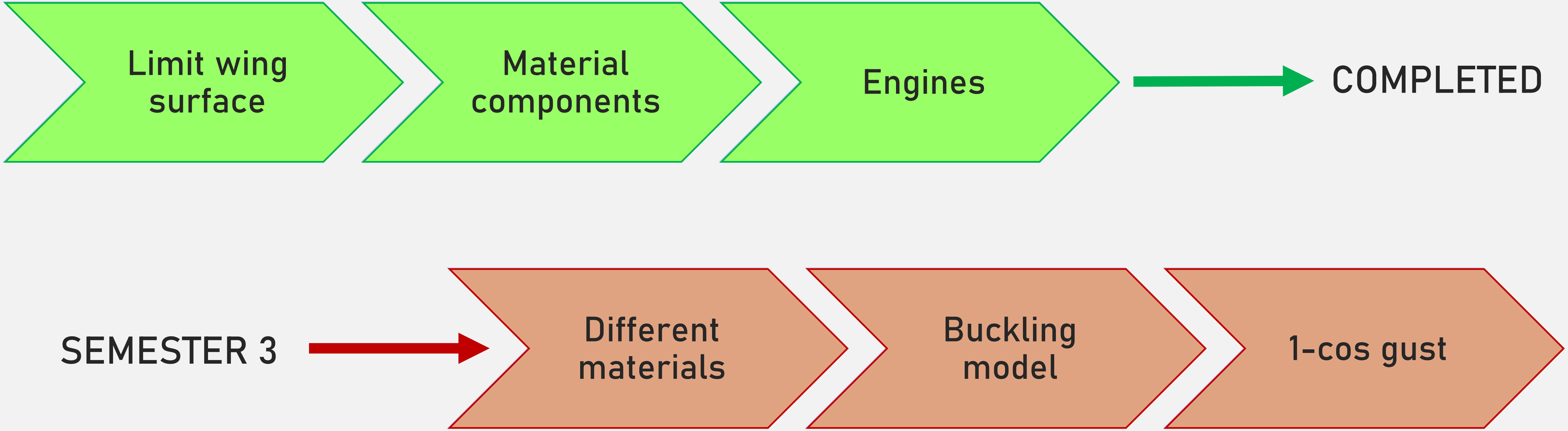


Fig. 3: Facebook's single-boom HALE [2]

[1] E. Duriez and J. Morlier, "Hale multidisciplinary design optimization with a focus on eco-material selection," ISAE Supaero, 2020.

[2] D. Colas, N. H. Roberts, and V. S. Suryakumar, "Hale multidisciplinary design optimization Part I: Solar-powered single and multiple-boom aircraft," in 2018 AviationTechnology, Integration, and Operations Conference, p. 3028, 2018.

MILESTONES OF THE PROJECT



ADD A CONSTRAINT ON THE WING SURFACE

- Reduce <u>snowball effect</u> ➤ Prevent the optimization from diverging

HALE Weight ↑ ➤ Propulsion Weight (batteries & solar panels) ↑ ➤ Structural Weight ↑ ➤ ~~Divergence~~

- Maximum wing surface threshold ➤ 200 m^2

TURN MATERIAL FUNCTION INTO OPENMDAO COMPONENTS

- Component ➤ The most efficient way for gradient-based optimization
- Replace the existing function by the component
- Access to material properties database and interpolate:
  - Young's modulus (E)
  - Shear modulus (G)
  - Failure strength
  - CO_2 emissions
- Get to know the OpenMDAO methodology

ADD ENGINES AS POINT MASSES

- Two symmetrical engines ➤ Two symmetrical point masses
- New design variable ➤ Engine spanwise location
- Same propulsion density as FB single-boom HALE [2]

$$d_{prop} = \frac{M_{prop}}{P_{prop}}$$

where d_{prop} is the propulsion density, M_{prop} is the propulsion mass, and P_{prop} is the power needed for propulsion

- Reduce the bending moment on the wing due to lift

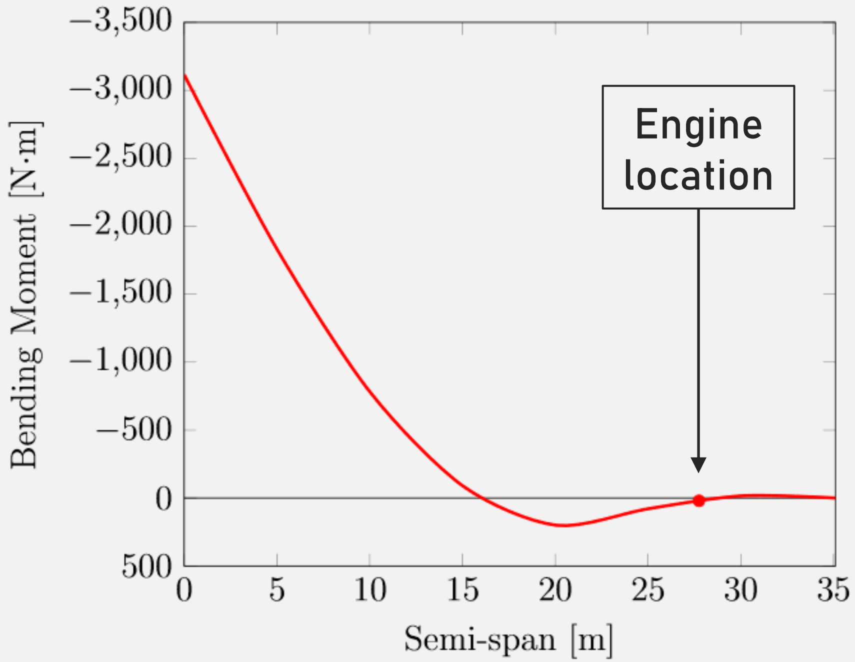


Fig. 4: Bending moment distribution along semi-span

[2] D. Colas, N. H. Roberts, and V. S. Suryakumar, “Hale multidisciplinary design optimization Part I: Solar-powered single and multiple-boom aircraft,” in 2018 AviationTechnology, Integration, and Operations Conference, p. 3028, 2018.

RESULTS

Table 1: Final design variable values for validation case

Variable	Units	HALE of [1]	FB HALE [2]	Results w/o engines	Results w/ engines
Span	m	97.5	-	93.5	70.2
Root chord	m	1.4	-	1.4	1.4
Taper ratio	-	0.32	-	0.33	0.30
Total mass	kg	378	320	435	362
Wing surface	m^2	86.6	71.8	83.4	61.3
Aspect ratio	-	94	29	105	80
C_L^{cruise}	-	1.31	1.33	1.56	1.77
$(C_L^{3/2}/C_D)^{cruise}$	-	44.1	40.1	57.8	72.1
$y_{engine}/(b/2)$	-	0	0.46	0	0.79

[1] E. Duriez and J. Morlier, “Hale multidisciplinary design optimization with a focus on eco-material selection,” ISAE Supaero, 2020.

[2] D. Colas, N. H. Roberts, and V. S. Suryakumar, “Hale multidisciplinary design optimization Part I: Solar-powered single and multiple-boom aircraft,” in 2018 AviationTechnology, Integration, and Operations Conference, p. 3028, 2018.

RESULTS

Table 2: Performance values of the optimization for validation case

Performance	Units	HALE of [1]	Results w/o engines	Results w/ engines
Cases	-	24	24	24
Convergences	-	7	12	11
Time	h	2	3	4

[1] E. Duriez and J. Morlier, “Hale multidisciplinary design optimization with a focus on eco-material selection,” ISAE Supaero, 2020.

CONCLUSIONS

- Without engines ➤ Better convergence and same results as in [1]
- With engines ➤ Worse convergence than without engines but better results
- Same differences with respect to [2] as in [1] ➤ Very high aspect ratio
- Need for 1-cosine gust and more complex buckling model

[1] E. Duriez and J. Morlier, "Hale multidisciplinary design optimization with a focus on eco-material selection," ISAE Supaero, 2020.

[2] D. Colas, N. H. Roberts, and V. S. Suryakumar, "Hale multidisciplinary design optimization Part I: Solar-powered single and multiple-boom aircraft," in 2018 AviationTechnology, Integration, and Operations Conference, p. 3028, 2018.

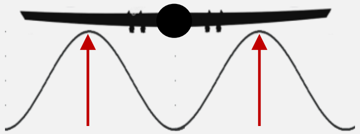
FUTURE WORK

COMPLETED

- Limit wing surface
- Material components
  - Young's modulus
  - Shear modulus
  - Yield strength
  - CO_2 emissions
- Engines
  - Position
  - Mass

SEMESTER 3

- Different materials
  - Two materials
    - Skins
    - Spars
- Buckling model
  - Curved plates
  - Compression
  - Shear
- 1-cos gust



"True optimization is the revolutionary contribution of modern research to decision processes"

George Dantzig

THANKS FOR YOUR ATTENTION!

ANY QUESTION?