Science and Technology Research Unit
Science and Technology Department

L’intelligence des composites pour prévenir de leur état de santé

Contact: anthonin.demarbaix@condorcet.be
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Province de HAINAUT HAUTE ÉCOLE CONDORCET

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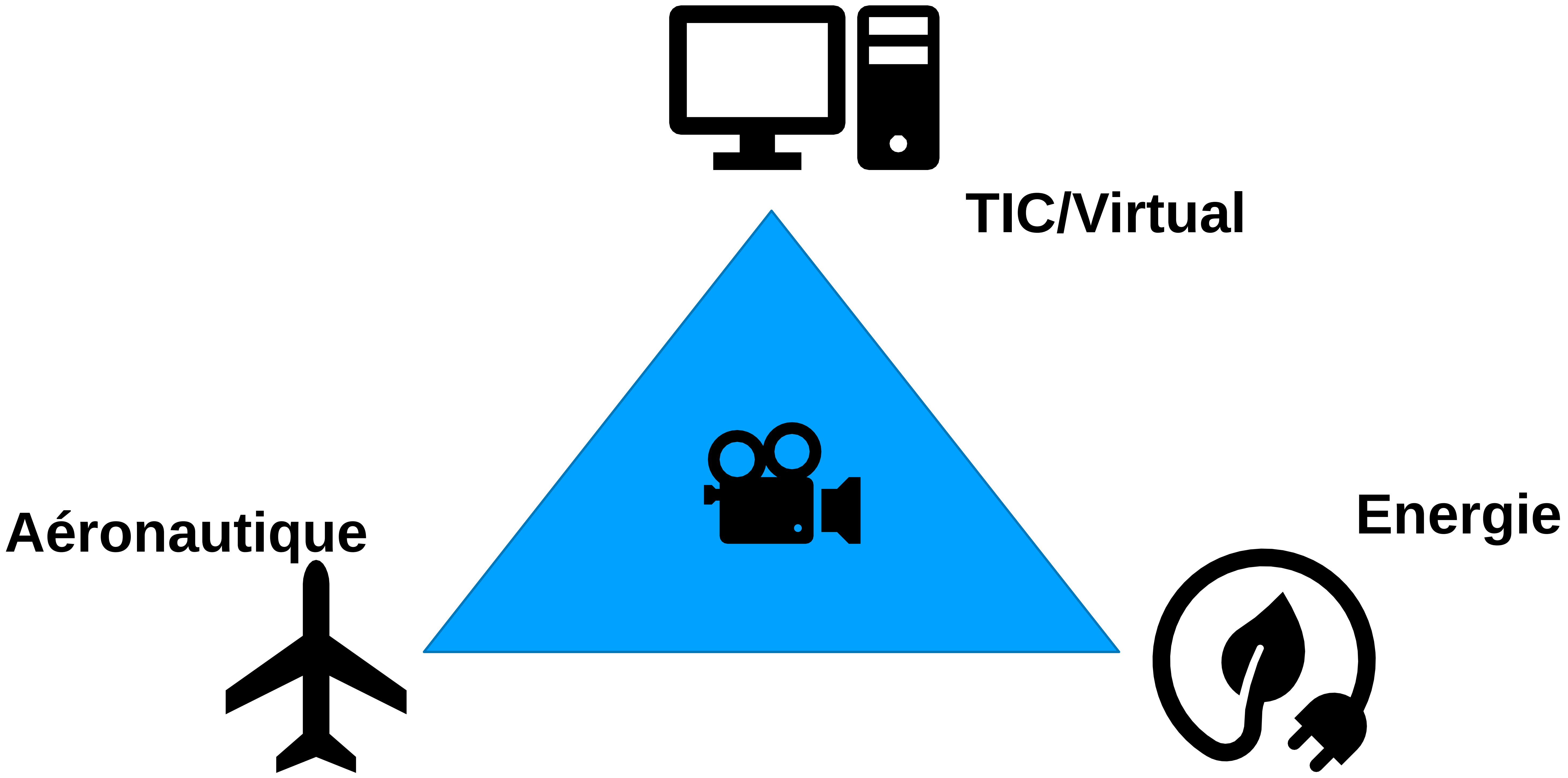
Thématique



ANDIM LAB

Advanced Non-Destructive Inspection and Manufacturing

- Additive Manufacturing
- ➢ Composite thermoplastique
  - ➢ SLS
  - ➢ FDM Coextrusion
- Contrôle non destructif
- ➢ Thermographie active (IRT)
- ➢ Ultrason immersive (UT)
- ➢ Courant Foucault
- Simulation numérique
  - Structure
  - Thermique

En² LAB

Energy and Environment Laboratory

- Performance énergétique
- Modélisation demande énergétique
- Système énergétique
- Simulation numérique
- Optimisation énergétique

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TEAM

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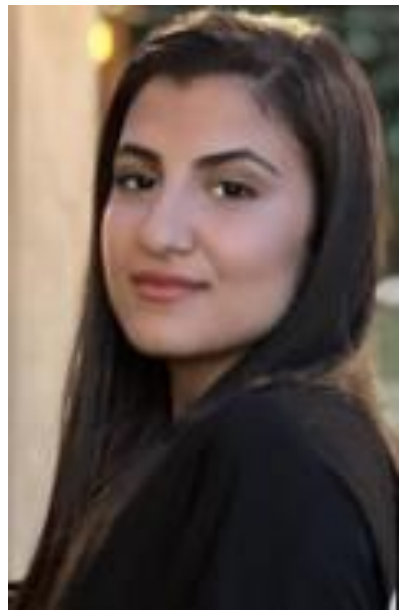
Responsable ANDIM LAB
Enseignant/Chercheur

Moonens Marc
Enseignant/Chercheur

Notebaert Arnaud
Chercheur
THERMPOCOMP



Ochana Imi
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SW_ICOM2C3D

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Valkenborgh Benjamin
Enseignant/Chercheur

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Chercheur
VIRTUAL LAB

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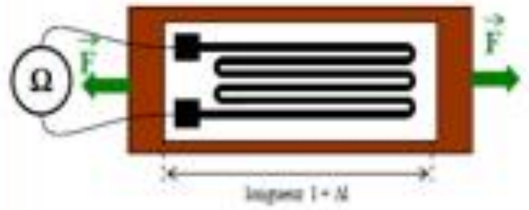
SW_ICOM2C3D

L’intelligence des composites pour prévenir de leur état de santé

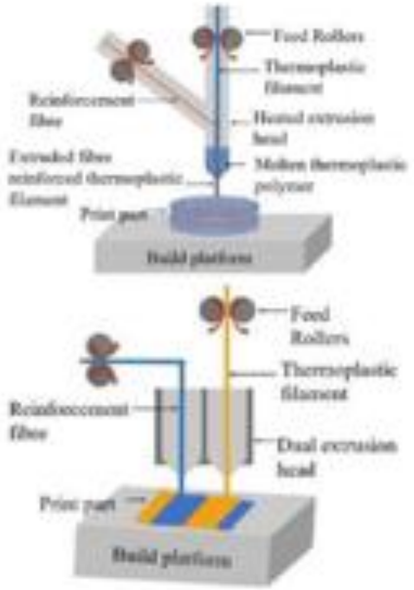
Principe physique



Résistance mesurée :
$R_0 + \Delta R$

Impression 3D Composite

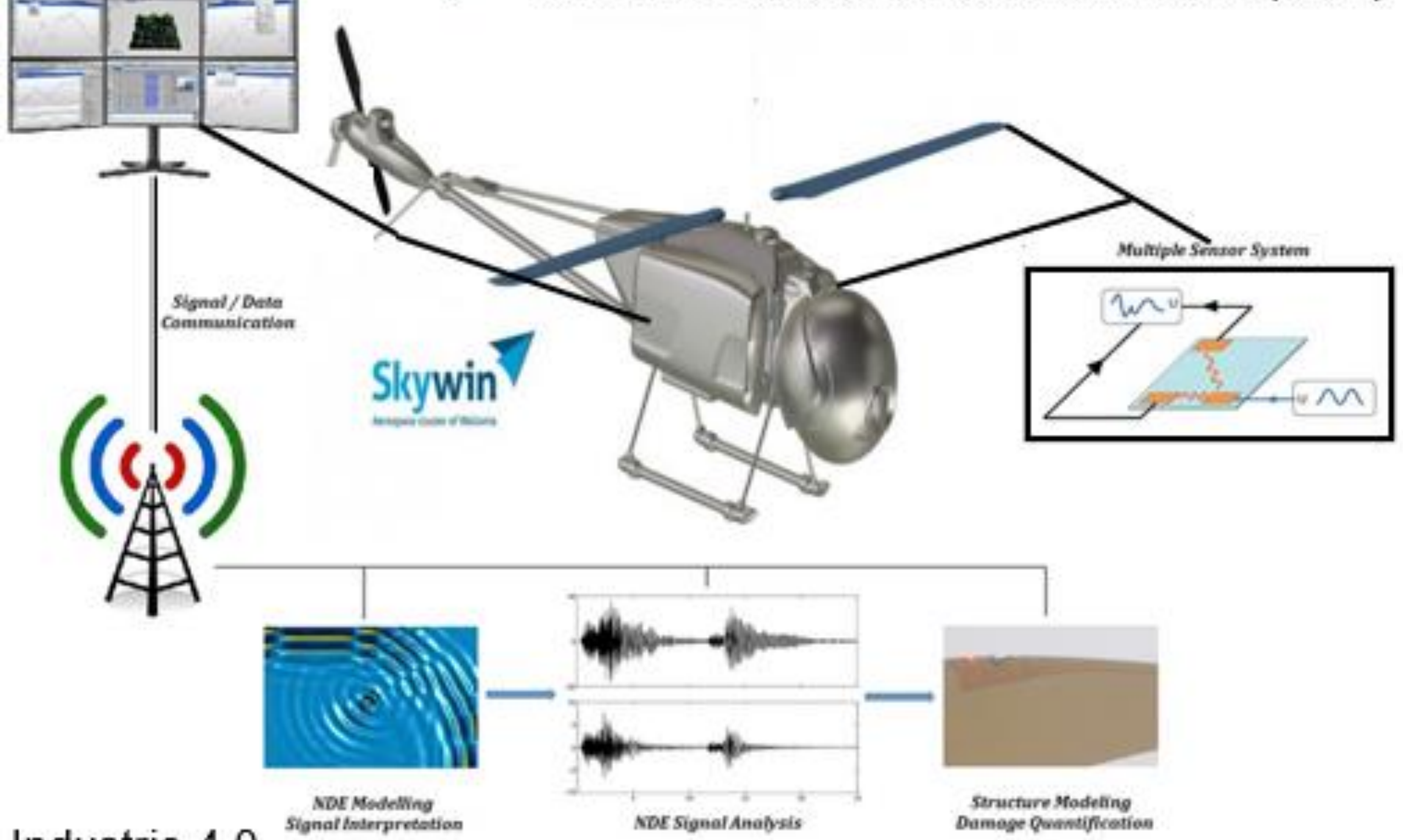
Fibre continue carbone (CCF)



Application

Monitoring de pièces structurelles (SHM)

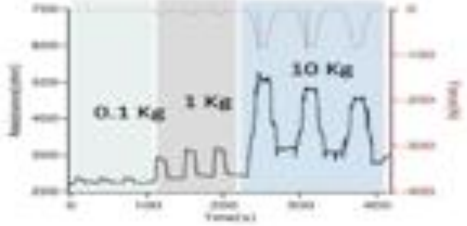
- Extension du contrôle non destructif (NDT)



- Industrie 4.0
  - Capteurs intelligents (i-Sensor)
  - Objets connectés (IoT Internet of Things)
  - Intelligence artificielle (IA)

Innovation

Connexion sur CCF



Démonstrateur
cadre du train d’atterrissage

AnyShape
FLYING-CAM
ALKAR Technology Raising Composites at the Best
UMONS Université de Mons
Advanced ANDIM Non Destructive Inspection Manufacturing

Projet issu d’un Financement de la Région Wallone
2023-2026

Wallonie service public SPW
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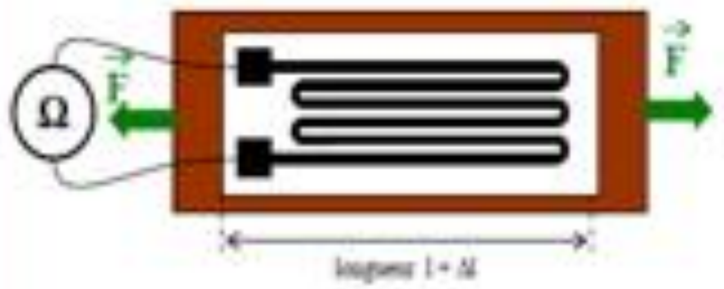
Principe physique

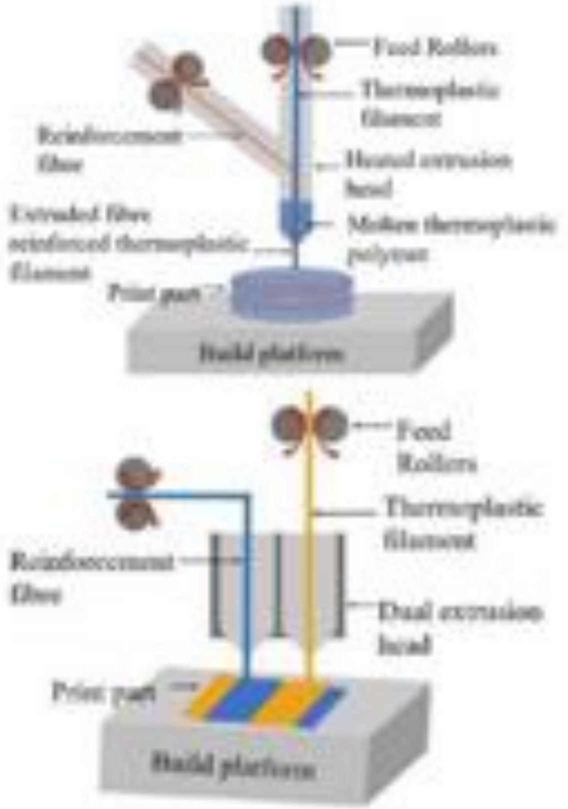


Résistance mesurée :

$R_0 + \Delta R$

Impression 3D Composite

Fibre continue carbone (CCF)



Application

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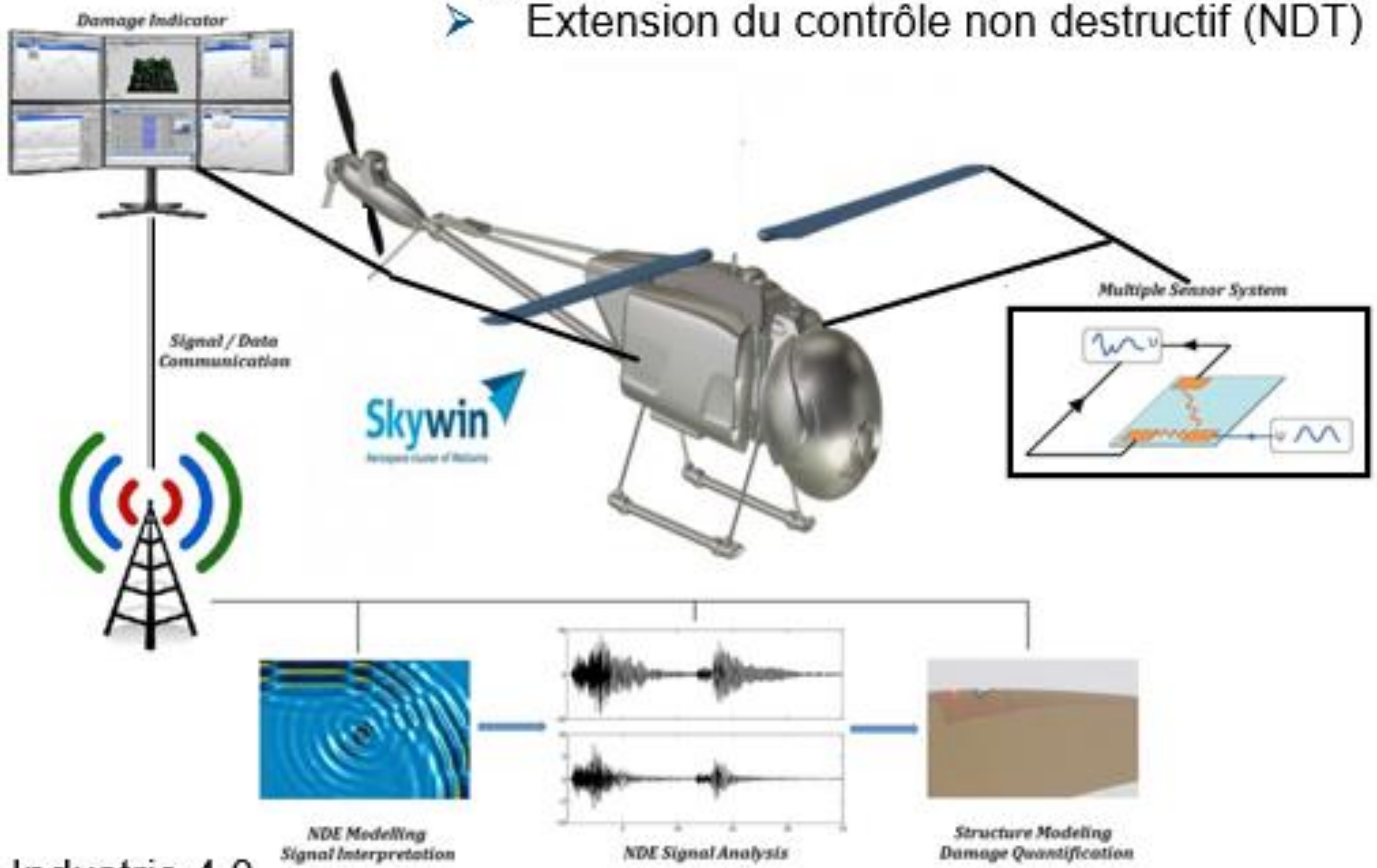
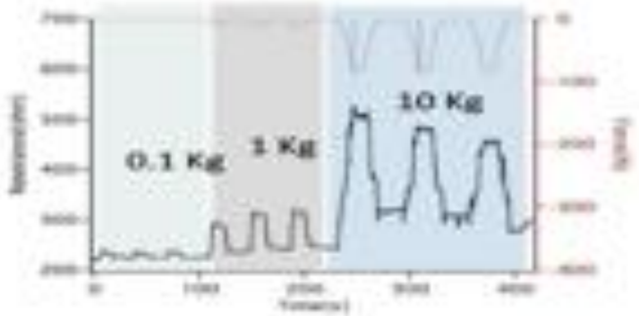
➢ Extension du contrôle non destructif (NDT)



➢ Industrie 4.0
  - ➢ Capteurs intelligents (i-Sensor)
  - ➢ Objets connectés (IoT Internet of Things)
  - ➢ Intelligence artificielle (IA)

Innovation

Connexion sur CCF



Démonstrateur

cadre du train d'atterrissage

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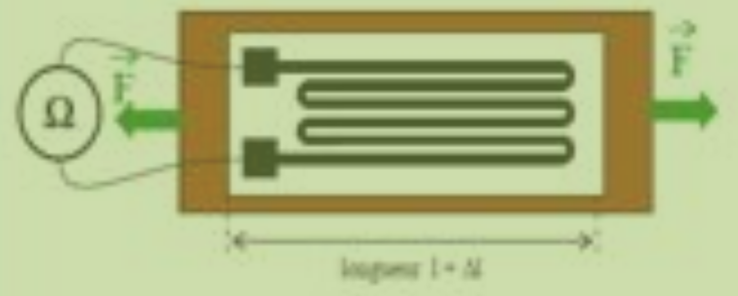
Principe physique



Résistance mesurée :
$R_0 + \Delta R$

Journal of Composites Science

MDPI

Article

Additively Manufactured Multifunctional Composite Parts with the Help of Coextrusion Continuous Carbon Fiber: Study of Feasibility to Print Self-Sensing without Doped Raw Material

Anthonin Demarbaix [1,*], Imi Ochana [1], Julien Levrie [1], Isaque Coutinho [2], Sebastião Simões Cunha, Jr. [2] and Marc Moonens [1]

1 Science and Technology Research Unit, Haute Ecole Provinciale de Hainaut Condorcet, Square Hiernaux 2, 6000 Charleroi, Belgium; marc.moonens@condorcet.be (M.M.)
2 Mechanical Engineering Institute, Federal University of Itajubá, Avenida BPS, 1303, Bairro Pinheirinho, Itajubá 37500-903, Brazil
* Correspondence: anthonin.demarbaix@condorcet.be

Abstract: Nowadays, the additive manufacturing of multifunctional materials is booming. The fused deposition modeling (FDM) process is widely used thanks to the ease with which multimaterial parts can be printed. The main limitation of this process is the mechanical properties of the parts obtained. New continuous-fiber FDM printers significantly improve mechanical properties. Another limitation is the repeatability of the process. This paper proposes to explore the feasibility of printing parts in continuous carbon fiber and using this fiber as an indicator thanks to the electrical properties of the carbon fiber. The placement of the fiber in the part is based on the paths of a strain gauge. The results show that the resistivity evolves linearly during the elastic period. The gauge factor (GF) increases when the number of passes in the manufacturing plane is low, but repeatability is impacted. However, no correlation is possible during the plastic deformation of the sample. For an equivalent length of carbon fiber, it is preferable to have a strategy of superimposing layers of carbon fiber rather than a single-plane strategy. The mechanical properties remain equivalent but the variation in the electrical signal is greater when the layers are superimposed.

Keywords: additive manufacturing composite; smart material; structural health monitoring

Citation: Demarbaix, A.; Ochana, I.; Levrie, J.; Coutinho, I.; Cunha, S.S., Jr.; Moonens, M. Additively Manufactured Multifunctional Composite Parts with the Help of Coextrusion Continuous Carbon Fiber: Study of Feasibility to Print Self-Sensing without Doped Raw Material. *J. Compos. Sci.* **2023**, *7*, 355. https://doi.org/10.3390/jcs7090355

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1. Introduction

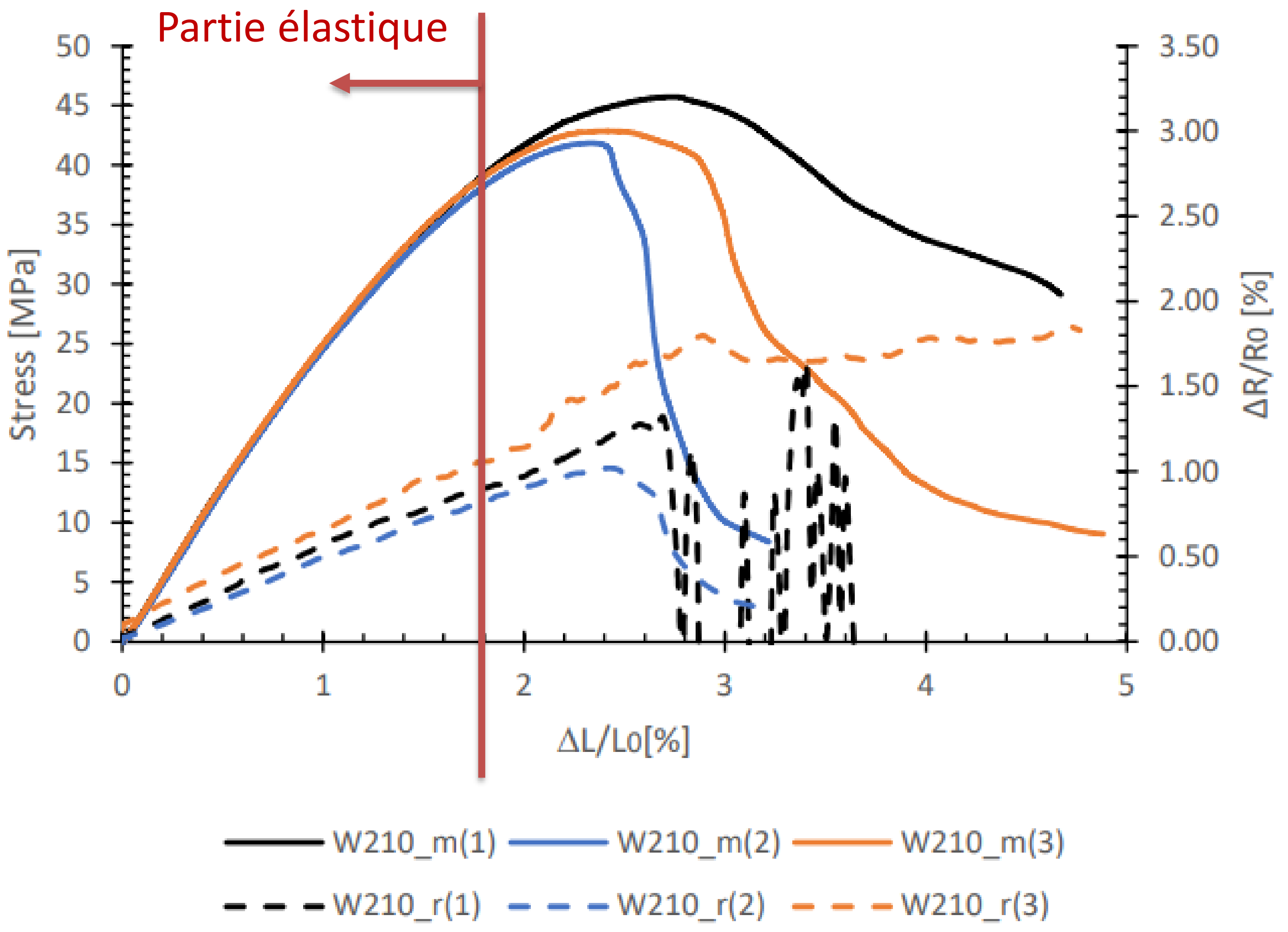
Additive manufacturing (AM) enables the production of mechanical parts with complex geometries in various sectors, such as automotive, robotics, aeronautics, and aerospace. This technology enables the use of just the right material to fulfill the required functions. This saves weight and raw materials while minimizing the assembly of multiple parts. These advantages make it a very competitive alternative to other manufacturing processes when it comes to small/medium production runs. This is one of the reasons why additive technology is gaining ground in the industrial world, particularly in aerospace and aeronautics, with the aim of lightening aircraft and thus reducing the carbon footprint of flights. AM is currently developing exponentially, with a growth rate of around 20%/year [1].

Fused deposition modeling (FDM) or fused filament fabrication (FFF) is a material extrusion (ME) 3D printing method for polymers and fiber-reinforced composites. This technology has been significantly growing especially in the aerospace, automobile, and medical industries. The main advantages of the FDM method are its reliability, low maintenance required, low investment cost, wide low-cost filament material availability, and cost-effectiveness, and it is highly customizable. However, it is limited to low-melting-point materials, and it is also a slow printing process. Single-screw extruders are usually used in mass-production applications where pure polymers are used as raw materials. There are

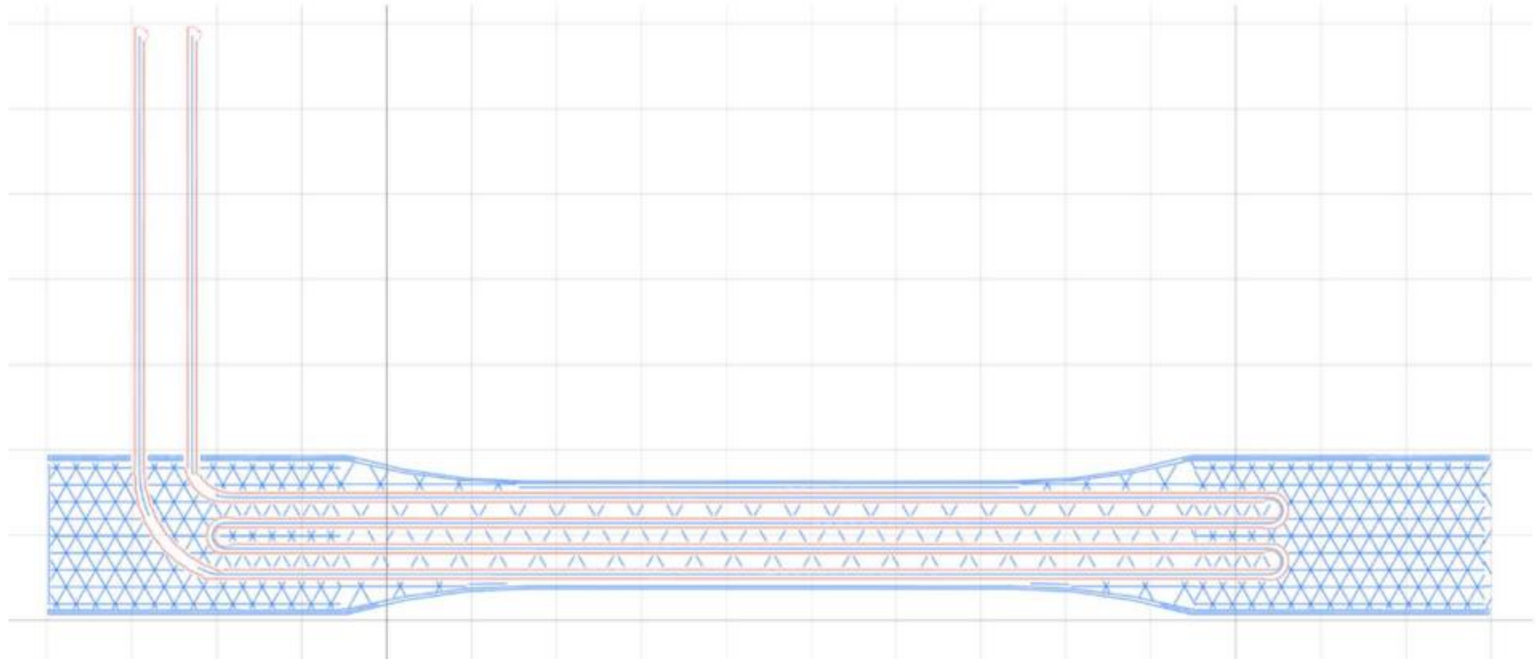
Jauge de déformation

Les jauges de déformation **permettent de mesurer de faibles déformations**

- Chemin d'un matériau conducteur
- Correspondance résistivité et faible allongement
- Patch à coller sur la structure



Impression de fibre de carbone continue



Principe validé par publication scientifique

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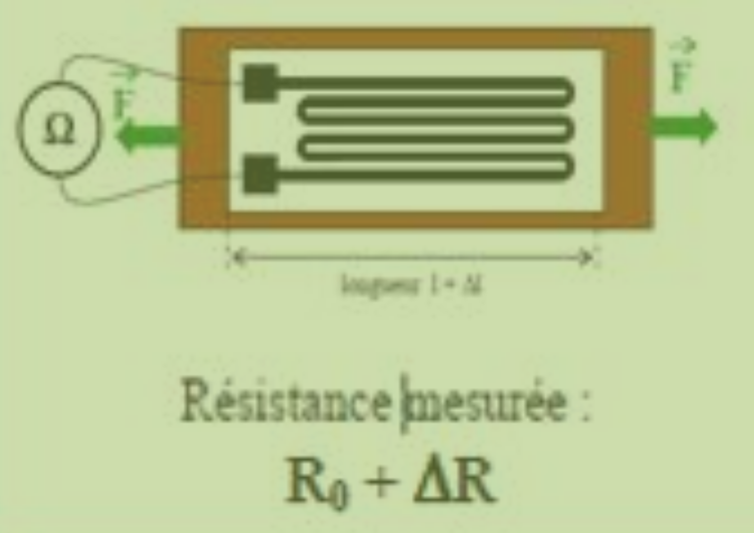
Principe physique



Journal of Composites Science
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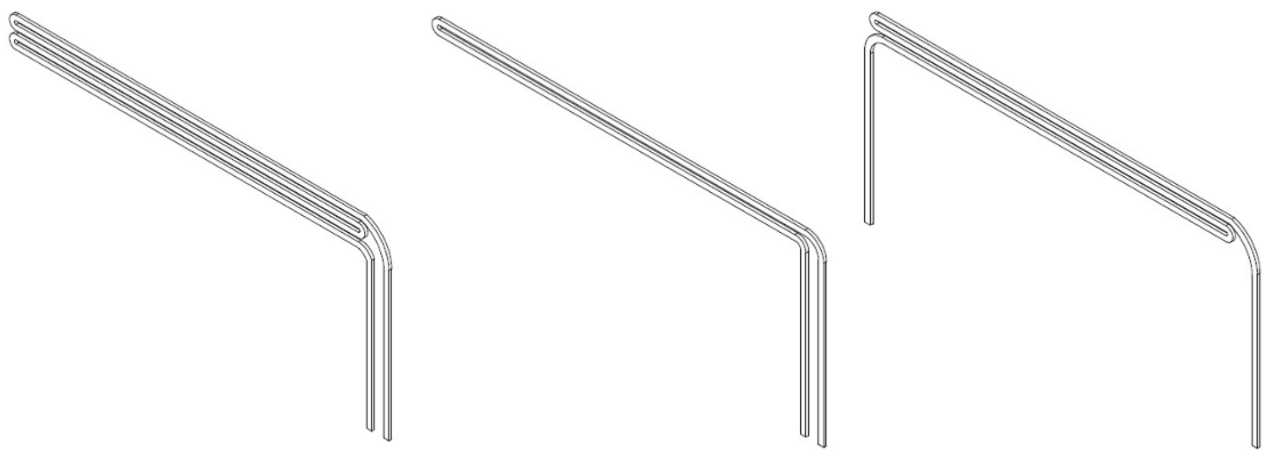
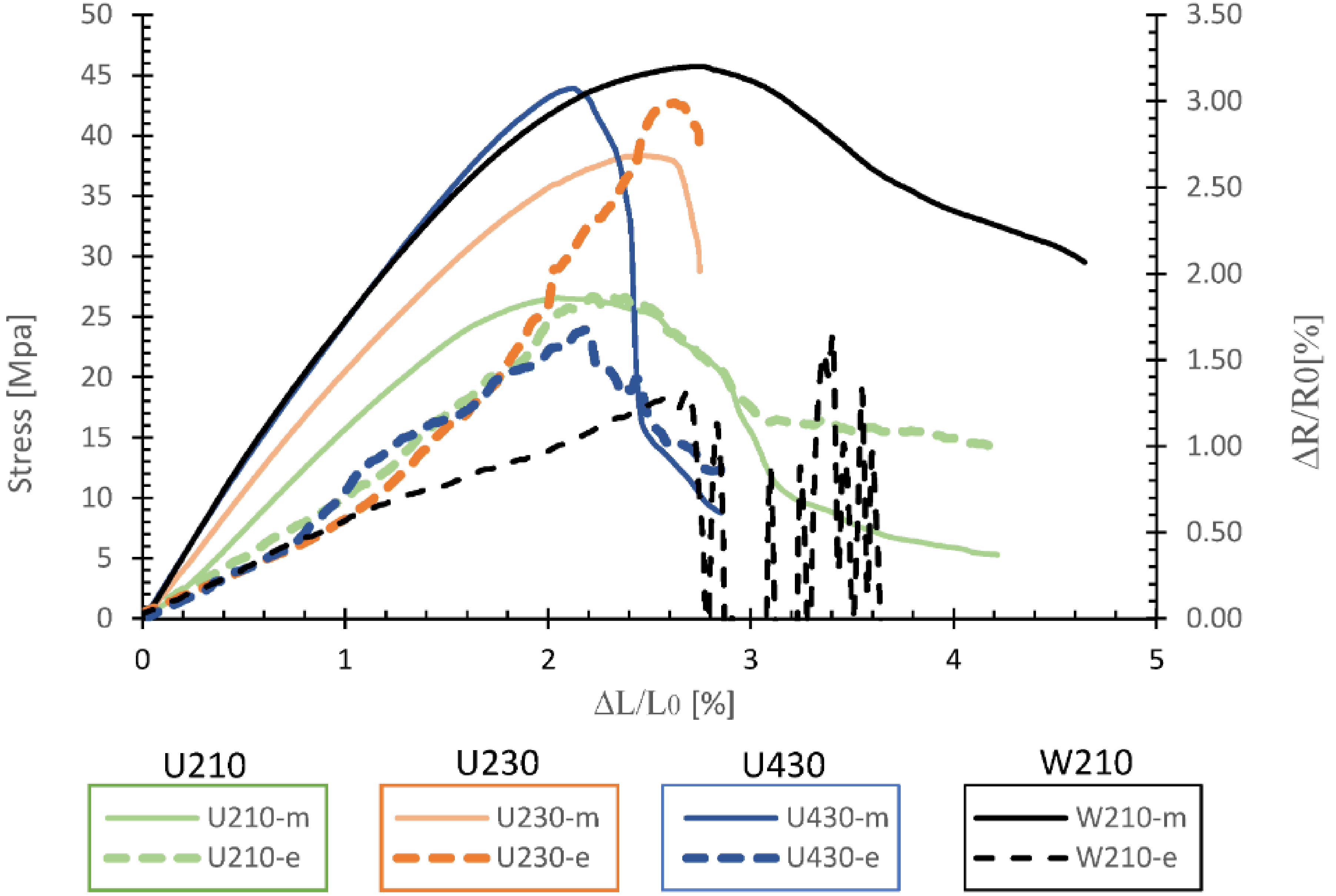
Jauge de déformation

Influence du chemin de la fibre sur les propriétés **mécanique** et **électrique**





À même longueur de fibre de carbone dans la pièce

- Influence du chemin sur la résistivité
- Sans influence sur les propriétés mécaniques

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MS # 1

Comparative accuracy analysis of continuous fiber composite printers: Coextrusion vs. Dual-Nozzle Technology

Imi Ochana[1,2,a*], François Ducobu[2], Laurent Spitaels[2], Mohamed Khalil Homrani[2], Anthonin Demarbaix[1]

[1] Science and Technology Research Unit, Haute Ecole Provinciale de Hainaut Condorcet, Square Hierneaux 2, 6000 Charleroi, Belgium

[2] Machine Design and Production Engineering Lab, Research Institute for Science and Material Engineering, University of Mons, Mons, Belgium

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Keywords: Continuous fiber reinforced thermoplastic, dimensional accuracy, 3D Printing.

Background.

The Fused Deposition Modeling (FDM) technology for continuous fiber reinforced thermoplastic composites (CFRTCs) is based on the extrusion of a continuous fiber to create three-dimensional composite objects layer by layer. This technology explores three distinct methods for reinforcing thermoplastic polymers with continuous fibers [1]. The first method, referred to as "pre-impregnated filament". The second method involves the use of two separate nozzles. The final method is known as coextrusion. The goal of this paper is to compare two printers, one using the dual nozzle and another employing coextrusion.

Procedure

As part of our comparative study on 3D printing technologies, we are examining two FDM printers, one from the Markforged brand and the second from Anisoprint brand. The first printer, Mark Two of Markforged, is based on a dual-nozzle technology. It allows for the printing of thermoplastic with one nozzle and, on a separate head, the printing of the continuous fiber using another nozzle. A cut is used to shear the fiber between each layer. Its print bed measures 320 mm x 132 mm x 154 mm.

The second printer, the Anisoprint Composer A4, stands out for its coextrusion method. The fibers are pre-impregnated with a thermosetting epoxy polymer, creating a filament consisting of 1K fibers. This filament is then directly impregnated into the nozzle by a thermoplastic material, thus forming the composite material that exits the nozzle directly. The printer offers a printing volume of 297 mm x 210 mm x 140 mm.

Five Geometrical Benchmark Test Artifacts (GBTA), proposed by Spitaels et al. [2] were fabricated with each printer to determine their dimensional and geometric accuracies. Due to varying printer volumes, it was necessary to adjust the dimensions of the GBTA for each printer. Indeed, the GBTA's dimensions for the Markforged are as follows: 121 mm x 121 mm x 28 mm, while the GBTA's dimensions for the Anisoprint are as follows: 170 mm x 170 mm x 28 mm. Measurements are taken using a Coordinate Measuring Machine (CMM) Wenzel LH 54. This study involved the examination of various parameters such as dimensional, cylindricity, perpendicularity, parallelism …

Key findings

The accuracy of the Z axis on the Anisoprint is greater than that of the other two axes. Analysis of Markforged's GBTA is currently in progress. This will enable us to compare the two technologies for the full paper and to show the impact of the technology on the accuracy of the printer.

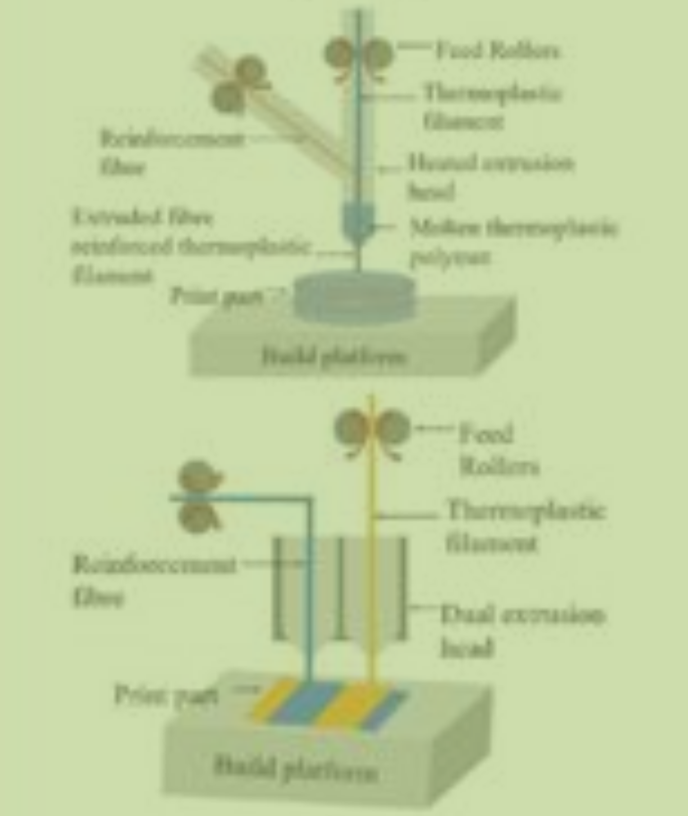
References

[1] Pandeli, C., Bateman, S., Piegert, S., Hoehner, R., Kelbassa, I., & Brandt, M. (2021). The technology of continuous fibre-reinforced polymers: a review on extrusion additive manufacturing methods. The International Journal of Advanced Manufacturing Technology, 21.

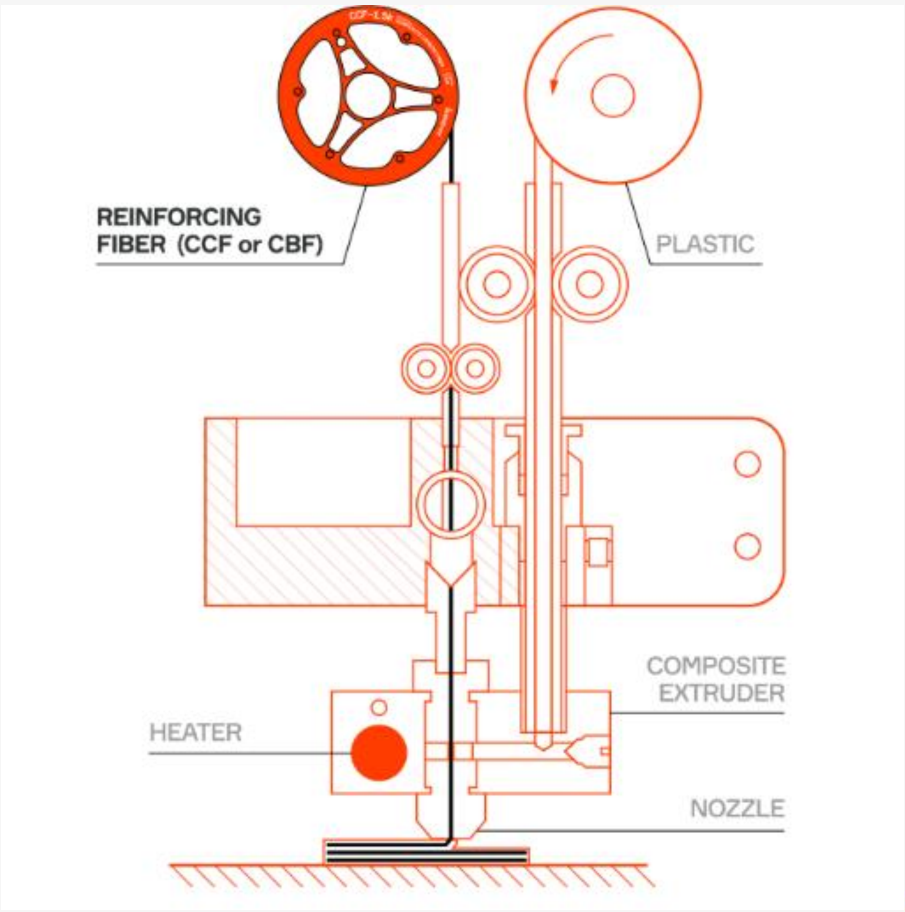
[2] Spitaels, L., Rivière-Lorphèvre, E., Demarbaix, A., & Ducobu, F. (2022). Adaptive benchmarking design for additive manufacturing processes. Measurement Science and Technology, 18.

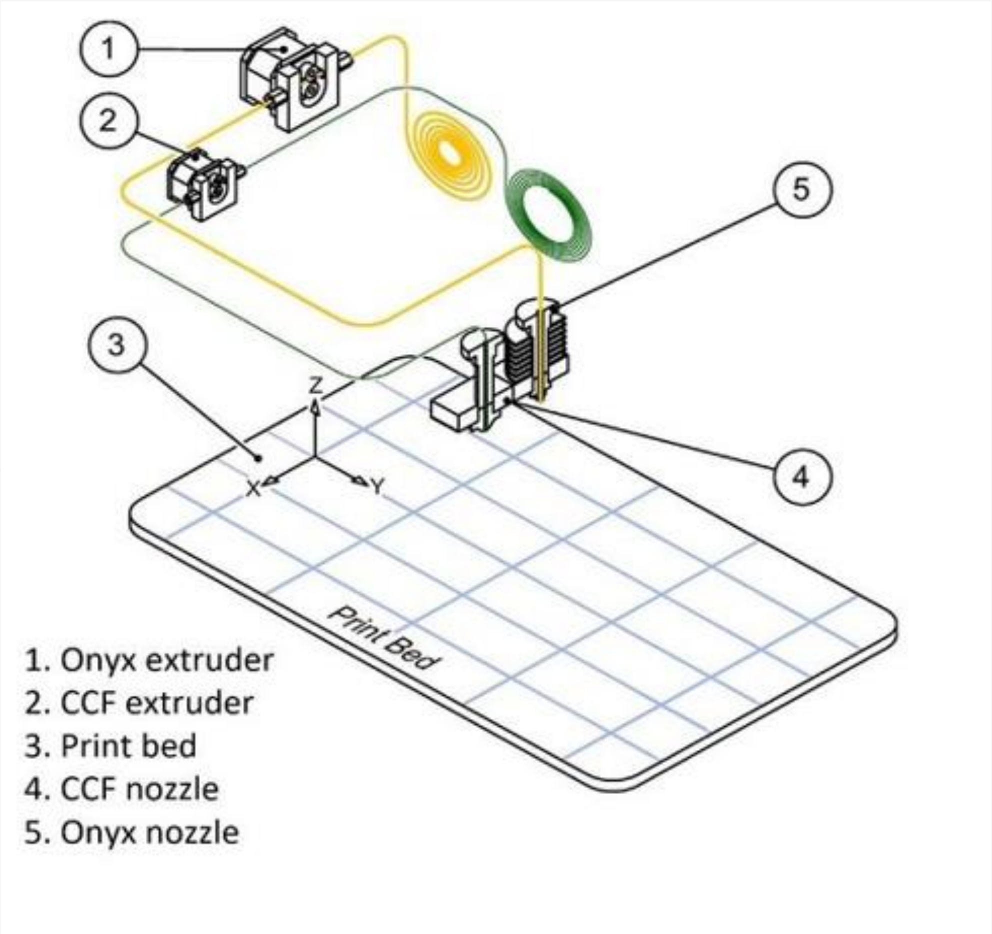
Composite print 3D

Fibre continue carbone (CCF)

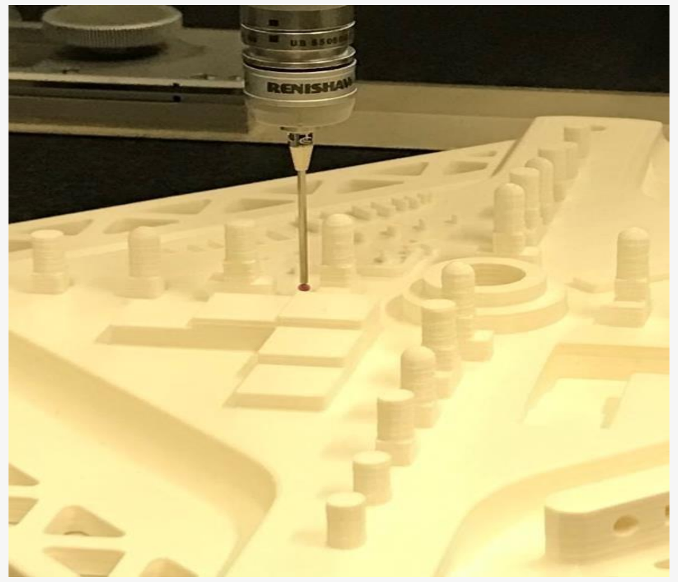


➢ Différentes technologies d'impression 3D composite fibre continue

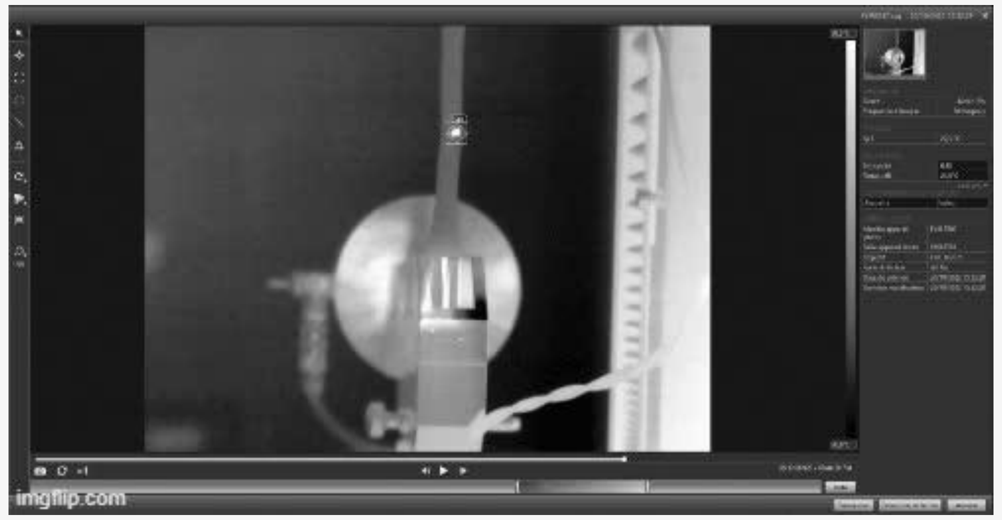




➢ Différents critères de comparaison sur les performances



Dimensionnel



Mécanique

Intégrité interne

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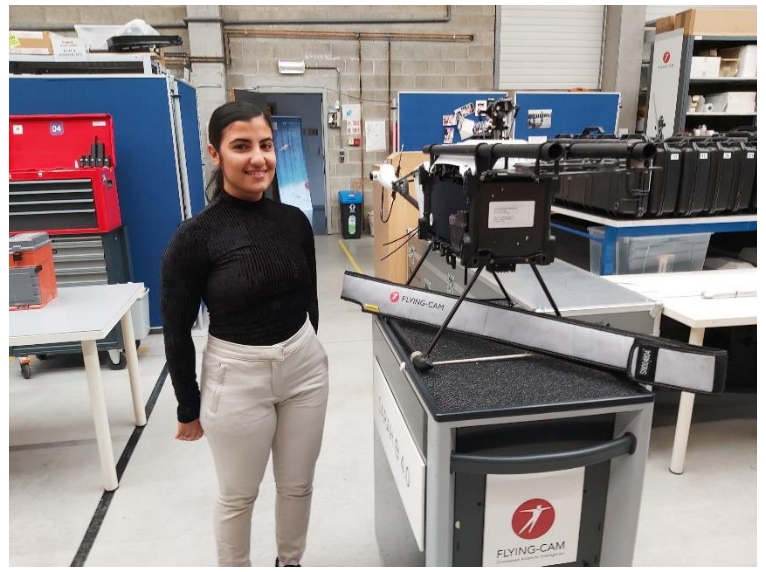
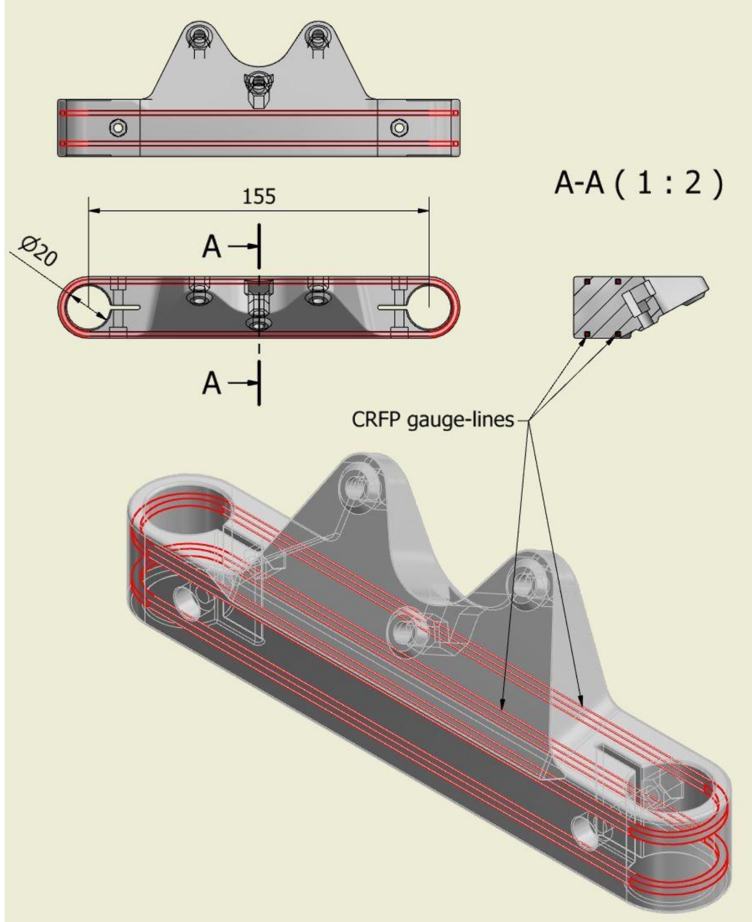
Choix de la pièce de démonstration

La pièce du démonstrateur est une pièce structurelle

- Multifonction à savoir mécanique et intelligent
- Utilisation de la technologie pour s’assurer de l’atterrissage





Etude de charges sur le train d’atterrissage

- Choix stratégique du placement de la fibre

Drop test

- Analyse du signal sur base d’essai

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