Manufacturing, mechanical simulations and wing optimization

Dipl. Ing. M. LEFEBVRE

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Content

- Wing design - How to choose the wing profile?
- Drone manufacturing
  - Composite manufacturing, composite molding
  - Additive manufacturing
  - Final version manufacturing
- Material analysis
  - Composite material characterization
  - Experimental wing simulation
  - Wing joiner experimental test
- CFD Simulations
  - To design the drone
  - To compare geometries

Wing design

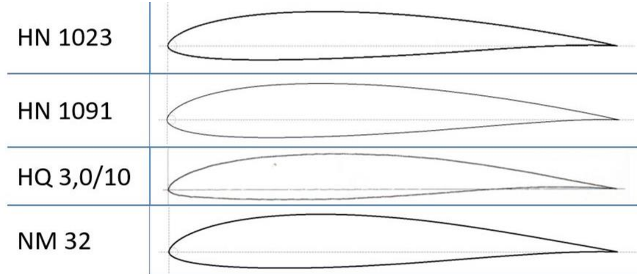
How to choose the perfect wing profile?

- Comparison between 4 wing profiles

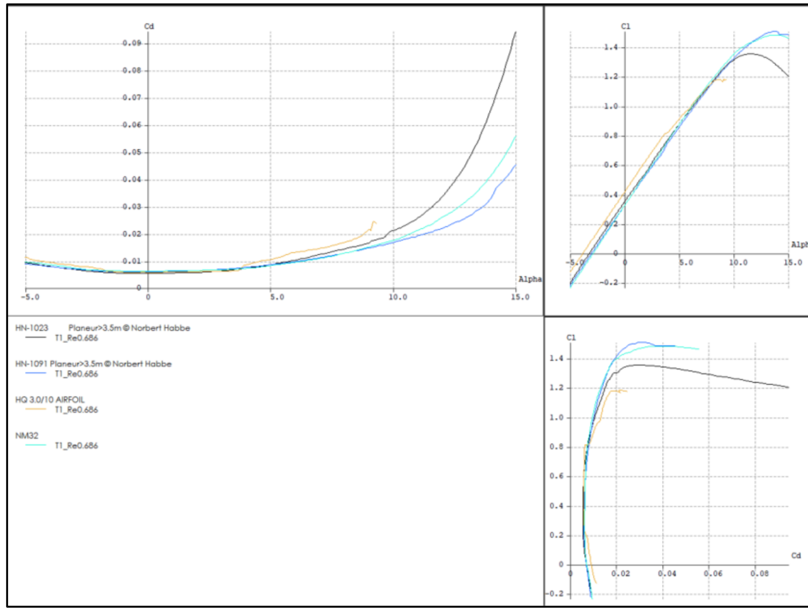
- Best Lift-to-drag ratio

- latest stall

- Profile selected: **NM32**



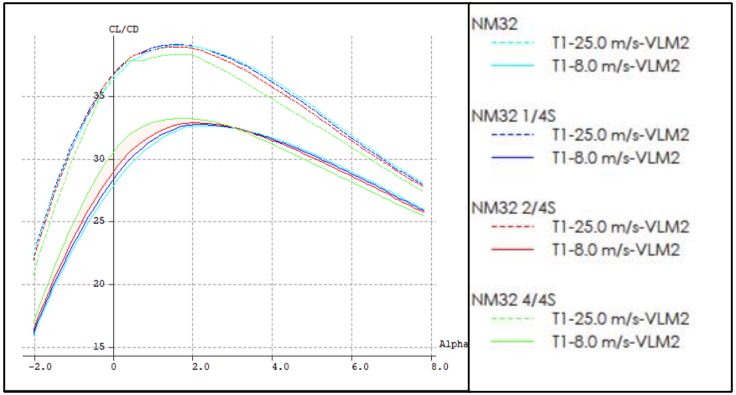
Wing profiles for glider geometry



Wing profile polar curves

Wing design

How to increase efficiency for the final drone?



Optimization of the wing profile

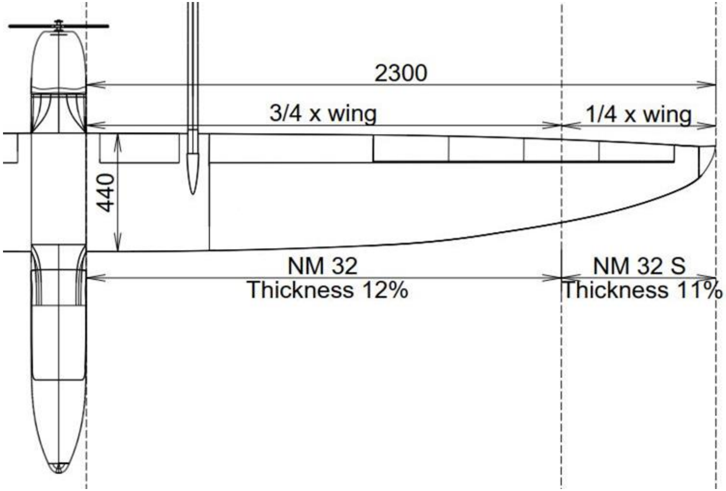
- Wing design:

¾ NM32

¼ NM32 S

→ To do not affect the L to D ratio at high speed

→ To get **elliptic lift distribution**

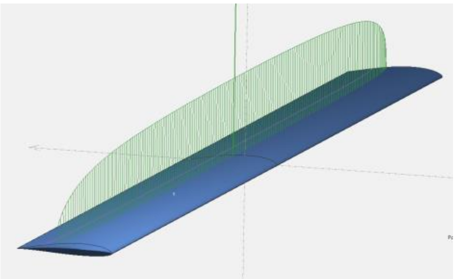


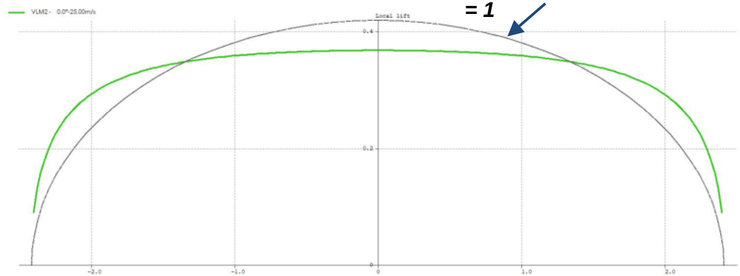
Sketch of the wing profile optimized

Wing design

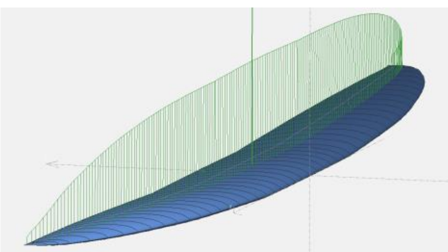
Elliptic lift distribution?

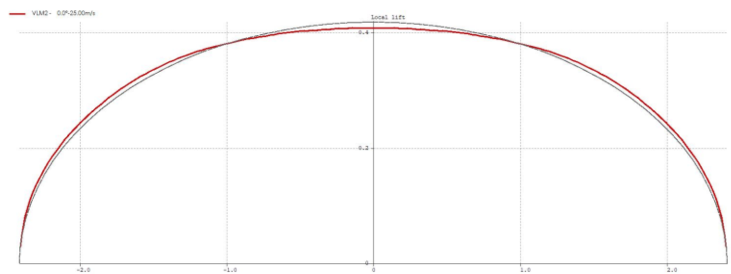
Target Efficiency elliptic lift (in black) = 1





Rectangular wing - Lift repartition in green





Elliptic wing - Lift repartition in red

Drone
manufacturing

Structure of the wing - sandwich composite

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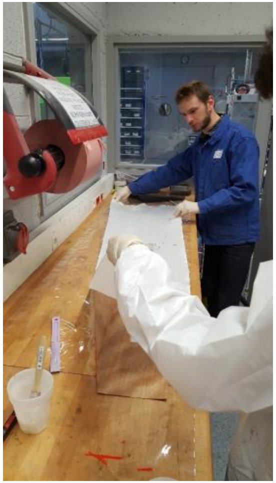
Drone manufacturing

Differents process:

- **Composite manufacturing**
  - **Vacuum technology**
  - **Composite molding**

- Additive manufacturing
  - Testing different shape
  - Low price
  - Low density



Vacuum Laminating (Wing, elevator, rudder)

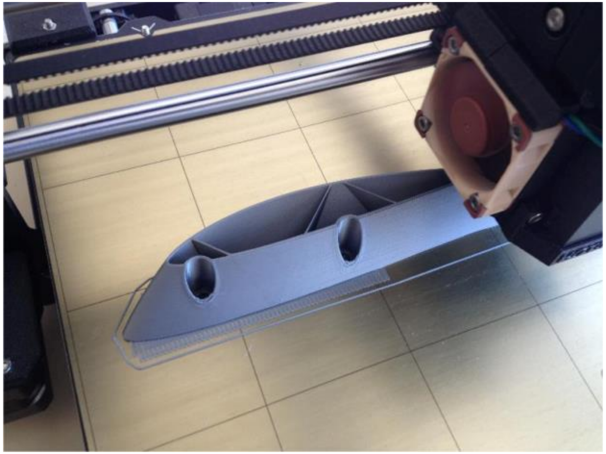
Fuselage composite molding

Drone manufacturing

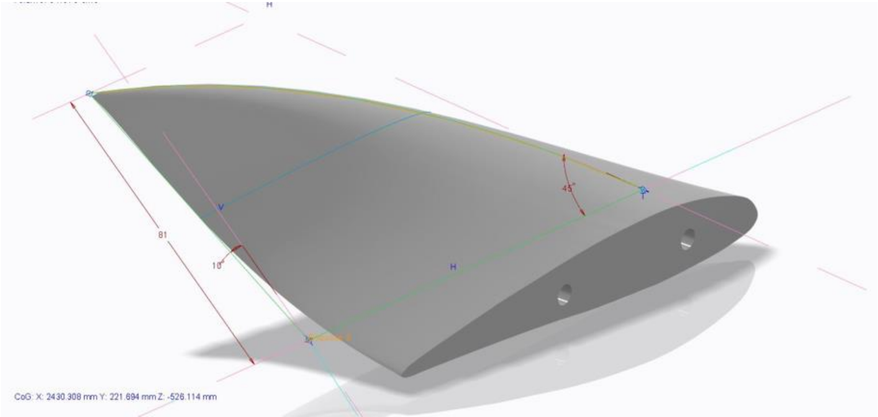
Differents process:

- Composite manufacturing
  - Vacuum technology
  - Composite molding

- **Additive manufacturing**
  - **Testing different shape**
  - **Low price**
  - **Low density**



Additive Manufacturing



Wingtip CAD to print

From the prototype to the final version

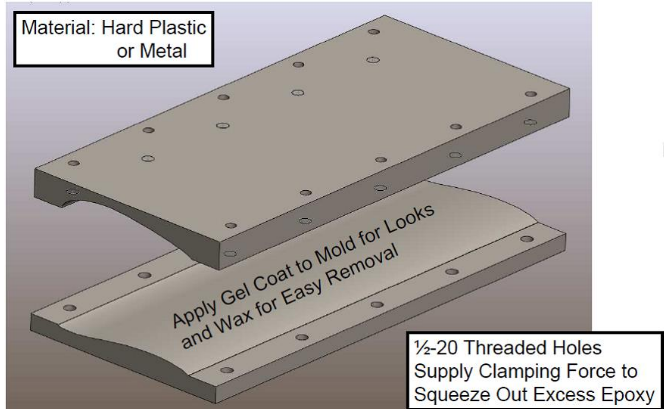
Material used:

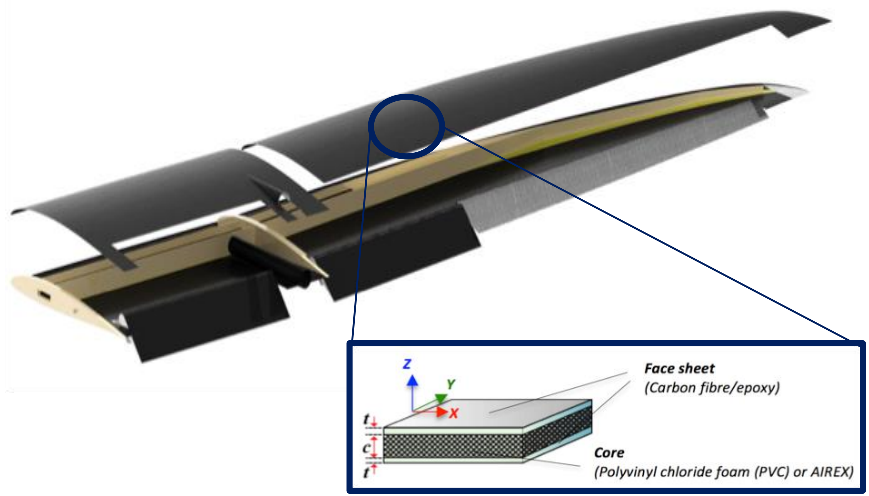
- Structure composite sandwich Carbon fibers/AIREX foam

Process used:

- Composite molding

Wing mold for final structure





Material analysis

Structure of the wing - sandwich composite

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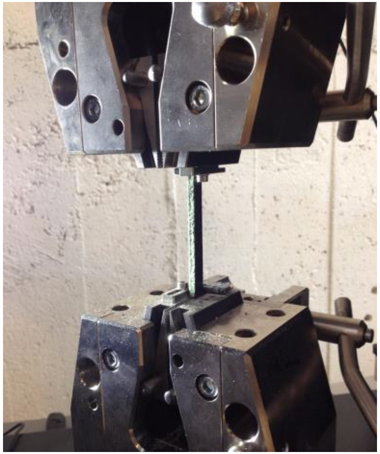
Composite material characterization

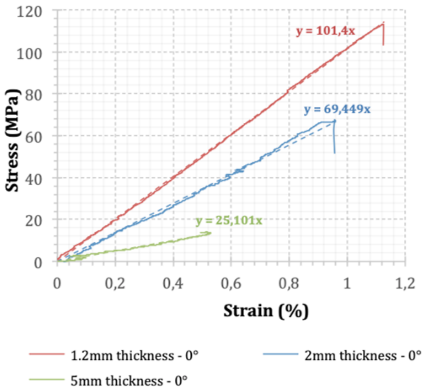
Material used:

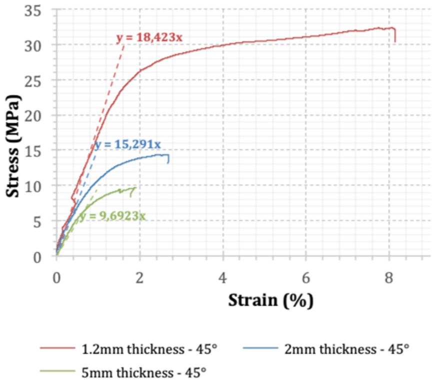
- Structure composite sandwich Carbon fibers/AIREX foam
- Tensile test on sandwich samples

Fiber Orientation: 0° & 45°

Tensile tests on sandwich samples







Comparison between **isotropic metal** & **anisotropic composite**

Composite material characterization

- Find mechanical properties of composite material
- Mandatory to study composite material in detail

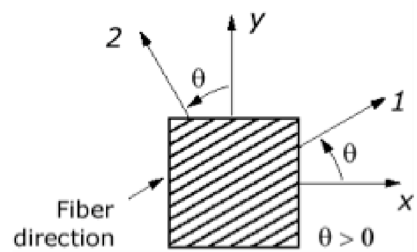
isotropic metal

$$\sigma = E\varepsilon$$

- **Hooke law**
- **Same mechanical properties in all directions**

anisotropic composite

$$\begin{Bmatrix} \sigma_l \\ \sigma_t \\ \tau_{lt} \end{Bmatrix} = [Q] \begin{Bmatrix} \varepsilon_l \\ \varepsilon_t \\ \gamma_{lt} \end{Bmatrix} = \begin{bmatrix} Q_{11} & Q_{12} & Q_{13} \\ Q_{21} & Q_{22} & Q_{23} \\ Q_{31} & Q_{32} & Q_{33} \end{bmatrix} \begin{Bmatrix} \varepsilon_l \\ \varepsilon_t \\ \gamma_{lt} \end{Bmatrix}$$



With

$$\begin{cases} Q_{11} = \dfrac{E_l}{(1-\nu_{lt}\nu_{tl})} \\ Q_{12} = \dfrac{\nu_{tl}E_l}{(1-\nu_{lt}\nu_{tl})} \\ Q_{21} = \dfrac{E_t}{(1-\nu_{lt}\nu_{tl})} \\ Q_{22} = \dfrac{\nu_{tl}E_t}{(1-\nu_{lt}\nu_{tl})} \end{cases}$$

Composite material characterization

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isotropic metal

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anisotropic composite

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Matrix behaviour :

$$* A_{ij} = \sum_{k=1}^{n} Q_{ij}{}^{k} e_k$$

$$* B_{ij} = \frac{1}{2} \sum_{k=1}^{n} Q_{ij}{}^{k} (h_k{}^2 - h_{k-1}{}^2)$$

$$* D_{ij} = \frac{1}{3} \sum_{k=1}^{n} Q_{ij}{}^{k} (h_k{}^3 - h_{k-1}{}^3)$$

$$[N] = \begin{bmatrix} A_{11} & A_{12} & 0 & | & B_{11} & B_{12} & 0 \\ A_{12} & A_{22} & 0 & | & B_{12} & B_{22} & 0 \\ 0 & 0 & A_{66} & & 0 & 0 & B_{66} \\ & — & & & & — & \\ B_{11} & B_{12} & 0 & & D_{11} & D_{12} & 0 \\ B_{12} & B_{22} & 0 & | & D_{12} & D_{22} & 0 \\ 0 & 0 & B_{66} & & 0 & 0 & D_{66} \end{bmatrix}$$

→ **Input for numerical simulations**

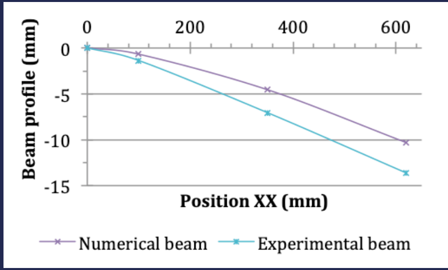
Composite material simulations

How accurate is the simulation ?

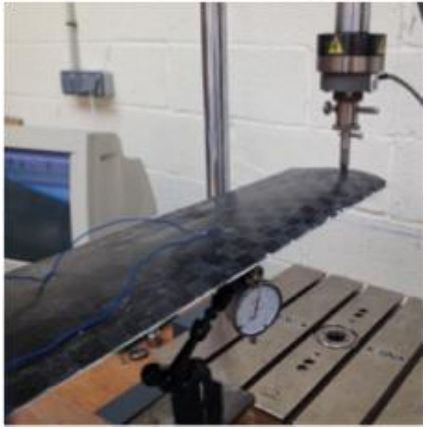
Comparisons

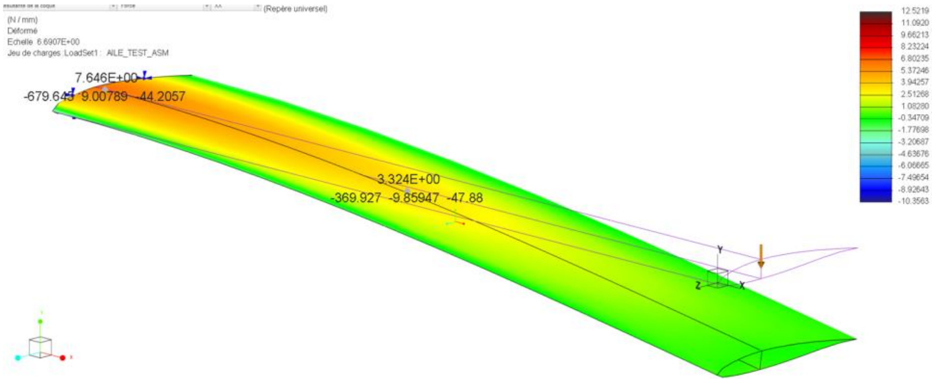
- Beam in 3 points
- Stress in 4 points

(tension/compression)



Comparison between numerical simulation and experimental test





Measure of the stress (MPa) in numerical simulation

Material analysis

Wing joiner

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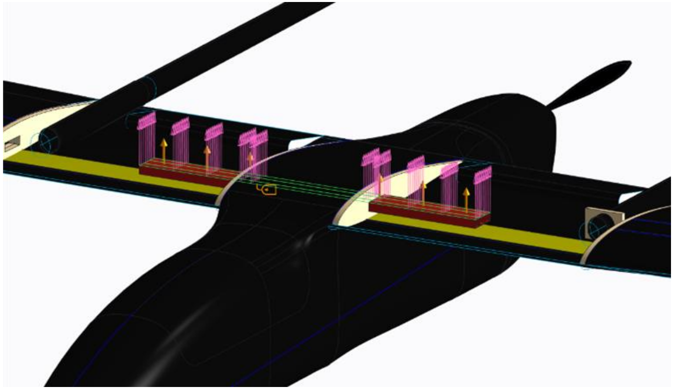
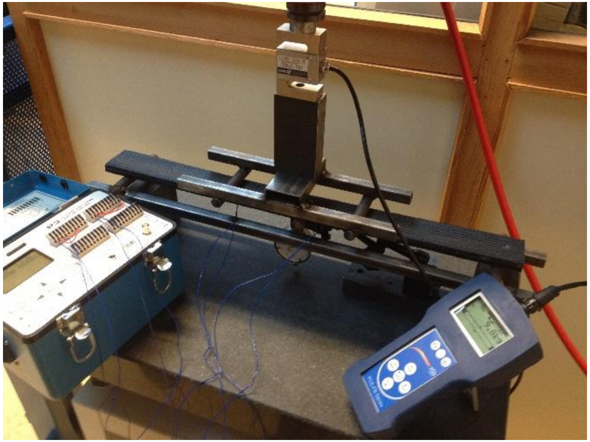
Strength experiments – 4 points Bending test

To determine material properties:

- Young’s modulus
- Failure stress
- Strain



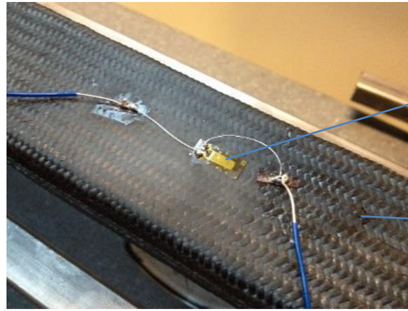
Wing joiner stress

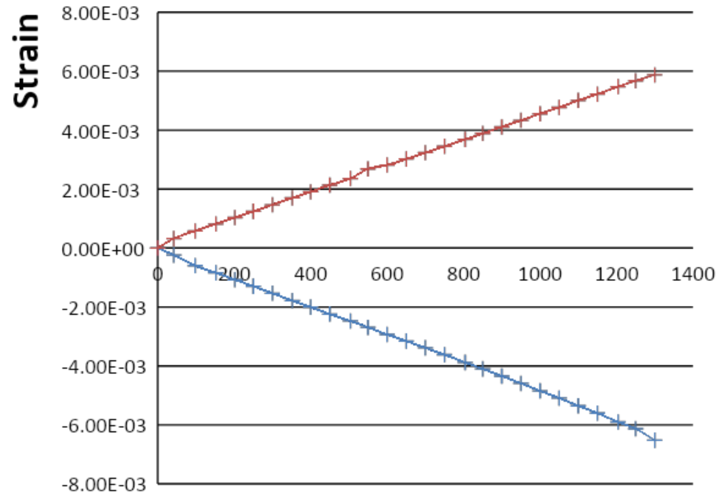


Experimental test bench

Bending test – Results : Wing joiner strain

- Determination of the failure stress
- Young's modulus:
  E=15,1 GPa
- Failure stress:
  σ_{max}=97MPa





$$\sigma_{max} = \frac{M_f}{I_G}.y = E.\varepsilon_{max}$$

Strain measure (tension & compression)

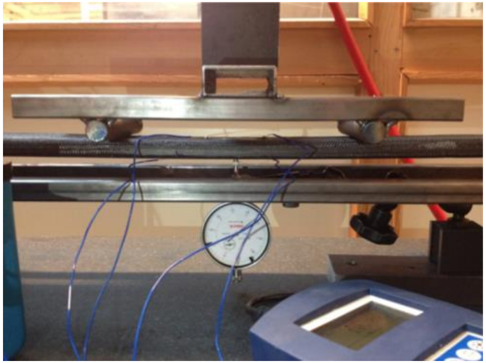
Bending test – Data processing

Goal:

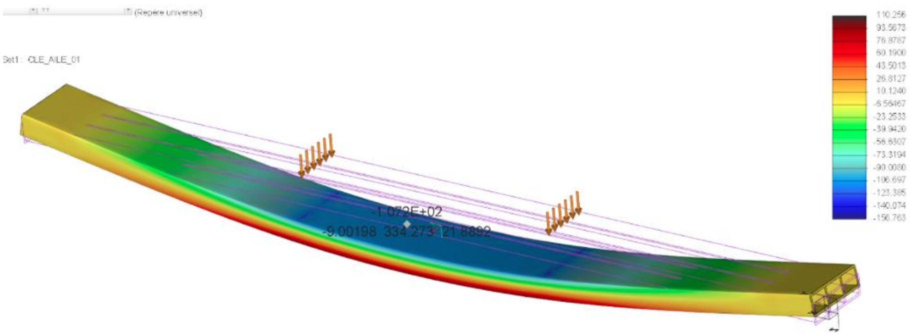
- To use real material properties in computer simulations

Relative error = 7,6%

(experimental / computer simulation)



Wing joiner bending test



CREO PTC Mechanical simulation

CFD Simulations

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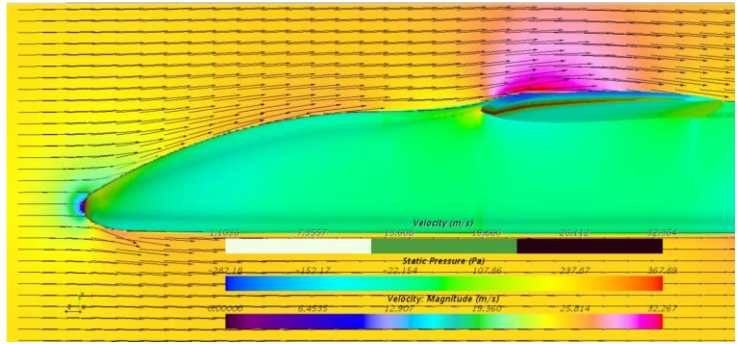
CFD Simulation Comparison

Goal:

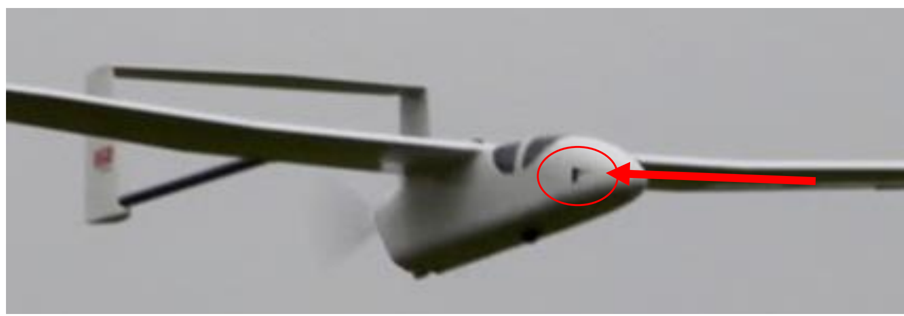
- **To improve drone efficiency**
- **To design the drone**
- To compare drones behaviour



Airflow on CFD simulation

CFD Simulations to check the perfect location for:

- Naca inlet (to cool down equipments)
- Pitot tube (parallel to the airflow)

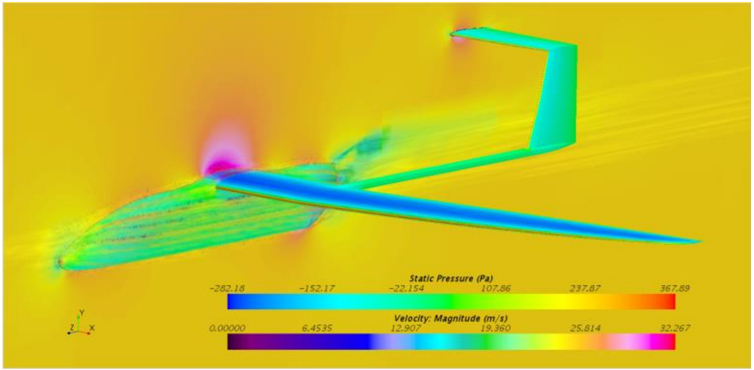


Naca inlet during the flight

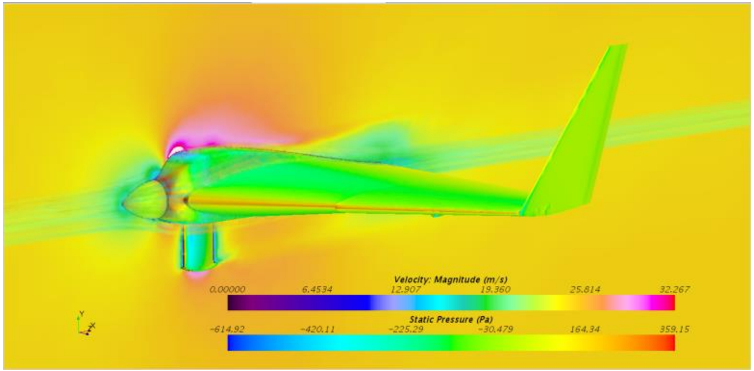
CFD Simulation Comparison

Goal:

- To improve drone efficiency
- To design the drone
- **To compare drones behaviour**



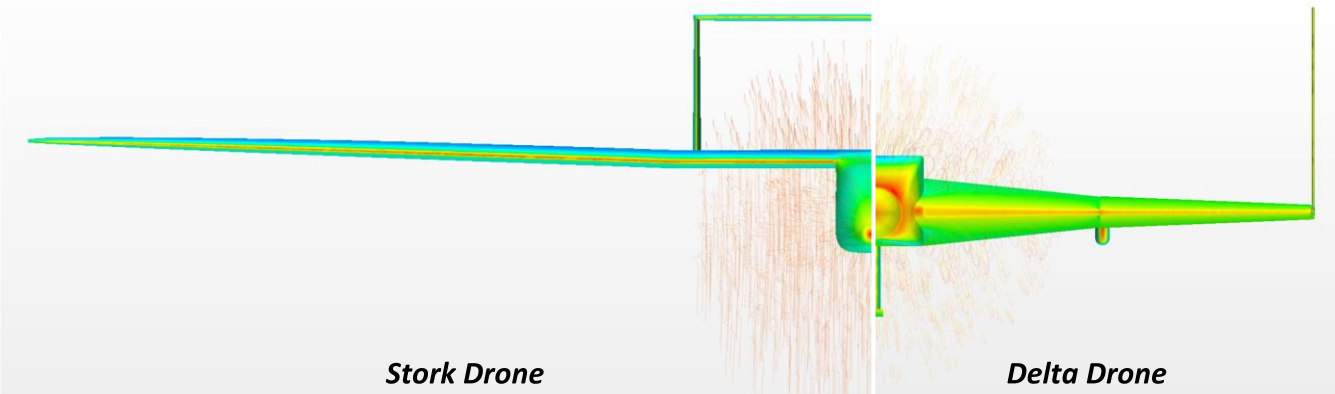
Stork drone - 25m/s



Delta drone - 30 m/s

CFD Simulation Comparison

Objective: To compare both geometries with CFD Simulations



Further work in mechanical studies

- Integrate equipments for the future missions

- Design & manufacture the molds for the final drone
    - Wings
    - Lateral fuselages

- Study innovative composite material for the drone structure
    - Biobased composite
    - Recycled composite

      → Ph.D. from october 2019

Thank you for your attention!