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Ph.D. thesis (2023-2026)
LGP2 (D. Beneventi; I. Desloges, J. Viguié)

Printing stiffeners on the surface of folding or corrugated boards: a bio-inspired approach to lighten packaging and optimize resource consumption

Impression de renforts à la surface d'emballages cartons: une approche bio-inspirée pour alléger les emballages et optimiser la consommation des ressources.

MatBio / FunPrint

Context

Paper industry consumption

- 15-25 m^3 of water / ton of paper
- 2.9 kWh / ton of paper
- 2-3 ton of wood / ton of paper

→ Two approaches to reduce the use of resources :

1. Lighten packaging
2. Increase the use of recycled pulps

→ Both raise an issue of mechanical strength

Ribbed structure

- High bending stiffness to weight ratio
- Ribs networks depend on the solicitation and geometry of the structure to reinforce

→ Could the printing of ribs of polymer on cardboard boxes be a virtuous way to stiffen them, addressing the above issue of strength ?

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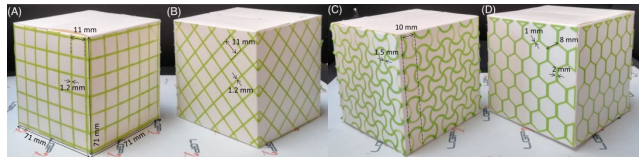
Objectives

1. Finding the best printing process & stiffening materials

- Lowest environmental impact
- Suitable adhesion of the printed patterns on boards
- Maximum mechanical properties, especially bending stiffness

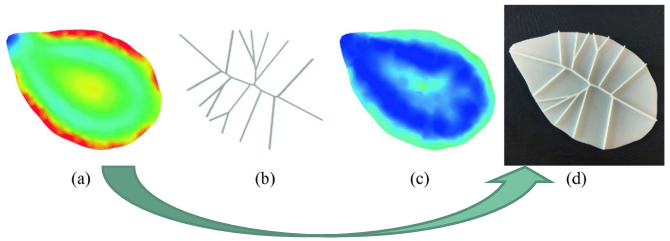
2. Characterizing the mechanical behavior of boxes

- Printing different types of rib pattern and identifying which one best stiffen a given geometry of box



3. Developing a numerical tool

- Optimizing the rib pattern to be printed depending on the geometry of the boxes



Methods

3D Printing

- Fused Deposition Modelling = 3D printing from a fused filament

→ Materials : PLA, Thermoplastic starch, …

- Liquid Deposition Modelling : 3D printing from a paste

→ Materials : cellulose ester suspension, potentially adding CNC / CNF, …

Characterizations

- On corrugated board plates :

→ 4 points bending, compression (ECT), DST

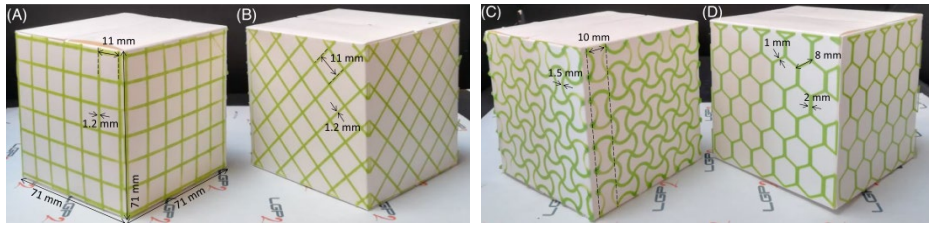
- On boxes :

→ Compression (BCT), cyclic loading, creep , digital image correlation (DIC) to measure the strain field on panel surfaces and observe how they are locally deformed

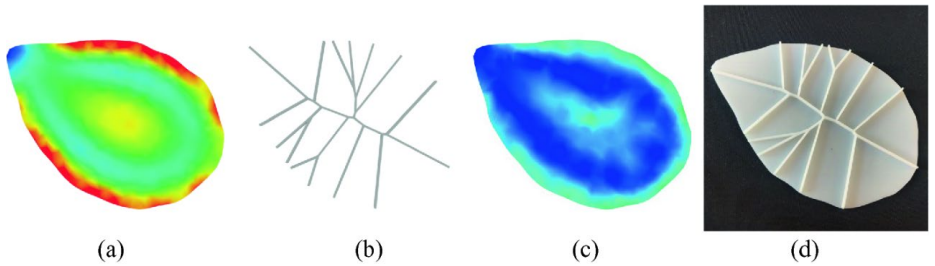
Towards the numerical tool :

- Calculation of stress maps from DIC strain maps using plate theory, then encoding an algorithm to calculate an optimized stiffening pattern from those maps

Sources des photos



N. Bonnet, J. Viguié, D. Beneventi, et D. Chaussy, « Reinforcing folding board boxes by printing a PLA patterned grid on their panels: A new approach for lightweighting stiff packaging », Packag Technol Sci, vol. 36, nº 3, p. 211-218, march 2023



A. Zheng et al., « Minimizing Material Consumption of 3D Printing with Stress-Guided Optimization », in Computational Science – ICCS 2020, vol. 12141, V. V. Krzhizhanovskaya, G. Závodszky, M. H. Lees, J. J. Dongarra, P. M. A. Sloot, S. Brissos, et J. Teixeira, Éd., in Lecture Notes in Computer Science, vol. 12141. , Cham: Springer International Publishing, 2020, p. 588-603

A picture of one of my own boxes taken by myself

Image taken on the web, at : https://brut-de-coques.com/nos-cacahuetes/

Image taken on the web, at : http://www.gourmandises-sauvages.com/site/le-tilleul-arbre-a-salade/