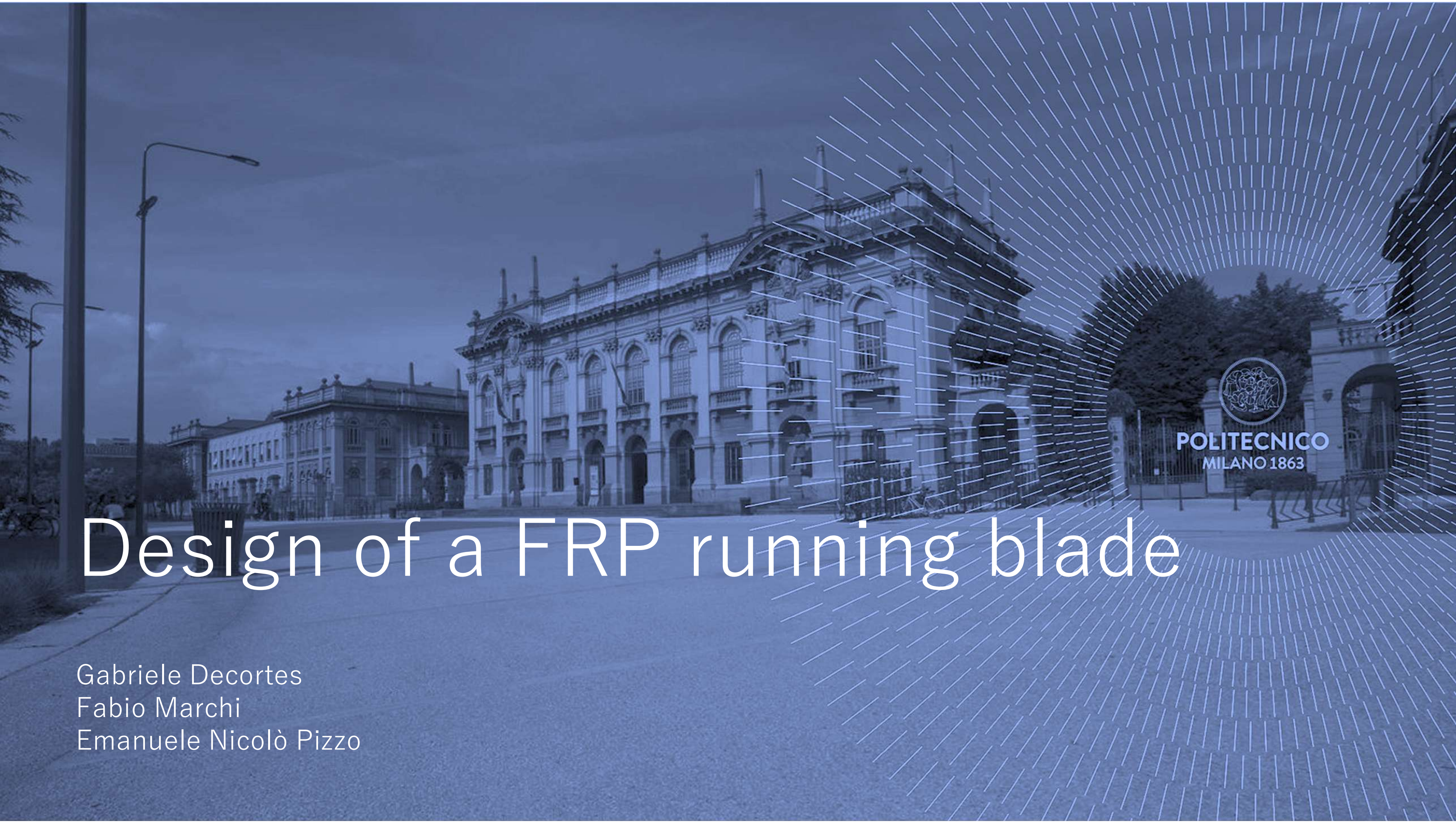


Design of a FRP running blade

Gabriele Decortes
Fabio Marchi
Emanuele Nicolò Pizzo

Project overview

FRP

- Stacking sequence
- Weight

Running blade

- Short distance running
- Long and high jumping

History of lower limb prostheses

Egyptians and Romans

Renaissance

Wars and conflicts

SACH foot

Terry Fox and Van Phillips

Today

Composition of RSPs

Liner

- Avoids friction and movements
- Silicon or polyurethane

Socket

- Allows control of the prosthesis
- Rigid or flexible

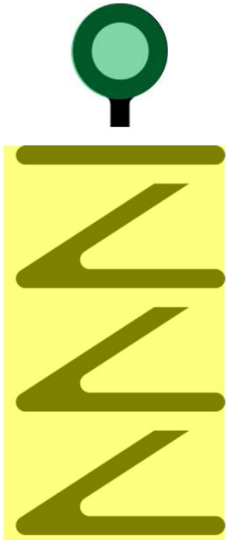
Blade

- Acts as a spring to transmit energy
- C-shaped or J-shaped

Composition of RSPs

Spring-mass system

Energy efficiency < 240%



Energy efficiency < 90%

Manufacturing technology

Preliminary work

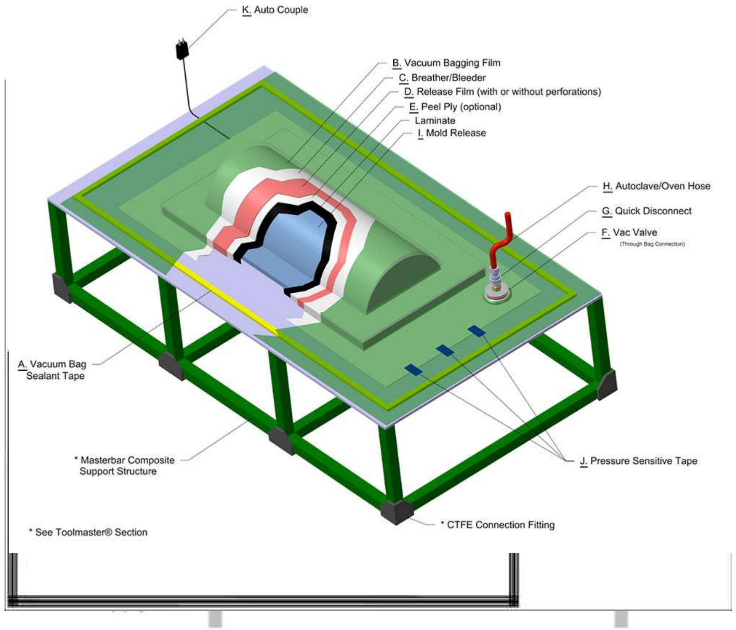
- 2D laminates
- 3D woven

Classical methods

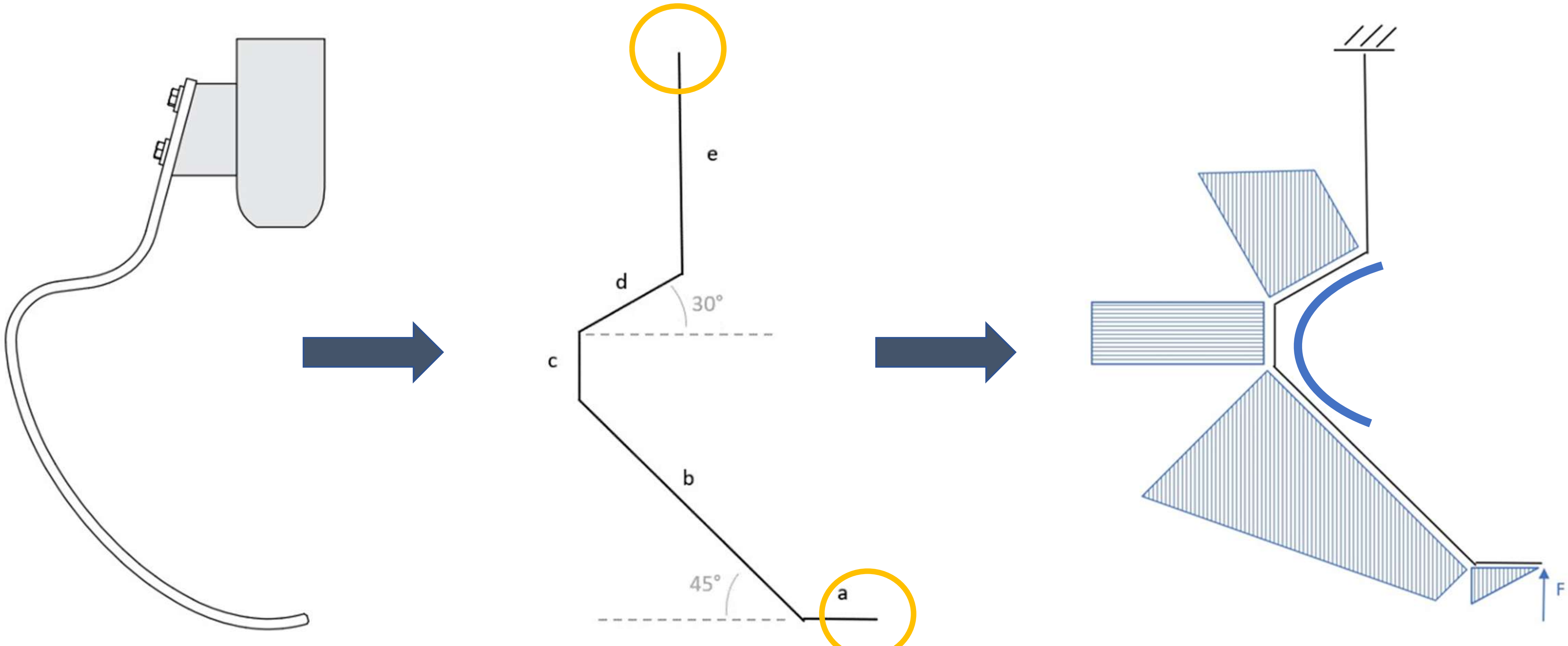
- Hand lay-up
- Prepreg Vacuum-Bagging
- Resin transfer moulding

Innovative methods

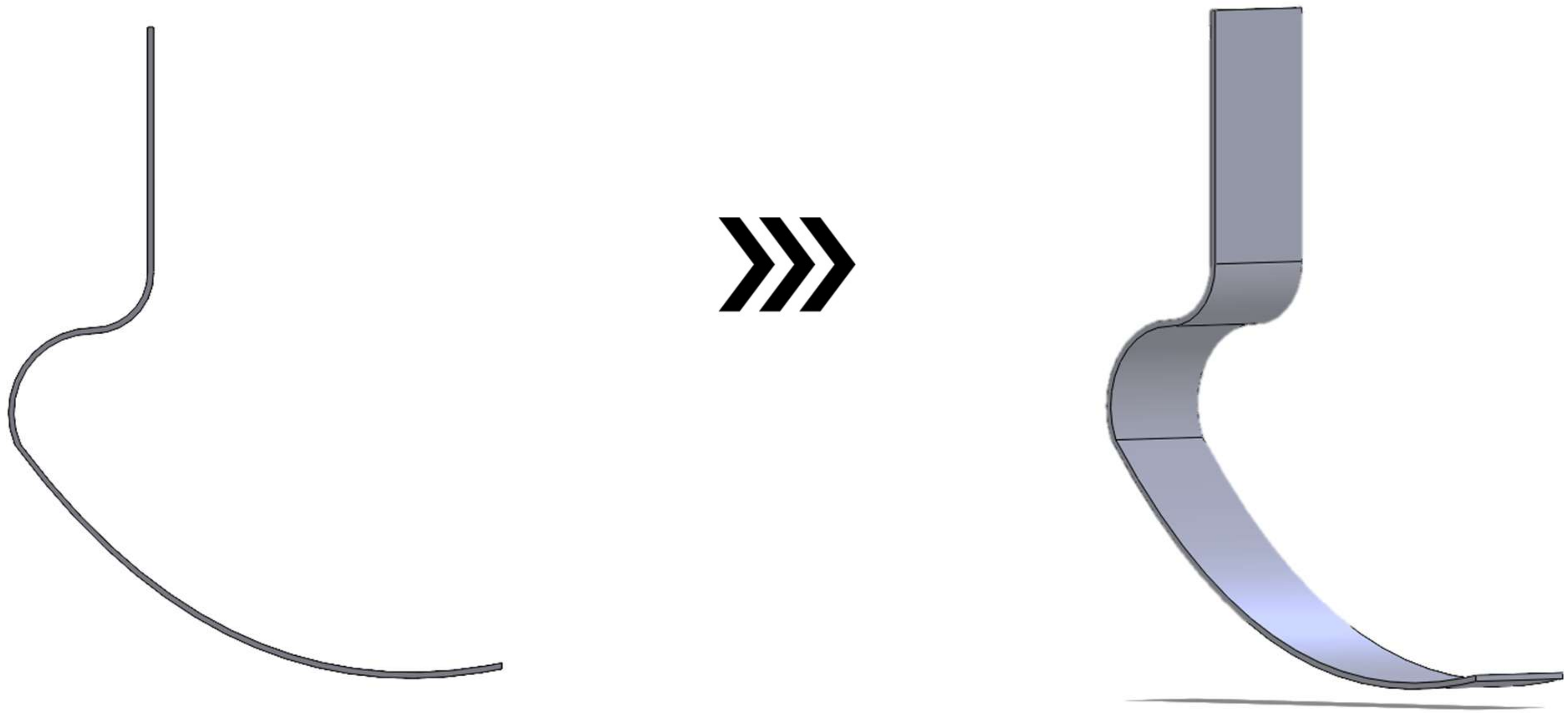
- Prior incorporation
- Incorporation in the nozzle
- Incorporation on the component

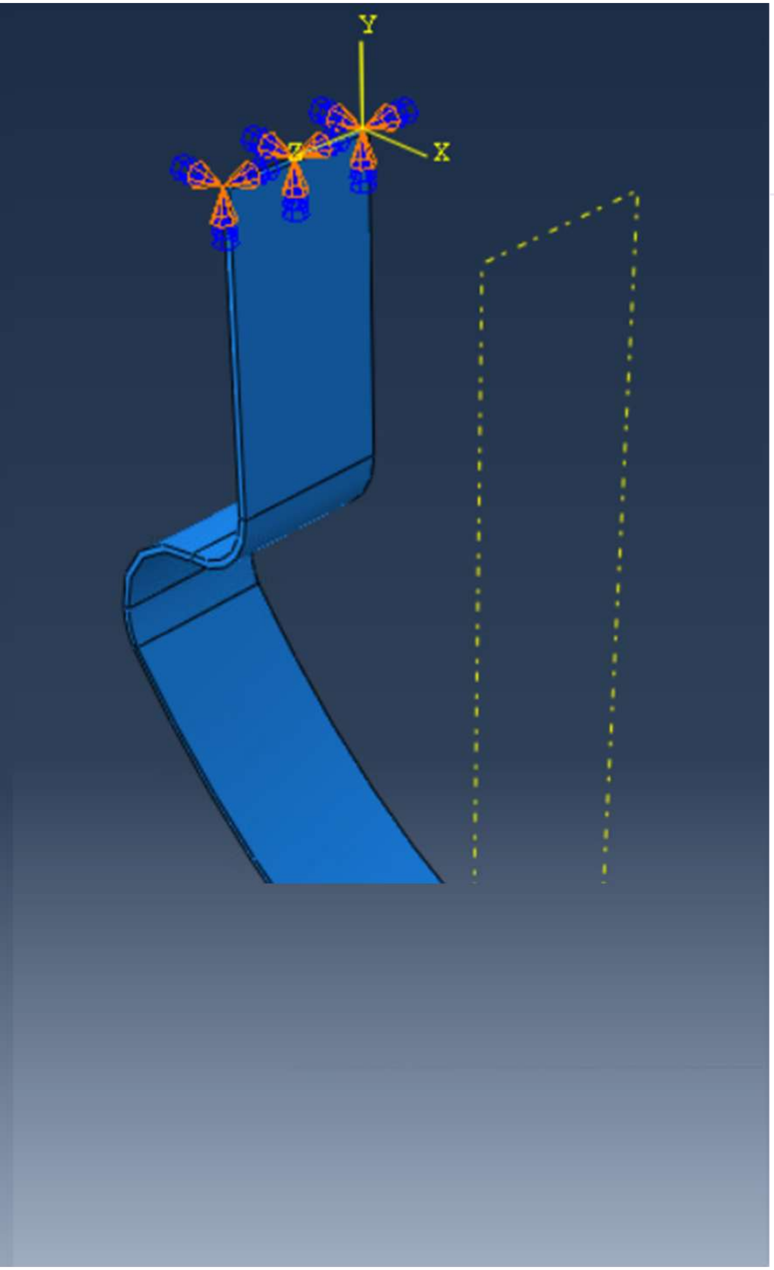


Static analysis



Model construction (1)

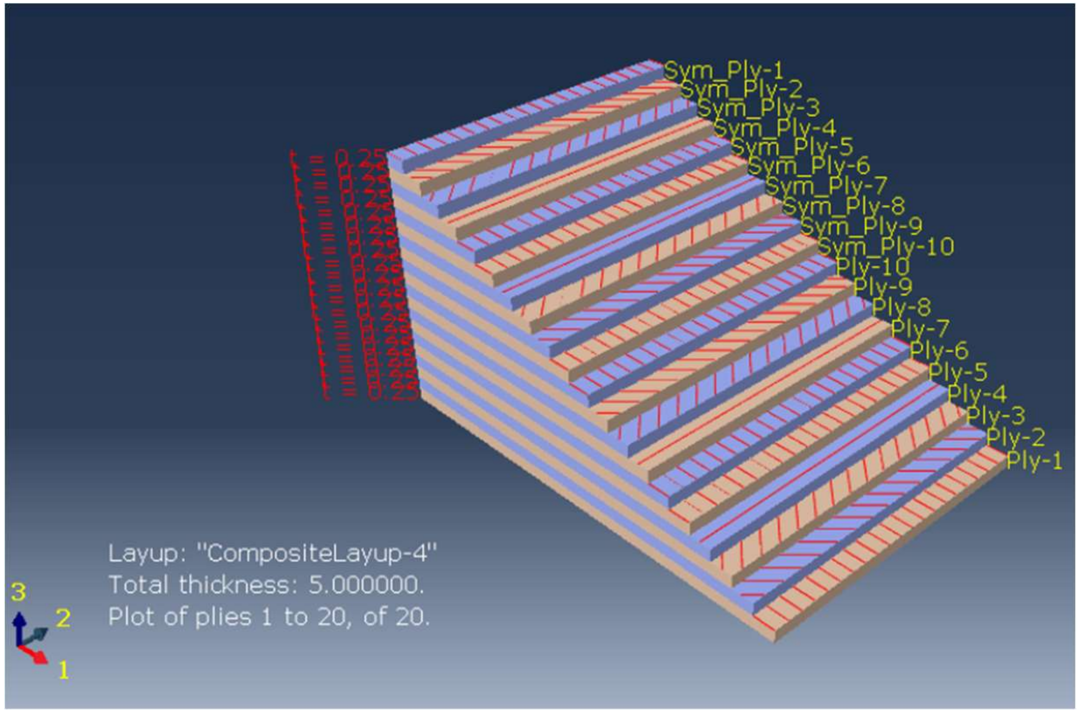


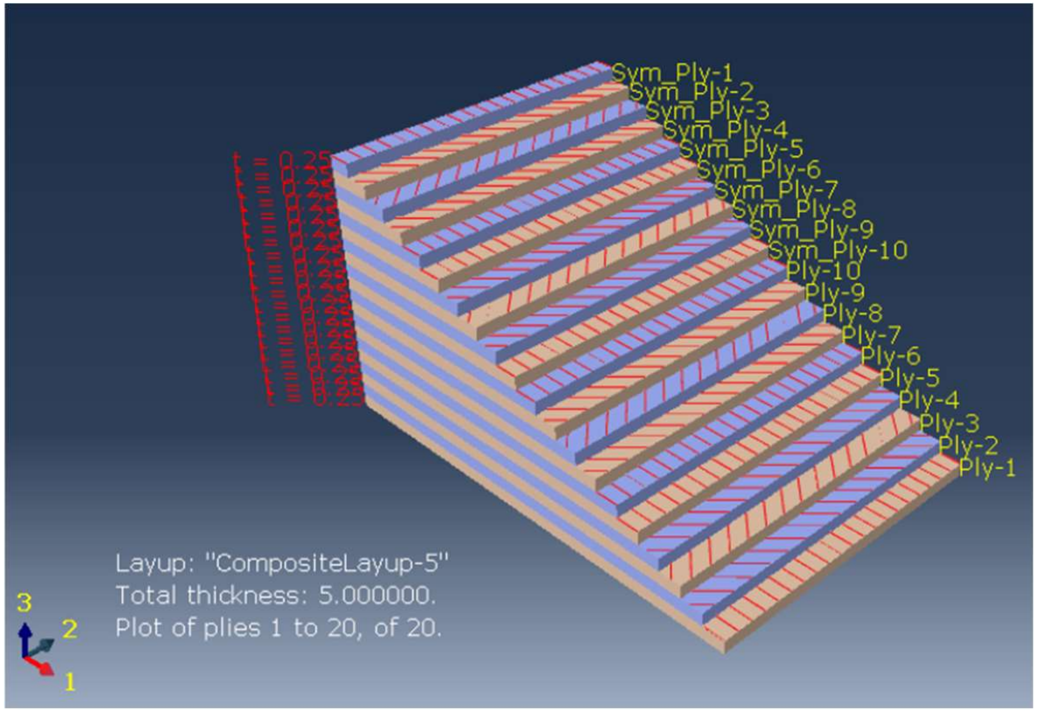


Model construction (2)

- **Material:** lamina
- **Mesh:** 2140 elements (S4R)
- **BCs:** encastre
- **Load type:** pressure

Composite layups; starting laminates





$[0, 45, -45, \mathbf{90}, 0, 0, \mathbf{90}, -45, 45, 0]_s$

$[0, 45, -45, 45, 0, 0, 45, -45, 45, 0]_s$

Composite layups: optimization pattern

$[0, 45, -45, 90, *, 0, 0, 90, -45, 45, *, 0]_s$

+

$[45, 90]_n$ packets at *

$[0, 45, -45, 45, *, 0, 0, 45, -45, 45, * 0]_s$

+

$[\pm 45]_n$ packets at *

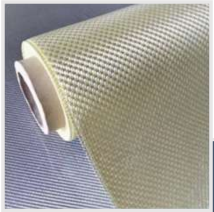
Tsai-Hill < 1

$\delta = 4$ cm

Materials

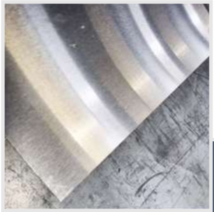
CFRP

- $\rho = 1.6\ g/cm^3$
- $E_1 = 177$ GPa
- $E_2 = 10.8$ GPa
- $\nu_{12} = 0.27$
- $G_{12} = 7.6$ GPa



GFRP

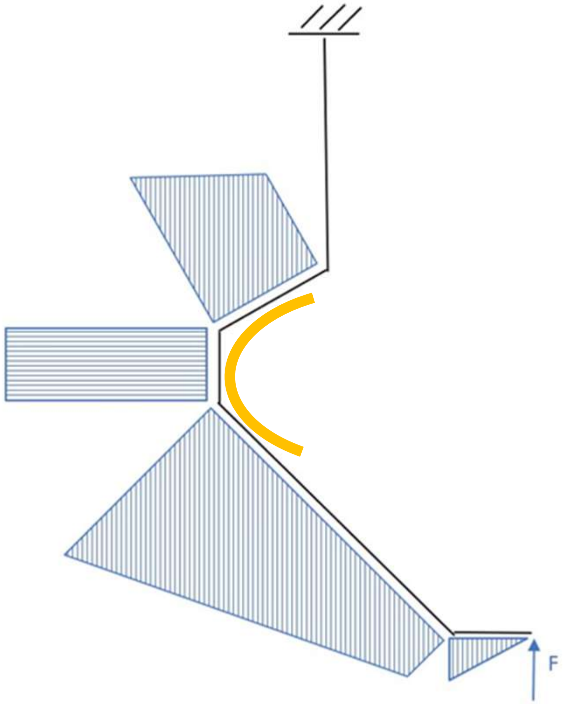
- $\rho = 2\ g/cm^3$
- $E_1 = 43$ GPa
- $E_2 = 8.9$ GPa
- $\nu_{12} = 0.27$
- $G_{12} = 4.5$ GPa

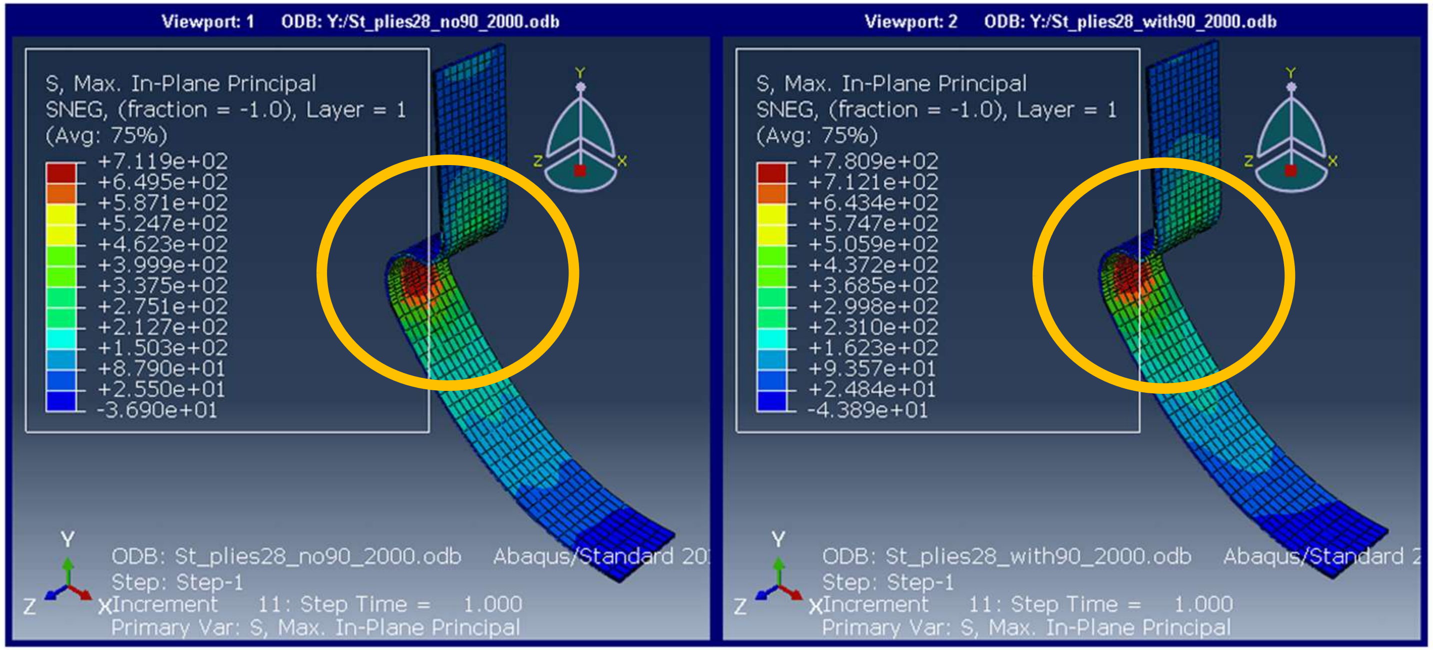


Aluminium

- $\rho = 2.8\ g/cm^3$
- $E = 72$ GPa
- $\nu = 0.33$

Results


F


Viewport: 1 ODB: Y:/St_plies28_no90_2000.odb
S, Max. In-Plane Principal
SNEG, (fraction = -1.0), Layer = 1
(Avg: 75%)
+7.119e+02
+6.495e+02
+5.871e+02
+5.247e+02
+4.623e+02
+3.999e+02
+3.375e+02
+2.751e+02
+2.127e+02
+1.503e+02
+8.790e+01
+2.550e+01
-3.690e+01
ODB: St_plies28_no90_2000.odb Abaqus/Standard 20
Step: Step-1
Increment 11: Step Time = 1.000
Primary Var: S, Max. In-Plane Principal
Viewport: 2 ODB: Y:/St_plies28_with90_2000.odb
S, Max. In-Plane Principal
SNEG, (fraction = -1.0), Layer = 1
(Avg: 75%)
+7.809e+02
+7.121e+02
+6.434e+02
+5.747e+02
+5.059e+02
+4.372e+02
+3.685e+02
+2.998e+02
+2.310e+02
+1.623e+02
+9.357e+01
+2.484e+01
-4.389e+01
ODB: St_plies28_with90_2000.odb Abaqus/Standard 2
Step: Step-1
Increment 11: Step Time = 1.000
Primary Var: S, Max. In-Plane Principal

Results

Objectives

- Stacking sequence
- Maximum displacement = 4 cm
- Lowest possible weight

Results

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- Stacking sequence
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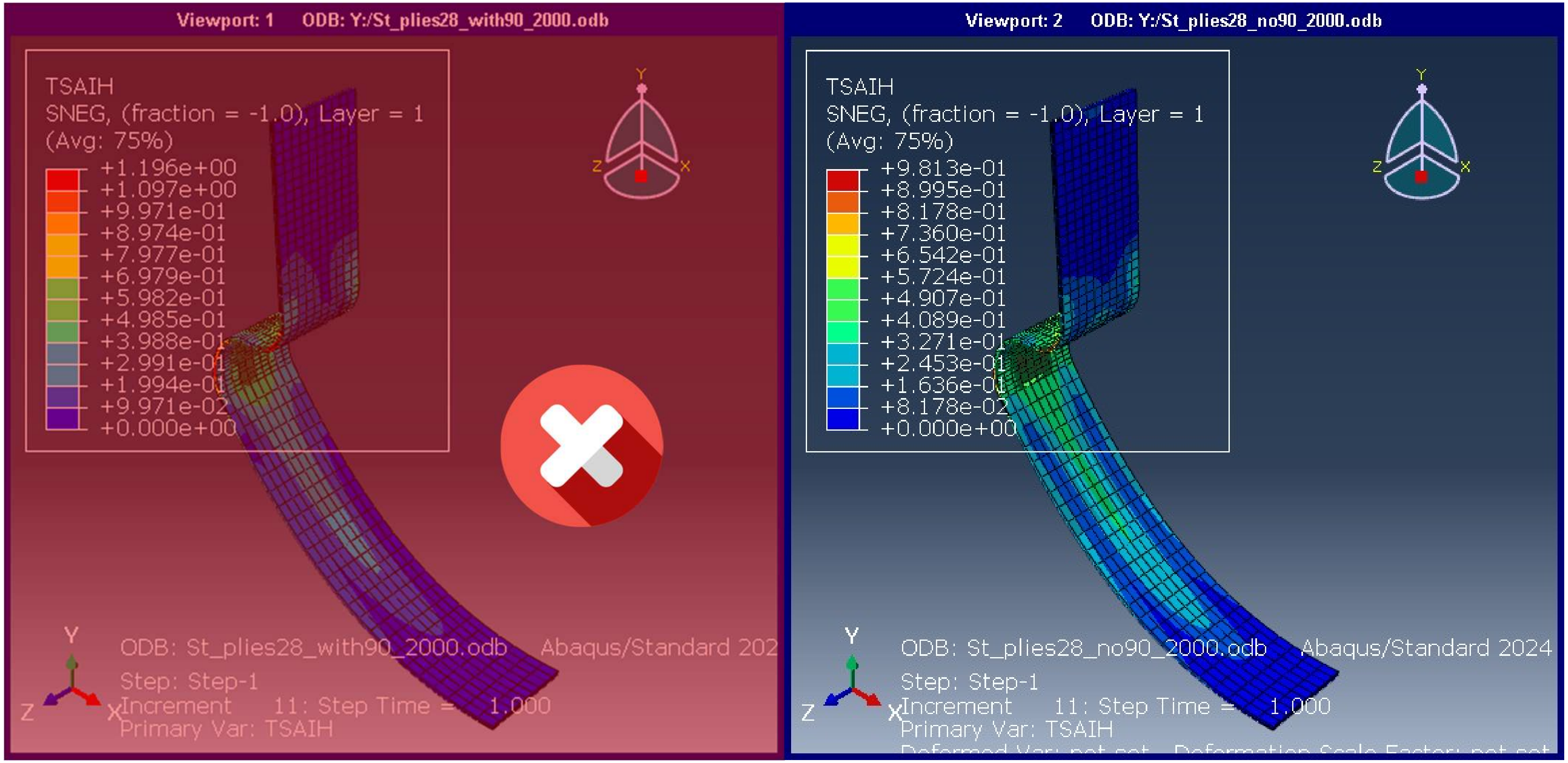
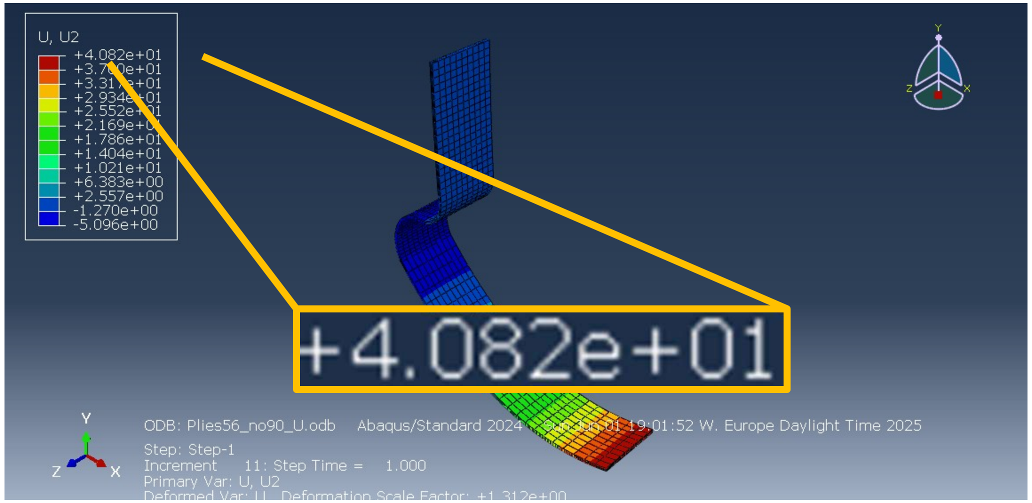


Results

Objectives

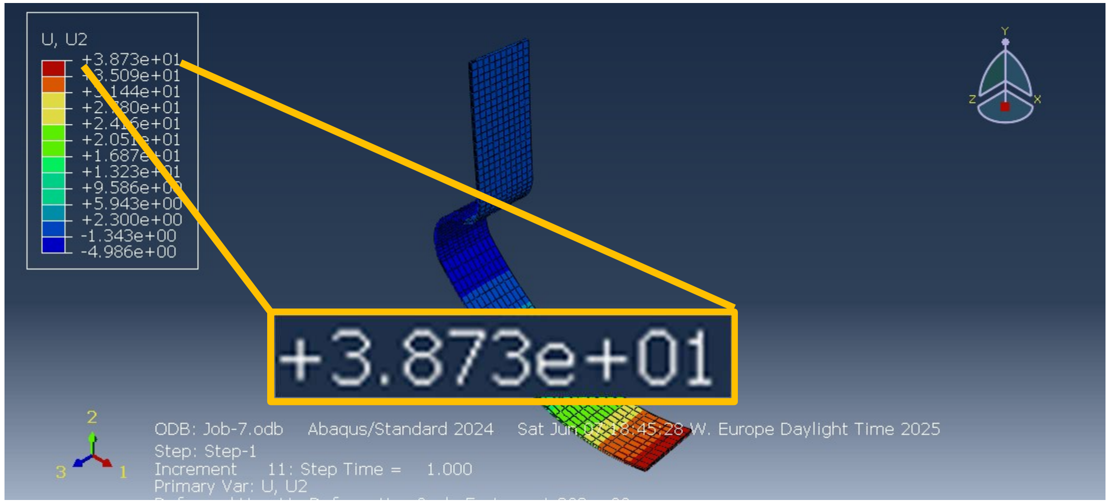
- Stacking sequence
- Maximum displacement = 4 cm
- Lowest possible weight

CFRP



- 52 plies
- 13 mm thickness
- 1.75 Kg

GFRP



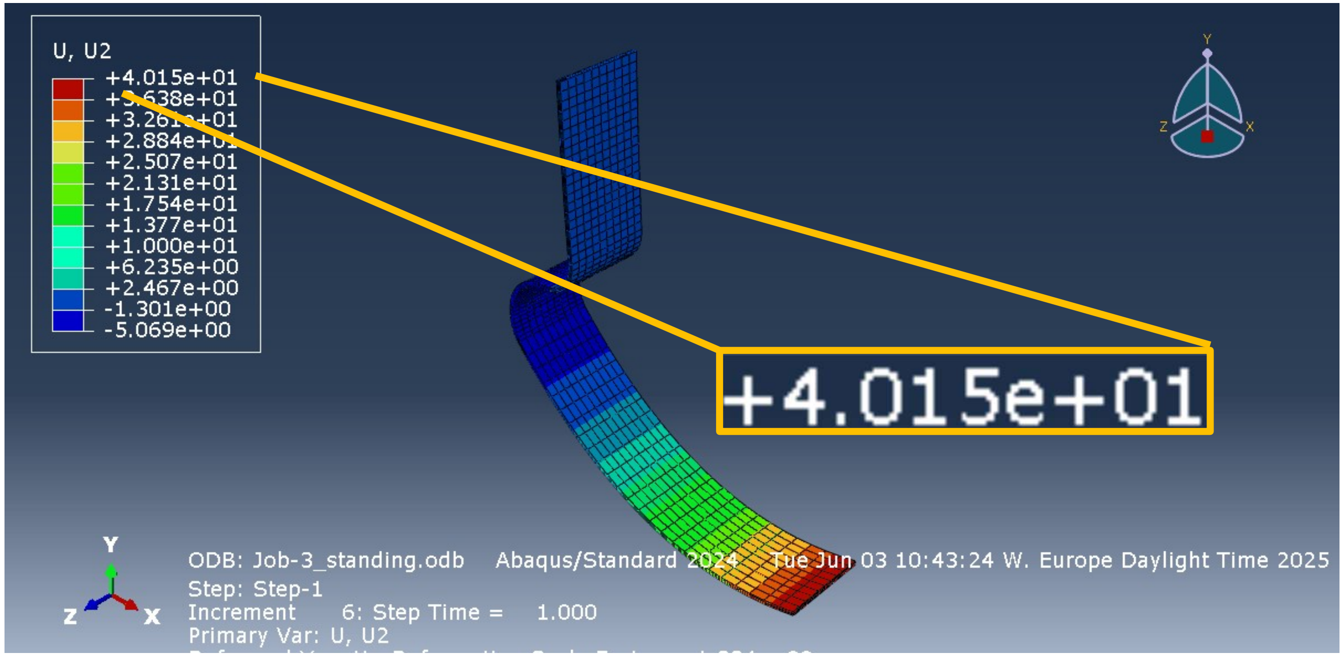
- 82 plies
- 20.5 mm thickness
- 3.5 Kg

Results

Objectives

- Stacking sequence
- Maximum displacement = 4 cm
- Lowest possible weight

Aluminum

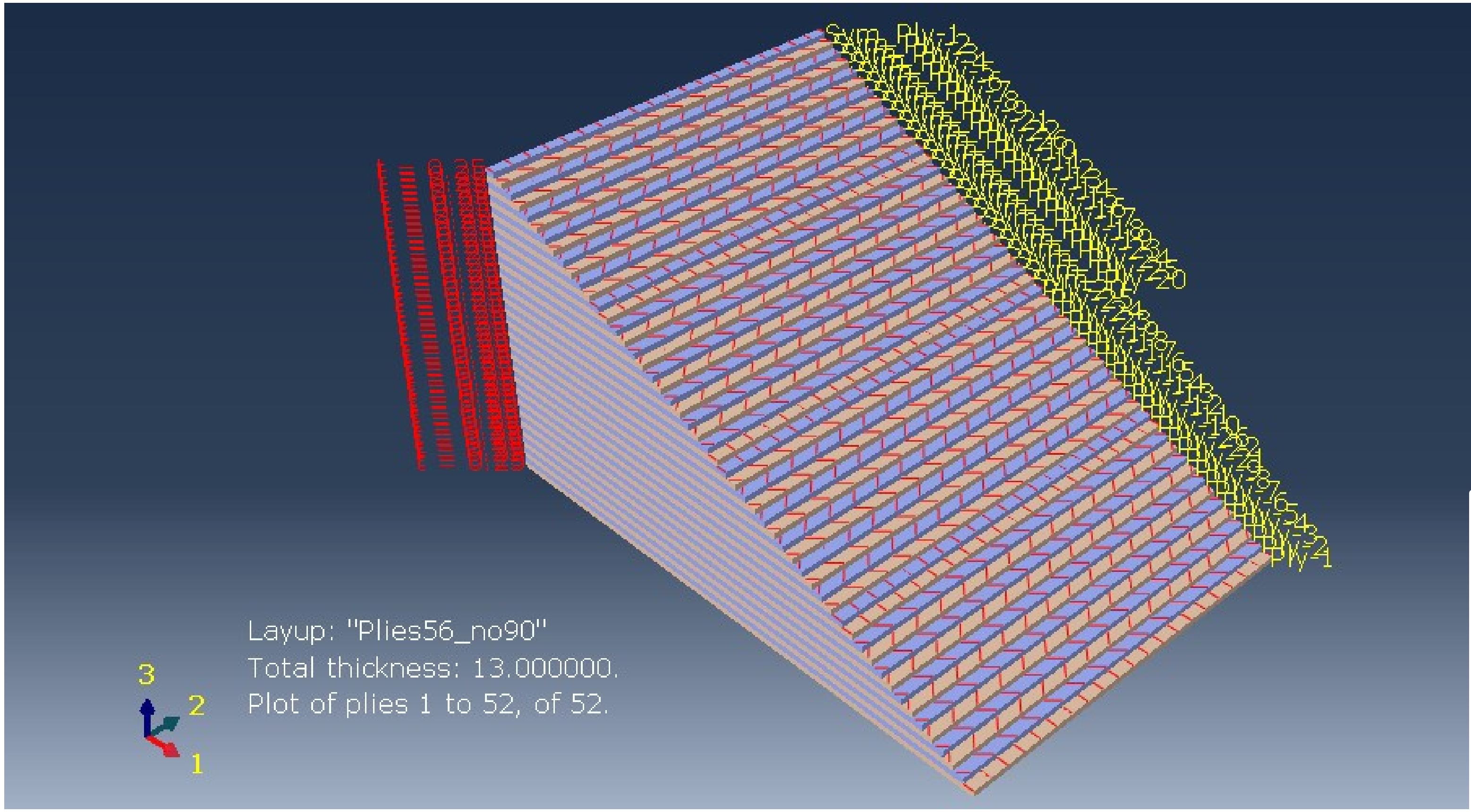


- 12 mm thickness
- 2.8 Kg

Results

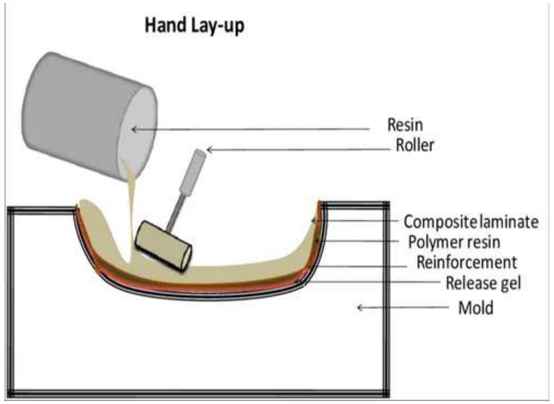
Objectives

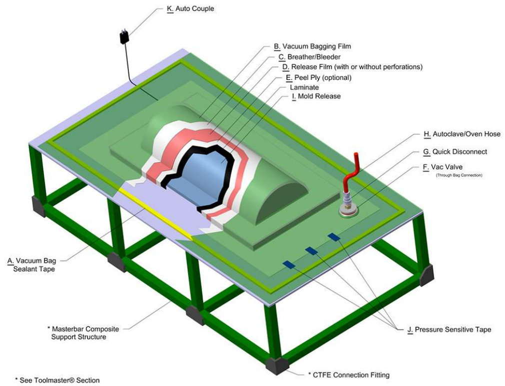
- Stacking sequence
- Maximum displacement = 4 cm
- Lowest possible weight

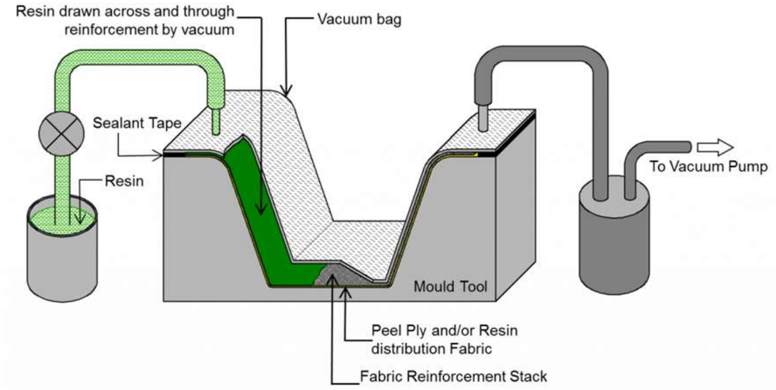


Manufacturing

Hand lay-up | **Prepreg Vacuum Bagging** | **RTM**







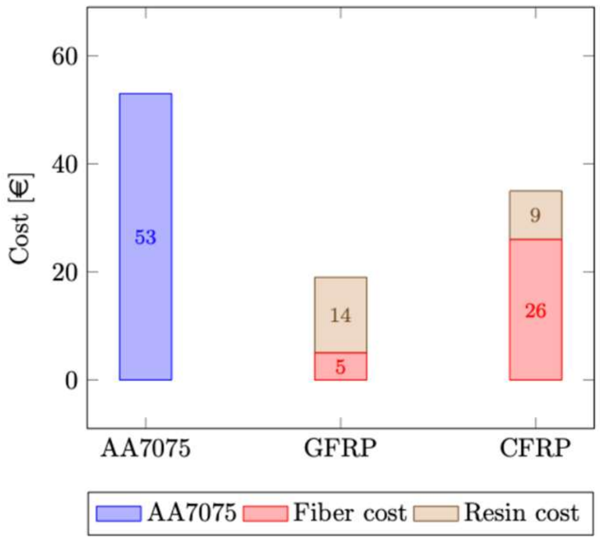
Cheap and simple process but subject to high variability and lower quality

Cheaper process with respect to RTM, still guranteeing high quality at lower costs

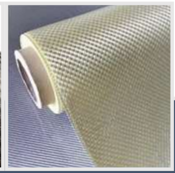
Fast process with high quality capability but the investment cost does not justify its use for running blades

Cost evaluation: contributions

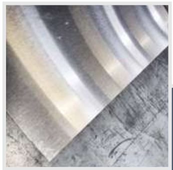
Raw materials



Post processing



- Prepreg vacuum bagging
- Personalization through optimization
- Low production numbers
- Metallic inserts
- Certifications and brand name



- No reference on the market for processes and brands

Cost evaluation: results

Raw materials

R&D

Manufacturing

+ Mark-up
3-5x

≅ 15000 €

Conclusions

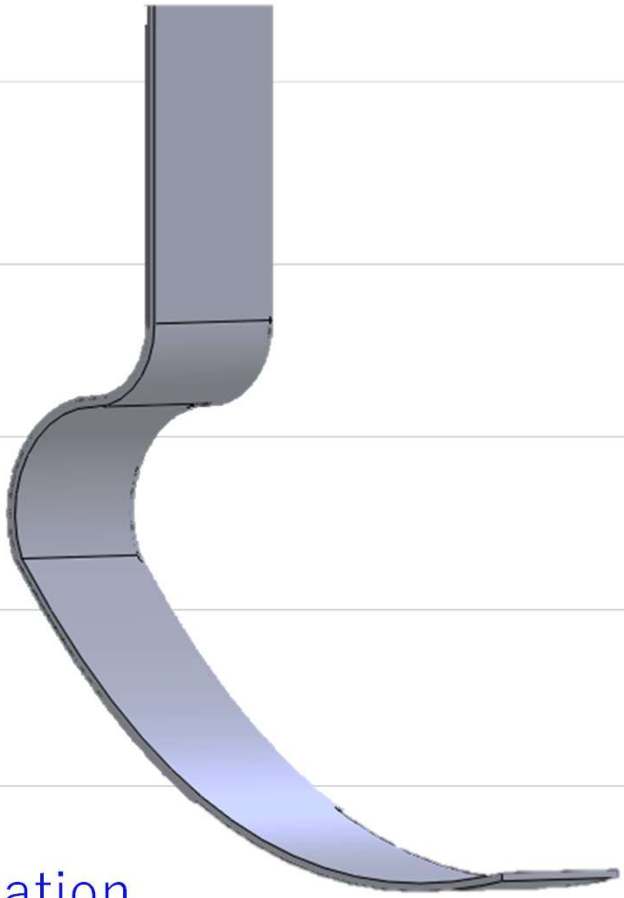
Geometry

Composite properties

Loads and BCs

Materials choice

Layup optimization




Thank you for your attention
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