Master of Aerospace Engineering - Research Project

HALE AEROECODESIGN

S2 – Progress Repot

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OUTLINE

- STATE OF THE ART
- GOAL OF THE PROJECT
- MILESTONES OF THE PROJECT

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

STATE OF THE ART

Table 1: Design variable values for validation case [1]

Variable	Units	HALE of [1]	FB HALE [2]
Span	m	97.5	-
Root chord	m	1.4	-
Taper ratio	-	0.32	-
Total mass	kg	378	320
Wing surface	m^2	86.6	71.8
Aspect ratio	-	94	29
C_L^{cruise}	-	1.31	1.33
$(C_L^{3/2}/C_D)^{cruise}$	-	44.1	40.1

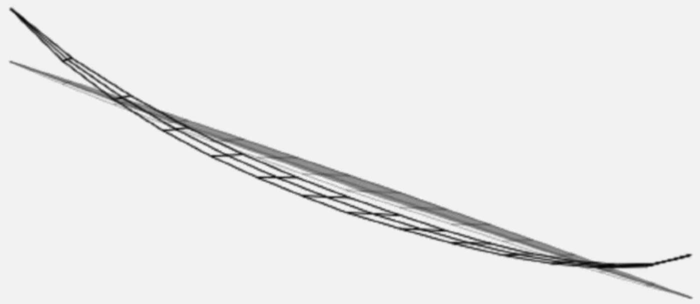

Fig. 2: Optimal HALE wing structure [1]

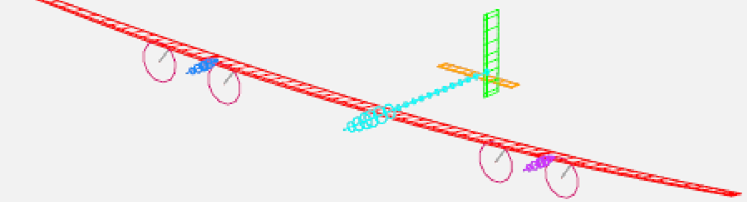

Fig. 3: Facebook's single-boom HALE [2]

[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 opti-mization part i: Solar-powered single and multiple-boom aircraft," in 2018 AviationTechnology, Integration, and Operations Conference, p. 3028, 2018.

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

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

MILESTONES OF THE PROJECT

- Task 1: Add a constraint on the wing surface
- Task 2: Fix some design variables
- Task 3: Turn material function into OpenMDAO component
- Task 4: Set different materials for different parts of the wing
- Task 5: Introduce a more complex buckling model
- Task 6: Add engines as point masses
- Task 7: Model a two dimensional discrete gust

TASK 1: ADD A CONSTRAINT ON THE WING SURFACE

- Reduce snowball effect ➤ Prevent the optimization from diverging
  - Maximum wing surface threshold

TASK 2: FIX SOME DESIGN VARIABLES

- Make the problem more computationally efficient
  - Fix some optimization variables ➤ tapper ratio, root chord…

TASK 3: TURN MATERIAL FUNCTION INTO OPENMDAO COMPONENT

- Currently ➤ Function to use material properties
- OpenMDAO ➤ Modular implementation in components
- Components ➤ More efficient for gradient-based optimization
- Replace the function by a component
- Get to know the OpenMDAO methodology

TASK 4: SET DIFFERENT MATERIALS FOR DIFFERENT PARTS OF THE WING

- Currently ➤ Sigle material for the hole wing
- Allow the optimization to use two different materials:
  - One for the spars
  - One for the skins
- Better solution in terms of CO_2 footprint and weight
- More design variables ➤ Longer optimization

TASK 5: INTRODUCE A MORE COMPLEX BUCKLING MODEL

- Currently ➤ Skins as rectangular flat plates under axial complexion
- Consider curved plates
- Under combined axial compression and shear
- Parabolic interaction:

$$R_S^2 + R_C = 1$$

where R_s and R_C are the stress ratios for shear and compression

- Use of empirical data [3]

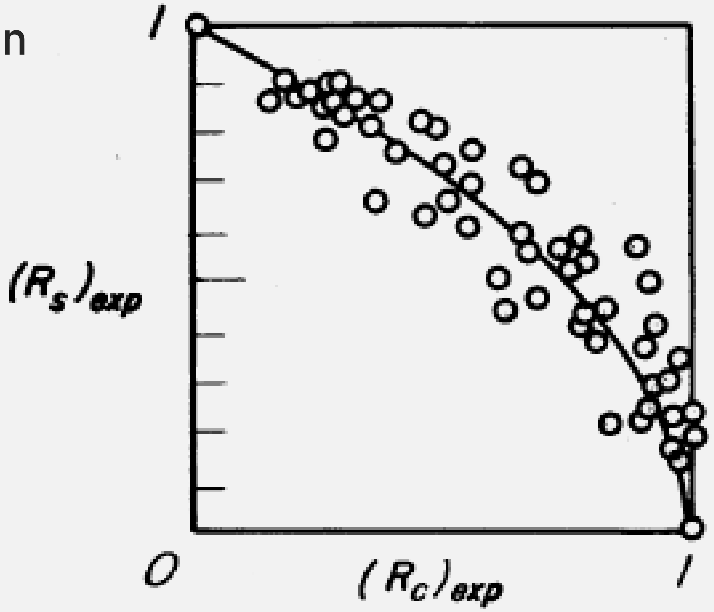

Fig. 4: Comparison of test data with parabolic interaction curves for curved plates under combined shear and axial compression [3]

[3] G. Gerard and H. Becker, “Handbook of structural stability. part 3. buckling of curved plates and shells.,” tech. rep., NATIONAL AERONAUTICS AND SPACE ADMIN-ISTRATION WASHINGTON DC, 1957.

TASK 6: ADD ENGINES AS POINT MASSES

- Currently ➤ Propulsion mass in the plane of symmetry
- Already implemented in OpenAeroStruct
- Two symmetrical engines ➤ Two symmetrical point masses
- New design variable ➤ Distance from the plane of symmetry
- Reduce the bending moment on the wing due to lift

TASK 7: MODEL A TWO DIMENSIONAL DISCRETE GUST

- Currently ➤ One-dimmensional shear gust

- Implement a 1-cosine gust profile [2]:

$$w_g(y) = \frac{U_{de}}{2}\left[1 - cos\left(\frac{2\pi y}{aL_{span}}\right)\right]$$

where w_g is the gust velocity, U_{de} is the derived equivalent gust velocity, L_{span} is the aircraft span, a is a factor and y is the spanwise coordinate

- Increase bending moment ➤ Penalize large aspect ratios

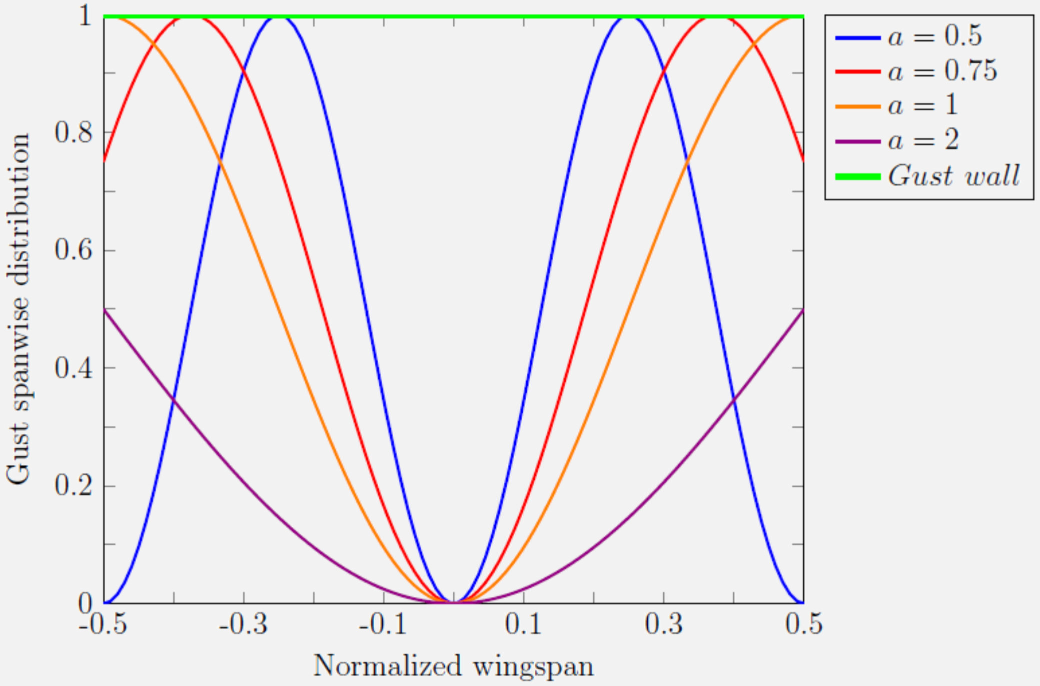

Fig. 5: Spanwise distribution of 1-cosine gusts

[4] Y. Yang, Y. Chao, and W. Zhigang, “Aeroelastic dynamic response of elastic aircraft with consideration of two-dimensional discrete gust excitation,” Chinese Journal of Aeronautics, 2019.

THANKS FOR YOUR ATTENTION!

ANY QUESTION?